

PROCEEDINGS

Twentieth International Tissue Elasticity Conference

Leipzig, Germany

September 23th – 25th, 2026

ITEC 2026

September 23-25 2026



Optical + Ultrasound + MR Elastography

BIO CITY Leipzig

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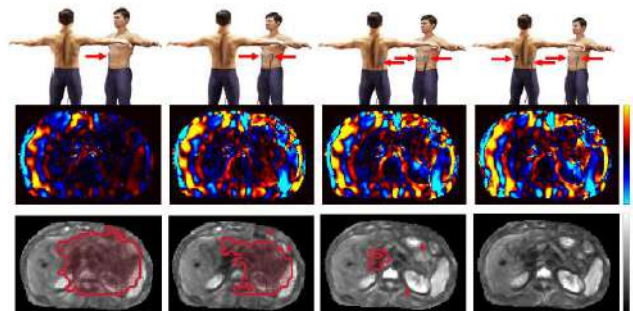
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The **VibroR42** is an MR elastography actuator system that generates continuous acoustic vibrations for applications across all body regions. The system is fully metal-free and supports multi-driver and multi-frequency operation, enabling multiplex MR elastography for tomographic visualization of tissue viscoelasticity with high-resolution mapping.

The VibroR42 provides access to freely selectable vibration frequencies and amplitudes in the range of 20 to 200 Hz, with phase-locked timing maintained over several minutes. Tissue vibrations can be detected using external measurement devices, including MRI scanners, ultrasound scanners, laser-based systems, or ultrasound beams.

In addition to elastographic imaging, the VibroR42 can be used to assess wavelength and amplitude changes within organs, providing complementary diagnostic information.



J. Schattenfroh et al. *Invest Radiol.* 2026 May 1;61(5):326-333

Simultaneous excitation of four vibration frequencies using four independent drivers provides full abdominal coverage for tomographic MRE of the liver, spleen, pancreas, and kidneys.



Multi-CAP technology
Flexible compressed-air drivers controlled by parallel air streams.

Large-field coverage
suitable, for example, for full abdominal coverage in tomographic MR elastography.

Multiplex MR elastography
suitable, for example, for full abdominal coverage in tomographic MR elastography.

Independent multi-driver control
up to four drivers can be operated independently with adjustable amplitude and frequency.

Multi-wave-source setup
four independent air streams can be split to operate 8, 16, 32, or more drivers wrapped around the body simultaneously, enabling highly flexible vibration coverage.



BENCHTOP MRE

Map stiffness. Reveal mechanics.

Magnetic Resonance Elastography for compact MRI - combining high-performance imaging with controlled mechanical vibration to visualize viscoelastic properties.

NON-INVASIVE

Tissue and material characterization

QUANTITATIVE

Elasticity and tissue stiffness mapping

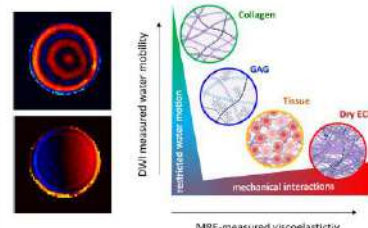
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Biomechanics, cancer research and materials

MULTIMODAL

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FROM WAVE MOTION TO QUANTITATIVE MAPS



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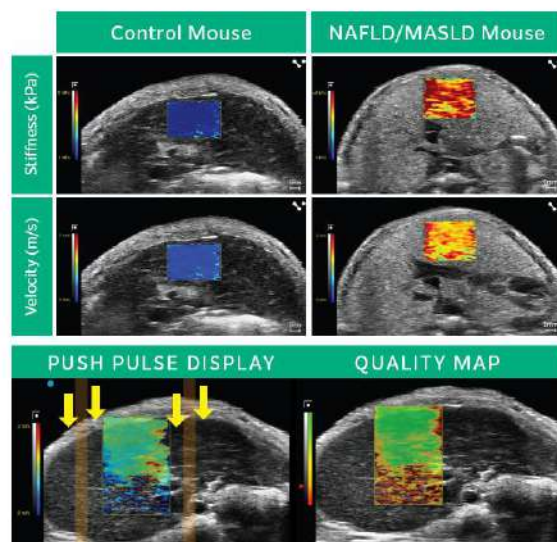


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Shear Wave Elastography (SWE)

on the Vevo F2xc Imaging system offers unparalleled sensitivity for assessing tissue stiffness in small animal models.

SWE is **fully integrated on the Vevo F2xc**; users can select 4 or 2 push pulses and easily manipulate data display.

Measure shear wave velocity and stiffness in kPa for precise assessment with **quantitative analysis** and **quality display maps**.



Time Harmonic Elastography THED



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Stand-alone MRE-like ultrasound elastography
no MRI scanner required

Time-harmonic shear-wave excitation

controlled external vibration for quantitative biomechanical imaging

Full-field-of-view mapping
regional analysis of lesions, organs, and surrounding tissue



Multifrequency operation

assessment of stiffness, viscosity, and dispersion-related tissue properties

Real-time and functional elastography

visualization of dynamic stiffness changes and pulsation patterns

Point-of-care capability

suitable for outpatient, bedside, and longitudinal monitoring

Applications across oncology, cardiology, and hepatology

one platform for cancer, cardiac mechanics, and liver function assessment

THED Shakers



<https://www.gampt.de>

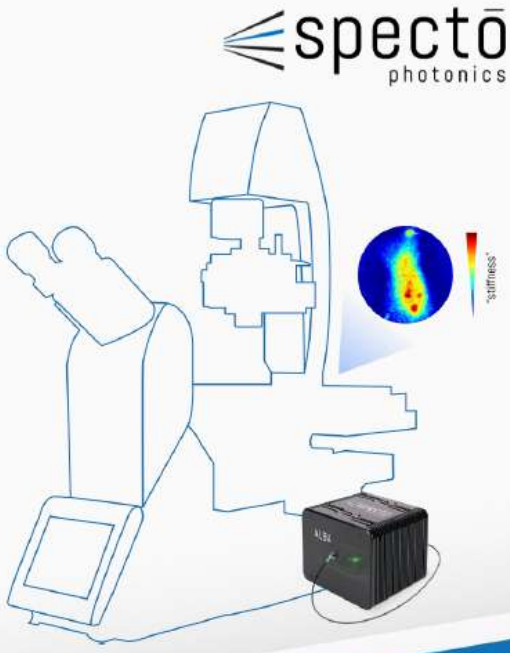
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Conference Venue

Biocity Leipzig - University of Leipzig
Center for Biotechnology and Biomedicine (BBZ)
Deutscher Platz 5, 04103 Leipzig, Germany



Organizing Committee

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LabTAU, INSERM, Centre Léon Bérard, Université Claude Bernard Lyon 1, Lyon, France

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Jorge Torres

LabTAU, INSERM, Centre Léon Bérard, Université Claude Bernard Lyon 1, Lyon, France

Treasurer

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LabTAU, INSERM, Centre Léon Bérard, Université Claude Bernard Lyon 1, Lyon, France

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Ivan (Vanya) Pelivanov

University of Washington, Department of Bioengineering, Seattle, WA, USA

Chair of ITEC 2026

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Charité - Universitätsmedizin Berlin, Department of Radiology, Berlin, Germany

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Josef Käs

University of Leipzig, Department of Soft Matter Physics, Leipzig, Germany

Berlin host

Tobias Schaeffter

Physikalisch Technische Bundesanstalt (PTB), Berlin, Germany

Coordinator

Melanie Estrella

Charité - Universitätsmedizin Berlin, Department of Radiology, Berlin, Germany



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Forschungsgemeinschaft



Detailed program

Session chairs

September 23rd, 2026

08:10-08:20	Welcome
08:20-09:00	Memorial Lecture
09:00-10:00	Session 1: Ultrasound Methods I
10:30-11:30	Session 2: Magnetic Resonance Methods I
11:30-12:30	Session 3: Optical Methods I
13:30-14:15	Plenary Talk
14:15-15:15	Session 4: Forward and Inverse Problems I
16:30-17:30	Session 5: Instrumentation

Chairs

Ingolf Sack, Melanie Estrella

Stefan Catheline, Ariana Cihan

Elijah Van Houten, Ingolf Sack

Kirill Larin, Ginger Schmidt

Ingolf Sack

Jean-Luc Gennisson,

Heiko Tzschätzsch

Bruno Giammarinaro,

Julia Martemyanova

September 24th, 2026

08:00-08:40	Keynote Talk 1
08:40-09:00	Impulse Talk
09:00-10:00	Session 6: Tissue Properties and Models I
10:30-11:15	Session 7: Numerical Simulations
11:15-12:30	Session 8: Clinical, Animal & Miscellaneous
13:30-14:30	Session 9: Magnetic Resonance Methods II
15:30-16:30	Session 10: Optical Methods II
16:30-17:30	Session 11: Ultrasound Methods II

Stefan Catheline

Ivan Pelivanov

Jorge Torres, Inas Faris

Paul Barbone, Joaquine Mura

Guy Cloutier, Frank Sauer

Tobias Navarro Schröder,

Anne-Sophie van Schelt

Brendan Kennedy, Salavat Aglyamov

Kathy Nightingale, Tom Meyer

September 25th, 2026

08:10-08:50	Keynote Talk2
08:50-09:10	Industrial Talk
09:10-10:10	Session 12: Optical Methods II
10:40-11:40	Session 13: Ultrasound Methods III
12:40-13:20	Keynote Talk 3
13:20-14:20	Session 14: Magnetic Resonance Methods III
15:00-16:00	Session 15: Tissue Properties and Models II
16:00-16:45	Student Awards, Introduction of ITEC 2027, and Closing Ceremony
16:45	End of Conference

Simon Chatelin

Ivan Pelivanov

Tom Royston, Jakob Jordan

Yasmine Safrdou, Hossein Aghamiry

Jeff Bamber

Heloise Bustin, Dieter Klatt

Tom Royston,

Anja Heeren-Hagemann

Jeff Bamber

Ingolf Sack, Stefan Catheline

Wednesday, September 23rd, 2026

07:30-08:10 **Registration**

08:10-08:20 **Welcome**

08:20-09:00 **Memorial Lecture in Honor of Professor Kevin J. Parker**

Marvin Dooley - University of Rochester, USA & Jeff Bamber - ICR – London, UK

09:00-10:00 **Session 1: Ultrasound Methods I**

09:00-09:15 **T1** A Feasibility Study of 4-D Pulse Wave Imaging Using a Row-Column-Addressed Array

Haokang Shi - Columbia University, USA

09:15-09:30 **T2** Cardiac Natural Mechanical Waves Trajectories as a Marker of Tissue Pathological State

Corentin Alix - Centre de Résonance Magnétique des Systèmes Biologiques, France

09:30-09:45 **T3** Cardiac Shear Wave Elastography: Echocardiography Parameters Influencing Shear Wave Speed Propagation after Mitral and Aortic Valve Closure

Andressa Araujo Andrade Sousa - KU Leuven, Belgium

09:45-10:00 **T4** Ultrasonic Cavitation-induced Shear Wave Elastography

Clément Foulounoux - LabTAU, France

10:00-10:30 **Morning Coffee Break**

10:30-11:30 **Session 2: Magnetic Resonance Methods I**

10:30-10:45 **T5** Cardiac-Resolved MRE Reveals Cerebral Stiffness Pulsation

Merijn Calis - University Hospital Ghent and Ghent University, Belgium

10:45-11:00 **T6** Effects of SNR and Tissue Displacement Amplitude on Cardiac MRE Stiffness Mapping

Julia Martemyanova - Oslo University Hospital and University of Oslo, Norway

11:00-11:15 **T7** Evidence for the Ultra-soft Brain Provided by Uniqueness in Intrinsic MR Elastography

Marius Burman Ingeberg - UMC Utrecht, Netherlands

11:15-11:30 **T8** Feasibility of in vivo Human Kidney Multifrequency DTI-MRE

Dieter Klatt - UIC, BME, USA

11:30-12:30 **Session 3: Optical Methods I**

11:30-11:45 **T9** Air-Jet Based Optical Coherence Elastography Towards in-situ Brain tumor Delineation and Fundamental Tissue Mechanical Research

Nicolas Detrez - Medical Laser Center Lübeck, Germany

11:45-12:00 **T10** Heartbeat Optical Coherence Elastography for Assessment of Corneal Biomechanics

Salavat Aglyamov - University of Houston, USA

12:00-12:15 **T11** High Frequency Optical Micro-elastography to Image the Temporal Impact of Inflammatory Phenotypes on Macrophage Mechanics

Hari S. Nair - University of Montreal Hospital Research Center and University of Montreal, Canada

- 12:15-12:30 **T12** Intracellular Mechanophenotyping of Macrophages: Cytoskeletal Contributions and Senescence-associated Changes Revealed by Optical Microelastography
Sajad Ghazavi - University of Montreal Hospital Research Center and University of Montreal, Canada
- 12:30-13:30 Lunch Break**
- 13:30-14:15 **Plenary Talk - The role of mechanics in brain development and disorder**
Kristian Franze - University of Erlangen, Germany
- 14:15-15:15 Session 4: Forward and Inverse Problems I**
- 14:15-14:30 **T13** Cross-modality Multifrequency Neural Network-based Wave Inversion
Héloïse Bustin - Deutsches Herzzentrum der Charité and Charité - Universitätsmedizin Berlin, Germany
- 14:30-14:45 **T14** Elastography of Prestressed, Heterogeneous and Anisotropic Viscoelastic Materials: Inverse Modeling Challenges and Strategies
Thomas J. Royston - University of Illinois Chicago, USA
- 14:45-15:00 **T15** Hybrid Convolution-Based Method for Inverting the Helmholtz Equation
Patricio González - Federico Santa Maria Technical University, Chile
- 15:00-15:15 **T16** Viscoelastic Inversions from Multifrequency Shear Wave Data
Paul E. Barbone - Boston University, USA
- 15:15-16:30 Afternoon Coffee Break + Poster session**
- 16:30-17:15 Session 5: Instrumentation**
- 16:30-16:45 **T17** Directional Clutter Filter Wave Imaging in Time Harmonic Elastography
Mahsa Sotoodeh Zikar - University of Oslo, Norway
- 16:45-17:00 **T19** Radial Energy-Quantile (REQ) Estimator for Robust Wavenumber Mapping across Directional and Diffuse Wavefields
Sara Gomez-Ramirez - University of Rochester, USA
- 17:00-17:15 **T20** Uncertainty Evaluation in Shear Wave Speed Measurements using ARFI Ultrasound Elastography
Andre Victor Alvarenga - National Physical Laboratory, UK
- 18:00-21:00 Welcome Reception at the Botanical Garden Leipzig** with acoustic presentation from Jörg Wilkendorf (former guitarist Rio Reiser, Gundermann...) (Linnéstraße 1, 04103 Leipzig - 15 min walk)

Thursday, September 24th, 2026

07:50-08:00 **Announcements for Day 2**

08:00-08:40 **Keynote Talk 1 - Shear Wave Elasticity Imaging: Opportunities and Challenges in Skeletal Muscle Characterization**

Kathryn Nightingale - Duke University, USA

08:40-09:00 **Impulse Talk - Can Biomechanics Detect Emergent Properties of Tumor Progression?**

Josef Käs - Leipzig University, Germany

09:00-10:00 **Session 6: Tissue Properties and Models I**

09:00-09:15 **T21** Flexural Pulse Wave velocity to Unveil Arterial Wall Elasticity

Shiva Ahsani - LabTAU, France

09:15-09:30 **T22** Assessing Pressure-Induced Stiffness and Volume Changes in Ex Vivo Kidney with Ultrasound and MRI

Ariana Cihan - Ghent University, Belgium

09:30-09:45 **T23** Blood Flow Restriction and Its Immediate Biomechanical Effects on Vastus Lateralis Muscle Assessed by Ultrasound Time-Harmonic Elastography

Hossein S. Aghamiry - Charité - Universitätsmedizin Berlin, Germany

09:45-10:00 **T24** Feasibility of Characterizing in vivo Skeletal Muscle as an Elastic ITI Medium Using High-Resolution Phase Velocity Estimation Algorithms in Arbitrarily Sampled Wavefields

Wren E. Wightman - Duke University, USA

10:00-10:30 **Morning Coffee Break**

10:30-11:15 **Session 7: Numerical Simulations**

10:30-10:45 **T25** Integrating in vitro and in silico Approaches for Natural Shear Wave Elastography in the Left Ventricle to Model Valve Closure

Andrea Resca Cacciari - Ghent University, Belgium

10:45-11:00 **T26** Modelling MR Elastography to Assess the Impact of Microstructural Variation on Brain Tissue Mechanics

Sarah Vandenbulcke - KTH Royal Institute of Technology, Sweden

11:00-11:15 **T27** Viscoelastic EXplicit Elastography (VEXEL): Shear Wave Simulation Platform for Fractional Models

José Cortés - University of Granada, Spain

11:15-12:30 **Session 8: Clinical, Animal & Miscellaneous**

11:15-11:30 **T28** Ultrasound Elastography for the Assessment of Aortic Stiffness: Preliminary Findings

Carolina Dominguez Aleixo - Charité - Universitätsmedizin Berlin, Germany

11:30-11:45 **T29** Towards Intravascular Elasticity Measurements via a Catheter with Asynchronous Optical Coherence Elastography

Ginger Schmidt - Harvard Medical School and Massachusetts General Hospital and Massachusetts Institute of Technology, USA

- 11:45-12:00 **T30** Wide-field Quantitative micro-Elastography for the Study of Human Prostate Tissue
Szymon Tamborski - Nicolaus Copernicus University, Poland
- 12:00-12:15 **T31** A Phase-based Volumetric Elastography Approach for Ultrasound and MR"
Enrique González-Mateo - CSIC - Universitat Politècnica de València, Spain
- 12:15-12:30 **T32** An Innovative Magnetic Resonance Elastography Setup to Characterize Klf10-dependent Skeletal Muscle Alterations in a Novel Murine Model
Aude Loumeaud - University of Strasbourg and Université de technologie de Compiègne, France
- 12:30-13:30 Lunch Break**
- 13:30-14:30 Session 9: Magnetic Resonance Methods II**
- 13:30-13:45 **T33** Optimal Control MR Elastography in a Murine Model of Hepatic Iron Overload: Preliminary Results
Tiffany Bakir Ageron - INSA Lyon, Université Lyon, France
- 13:45-14:00 **T34** Seeing Prestress Distribution through MR Elastography
Yuan Feng - Shanghai Jiao Tong University, China
- 14:00-14:15 **T35** MR-Elastography for Patients with Pseudocirrhosis - a Pilot Comparison with Healthy Volunteers
Owen White - The Royal Marsden NHS Foundation Trust and The Institute of Cancer Research, UK
- 14:15-14:30 **T36** Self-gating with Compressed Sensing Enables Free-breathing, ECG-free, Time-efficient Cardiac MR Elastography in Rats
Kasper Klausen - Oslo University Hospital and University of Oslo, Norway
- 14:30-15:30 Afternoon Coffee Break + Poster session**
- 15:30-16:30 Session 10: Optical Methods II**
- 15:30-15:45 **T37** Mechanical Phenotyping of Triple Negative Breast Cancer using Brillouin Microscopy and a Microtester Compression Technique
Irina Kabakova - UTS Sydney, Australia
- 15:45-16:00 **T38** Mechanical Characterization of Endometrial Patients-Derived Tumor Organoids Using Optical micro-Elastography
Malauri Devissi - LabTAU, France
- 16:00-16:15 **T39** Optical Scanning Tomography Elastography: First Experiences with a Novel Elastography Method
Elijah Van Houten - Université de Strasbourg, France
- 16:15-16:30 **T40** Quantifying Corneal Biomechanical Alterations in Primate Models of Glaucoma and Form-Deprivation Myopia Using Optical Coherence Elastography
Kirill Larin - University of Houston, USA
- 16:30-17:30 Session 11: Ultrasound Methods II**
- 16:30-16:45 **T41** HIFU-based Elasticity Mapping for Prostate Ablation Treatment
Gerald Lee - University of Washington, USA
- 16:45-17:00 **T42** In vivo Quantification of Tensile Elasticity and Anisotropy of Human Peripheral Nerves using Angle-resolved Ultrasound Shear Wave Elastography
Ricardo J. Andrade - Nantes Université, France

- 17:00-17:15 **T43** Multiparametric Ultrasound Time-Harmonic Elastography for Characterization of Focal Liver Lesions
Tom Meyer - Charité - Universitätsmedizin Berlin, Germany
- 17:15-17:30 **T44** Non-Invasive Electromechanical Wave Velocity Mapping for Functional Substrate Characterization in Ischemic and Non-Ischemic Cardiomyopathy
Cagla Ozsoy - Columbia University Irving Medical Center, USA
- 18:30-21:30** **Networking Dinner at Eisengießerei Westwerk** with Jazz music by the Acoustic Image Quartett (Karl-Heine-Straße 93b, 04229 Leipzig - bus transfer)

Friday, September 25th, 2026

- 08:00-08:10 Announcements for Day 3
- 08:10-08:50 Keynote Talk 2 MR Elastography of the Poro-Viscoelastic Brain**
Elijah Van Houten - University of Strasbourg, Strasbourg, France
- 08:50-09:10 Industrial Talk - T.H.E.A. devices**
- 09:10-10:10 Session 12: Optical Methods III**
- 09:10-09:25 **T45** Recent Advances in High-speed Volumetric Optical Coherence Elastography: Full-field and Point-scanning Techniques
Brendan F. Kennedy - University of Western Australia, Australia
- 09:25-09:40 **T46** Resolving the Mechanics of the Tumor Boundary Using Optical Multifrequency Elastography in Colorectal Liver Metastasis
Jakob Jordan - Charité - Universitätsmedizin Berlin, Germany
- 09:40-09:55 **T47** Solid Stress is a Marker of the Non-proliferative Cirrhotic Liver Disease
Yasmine Safraou - University of Pennsylvania, USA
- 09:55-10:10 **T48** Reconstruction of All Three Elastic Moduli in Skin from Phase Velocities of Rayleigh Waves: Data Processing and Optimization Algorithms
Ivan (Vanya) Pelivanov - University of Washington, Seattle, USA
- 10:10-10:40 Morning Coffee Break**
- 10:40-11:40 Session 13: Ultrasound Methods III**
- 10:40-10:55 **T49** Regime-Dependent Optimization of Shear Wave Generation in Harmonic Elastography
Gilmer A. Flores Barrera - University of Rochester, USA
- 10:55-11:10 **T50** Shear Wave Elastography For Quantifying the Mechanical Response of the Respiratory Muscles to Functional Electrical Stimulation
Arthur Begoc - Université Paris-Saclay and Sorbonne Université, France
- 11:10-11:25 **T51** Reliability Assessment of Vibration-based Shear Wave Elastography Using Signal Energy
Saramu Abe - Institute of Science Tokyo, Japan
- 11:25-11:40 **T52** Two-Point Model-Free Estimation of Shear Wave Attenuation in Ultrasound Elastography
Piotr Kijanka - AGH University of Krakow, Poland
- 11:40-12:40 Lunch Break**
- 12:40-13:20 Keynote Talk 3 - Compression-Based Optical Coherence Elastography: Applications in Cancer Imaging**
Brendan Kennedy - University of Western Australia, Australia
- 13:20-14:20 Session 14: Magnetic Resonance Methods III**
- 13:20-13:35 **T53** Single-Breathhold 3D MR Elastography in the Liver, with Simultaneous R2* and PDFF Mapping
Anne-Sophie van Schelt - King's College London, UK

- 13:35-13:50 **T54** Spatially Resolved Compact Tabletop Magnetic Resonance Elastography for Mapping Biomechanical Heterogeneity
Weijie Zhao - Charité - Universitätsmedizin Berlin, Germany
- 13:50-14:05 **T55** The Prognostic Characterization Of Breast Cancer Tissue Biomechanics With Magnetic Resonance Elastography
Nicole Bens - Mayo Clinic, USA
- 14:05-14:20 **T56** Sensitivity of Multifrequency Brain MRE to Acute Caffeine Intake
Simon Murk - University Hospital and University Erlangen-Nürnberg, Germany
- 14:20-15:00 Afternoon Coffee Break**
- 15:00-16:00 Session 15: Tissue Properties and Models II**
- 15:00-15:15 **T57** Analytical Investigation of Pressure-Stiffness Uncoupling during Shear Wave Elastography of Interstitially Pressurized Organs
Ariana Cihan - Ghent University, Belgium
- 15:15-15:30 **T58** Shear Excitation Differentially Modulates 3D Tumour Spheroids
Inas Faris - University of Granada and Instituto de Investigación Biosanitaria, Spain
- 15:30-15:45 **T59** Ultrasound Micro Time-Harmonic Elastography for In Vivo Viscoelasticity Mapping in Preclinical Research
Mareike Wolff - Charité - Universitätsmedizin Berlin, Germany
- 15:45-16:00 **T60** Longitudinal Shear Wave Elastography Monitors Response to Combined Radiation and Immunotherapy in a Murine Model of Pancreatic Ductal Adenocarcinoma
Marvin Doyley - University of Rochester, USA
- 16:00-16:45 Student Awards, Introduction of ITEC 2027, and Closing Ceremony**
- 16:45 End of Conference

Posters

Poster session I - Wednesday, September 23rd, 2026, 15:15-16:30

Poster session II - Thursday, September 24rd, 2026, 14:30-15:30

- P1** Cardiac time harmonic elastography: validation against invasive left ventricular pressure in patients
Tom Meyer - Charité - Universitätsmedizin Berlin, Germany
- P2** Effect of Transmit Voltage and Vibration Amplitude on Shear Wave Speed Estimates in Phase-Gradient Elastography
Mitra Gupta - University of Glasgow, UK
- P3** Median Nerve Stiffness Assessment in Carpal Tunnel Syndrome Using Time-Harmonic Elastography: a pilot study
Pondorf Nora - Martin-Luther-University Halle-Wittenberg, Germany
- P4** Sensitivity of Ultrasound Time-Harmonic Elastography to Mechanical Changes in the Multifidus Muscle
Aghamiry Hossein - Charité - Universitätsmedizin Berlin, Germany
- P5** Toward a Renal Digital Twin: Dispersion-Based 3D Elastography for Early CKD Detection
Amresh Tiwari - Indian Institute of Technology Madras, India
- P6** High-Efficiency Quasi-Static Displacement Estimation in B-mode Ultrasound via Structured Deep Learning
Mura Joaquin - Federico Santa María Technical University, Chile
- P7** Momentum equation-based regularization and image registration for two-dimensional ultrasound elasticity imaging
Olalekan Babaniyi - Rochester Institute of Technology, USA
- P8** Reduction of shear wave phase errors using a single-block scan sequence in continuous shear wave elastography
Shunichiro Tanigawa - GE HealthCare, Japan,
- P9** The Impact of Acoustic Push Duration on Shear Wave Signal Quality
Fatemeh Mashayekhi - KU Leuven, Belgium
- P10** Mechanical properties of textiles investigated through wave propagation
Jiayuan Zhu - LabTAU, France
- P11** Viscoelastic characterization of polyacrylamide microbeads: cross-method comparison of atomic force microscopy and optical microelastography
Sajad Ghazavi - University of Montreal Hospital Research Center and University of Montreal, Canada
- P12** Evaluating Age Related Biomechanical Changes in the Psoas Major Following Spinal Manipulative Therapy Using Magnetic Resonance Elastography
Jonas Schmidt - Silkeborg Regional Hospital, Denmark
- P13** Genetic Correlates of Brain Mechanical Properties
Isa Rietveld - Kavli Institute of Systems Neuroscience, NTNU, Norway

- P14** Repeatability and reproducibility of 2D and 3D MRE at 1.5T and 3T in the liver of healthy volunteers
Owen White - The Royal Marsden NHS Foundation Trust and The Institute of Cancer Research, UK"
- P15** Thyroid MR Elastography for Small-Organ Viscoelastic Assessment
Jakob Schattenfroh - Charité - Universitätsmedizin Berlin, Germany
- P16** Longitudinal tabletop magnetic resonance elastography in a bioreactor for monitoring tissue mechanics
Meryhan M. Sallam - Charité - Universitätsmedizin Berlin, Germany
- P17** Inter-scanner reproducibility of multifrequency brain MRE
Simon Murk - Uniklinik Erlangen, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
- P18** Applications of Atomic Force Microscopy in Cardiac Micromechanics
Jing Zeng - Charité - Universitätsmedizin Berlin, Germany
- P19** LABOU: Iterative Laplace-Based Bi-Level Optimization Phase Unwrapping for MR Elastography
Michael Fedders - Charité - Universitätsmedizin Berlin, Germany
- P20** Improved Full-Waveform Inversion in Time-Harmonic Elastography
Mohamed Aziz Boukraa - University of Oslo, Norway
- P21** Physics-Informed Deep Learning for Rapid MR Elastography
Stefan Martin – Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany
- P22** System Identification for Magnetic Resonance Elastography
Hampus Moller - KTH Royal Institute of Technology, Sweden
- P23** Open-Source FEM Framework - MRE Phantom Simulations
Henrik Palme - KTH Royal Institute of Technology, Sweden
- P24** Viscoelastic tissue characterization using shear-wave focal spot imaging: numerical experiments
Goulven Le Moign - ISTERre, CNRS, Univ. Grenoble Alpes, France
- P25** Histology-inspired reconstruction and analysis of microscopic tissue structure using sonography: SonoHisto
Heiko Tzschaetzsch - Charité - Universitätsmedizin Berlin, Germany
- P26** Bubble dynamics in soft matter driven by Bjerknes forces generate shear waves
Antoine Penneron - Institute of Physics (IFP), Soft Matter, Germany
- P27** Experimental Detection of Tumor-Like Inclusions in Soft Tissue Using Torsional Wave Elastography
Yousef Almashakbeh - The Hashemite University, Jordan
- P28** Transverse Oscillation based Displacement Estimation in Ultrasound Time Harmonic Elastography
Chaoran Han - University of Oslo, Norway

Abstracts



Talks (T1 to T60) and Posters (P1-P29)

A Feasibility Study of 4-D Pulse Wave Imaging Using A Row-Column-Addressed Array

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Background, Motivation and Objective

Pulse wave imaging (PWI) is a non-invasive, high-frame-rate ultrasound elastographic technique for characterizing arterial mechanics that has conventionally utilized a 1-D transducer. However, volumetric imaging can offer a distinct advantage by capturing the full arterial geometry in all spatial dimensions (x, y, z) and time (t) through a single scan. The objective of this study is to investigate the feasibility of 4-D PWI using a row-column-addressed (RCA) array.

Statement of Contribution/Methods

A polyvinyl alcohol (PVA) phantom mimicking the common carotid artery (CCA) was built, embedded in gelatin, and connected at both ends to a pump that generated a physiological CCA blood flow waveform. A plane wave sequence with coherent compounding (7 angles per orientation, maximum steering angle of 10°, PRF = 7000 Hz) was implemented on the RCA array, which was connected to a Verasonics Vantage 256 acquisition system. In post-processing, the acquired data was beamformed and temporally linear interpolated by a factor of 6, achieving a frame rate of 3000 Hz. Semi-automatic segmentation was performed on the B-mode images to delineate the phantom wall. For each cross-sectional view, 16 points near the center were selected on the anterior and posterior walls, respectively (Fig. 1a). Axial displacements were estimated using a 1-D normalized cross-correlation, and a 3-D spatiotemporal map of axial wall velocity was generated by tracking the selected wall points (Fig. 1b). Pulse wave velocity (PWV) was computed via planar linear regression at the point of peak acceleration at end-diastole (Fig. 1c). To validation the phantom elastic modulus, nanoindentation was performed on a section of the PVA phantom, and a reference PWV was calculated from the measured Young's modulus using the modified Moens–Korteweg equation with $v = 0.5$.

Results/Discussion

Nanoindentation testing yielded a Young's modulus of 263.1 ± 56.6 kPa for the PVA phantom. The PWV estimated from the PWI RCA array scan (8.08 ± 0.62 m/s) showed good agreement with the PWV derived from nanoindentation via the modified Moens–Korteweg equation (8.23 ± 0.87 m/s) (Fig. 1d).

Conclusions

This study showed the potential of utilizing an RCA array for 4-D PWI. Ongoing work aims to validate the proposed 4-D PWI framework against the conventional 1D-system *in vivo* as well as investigate the sensitivity of 4D PWI in assessing different moduli in 3D and thereby anisotropies as well as mapping stiffnesses across distinct plaque constituencies.

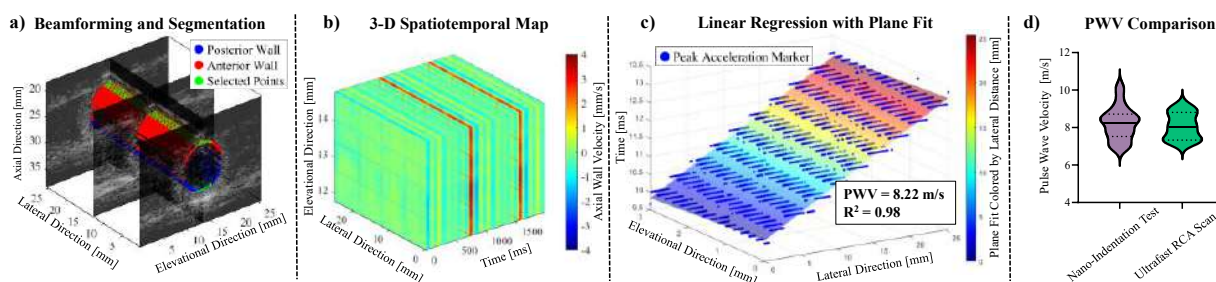


Fig. 1. a) RCA beamforming of the acquired data and segmentation of the B-mode volume. b) 3-D spatiotemporal map of axial wall velocity. c) Planar linear regression at the point of peak acceleration at end-diastole. d) Comparison of PWV estimated from the PWI RCA scan with that derived from nanoindentation via the modified Moens–Korteweg equation (solid line: mean; dashed line: quartiles).

Cardiac natural mechanical waves trajectories as a marker of tissue pathological state

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Background, Motivation and Objective

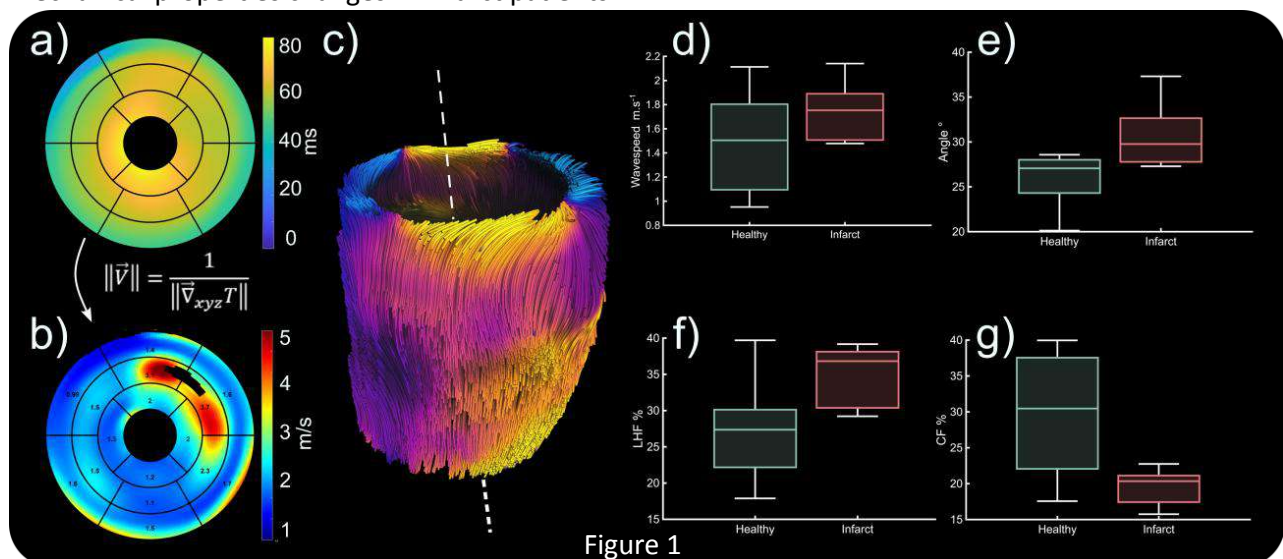
Many cardiac pathologies such as fibrosis, aortic valve stenosis or heart failure eventually lead to cardiac tissue rigidity and remodeling. Cardiac natural waves speed has been shown as marker of tissue stiffness in aortic stenosis and myocardial infarction. Using 3D high frame rate (HFR) ultrasound imaging we show that the atrial kick wave (AKW) speed and its trajectory can be used as myocardial infarction biomarkers.

Statement of Contribution/Methods

Using a 3D HFR imaging sequence implemented on a GE scanner, 6 infarct patients and 8 healthy volunteers LV were acquired at 800 V/s. Tissue displacements induced by the AKW were extracted using a clutter filter wave imaging. In the figure 1.a), a time of flight (TOF) map representing the arrival of the wave at each voxel was drawn from the passage of maximum tissue acceleration. In the figure 1. b), AKW speed was then estimated using a 3D gradient of this time of flight map. Finally, the wave trajectories are computed with DSI studio as the streamlines estimated on this 3D time of flight gradient. Figure 1. c) represents those streamlines and the colormap their helical angle with the base to apex axis.

Results/Discussion

In the figure 1. b) a focal high velocity area is present on this infarct patient. From figure 1. d), on average, AKW velocity is higher for infarct patients compared to healthy volunteers. From figure 1. e), the AKW trajectories also display a higher helical angle. Figure 1. f) displays a higher ratio of low angled trajectories, below a helical angle of 60° (CF) for healthy volunteers. The opposite trend is noticed figure 1. g) on highly left angled trajectories above 60°, suggesting that the AKW path is altered due to local mechanical properties changes in infarct patients.



Conclusions

The AKW speed and its trajectories across the LV are a promising marker for evaluating the cardiac tissue pathological state.

Cardiac shear wave elastography: echocardiography parameters influencing shear wave speed after mitral and aortic valve closure

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Background, Motivation and Objective

Cardiac shear wave elastography (SWE) uses ultrafast echocardiographic to assess myocardial stiffness via the propagation speed of shear waves (SW). SWs can be naturally generated after mitral valve closure (MVC) and aortic valve closure (AVC). While SW after MVC have been described, the determinants influencing SW speed after AVC remain poorly established and have not been directly compared between MVC and AVC generated waves. This study aims to identify independent echocardiography and demographic determinants of SW speed after MVC and AVC in a diverse cohort.

Statement of Contribution/Methods

A total of 116 subjects (age: 53 ± 15 years) were analyzed. The study included healthy volunteers and a diverse patient population. All subjects underwent a standard echocardiography evaluation and SWE measurements. In the parasternal long axis view, SW speeds were assessed by placing anatomical M-modes along the interventricular septum after MVC and AVC. Using tissue acceleration maps, SWs were visualized as tilted green bands, and their velocities were calculated from the slope in the spatiotemporal display. To identify variables associated with SW speed after MVC and AVC, univariate and multivariable linear regression analysis were performed incorporating a comprehensive range of conventional echocardiography parameters.

Results/Discussion

Several clinical parameters showed significant associations with SW speed in univariate analysis. In the multivariate models, independent predictors of SW after MVC included intraventricular septum thickness (IVSd), left atrial volume index (LAVI), early diastolic mitral annular tissue velocity (e'), heart rate, ejection fraction (EF), end-diastolic volume and isovolumetric contraction time (IVCT), mentioned in order of importance ($R = 0.88$). For SW after AVC, independent predictors in order of importance included LAVI, IVSd, global longitudinal strain (GLS), EF and isovolumetric relaxation time (IVRT) ($R = 0.76$).

Conclusions

The MVC-based SW model demonstrated higher explanatory power than the AVC model. SW speed after MVC was strongly influenced by markers of LV filling pressure (LAVI, e'), myocardial structure (IVSd), and systolic function (EF). Although comparable, AVC-related SWs showed fewer and weaker associations, suggesting a more complex or less robust physiological mechanism.

Ultrasonic Cavitation-induced Shear Wave Elastography

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Background, Motivation and Objective

The aim of this paper is to observe and study cavitation-induced shear wave (CSW) in the context of progressive tissue softening using ultrasonic cavitation.

Statement of Contribution/Methods

Analytically, we expect the incident wave on the cavitation cloud to generate a push similar to a radiation force of a point, showing a distinctive clover-shape pattern on the particular velocity map, characteristic of a dipolar source. Experimentally, four confocal transducers with a driving frequency of 1.1MHz powered by a 2kW pulser were used to nucleate cavitation in a 1% agarose phantom loaded with 0.5% glass beads. A high-speed phantom v12.1 camera was positioned to visualize bubble clouds. To capture CSW, ultrasonic B-mode were acquired at framerate of 2500 fps using a Verasonics Vantage system with an L7-4 probe. The B-mode images were post-processed using a phase tracking algorithm resulting in the time-varying particular velocity map. In a first experiment, we aimed at testing the reproducibility of the CSW generation. Then, the medium was exposed to cavitation from 1 to 10 min at multiple locations (N=3). CSW amplitudes were monitored before and after sonication using a single generated cloud. Passive shear wave elastography (PSWE) was also performed before and after to monitor SW velocity V_s .

Results/Discussion

Although bubble clouds varied in size and shape, SW were observed with a spherical front wave (Figure 1.(a)), consolidating our hypothesis that SW generation is mainly due to radiation force enhanced by bubble attenuation rather than a consequence from bubble cloud asymmetry. After cavitation exposure, no significant change in V_s was measured at target location using PSWE ($\sim 2.8 \text{ m.s}^{-1}$). However, the CSW amplitude seems to correlate ($R=0.98$ at 10min) with the exposure time (thus potentially the Young Modulus) (Figure 2.(b)).

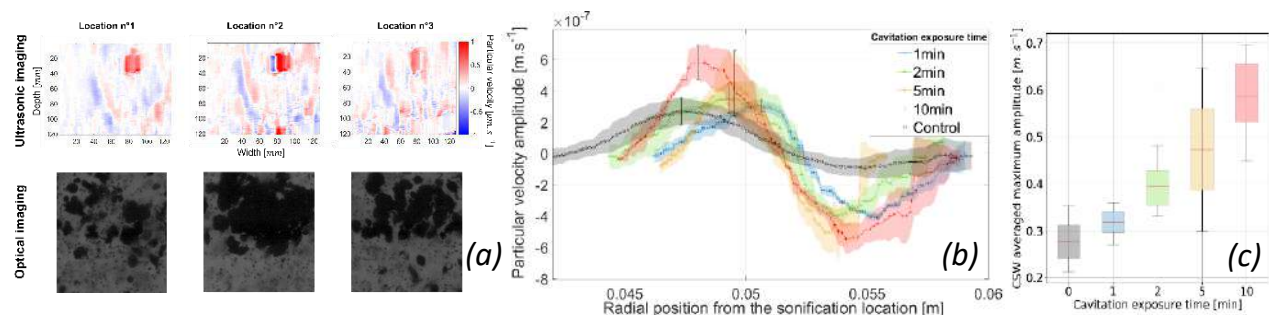


Figure 1 – (a) Velocity maps obtained through ultrasonic imaging and optical imaging of cavitation event, (b) 1D-CSW particular velocity for different cavitation exposure times and (c) Maximum values of particular velocity (red solid line refers to mean values and black error bars to standard deviation)

Conclusions

Those results suggest that CSW amplitude could be used as a proxy to monitor local tissue softening which open new perspective for ultrasonic treatment monitoring.

Cardiac-Resolved MRE Reveals Cerebral Stiffness Pulsation

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Background, Motivation and Objective

Cerebral arterial pulsation induces cyclic mechanical changes in brain tissue that reflect vascular compliance, a key determinant of cerebrovascular health¹. This study uses a novel 3D spiral, cardiac-resolved magnetic resonance elastography (MRE) sequence to quantify stiffness variations across the cardiac cycle and perform region-specific analyses based on time-of-flight-derived vascular segmentation.

Statement of Contribution/Methods

Fifteen healthy volunteers (age 30 ± 6.5 years) underwent MRE on a 3T Siemens Lumina scanner using a 3D spiral sequence to assess shear wave speed (SWS) across the cardiac cycle (60 ms temporal resolution). SWS maps were reconstructed using k-MDEV (BIOQIC-Apps)². Time-of-flight imaging enabled vessel-based analysis, and anterior cerebral artery flow was measured using single-slice 2D phase-contrast MRI.

Results/Discussion

Cardiac-resolved MRE showed cyclic stiffness variations that increased during systole and decreased during diastole (Fig. 1a), consistent with prior ultrasound elastography findings³. A vessel-centered stiffness gradient was observed, with a stronger effect during systole than diastole (Fig. 1b).

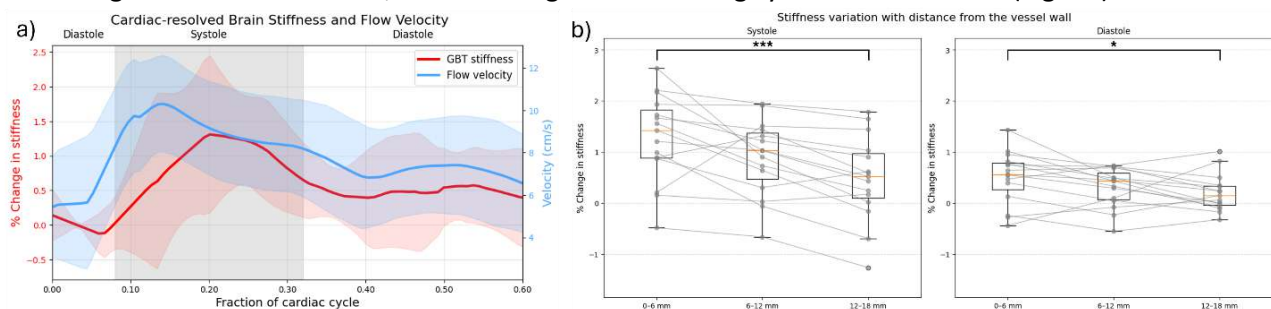


Figure 1. (a) Cardiac-resolved changes in global brain tissue (GBT) stiffness (red) and flow velocity (blue). (b) Stiffness vs. distance from vessel wall during systole and diastole. *** $p < 0.001$, * $p < 0.05$.

Conclusions

We demonstrate that cerebral stiffness pulsations are temporally and spatially linked to vascular dynamics, confirming previously reported ultrasound findings and supporting cardiac-resolved MRE as a non-invasive marker of cerebrovascular compliance.

[1] Adams et al., NMR Biomed., 2018

[2] Meyer et al., Magn. Res.Med., 2022

[3] Meyer et al., Front. Bioeng. Biotechnol., 2023

Effects of SNR and Tissue Displacement Amplitude on Cardiac MRE Stiffness Mapping

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Background, Motivation and Objective

Myocardial stiffness is a clinically relevant marker of cardiac function, yet its reliable quantification using Magnetic Resonance Elastography (MRE) remains challenging. We systematically characterize how signal-to-noise ratio (SNR) and mechanical vibration amplitude affect the stability and precision of cardiac stiffness estimates in vivo.

Statement of Contribution/Methods

Cardiac MRE was performed in 16 healthy volunteers using a spin-echo planar imaging sequence with 100 Hz vibrations. Effects of SNR and tissue displacement amplitude (A_{th}) on shear wave speed (SWS) reconstruction were evaluated. As a computational experiment, controlled noise was added to high-SNR reference to quantify SNR-dependent variability. Two acquisition conditions—with ('shake') and without ('no-shake') external vibration—were directly compared.

Results/Discussion

SWS estimates were sensitive to phase noise: low SNR and low A_{th} amplified noise during k-MDEV inversion, yielding lower and more variable SWS values relative to high-quality acquisitions. 'Shake' acquisitions consistently produced substantially higher A_{th} and more robust reconstruction than 'no-shake' case, which were dominated by physiological noise.

Conclusions

Reliable myocardial stiffness mapping requires sufficient SNR and harmonic amplitude. External mechanical excitation enhances robustness and consistency, facilitating bias-free quantification across the cardiac cycle.

Evidence for the ultra-soft brain provided by uniqueness in intrinsic MR elastography

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Background, Motivation and Objective

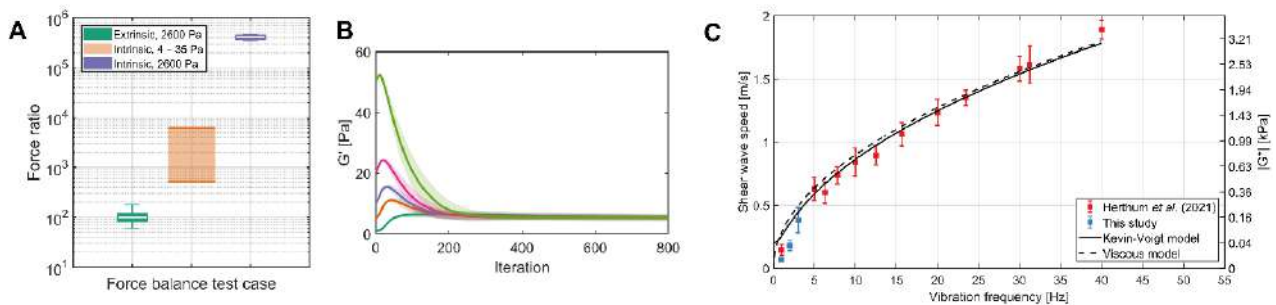
Intrinsic MRE (iMRE) suggests the living brain is ultra-soft (5–30 Pa), far below conventional MRE estimates (2–3 kPa). This challenges previous assumption that low-frequency viscoelastic inversion is non-unique, which has led to imposed stiffness bounds. **Objective:** To assess whether ultra-low stiffness restores elastic–inertial balance, enabling unique, stable inversion without imposed constraints.

Statement of Contribution/Methods

iMRE displacement data from 8 healthy subjects and conventional MRE data from 38 subjects were analyzed. Elastic-to-inertial force ratios were evaluated under three conditions: (1) conventional MRE (~2600 Pa, 50 Hz), (2) iMRE (4–35 Pa, ~1 Hz), and (3) low-frequency MRE with high stiffness assumptions (~2600 Pa, 1 Hz). Inversion stability was assessed across a range of initializations for storage and loss moduli. Frequency dependence was evaluated using harmonic motion components at ~1–3 Hz.

Results/Discussion

Ultra-low stiffness restores elastic–inertial balance, supporting uniqueness (Figure 1A). Inversion converged consistently without bounds, yielding stable stiffness estimates (Figure 1B). Recovered viscoelastic properties exhibited clear frequency dependence, with stiffness increasing at higher harmonics. Despite reduced signal-to-noise at higher frequencies, trends were consistent with prior literature, showing steep low-frequency dispersion. Deviations from viscoelastic predictions at low frequencies further support the relevance of poroelastic effects in this regime (Figure 1C).



Conclusions

iMRE enables unique, stable viscoelastic inversion without imposed stiffness bounds, supporting the view that the intact brain is ultra-soft and that its mechanical properties can be reliably quantified at low frequencies.

Feasibility of *in vivo* human kidney multifrequency DTI-MRE

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Background, Motivation and Objective

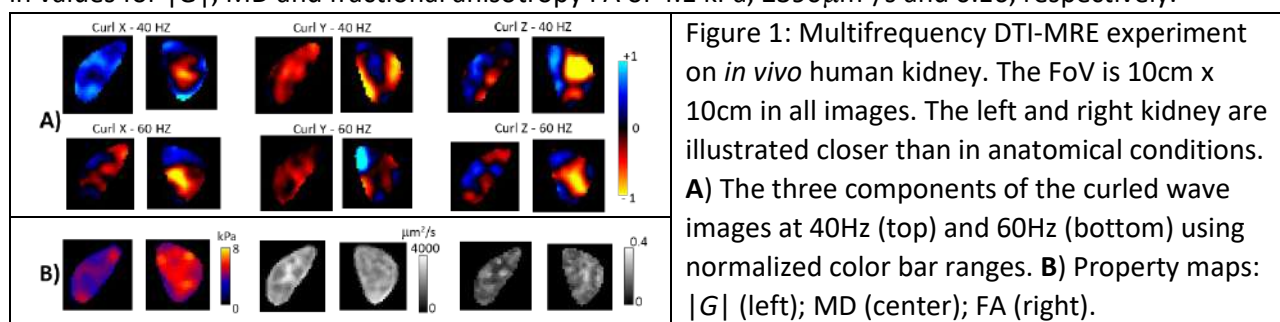
Chronic kidney disease (CKD) is characterized by progressive damage to the renal parenchyma and a gradual loss of renal function. Both DTI and MRE show promise for biomarker generation in CKD. Current evidence suggests that the techniques are both sensitive measures of microstructural integrity and provide overlapping but not identical information regarding the microstructural integrity of regions of the kidney cortex. This motivates a combination of the two techniques to advance the ability to detect disruptions of the microstructural environment of the kidney.

Statement of Contribution/Methods

Multifrequency (mf) DTI-MRE has already been applied to the *in vivo* human brain for concurrent DTI and MRE acquisitions using a modified SS-SE-EPI sequence. We translate the technique for *in vivo* human kidney applications using experimental parameters for diffusion and vibration encoding that are typical in conventional MRE (vibration frequencies f of 40 Hz; 60 Hz) and DTI of the kidney ($b = 407 \text{ s/mm}^2$; $b = 403 \text{ s/mm}^2$). The diffusion-attenuated images were acquired for 24 equally distributed directions and each of the parameter two sets (f/b) were linked to three directions for each of the four time instances.

Results/Discussion

An *in vivo* human kidney mfDTI-MRE experiment on a volunteer is shown in Figure 1. Longer wavelength structures are visible in the right kidney. Hence, the wave field inversion results in stiffness maps $|G|$ with slightly higher values in the right kidney. Interestingly, the opposite is observed for the mean diffusivity (MD), which appears higher in the left organ indicating that the well-known inverse relation between $|G|$ and MD in the liver also holds for kidney tissue. Spatial averaging over both kidneys in Figure 1.B results in values for $|G|$, MD and fractional anisotropy FA of 4.1 kPa, $2390 \mu\text{m}^2/\text{s}$ and 0.16, respectively.



Conclusions

Concurrent DTI and MRE acquisitions of the human kidney are feasible. Future work includes identifying the optimal experimental parameter ranges for data quality improvement of human kidney mfDTI-MRE.

Air-Jet based optical coherence elastography towards in-situ brain tumor delineation and fundamental tissue mechanical research

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Background, Motivation and Objective

Optical coherence elastography (OCE) has shown success in breast cancer delineation [1], we explore its use in brain tumor tissue analysis. Furthermore, present an *ex vivo* system that quantifies mechanical tissue properties in brain tumor biopsies. As well the first application and results of an *in-situ* system.

Statement of Contribution/Methods

The excitation system is a self-developed air-jet (200 ms duration at 70 μ N load)[2]. Displacement is measured by a 3.2 MHz optical coherence tomography system (OCT) [3]. Within the depth scan, Pixel-wise steady-state and dynamic mechanical properties are computed [4].

Results/Discussion

Key mechanical properties like stiffness, creep and relaxation are extracted and classified as elastic, ductile or viscous. Visualized through pixel-wise spider plots (Figure. 1 D.) for intuitive interpretation [4].

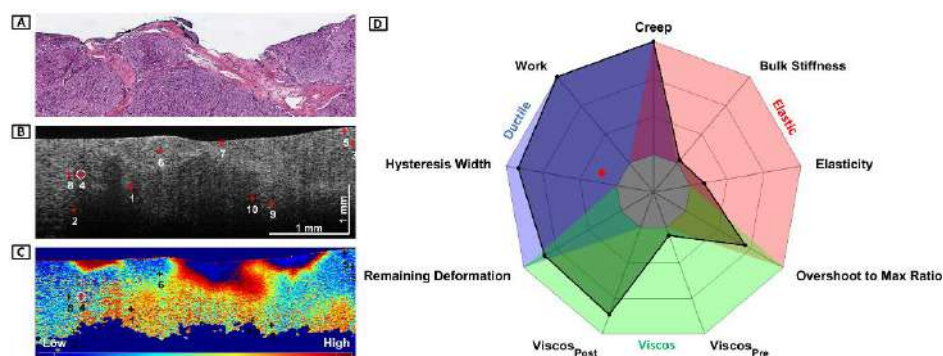


Figure 1: A) Sample histology meningioma (WHO Grade 2), B) OCT Intensity Scan, C) Bulk Stiffness map, D) Mechanical "Fingerprint" the distribution indicates that the sample is primarily ductile.

Conclusions

We demonstrate *ex vivo* the capability to measure and visualize critical mechanical parameters of brain tumor samples. This technique opens new avenues for investigating fundamental tissue mechanics with optical resolution. First *in-situ* results show the feasibility of the method but challenges remain.

1. K. M. Kennedy et al., [10.1038/srep15538](https://doi.org/10.1038/srep15538), 2. N. Detrez et al., [10.1109/TBME.2024.3484676](https://doi.org/10.1109/TBME.2024.3484676),
3. S. Burhan et al., [10.1364/BOE.510020](https://doi.org/10.1364/BOE.510020) 4. N. Detrez et al., [10.1364/BOE.584263](https://doi.org/10.1364/BOE.584263)

Heartbeat Optical Coherence Elastography for Assessment of Corneal Biomechanics

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Background, Motivation and Objective

Accurate quantification of corneal biomechanical properties is essential for understanding corneal function, improving the diagnosis of ectatic disorders such as keratoconus, and evaluating biomechanical outcomes of therapeutic procedures, including corneal crosslinking (CXL). Optical coherence elastography (OCE) has emerged as a promising modality for noninvasive biomechanical imaging of the cornea. Previously, we developed wave-based OCE methods that estimate corneal elastic properties from the propagation of mechanically induced elastic waves. However, these approaches remain limited by the need for external mechanical stimulation. In this work, we present heartbeat optical coherence elastography (Hb-OCE), a stimulation-free approach that uses intrinsic heartbeat-induced fluctuations in intraocular pressure (IOP) as a natural source of corneal deformation.

Statement of Contribution/Methods

In this study, we review our recent advances in corneal Hb-OCE. This approach was evaluated ex vivo in fresh rabbit and porcine corneas before and after CXL, in a keratoconus-like model, and in vivo in rabbit corneas. Corneal strain was measured using phase-sensitive spectral-domain OCT systems, while a custom-built closed-loop IOP control system was used to simulate IOP variations associated with the ocular pulse. Both whole and half corneal CXL were performed, enabling assessment of both global and localized stiffening. A keratoconus-like model was created using enzyme-mediated collagen degradation to induce a localized region of weakening, followed by crosslinking treatment to evaluate the ability of Hb-OCE to detect both softening and subsequent mechanical recovery. Finally, in vivo measurements were performed in rabbit corneas to assess feasibility under physiological conditions.

Results/Discussion

The results demonstrate that Hb-OCE can detect changes in corneal elastic behavior associated with IOP variation, localized weakening, crosslinking-induced stiffening, and spatial biomechanical heterogeneity. Standard CXL produced approximately a twofold increase in corneal stiffness in both ex vivo and in vivo models. By eliminating the need for external excitation, Hb-OCE simplifies system implementation and enhances translational potential, while also providing sensitivity to local mechanical contrast compared with conventional wave-based approaches.

Conclusions

These findings support Hb-OCE as a promising high-resolution, noninvasive approach for corneal elasticity imaging and as a potential tool for future clinical assessment of keratoconus and treatment response.

This study was supported by the National Institute of Health grant EY033978.

High frequency optical micro-elastography to image the temporal impact of inflammatory phenotypes on macrophage mechanics

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Background, Motivation and Objective

Macrophages play a crucial role in the immune response, and their mechanical properties influence adhesion, migration, activation, and phagocytosis. Lipopolysaccharide (LPS), a Toll-like receptor 4 (TLR4) agonist from Gram-negative bacteria, induces a pro-inflammatory phenotype in macrophages. Measurements of mechanical properties have shown that pro-inflammatory cues, including LPS and interferon-gamma, increase macrophage elasticity via actin polymerization and Rho-GTPase-dependent cytoskeletal reorganization. Moreover, LPS activation induces temporal changes in their mRNA, protein, and cytokine expression, suggesting that mechanical reorganization can also adapt over time. In this study, optical micro-elastography (OME) was used to assess temporal changes in the mechanical properties of macrophage-induced inflammation.

Statement of Contribution/Methods

OME has emerged as a powerful technique for mapping the viscoelastic properties of cells at high spatial and temporal resolutions, as validated in mouse spherical oocytes (~80 µm in diameter). Here, OME was used to map the high-resolution shear storage and loss moduli of individual macrophages (~20 µm in their long axis) at multiple time points after LPS stimulation, thereby capturing the spatially heterogeneous evolution of mechanical properties within cortical, cytoplasmic, and nuclear regions. This work presents quantitative assessments of viscoelastic properties of small adherent immune cells, specifically THP-1 (human leukemia monocytic cell line) derived macrophages, using OME at 60 kHz excitation.

Results/Discussion

Shear modulus was estimated at 0 hours (M0), 4 hours, 8 hours, 24 hours and 48 hours of LPS induction. The maximal effect was observed at 48 hours, with the storage modulus significantly increasing ~1.6-fold and ~1.5-fold for the nucleus and cytoplasm, respectively, after 48 hours of LPS activation, while the loss modulus increased ~1.4-fold for both cellular structures ($p < 0.05$). These findings reflect the time-dependent reorganization of the cytoskeletal architecture during inflammatory activation and provide a quantitative framework for studying immune cell function beyond conventional biochemical markers.

Conclusions

The effect of LPS-induced inflammation on the viscoelasticity of THP-1 macrophages over time has been determined using OME. This approach opens new avenues for investigating immune cell mechanobiology and offers potential for mechanical phenotyping as a complementary biomarker of inflammatory states.

Intracellular mechanophenotyping of macrophages: cytoskeletal contributions and senescence-associated changes revealed by optical microelastography

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Background, Motivation and Objective

Macrophage mechanical properties are tightly coupled to cytoskeletal architecture and cellular state, yet intracellular viscoelastic changes across these biologically distinct conditions remain poorly characterized. Conventional techniques, such as atomic force microscopy (AFM), mainly probe localized surface mechanics and cannot capture spatially heterogeneous intracellular mechanical behavior. Optical microelastography (OME) provides full-field maps of intracellular viscoelastic properties at high frequencies with subcellular resolution. Here, OME was used to uncover how intracellular mechanics are remodeled under cytoskeletal perturbations and cellular senescence.

Statement of Contribution/Methods

THP-1 cells, a human acute monocytic leukemia cell line, were differentiated into macrophages and subjected to two experimental protocols. Firstly, cytoskeletal and nuclear structures were selectively perturbed using Cytochalasin D (actin depolymerization), Nocodazole (microtubule disruption), and Trichostatin A (chromatin decondensation). Secondly, cellular senescence was induced by ionizing radiation (5 Gy) and confirmed using established senescence markers. OME was applied to map spatially resolved cytoplasmic and nuclear viscoelasticity using elastic wave propagation at 40 kHz, processed via a subzone nonlinear inversion (NLI). All results are reported as median values. Statistical comparisons were performed separately for storage and loss moduli in the cytoplasm and nucleus using Kruskal–Wallis test with Dunn's post hoc test and Sidak correction; all analyses were conducted in MATLAB (MathWorks, R2019b).

Results/Discussion

Cytoskeletal perturbations produced structure-specific mechanical changes. Actin depolymerization reduced cytoplasmic storage modulus G' by 0.68-fold to control ($p < 0.01$), indicating intracellular softening, while microtubule disruption increased cytoplasmic loss modulus G'' by 2-fold ($p < 0.01$), reflecting heightened viscous dissipation. Trichostatin A reduced nuclear storage modulus G' by 0.5-fold to control ($p < 0.001$). In contrast, senescent macrophages exhibited globally stiffer intracellular phenotypes, with cytoplasmic storage and loss moduli 2-fold and 1.5-fold higher than control, respectively ($p < 0.001$).

Conclusions

Optical microelastography uncovers full-field intracellular viscoelastic properties of macrophages, exposing distinct mechanical fingerprints driven by cytoskeletal remodeling and cellular senescence. This capability establishes OME as a powerful approach for mechanophenotyping of immune cells.

Cross-modality multifrequency neural network-based wave inversion

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Background, Motivation and Objective

Time harmonic elastography (THE) uses externally induced shear waves to quantify tissue stiffness across organs and modalities. Ill-posed inverse problems must be solved to reconstruct maps of tissue stiffness from encoded wave displacements. Acquiring multiple vibration frequencies can improve spatial resolution and robustness. However, the inversion requires modality-specific tuning and is typically performed separately for each frequency, underutilizing inter-frequency relationships.

Statement of Contribution/Methods

We present MF-ElastoNet¹, a fully multifrequency neural network wave inversion for THE by magnetic resonance elastography (MRE) and ultrasound elastography (USE), performing simultaneous reconstruction of all acquired frequencies. We trained a hierarchical vision transformer-based neural network on multifrequency 4x4 image patches of synthetically generated displacement wavefields for known viscoelastic material properties, assuming local material homogeneity. Once trained, it processes full images patch-wise, making it independent of image resolution, vibration frequency, and imaging modality, eliminating the need for modality-specific tuning or filtering. We compared our method with k-MDEV² and ElastoNet³, traditional and single-frequency neural network-based inversion methods.

Results/Discussion

We successfully demonstrated the performance of MF-ElastoNet in abdominal MRE *in vivo* data, focusing on the liver, spleen, as well as in liver USE *in vivo* data (Fig. 1). MF-ElastoNet achieved robust maps with high anatomical detail and was more robust to frequency-based quality variability.

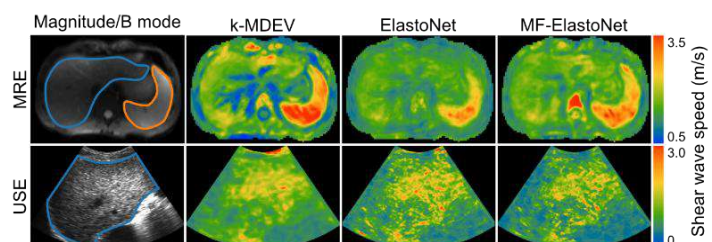


Figure 1: Comparison of liver (blue) and spleen (orange) MRE and USE shear wave speed map reconstructions between k-MDEV, ElastoNet, and MF-ElastoNet.

Conclusions

We presented MF-ElastoNet, a fully multifrequency neural network-based inversion for THE, enabling unified, accurate, and robust viscoelasticity reconstruction across the full field-of-view in MRE and USE.

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2. Tzschätzsch, H., et al.: Tomoelastography by multifrequency wave number recovery from time-harmonic propagating shear waves. Medical Image Analysis. 30, 1–10 (May 2016).
3. Bustin, H., et al.: ElastoNet: Neural network-based multicomponent MR elastography wave inversion with uncertainty quantification. Medical Image Analysis. 105, 103642 (Oct 2025).

Elastography of prestressed, heterogeneous and anisotropic viscoelastic materials: Inverse modeling challenges and strategies

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Background, Motivation and Objective

The functional role and structure of some biological tissues, such as skeletal muscle, results in anisotropy in both material properties and imposed stresses. Dynamic elastography reconstruction methods to estimate viscoelastic properties that assume isotropy and neglect the stress field will produce inaccurate estimates. The superposition of axially-aligned orthotropy (transverse isotropy) and uniaxial prestress due to passive loading or muscle activation makes it difficult to independently discern what part of the apparent anisotropy is due to material versus stress field anisotropy. Separating this would have clinical value, by differentiating changes in muscle tissue structure versus load conditions, both of which are uniquely affected by disease, injury and response to therapy. A differentiation strategy is introduced and evaluated with a series of in silico and experimental elastography studies.

Statement of Contribution/Methods

Shear wave motion is studied in a heterogeneous polymeric muscle phantom with transverse isotropic material properties subjected to uniaxial prestress that is not aligned with the axis of isotropy. Local geometric distortion of the acquired wave image is used to make the anisotropic problem appear isotropic. Helmholtz inversion of the isotropic problem is used to obtain baseline estimates of viscoelastic properties of the material. The geometric distortion map that was applied to the problem under different prestress conditions is then used to estimate the anisotropic and prestress conditions. This study expands upon our recent work (Vorobyeva et al. ITEC 2025) by considering local heterogeneities in material properties and uniaxial prestress not parallel to the axis of isotropy.

Results/Discussion & Conclusions

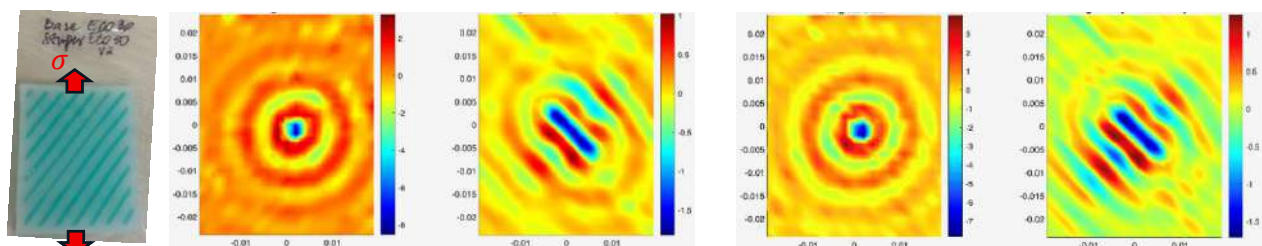


Figure 1. (a) Anisotropic phantom. Parallel fibers of a stiffer material (Ecoflex-50) embedded in softer matrix material (Ecoflex-30). (b-c) Wave motion measured by scanning laser Doppler vibrometry at 1000 Hz generated by rod inserted through the phantom oscillating normal to surface. No prestrain: $\sigma = 0$. Without/with directional filtering. (d-e) With 10% prestrain: $\sigma \neq 0$. Without/with directional filtering.

The reconstruction approach to decouple material anisotropy from stress field anisotropy works well for the controlled phantom study. Challenges and strategies for future in vivo adaptation are discussed.

Hybrid Convolution-Based Method for Inverting the Helmholtz Equation

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Background, Motivation, and Objective

Currently, time-harmonic elastography is performed using fast and direct inversion methods, such as phase gradient methods (PG) and algebraic Helmholtz inversion, among others. While these methods are efficient and provide robust global estimates, their accuracy can be compromised when searching for inclusions and discontinuities. The goal of this contribution is to develop a hybrid convolution-based inversion scheme, acting as an iterative refinement module coupled to the initial fast estimates to correct waveform artifacts, enhancing local sharpness in the shear modulus.

Methods

The proposed method estimates background tissue motion using wavenumber-based multi-PG inversion (k-MDEV). This, combined with a convolution-based integral inversion solves the Helmholtz equation without considering boundary conditions by sequential improvements of stiffness features.

Results/Discussion

Simulations show that the iterative convolution and filtering stage successfully removes noise at the edges. The algorithm achieves convergence by sequentially updating the stiffness matrix at intermediate iterations while purging high-energy noise.

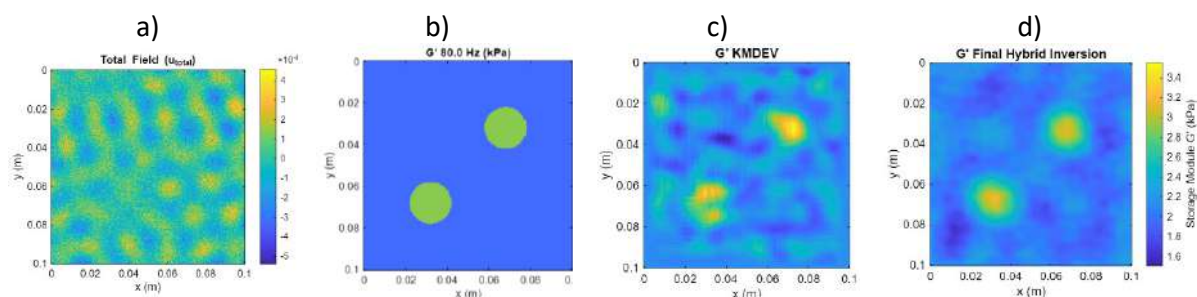


Figure 1. a) Simulated reverberant displacement field in a viscoelastic media with added noise. b) Simulated scalar field of the storage module. Estimated magnitude of the storage modulus using: c) KMDEV, and d) Hybrid Inversion.

Conclusions

Using hybrid convolution-based Helmholtz inversion as an iterative refinement allows combining the global robustness of traditional fast methods with the accuracy of iterative methods, providing a useful tool for stable recovery of viscoelastic properties in time-harmonic elastography.

Viscoelastic inversions from multifrequency shear wave data

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Background, Motivation and Objective

Kevin Parker dedicated many print pages to the topic of the rheological properties of soft tissues, and would by any measure be considered among, if not the, greatest scholar on soft tissue viscoelasticity. A favorite subject of his was the frequency dependence of the viscoelastic shear modulus. Creating a spatial map of viscoelastic properties of soft tissues presents many challenges. Among them are: (a) instability of the viscoelastic inversion problem; and (b) lack of a universally accepted viscoelastic model.

Statement of Contribution/Methods

Here we report our recent efforts to recover maps of the frequency dependent viscoelastic shear modulus. To do so we formulate an inverse problem in the frequency domain for loss and storage shear modulus. The problem may be stabilized by utilizing wave fields measured at multiple different frequencies, but at the loss of frequency resolution in the viscoelastic model. We base our analysis on an axisymmetric model suitable for wavefields excited by a compact indenter or by ARFI.

Results/Discussion/Conclusions

The inverse problem is quite ill-conditioned with a single wave field. The sensitivity is particularly apparent in the loss modulus field. The inverse problem may be stabilized by utilizing multiple wave fields, possibly at different frequencies. Combining measurements from multiple frequencies requires use of a (frequency) local viscoelastic model, and thus results in a loss in frequency resolution.

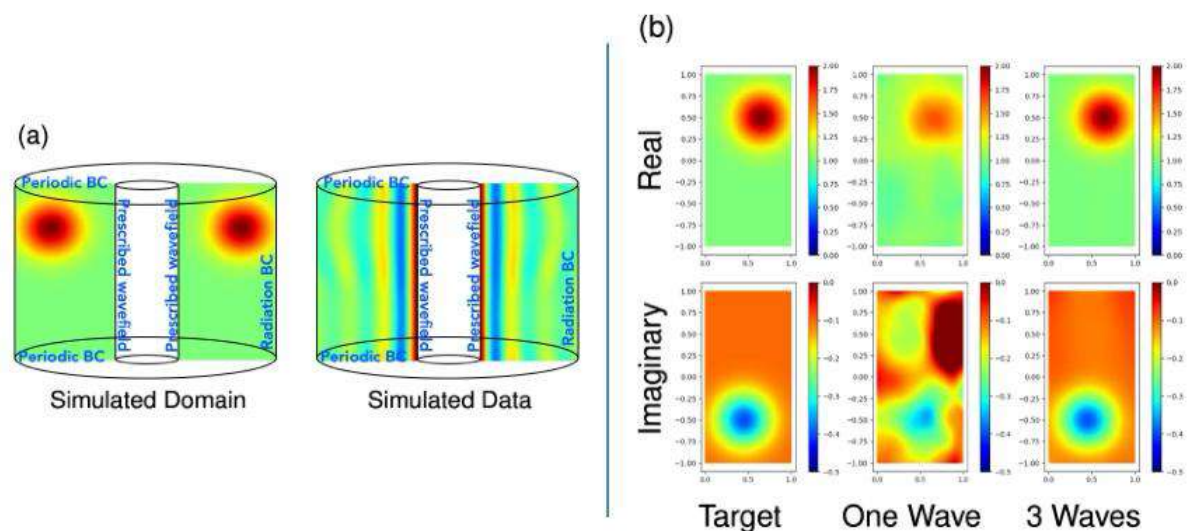


Figure 1. Simulated data and reconstructed storage and loss modulus fields. (a) Simulated axisymmetric domain. Computed shear wave fields resulting from excitation on inner cylinder provide simulated data for inverse-problem formulation. (b) Target storage and loss modulus fields and their reconstructions. With one wave as data, reconstructions are poor; combining data from several wave fields stabilizes the reconstruction and results in improved reconstructions.

Directional Clutter Filter Wave Imaging in Time Harmonic Elastography

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Background, Motivation and Objective

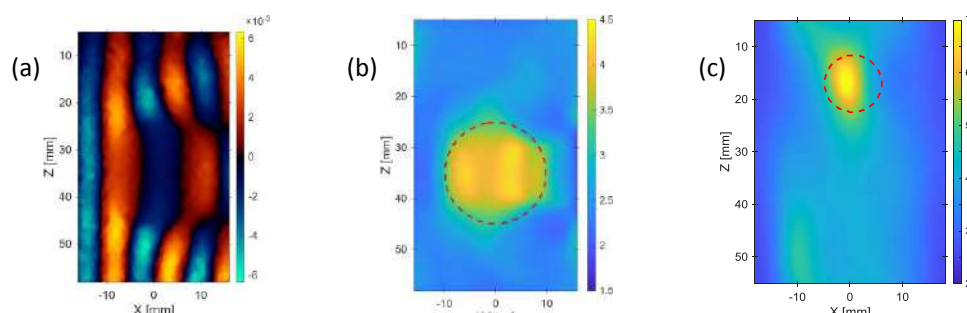
Clutter Filter Wave Imaging (CFWI) enables detection of mechanical waves and wave propagation velocity, with improved feasibility for myocardial wave assessment [1]. Directional CFWI (DCFWI) further enhances wave visualization by preserving the propagation direction in the estimated velocity field. However, its application has so far been limited to transient or natural waves. In this work, we investigate the feasibility of applying DCFWI for shear wave speed (SWS) estimation in time harmonic elastography (THE).

Statement of Contribution/Methods

Data acquired using plane wave transmissions were processed using DCFWI to estimate velocity signals. Harmonic vibration components were then extracted, followed by directional filtering to separate waves propagating in different directions. SWS was subsequently estimated using an autocorrelation-based method applied to the phase images [2].

Results/Discussion

The method was evaluated on simulated phantom data generated with Field II and k-Wave, and on experimental data recorded with an L7-4 probe ($f_0 = 4.46$ MHz, 3000 fps), at a vibration frequency of 200 Hz. The estimated displacement field and corresponding elastogram for simulation are shown in (a) and (b), respectively, with bias of -0.654 m/s (std: 0.189 m/s) in the inclusion and 0.166 m/s (std: 0.104 m/s) in the background. The experimental result obtained from an elasticity phantom is shown in (c), where the inclusion was successfully detected (highlighted by the dashed red circle).



Conclusions

The results demonstrate that DCFWI enables reliable velocity estimation for SWS imaging in THE. Future work will extend this approach to myocardial displacement estimation.

[1] Fiorentini, Stefano, et al. "Detection of natural mechanical waves in the heart using Directional Clutter Filter Wave Imaging (DCFWI)." 2023 IEEE International Ultrasonics Symposium (IUS). IEEE, 2023.

[2] Ziksari, Mahsa Sotoodeh, et al. "An Autocorrelation-Based Approach for Estimating Shear Wave Speed using 2D Velocity Vector." 2024 IEEE Ultrasonics, Ferroelectrics, and Frequency Control Joint Symposium (UFFC-JS). IEEE, 2024.

cancelled

Radial Energy–Quantile (REQ) Estimator for Robust Wavenumber Mapping Across Directional and Diffuse Wavefields

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Background, Motivation and Objective

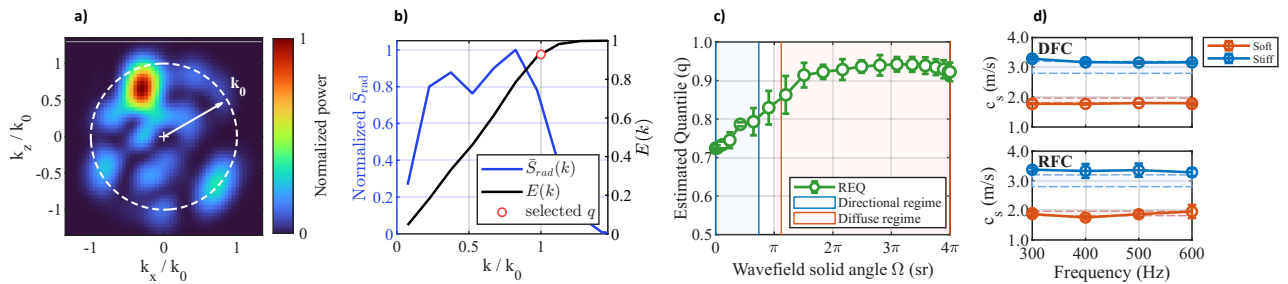
Harmonic shear wave elastography (HSWE) relies on local wavenumber estimation to recover shear wave speed maps. However, measured wavefields can range from directional to reverberant or diffuse, and many existing estimators are tailored to a single regime. This motivates a unified local estimator for partially diffuse HSWE wavefields.

Statement of Contribution/Methods

We propose the Radial Energy–Quantile (REQ) estimator, which computes wavenumber from the local radial power spectrum and cumulative energy, as shown in Figure 1(a,b). The selected quantile q defines the wavenumber used for shear-wave speed estimation. REQ is designed for directional and diffuse wavefields and is evaluated through controlled-aperture analysis and experimental HSWE datasets.

Results/Discussion

Figure 1(c) shows a systematic increase of the REQ quantile q with wavefield solid angle Ω , consistent with the directional-to-diffuse transition. Figure 1(d) shows experimental homogeneous phantom results under directional field configuration (DFC) and reverberant field configuration (RFC), with stable REQ-based shear-wave speed estimates across frequency for both soft and stiff phantoms.



REQ method and representative results across directional and diffuse wavefields. **(a)** Local normalized 2D power spectrum. **(b)** Radialized spectrum and cumulative energy used to select the quantile q . **(c)** REQ quantile q versus wavefield solid angle Ω . **(d)** Experimental REQ results in homogeneous phantoms under DFC and RFC.

Conclusions

REQ captures the directional-to-diffuse transition and yields stable shear-wave speed estimates under both controlled and experimental conditions. These results support its use as a robust estimator for HSWE.

Uncertainty Evaluation in Shear Wave Speed Measurements using ARFI Ultrasound Elastography

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Background, Motivation and Objective

Shear Wave Elastography (SWE) is a widely adopted ultrasound-based technique for quantifying tissue stiffness, a key biomarker in diagnosing conditions such as liver fibrosis and cancer. Central to SWE is the measurement of shear wave speed (SWS), which correlates with tissue elasticity and enables estimation of Young's modulus. However, SWS measurements are influenced by multiple sources of uncertainty, impacting clinical reliability and standardization efforts. This study systematically investigates uncertainty in SWS measurements using Acoustic Radiation Force Impulse (ARFI) technology implemented on a Verasonics research ultrasound system.

Methods

Experiments were conducted on four tissue-mimicking phantoms with known mechanical properties. Shear waves were generated using two ARFI approaches—focused push and unfocused comb-push—and tracked via plane-wave imaging. Displacement estimation employed the Kasai 1-D autocorrelator, complemented by filtering and cross-correlation algorithms to construct SWS maps. Young's modulus was derived under assumptions of isotropy and linear elasticity.

An uncertainty budget was developed in accordance with the Guide to the Expression of Uncertainty in Measurement (GUM), incorporating Type A (statistical) and Type B (systematic) contributions. Key factors included displacement estimator variance, speckle noise, temperature variation, beam position calibration, and ROI variability.

Results/Discussion

Results indicate an expanded uncertainty of 8% for SWS and 16% for Young's modulus, with dominant contributions from displacement estimation and region of interest dispersion. Statistical analysis confirmed that the measured values across different methods (focused push and comb-push) were consistent with the phantom nominal values within the uncertainty.

Conclusions

Findings highlight the importance of uncertainty quantification for SWE standardization and clinical adoption. The proposed framework aligns with QIBA (Quantitative Imaging Biomarkers Alliance) recommendations and IEC (International Electrotechnical Commission) standardization efforts, offering a baseline for phantom validation and inter-system comparisons. Future work should extend this study to phantoms with inclusions, where additional variability from tissue heterogeneity is expected. This research provides critical insights for improving the accuracy, reproducibility, and traceability of elastography measurements in diagnostic practice.

Flexural pulse wave velocity to unveil arterial wall tissue elasticity

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Background, Motivation and Objective

Cardiovascular diseases remain one of the leading causes of mortality worldwide, and arterial stiffness has emerged as a key biomarker for assessing vascular health and the early development of pathologies such as atherosclerosis. In clinical practice, arterial stiffness is commonly evaluated using pulse wave velocity (PWV). Although PWV provides a useful global indicator of vascular stiffness, it presents a lack of spatial resolution and provides limited information about the local mechanical behavior of arterial walls. However, another mode of propagation corresponding to flexural waves propagates along arteries. They are much slower and dispersive. We assume that they allow an accurate estimate of the arterial tissue elasticity. The objective is therefore to leverage flexural wave velocities in order to estimate and assess the elasticity of arterial walls.

Methods

Experiments are performed in vivo on different sites: carotid, brachial and femoral arteries. They have different mechanical and geometric properties requiring an adaptive imaging method. We propose to use L22-8v CMUT probe coupled with an open research ultrasound scanner Vantage 256 (Verasonics, Kirkland, USA) to estimate the arteries wall displacements at 500 frames per second. Wall displacements are estimated from complex IQ ultrasound data using a Kasai's phase-based motion estimator. Wave propagation is analyzed by separating symmetric and antisymmetric motion components derived from the dynamics of the upper and lower arterial walls. These components are related to guided wave propagation in the arterial wall, analogous to Lamb-type modes in thin structures, and exhibit distinct dispersion behaviors. Noise correlation algorithm are then used to obtain flexural wave phase velocities [1] ; allowing the application of Beam theory to estimate the Young modulus [2]

Results and Discussion

The proposed methodology has already been applied to the carotid artery. Ongoing work aims to extend this approach to other arterial sites, including for example, the femoral artery. Such comparative investigations will help identify which arteries provide the most relevant observations for the detection of vascular pathologies, while also contributing to a better understanding of the relationship between arterial stiffness and cardiovascular diseases.

Conclusions

This passive elastography framework provides a promising non-invasive approach for the local characterization of arterial biomechanics and may contribute to improved assessment of vascular stiffness beyond conventional PWV measurements.

- [1] G. Laloy-Borgna, L. Puyo, H. Nishino, M. Atlan, et S. Catheline, « Observation of natural flexural pulse waves in retinal and carotid arteries for wall elasticity estimation », *Sci. Adv.*, vol. 9, n° 25, p. eadf1783, juin 2023, doi: 10.1126/sciadv.adf1783.
- [2] S. Grégoire, G. Laloy-Borgna, J. Aichele, F. Lemoult, et S. Catheline, « Flexural pulse wave velocity in blood vessels », *J. Acoust. Soc. Am.*, vol. 155, n° 5, p. 2948- 2958, mai 2024, doi: 10.1121/10.0025855.

Assessing Pressure-Induced Stiffness and Volume Changes in Ex Vivo Kidney with Ultrasound and MRI

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Background, Motivation and Objective

Renal elastography measurements are affected by both intrinsic tissue stiffness and intrarenal pressure, limiting reliable differentiation of fibrosis and elevated pressure. To explore whether these influences can be separated, we assessed the sensitivity of ultrasound (US) and magnetic resonance imaging (MRI)-based modalities to pressure-induced changes in volume and stiffness in the ex vivo kidney.

Statement of Contribution/Methods

Six ex vivo porcine kidneys were pressurized through the renal artery (0-60 mmHg) with ligated renal vein and ureter (fig. 1a). Volume was approximated from cross-sectional areas of MRI T1-weighted images and US B-modes. Stiffness was assessed with US shear wave elastography (SWE; Canon Aplio i800), US time harmonic elastography (THE; GAMPTmbH), and MR elastography (MRE; 3T Siemens Lumina), as the shear wave speed (SWS) of waves induced acoustically (SWE) or by external vibration (THE & MRE; 60-80 Hz).

Results/Discussion

Kidney volumes are sensitive to pressure (Fig. 1b), with slopes of 0.23 and 0.15 cm²/mmHg and intercepts of 35.87 and 39.05 cm² for US and MRI (both $p < 1e-2$), respectively. SWS-pressure curves are displayed in Fig. 1d-f, with slopes of 0.02, 0.01, and 0.01 m/s/mmHg for SWE, THE, and MRE, respectively. While trends match between modalities, the kidneys show inter- and intra-variability, potentially attributable to differences in measurement locations, amongst other factors. Fig. 1c shows MRE maps at baseline and highest pressure, with visible increases in volume and stiffness.

Conclusions

We present preliminary results combining renal volume and stiffness measurements across controlled pressure levels using multiple imaging modalities. Consistent volume-pressure trends suggest volume may help separate stiffness from pressure effects, though SWS-pressure variability requires further research. Ongoing analyses of additional imaging modalities and shear wave characteristics aim to clarify the pressure-volume-stiffness relationship further.

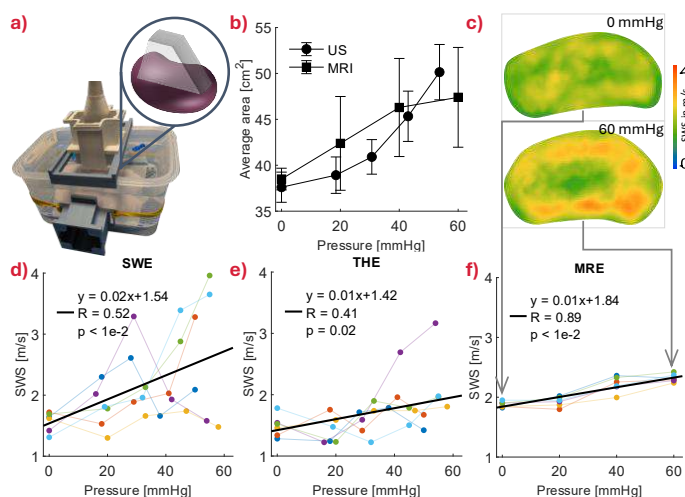


Figure 1. a) US measurement setup. b) pressure-induced volume changes. c) Representative MRE elastograms. d-f) SWS estimated with SWE, THE, and MRE, with added linear regressions results.

Blood Flow Restriction and Its Immediate Biomechanical Effects on Vastus Lateralis Muscle Assessed by Ultrasound Time-Harmonic Elastography

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Background, Motivation and Objective

Biomechanical properties of muscles can change in different physiological conditions, including voluntary contraction and haemodynamic changes induced by blood flow restriction (BFR). A systematic comparison of contraction and BFR by elastography is needed to understand their individual contributions to muscle stiffness. Therefore, we study the independent and superimposed effects of isometric contraction and passive BFR on vastus lateralis (VL) mechanics, using ultrasound time-harmonic elastography (THE) to simultaneously quantify elastic (shear wave speed, SWS) and viscous (penetration rate, PR) properties.

Statement of Contribution / Methods

Twenty-six healthy adults (25.0 ± 4.1 yr; 15 men, 11 women) underwent multi-frequency THE (60-80 Hz) under six conditions: rest and 15%, 30% maximal voluntary contraction (MVC) before BFR, resting during passive BFR at 4 min (80% arterial occlusion pressure), and 15%, 30% MVC within 20 s of cuff release. The k-MDEV algorithm extracted SWS and PR maps from the steady-state wavefield [1,2].

Results / Discussion

As shown in Fig. 1, isometric contraction produced a dose-dependent SWS increase and PR decrease under pre-BFR conditions (both $p < 0.001$). Passive BFR superimposed an additional SWS elevation and PR reduction on top of each contraction level (all Holm-corrected $p < 0.011$), demonstrating that haemodynamic and contractile contributions to muscle stiffness can be separated. The resting BFR-induced SWS rise ($+0.31$ m/s, $dz = 1.83$) without any change in voluntary contraction directly implicates non-contractile mechanisms. Men showed nearly a double resting BFR-induced SWS elevation compared to women ($+0.40$ vs. $+0.20$ m/s, $p = 0.008$).

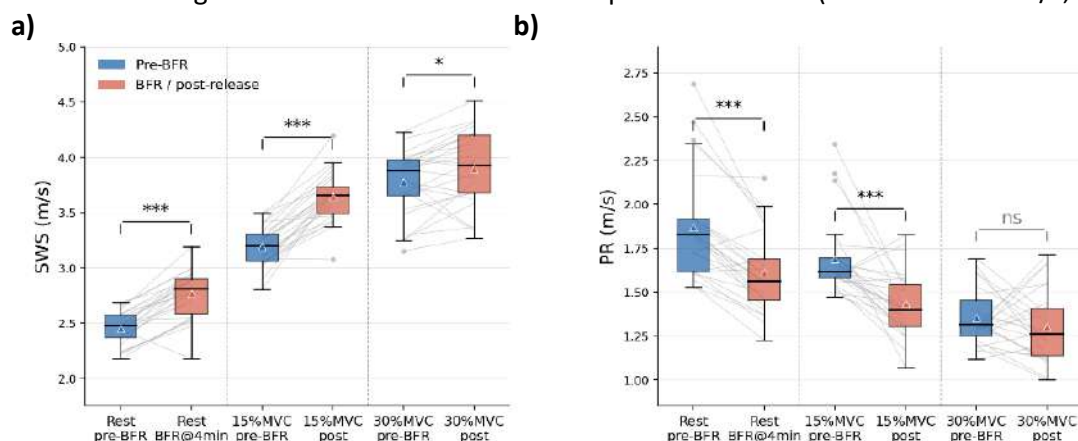


Fig 1a-b. (a) SWS and (b) PR across all six conditions. Box plots with individual trajectories. BFR elevated SWS and reduced PR at rest and both contraction levels (***) $p < 0.001$, (*) $p < 0.05$.

Conclusions

THE successfully disentangles the independent contributions of voluntary contraction and acute passive BFR to muscle viscoelasticity, revealing passive stiffening and condition-dependent viscous damping as separable haemodynamic components. Pronounced sex-specific differences further highlight the potential of THE for individualised monitoring in rehabilitation and sports science.

References: [1] <https://doi.org/10.1016/j.media.2016.01.001>. [2] <https://doi.org/10.1101/2025.09.30.25336813>.

Feasibility of Characterizing *in vivo* Skeletal Muscle as an Elastic ITI Medium Using High-Resolution Phase Velocity Estimation Algorithms in Arbitrarily Sampled Wavefields

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Background, Motivation and Objective

Ultrasound-based mechanical characterization of transversely isotropic tissues requires the measurement of shear wave velocity (SWV) along multiple trajectories relative to the material symmetry axis $\hat{A}$. To do this, our group has developed ultrasonic 3D rotational SWEI (3D-RSWEI), in which the group shear wave velocity (V_g) is measured along rotationally sampled rays perpendicular to the direction of the ARFI generated shear wave source $\vec{F}$ (Figs a and c). Though robust, measurements of V_g require strong assumptions about the geometry of $\vec{F}$, material homogeneity, and can require more complicated fitting schemes to relate V_g back to an assumed elastic incompressible transversely isotropic (ITI) material model.

Statement of Contribution/Methods

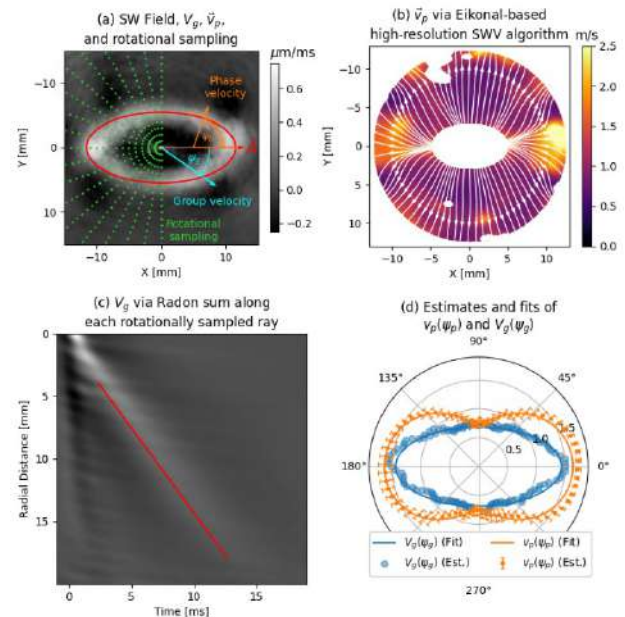
In this work, we use a high resolution Eikonal-wave equation-based algorithm to estimate the local direction dependent phase velocity $\vec{v}_p$ in rotationally sampled *in vivo* skeletal muscle data (Fig. b), using both the magnitude and trajectory of $\vec{v}_p$ at each point to fit the phase velocity elastic ITI material model. Following our current gold standard, V_g is estimated with a Radon sum (Fig. c) and compared to $\vec{v}_p$.

Results/Discussion

Fig. b shows the map of $\vec{v}_p$ within one plane perpendicular to $\vec{F}$. Fig. d shows V_g and $\vec{v}_p$ plotted as a function of ψ_g and ψ_p relative to $\hat{A}$. The values of $v_p(\psi_p = 0^\circ)$ exhibited a $13.5 \pm 3.8\%$ bias relative to $V_g(\psi_g = 0^\circ)$, and $v_p(\psi_p = 90^\circ)$ exhibited a $14.2 \pm 4.0\%$ bias relative to $V_g(\psi_g = 90^\circ)$. The inlier RMSE values of the fits of $V_g(\psi_g)$ and $v_p(\psi_p)$ averaged through depth were 0.08 ± 0.03 and 0.12 ± 0.02 m/s respectively.

Conclusions

These results show that our algorithm was able to directly estimate the direction dependent phase velocity in rotationally sampled coordinates with less than 20% bias and a similar model fitting error when compared to our current gold standard fitting approach. The feasibility of this technique supports potential future applications in simpler ITI model inversion techniques and the characterization of tissues exhibiting both heterogeneity and anisotropy.



Integrating *in vitro* and *in silico* approaches for natural shear wave elastography in the left ventricle to model valve closure

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Background, Motivation and Objective

Left ventricular (LV) myocardial stiffness is commonly increased in many cardiac diseases. Natural shear wave (SW) elastography enables non-invasive stiffness assessment by tracking SWs generated after e.g. mitral valve closure, but the mechanisms that affect SW excitation and propagation remain poorly understood. We combine *in vitro* and *in silico* methods to identify a simple yet high-fidelity model of valve closure for realistic SW generation, specifically focusing on the effect of excitation duration.

Statement of Contribution and Methods

A polyvinyl alcohol (PVA) phantom resembling LV geometry was imaged using high-frame-rate ultrasound while SWs were induced by dropping a marble onto the LV base (Fig. 1A). Marble mass and drop height were varied. In parallel, we developed a finite element LV model in Abaqus and varied the SW excitation in an analogous manner by adjusting the excitation duration. The *in silico* model reproduced healthy pressure-volume behavior and incorporated realistic myocardial tissue properties.

Results and Discussion

Experimental tests yielded a SW speed of 2.8 ± 0.1 m/s and a peak frequency of 79.5 ± 42.4 Hz (Fig. 1A), both consistent with values reported for *in vivo* natural SW elastography in the literature. Frequency increased with greater drop height and marble mass, while no clear trend was observed for SW speed. In contrast, SW speed decreased *in silico* (-24%) with longer excitation duration (Fig. 1B). Increasing the excitation duration in the simulations also led to a marked increase in wavelength (+ 63%).

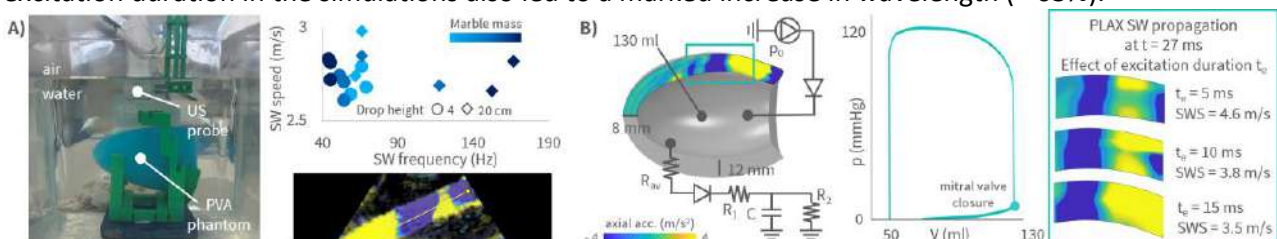


Fig. 1. Comparison between *in vitro* (A) and *in silico* (B) methods and results.

Conclusions

This study combines *in vitro* and *in silico* approaches to investigate how natural SW excitation influences SW propagation. Experiments identified realistic loading conditions for SW generation in terms of peak frequency and SW speed. Simulations complemented these findings, revealing a dependence of SW speed on excitation duration, and provide a framework for future natural SW elastography studies, including systematic exploration of factors such as force orientation relevant to valve closure modeling.

Modelling MR elastography to assess the impact of microstructural variation on brain tissue mechanics

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Background, Motivation and Objective

Magnetic resonance elastography (MRE) noninvasively measures brain stiffness but the link with the underlying microstructure is not well understood. This study investigates how advanced diffusion imaging parameters relate to brain stiffness by assessing the influence of microstructural variation (as provided by the diffusion imaging) on shear wave propagation.

Statement of Contribution/Methods

We simulate shear wave propagation as induced during MRE acquisition in a finite element (FE) model of brain tissue, which is considered poroelastic. To evaluate the effects of microstructural variation, different non-uniform distributions of isotropic and anisotropic material parameters are implemented, and the corresponding shear wave speeds and attenuations are calculated.

Results/Discussion

Figure 1 shows how attenuation depends on both the uniform distribution of Young's modulus and permeability (as predicted by analytical solutions) and their variation within the voxel (V_E and V_K).

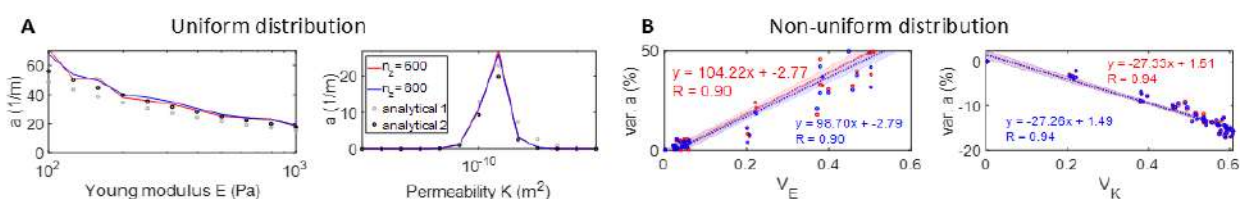


Figure 1. Shear wave attenuation (a) for two mesh densities (600, red, and 800, blue, elements in the wave propagation direction) in function of A) uniform Young's modulus and permeability and compared to two analytical solutions, and B) variance of Young's modulus (V_E) (with mean $\mu_E = 600$ Pa) and permeability (with mean $\mu_K = 1\text{E-}9$ m²).

Conclusions

The results indicate that voxel composition (i.e., spatial variation in material properties) affects shear wave attenuation. The decrease associated with the permeability distribution is in line with the reduction for higher and lower values of uniform permeability, while the increase with changing Young's modulus distribution may result from internal reflections due to steep material (Young's modulus) gradients.

Viscoelastic EXplicit Elastography (VEXEL): Shear Wave Simulation Platform for Fractional Models

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Background, Motivation and Objective

Biological tissues exhibit complex frequency-dependent attenuation and dispersion that deviate from purely elastic or simple viscous behaviors. These physics are most accurately captured using fractional derivative viscoelastic models. Despite the consensus on the importance of fractional rheology in tissue characterization, there is a lack of accessible simulation platforms that natively integrate these constitutive equations. Existing tools are often restricted to standard integer-order models. The objective of this work is to introduce VEXEL, a novel simulation platform developed to bridge this gap by providing a fast, dedicated, and user-friendly environment for modeling shear wave propagation under complex fractional viscoelastic assumptions.

Statement of Contribution/Methods

VEXEL is based on an 2D explicit finite-difference time-domain framework optimized for elastography applications. Users can switch between purely elastic, standard Kelvin-Voigt (KV), Kelvin-Voigt Fractional Derivative (KVFD), and spring-pot models to define tissue mechanics. The geometry editor supports the use of heterogeneous media, including inclusions. Both in-plane, with coupled p-waves, and out-of-plane cases can be simulated, with either steady-state or time-domain solvers. Multiple sources can be added, for example, to create a diffuse wave field. Absorbing boundary conditions are incorporated as Perfectly Matched Layers.

Results/Discussion

VEXEL demonstrates highly stable and computationally efficient simulations across all supported rheological configurations. This relies on specific mathematical formulations tailored to the simulated medium. When simulating heterogeneous tissues containing inclusions, to ensure accuracy at material interfaces, a harmonic mean of the complex shear modulus is applied to ensure stress continuity. The spatial step is determined by the highest simulation frequency, with a recommended Points-Per-Wavelength (PPW) parameter of 10 to 15 to minimize dispersion errors. The time step is dictated by the CFL condition. It is recommended to use $CFL < \frac{1}{\sqrt{8\xi}}$, where ξ represents the stiffness ratio between the inclusion and the background medium.

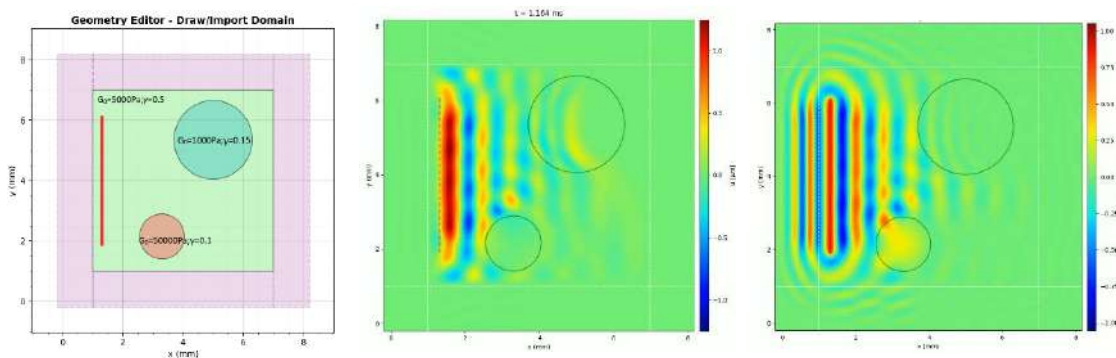


Figure: Example of out-of-plane simulations. The geometry editor generates the medium distribution. The time and steady-state solutions for the spring-pot model are plotted, respectively.

Conclusions

VEXEL is an accessible simulation platform for investigating viscoelastic tissue biomechanics. Future development will expand the platform's capabilities to include full 3D wave equation solvers and incorporate complex excitation patterns, such as Acoustic Radiation Force (ARF) impulses and vortex beams. $G_0=5000\text{Pa}; \gamma=0.5$

Ultrasound Elastography for the Assessment of Aortic Stiffness: Preliminary Findings

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Background, Motivation and Objective

Assessing aortic stiffness is critical for evaluating cardiovascular risk and early vascular aging. While methods such as pulse wave velocity are well-established, ultrasound elastography offers a direct, localized approach to quantifying aortic wall mechanics. The stiffness of the aortic wall shows differences between males and females. This study evaluates the feasibility of using ultrasound elastography with a custom portable vibration pillow to measure aortic stiffness in male and female participants. Our investigation on the use of elastography in aortic health and disease is part of a prospective monocentric study (<https://www.drks.de/DRKS00039426>).

Statement of Contribution/Methods

Twenty-one participants (11 female) were assessed. Multifrequency vibrations (60, 70, 80 Hz) were induced using a custom portable vibration pillow placed beneath the subject's back. A customized ultrasound scanner acquired sagittal views of the upper abdomen during breath-holds at a 100Hz frame rate. Measurements were obtained at the abdominal aorta during diastole. Time-resolved shear wave speed (SWS) maps were generated using k-MDEV inversion. These localized findings were compared to global PWV, measured via Arteriograph on the upper arm. Group comparisons utilized two-sided Welch's t-tests.

Results/Discussion

The technique was successfully performed in all 21 patients, proving viable for detecting aortic wall mechanics, though occasionally limited by patient habitus or vessel depth. There were no significant sex differences in SWS-derived parameters; mean SWS was identical between sexes (1.67 vs. 1.67 m/s, $p = 0.99$). Conversely, mean PWV was higher in females compared to males (8.59 vs. 7.38 m/s), demonstrating a trend toward statistical significance ($p = 0.058$). This observation remains, however, exploratory due to the small sample size and lack of adjustment for potential confounders such as age, body mass index, or cardiovascular risk factors, which was not performed. Additionally, multiple comparisons were not corrected for, increasing the risk of type I error.

Conclusions

Ultrasound elastography of the abdominal aorta using a portable vibration pillow is a feasible method for obtaining localized stiffness values. While SWS did not differ between sexes in this small cohort, the trend toward higher PWV in females warrants further investigation. Larger longitudinal studies are needed to adjust for confounders, establish normative reference values, and validate the technique's prognostic capabilities.

Towards intravascular elasticity measurements via a catheter with asynchronous optical coherence elastography

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Background, Motivation and Objective

Optical coherence tomography (OCT) enables minimally invasive imaging and is widely used in intravascular applications; however, it lacks the ability to quantify tissue mechanics. Shear wave optical coherence elastography (OCE) can provide this information but is difficult to implement in catheter-based systems due to scanning constraints and the need for phase-locked acquisition. This work aims to enable shear wave elastography in catheter-based OCT using asynchronous OCE (AsyncOCE), which is compatible with continuous scanning.

Statement of Contribution/Methods

We present the first demonstration of shear wave elastography in a catheter-based OCT system using AsyncOCE. This approach reconstructs coherent shear wave fields from continuously acquired scans without requiring repeated excitations. Shear waves were generated using a piezoelectric actuator, and signal processing included demodulation, correction for non-uniform rotation, and phase alignment in the pullback direction.

Results/Discussion

AsyncOCE enabled catheter-based visualization of shear waves in a tissue-mimicking phantom.

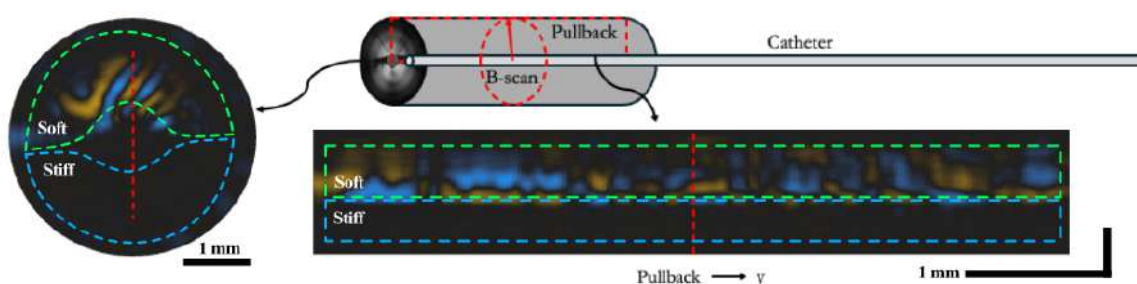


Figure 1. Shear wave B-scan and corresponding longitudinal reconstruction showing shear wave propagation predominantly in the soft region. Waves unable to propagate through air gap to stiff region.

Conclusions

This work establishes the feasibility of shear wave elastography in catheter-based OCT using AsyncOCE. Future work will focus on in vivo translation, optimization of volumetric imaging along the pullback direction, and comprehensive viscoelastic analysis of multi-frequency shear wave speeds.

Wide-field quantitative micro-elastography for the study of human prostate tissue

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Background, Motivation and Objective

In prostate cancer treatment, the development of new methods for improved diagnosis and reduced invasiveness is critical to improving survival rates while minimizing treatment-related adverse effects. In particular, there is a need for medical imaging solutions to guide clinicians during biopsy procedures and prostatectomy, enabling precise assessment of tumor stage and improved intraoperative decision-making.

Statement of Contribution/Methods

We evaluate the potential of quantitative micro-elastography (QME) for imaging human prostate tissue. QME is an extension of compression-based optical coherence elastography, providing mechanical contrast based on tissue elasticity. QME generates three-dimensional (3-D) maps of entire transverse cross-sections of freshly excised prostate tissue, including both healthy and cancerous regions, highlighting differences in scattering and mechanical properties and enabling co-registration with histological images.

Results/Discussion

The results show that, while the standard optical backscattered signal does not reliably distinguish tumor from benign tissue, the 3-D strain maps reveal a qualitatively different contrast, with the tumor region appearing stiffer than the surrounding benign tissue. Elasticity maps further enhance this differentiation by delineating regions of increased stiffness and providing quantitative measurements of local elasticity. Co-registration with standard histological images shows a high level of correlation in tumor localization.

Conclusions

QME provides additional contrast compared to conventional bright-field and optical coherence tomography imaging. Strain and elasticity images offer three-dimensional information on the mechanical properties of both benign and cancerous tissue, enabling tumor segmentation and demonstrating potential for clinical applications.

A phase-based volumetric elastography approach for ultrasound and MR

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Background, Motivation and Objective

Volumetric shear-wave elastography can reveal tissue mechanical structure beyond conventional imaging, but robust 3D spectral reconstruction remains challenging. This work extends phase-gradient elastography (PGE), previously introduced in 2D ultrasound [Comput Methods Programs Biomed, 260:108529, 2025], to a unified 3D framework for ultrasound and magnetic resonance elastography (MRE).

Statement of Contribution/Methods

The method extends 2D directional filtering to 3D spherical filtering and estimates the full wavevector from spatial efficient phase gradients to recover the full wavevector and local phase velocity. Validation included 3D ultrasound spherical inclusion simulations using a 7.6-MHz probe model with 32-element ARF and 100- μ s push, an MR abdomen phantom (30, 36, 42, 48 Hz), and one *in-vivo* head MR case acquired with an external shaker near the parotid gland (60, 90 and 120 Hz). The MRE datasets were compared with benchmark methods MDEV [Magn Reson Med, 71:267–277, 2014] and k-MDEV [Med Image Anal, 30:1–10, 2016].

Results/Discussion

In ultrasound simulations (Fig. 1a), volumetric PGE recovered stiff and soft inclusions with correct contrast. In the MR abdomen simulation (Fig. 1b), volumetric and slice-wise PGE reproduced the main stiffness patterns observed in the ground truth and agreed with k-MDEV. In *in-vivo* parotid data (Fig. 1c), PGE volumetric and slice-wise maps were consistent and exhibited higher parotid contrast compared to MDEV.

Conclusions

Volumetric PGE extends phase-gradient elastography to a unified 3D framework for ultrasound and MRE, enabling local phase-velocity imaging in both modalities and showing promise for structurally complex targets such as the parotid gland.

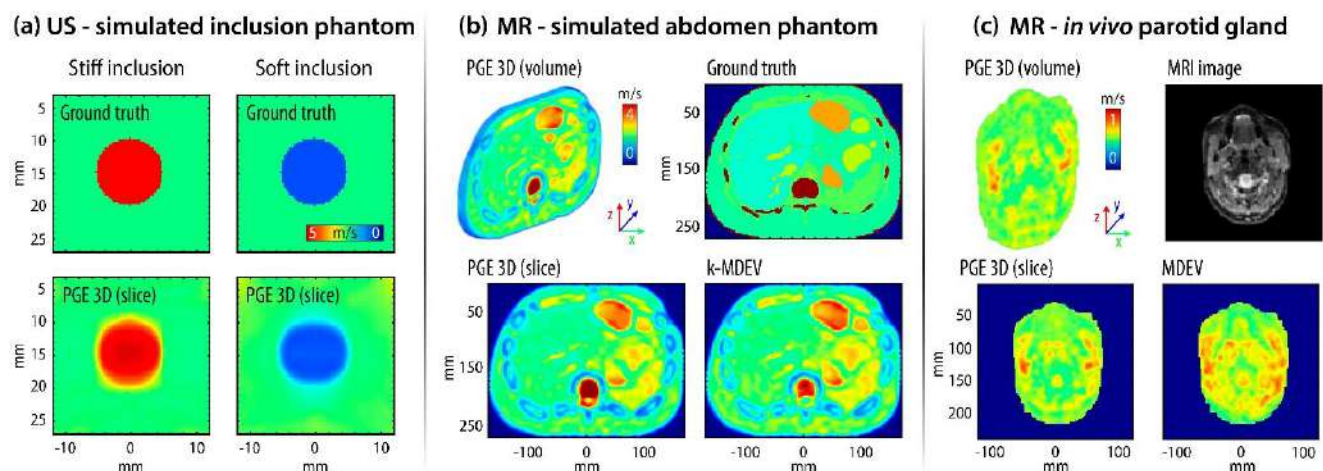


Figure 1. Volumetric PGE in ultrasound and MR. (a) Ultrasound simulated stiff and soft inclusions. (b) MR simulated abdomen phantom compared with ground truth and k-MDEV. (c) *In-vivo* parotid gland compared with MRI and MDEV.

An innovative magnetic resonance elastography setup to characterize *Klf10*-dependent skeletal muscle alterations in a novel murine model

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Background, Motivation and Objective. The *Klf10* gene is involved in the development and metabolism of human skeletal muscle (1,2). In the absence of the *Klf10* gene, the *in vitro* mechanical properties of the soleus and EDL muscles are altered (3). Studying muscle mechanical properties *in vivo* would provide a better understanding of this gene's impact across the entire musculature. The objective of the work is to develop a magnetic resonance elastography (MRE) protocol to quantify muscle shear modulus in mice that express (CTRL: *control*) or not (KO: *Knock-Out*) this gene.

Statement of Contribution/Methods. A new mouse model (skmKO), characterized by the specific inhibition of the *Klf10* gene in skeletal muscle, has been developed. Control animals from the same litters, expressing the *Klf10* gene, are also being studied. Our vibration device for preclinical multi-organ MRE (4) has been adapted for mouse muscles (Fig. 1A). It consists of 3D-printed subassemblies and a multilayer piezoelectric plate actuator synchronized with the MRI sequence. The muscles of the right hindlimb of CTRL (N = 8) and KO (N = 8) mice were imaged in two distinct positions (extended and flexed) using a 7T Bruker MRI scanner equipped with a surface coil (Ø10 mm) for reception and a volumetric coil (Ø86 mm) for transmission. The mice were anesthetized and continuously monitored. The MRI protocol was summarized Figure 1: (A) T2 RARE for positioning the field of view encompassing 2 muscle groups (ROI 1 & 2); (B) MRE RARE for elastography acquisition using sinusoidal motion encoding gradients (5). 4 phase images at 3 vibration frequencies (800 Hz, 1 kHz, 1.2 kHz) were acquired. After phase unwrapping, a local frequency estimation algorithm enabled the reconstruction of multi-slice shear modulus maps (Fig. 1B).

Results/Discussion. Shear modulus values were measured in two regions for two paw positions (Fig. 1A). The results showed no significant difference between the CTRL and KO cohorts in ROI 1, regardless of paw position, nor in ROI 2 when the paw was flexed. Conversely, a significant difference was observed in ROI 2 when the paw was extended (Fig. 1C). Gene inhibition increases muscle stiffness for this position.

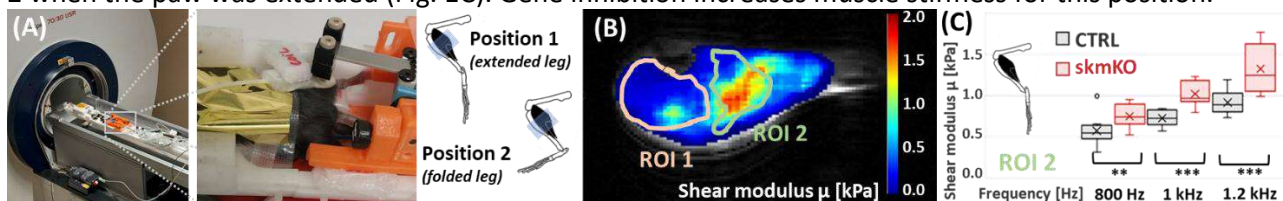


Figure 1. Experimental setup (A), shear modulus map (B), and results (C) obtained with MRE on KO and CTRL mouse muscles ($P < 0.05$, Wilcoxon-Mann-Whitney statistical tests).

Conclusions. This study presents an innovative device for mouse muscle assessment, applied to a *Klf10* knock-out model, and reveals *in vivo* muscle changes induced by the absence of *Klf10* gene expression, which significantly affect the mechanical properties of specific muscle groups under defined paw loading conditions.

References. 1. Subramaniam et al, *Nuc Ac Res* 23, 1995; 2. Kammoun et al, *Muscle Nerve* 64(6), 2021; 3. Tatarenko et al, *JMBBM*, 150, 2024; 4. Loumeaud et al, *Multidisc Biomech J* 14507, 2025; 5. Sango Solanas et al, *NMR Biomed* 34(2), 2021.

Acknowledgments. This work was funded by ITI HealthTech (2021–2028 University of Strasbourg, CNRS, Inserm), IdEx Unistra (ANR-10-IDEX-0002) and SFRI (ANR-20-SFRI-0012), ANR MyoClock (ANR-24-CE14-0066), France Life Imaging (ANR-11-INBS-0006), and the CNRS Institute of Engineering (INSIS).

Optimal Control MR Elastography in a murine model of hepatic iron overload: preliminary results

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Background, Motivation and Objective

Diagnosing liver fibrosis with MR Elastography (MRE) is particularly challenging in patients with hepatic iron overload, as signal loss often renders images unexploitable [1]. This is mainly due to the presence of motion encoding gradients (MEGs) in the classical MRE sequence, which increase echo time (TE) and worsen signal decay in short T2 tissues. To address this, we developed Optimal Control-based MRE (OC MRE) where motion encoding is achieved by the slice selective RF excitation pulse, enabling shorter TE and efficient encoding even in short T2 tissues [2-3]. OC MRE and classical MEG MRE images and stiffness quantification were compared on healthy mouse and a mouse with hepatic iron overload.

Statement of Contribution/Methods

One healthy mouse and one hepcidin-1 deficient mouse presenting hepatic iron overload were examined *in vivo* in accordance with ethical standards. Liver MRE acquisitions were performed using a classical RARE MEG sequence (MEG MRE) and an optimal control RARE sequence (OC MRE), where RF pulses generated via an optimal control algorithm simultaneously ensured slice selection and motion encoding. Acquisitions were made at excitation frequencies of 300 and 600 Hz, with identical acquisition times for both methods. Additional T2 and T2* mapping acquisitions were included to characterize relaxation times change associated with iron deposition. Shear storage modulus G' and SNR were measured on a ROI on the liver.

Results/Discussion

Measured transverse relaxation times were $T_2=24.7$ and 11.7 ms; $T_2^*=14.9$ and 2.6 ms on the healthy and the iron mice respectively. OC MRE acquisitions showed better SNR both on healthy mouse (90.9 vs 41.9) and hepcidin-1 deficient mouse (38.1 vs 11.7). Elastograms showed similar liver stiffness $G'_{300\text{Hz}}=2.1\pm0.2$ vs 2.2 ± 0.4 kPa, $G'_{600\text{Hz}}=3.9\pm0.7$ vs 4.0 ± 1.2 kPa for healthy and iron mouse, respectively.

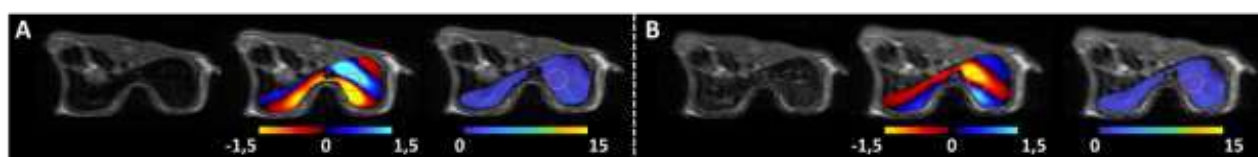


Figure 1. Magnitude, phase images and elastograms (kPa) on the hepatic iron overload mouse using both methods (A, MEG MRE; B, OC MRE)

Conclusions

OC MRE is validated for *in vivo* G' estimation in a mouse with hepatic iron overload, showing improved SNR compared to classical MEG MRE. In the presence of reduce signal decay, MEG MRE operates close to its sensitivity limits, whereas OC MRE remains reliable. A longitudinal study with more animals is ongoing.

References: 1) Ghoo et al., *QIMS*, 2019; 2) Van Reeth et al., 2018; *JMR*; 3) Sango-Solanas et al., 2021, *NMR*.
Acknowledgements: LABEX PRIMES (ANR 11 LBX 0063), PIONEER (ANR 22 CE19 0023 01), PILoT platform.

Seeing Prestress Distribution through MR Elastography

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Background, Motivation and Objective

Biomechanical conditions, such as boundary attachment and mechanical loading, are pervasive in organs and tissues. Soft biological tissues experience prestress, a state of internal stress that can serve as a critical indicator of tissue health and disease progression [1-2]. However, assessing these stress conditions in vivo remains a significant challenge [3]. In this study, we introduce a novel approach using magnetic resonance elastography (MRE) to evaluate stress conditions in soft biological tissues.

Statement of Contribution/Methods

Prestress-induced large deformations in hyperelastic biological tissues generate acoustoelastic effects [4], which manifest as pronounced variations in wave speed within superimposed low-amplitude shear waves. Building on analytical solutions for wave speed and polarization in hyperelastic materials under uniaxial tension [5], we integrated the TWE with a computational framework [6-7] to decompose complex wavefields into their constituent traveling waves.

Results/Discussion

Experimental studies involving a cylindrical gel phantom subjected to compression by a spherical object demonstrated strong consistency between experimentally measured and numerically simulated shear wave fields. This method not only facilitates the accurate estimation of elastic properties but also provides insights into the spatial variation of stretch rates (Figure 1).

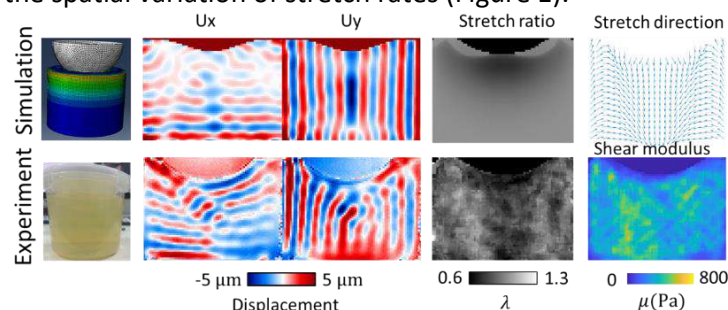


Figure 1. Simulated wavefield, heterogeneous stretch rate mapping λ , and stretch direction are presented alongside experimentally measured wavefield, recovered stretch rate λ , and shear modulus μ map.

Conclusions

The proposed method holds significant promise for advancing mechanobiology research and clinical applications, offering a comprehensive biomechanical assessment beyond traditional elastography.

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MR-Elastography for patients with pseudocirrhosis - a pilot comparison with healthy volunteers

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Background: Pseudocirrhosis is increasingly prevalent in patients with metastatic breast cancer (MBC) in the context of improved outcomes on contemporary systemic therapies, and may yield the risk of severe complications, including variceal bleeding, portal hypertension, and liver failure (Villani, 2022, Sci Rep). There are no established early detection or surveillance pathways. MRE is established for staging liver fibrosis (Yin, 2016, Radiology) and used for evaluating portal hypertension (Singh, 2021, Eur J Gastroenterol Hepatol). We hypothesise that MRE can identify a distinct biomechanical phenotype associated with pseudocirrhosis and may detect changes earlier than conventional imaging.

Objective: To evaluate the repeatability of 3D MRE in the liver of healthy volunteers at 1.5T using a gravitational MRE device, and report pilot data from an ongoing study in MBC patients with pseudocirrhosis.

Methods: Eight MBC patients with liver metastases (54-74 years, BMI range 22.6-35.0 kg/m²) were recruited, where 2-of-8 have pseudocirrhosis. MRE was performed at 60Hz using a Gravitational Transducer (Runge, 2019, Phys Med Biol) (Quality Electrodynamics, Mayfield OH, USA) on a 1.5T scanner (MAGNETOM Sola, Siemens Healthcare, Forchheim, Germany). 2D and 3D MRE was acquired alongside matched fat (PDFF), diffusion (ADC) and relaxation time (T₁, T₂) estimates in 15-minutes. A short-term repeatability study at 1.5T was performed in 11-exams of healthy volunteers (6/F, median 41 years, range 29-59, median BMI 22.5 kg/m², range 19.1-28.3 kg/m²), assessed using Bland-Altman analysis and the Repeatability Coefficient (RC) with 95% confidence interval (CI).

Results: Patients with pseudocirrhosis had elevated liver stiffness, and a distinctive heterogeneous appearance, compared to unaffected patients/volunteers (Fig. 1). The repeatability analysis at 1.5T showed no test-retest bias ($p=0.3$) with a RC of 13.3% (95%CI 10.6-19.9%) for $|G^*|$, 14.6% (95%CI 11.1-21.1) for G' , and 27.7% (95%CI 17.7-33.0) for G'' .

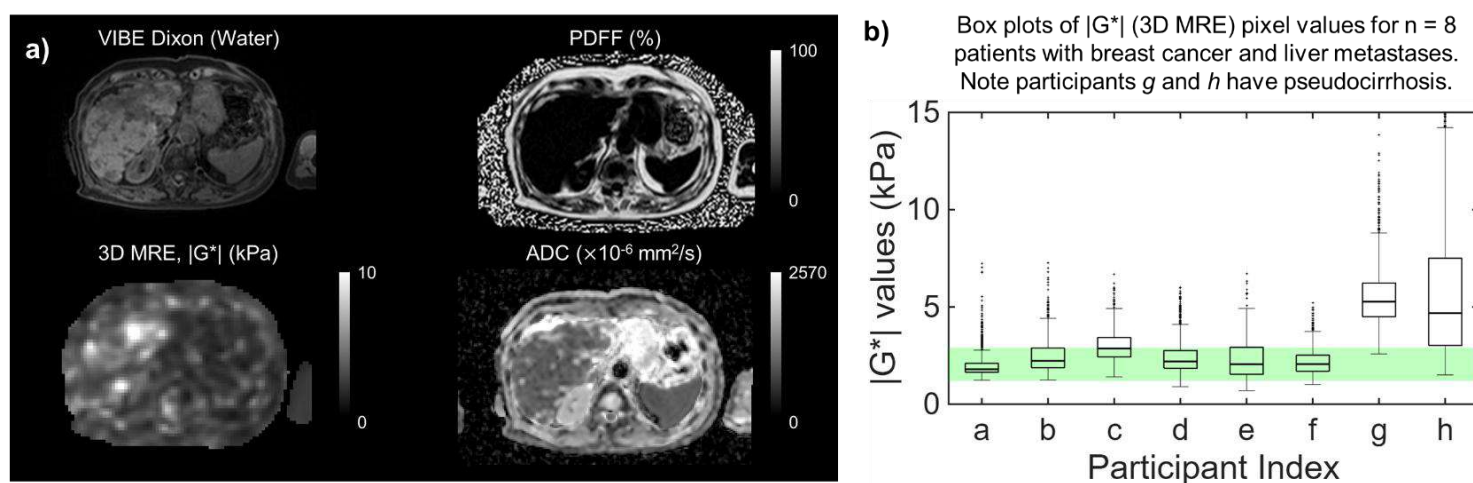


Fig 1: a) Example images from a 74-year-old patient with ER-positive HER2-negative metastatic breast cancer and pseudocirrhosis. **b)** See in-figure caption. The green shaded area shows the mean $|G^*| \pm 2$ standard deviations for 11 healthy volunteers.

Conclusion: MRE can be measured repeatably in the liver. These preliminary findings suggest that 3D MRE is feasible and may be able to detect biomechanical changes in MBC patients with pseudocirrhosis. Future studies should evaluate the utility of MRE for the early detection and monitoring of pseudocirrhotic changes.

Acknowledgements: We gratefully acknowledge QED (Mayfield, OH, USA) for the loan of the research prototype hardware and Software, and also Siemens Healthineers for their technical support and helpful discussions. This was a prospective, single-centre study approved by a national research ethics committee (ClinicalTrials.gov Identifier: NCT05118555). Consent was obtained from all participants. This project represents independent research funded by the National Institute for Health and Care Research (NIHR) Biomedical Research Centre at The Royal Marsden NHS Foundation Trust and The Institute of Cancer Research, London, by the Royal Marsden Cancer Charity, and Cancer Research UK (CRUK) National Cancer Imaging Trials Accelerator (NCITA). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. This work uses data provided by patients and collected by the NHS as part of their care and support.

Self-gating with compressed sensing enables free-breathing, ECG-free, time-efficient cardiac MR elastography in rats

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Background, Motivation and Objective

Cardiac MR elastography (cMRE) detects cardiac stiffness, but is time-consuming, requires long breath-holds, and is vulnerable to vibration-induced ECG artifacts. These challenges are amplified for rodents, rendering preclinical cMRE impractical for basic research. This work aims to meet these challenges by using self-gating (SG) and compressed sensing (CS) to create an ECG-free, time-efficient pulse sequence.

Methods

All experiments were performed on male Wistar rats at 9.4T (Agilent) using Paravision software (Bruker). A cartesian FLASH GRE cMRE sequence was modified to enable SG and CS. Every second read-out was acquired without phase encoding and used as a navigator. Cardiac and respiratory phases were extracted by principal component analysis and used to retrospectively bin acquisitions. For CS, an incoherent, Laplacian-distributed sampling scheme was used, and reconstruction was performed using a kt, soft-thresholding algorithm. Wave speed was estimated by the kMDEV inversion algorithm.

Results/Discussion

In a proof-of-concept experiment, navigators (Figure 1a) allowed for successful detection of cardiac and respiratory rhythms (b). After binning, this dataset was 16% filled. CS reconstruction was successful (approx. 6x acceleration). (c) and (d) show the magnitude and phase images, while (e) shows the elastogram. Scan time was 232s per MEG, while theoretical scan time with full sampling and ECG-gating was 527s. Reconstruction time was approx. 90s per MEG. Wave penetration was a current limitation.

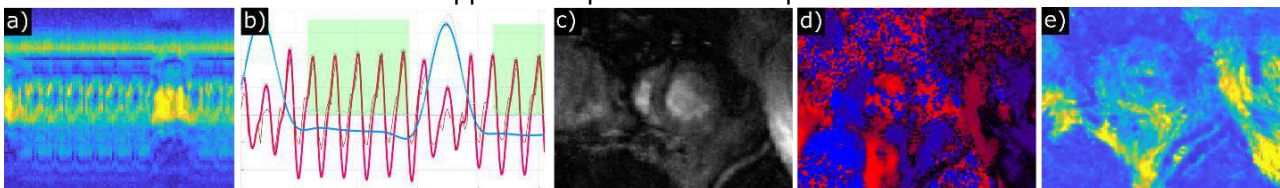


Figure 1: Proof of concept in one animal

Conclusions

The combination of SG and CS enables reliable, ECG-free cMRE acquisition in rats, while reducing scan time by >50%. The method could be translated to clinical research to enable accelerated and ECG-/breath-hold-free acquisitions. This would allow acquisition of more data, scanning in patients unable to perform breath-holds, and a more streamlined workflow by eliminating ECG setup. Future work includes improving the vibrational device, transitioning to a radial or spiral readout, and applying the method to disease models to elucidate the development of myocardial stiffness in relevant conditions.

Mechanical Phenotyping of Triple Negative Breast Cancer using Brillouin Microscopy and a Microtester Compression Technique

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Background, motivation and objectives

Recent advances in cancer diagnostic techniques have improved survival rates, prolonging patient life expectancy. Still, challenges persist due to the nonspecific symptoms, compromised sensitivity in cases of low tumor burden, drug dosages and treatment evaluation within the complex tumor microenvironment (TME). Accumulating evidence indicates that tumour progression and therapeutic resistance are influenced by tumor biomechanics (how stiff or soft the sample is), which respond sensitively to biochemical and physicochemical cues.^{1,2,3} Conventional techniques, used for analysis of micromechanics such as compression testing, rheology, elastography, atomic force microscopy (AFM), are either time-consuming or lead to sample destruction. This study explores the feasibility of a confocal Brillouin imaging as a novel technique for real-time, non-invasive and label-free tumour diagnostics by mechanical phenotyping of cancerous tissues and early prediction of chemotherapeutic responses to drugs, even before any physical shrinking or visible phenotypic changes occur.

Methods

In this work, we explore mechanical responses of triple negative breast cancer cell (MDA-MB-231) monolayers and spheroids to a common chemotherapy drug paclitaxel. The drug is known to arrest the cell cycle in G1 state, which is verified using Fucci reporters and confocal fluorescence imaging. The spheroids are grown using ultra-low-attachment plates to the size of approximately 250 μm in diameter. The drug is applied in concentrations between 1-25 nM to a treatment group, after which the samples are left in physiological conditions for 24-48 hours. The control group does not receive any drug. The mechanical properties of single cells and 3D spheroids are tested using Brillouin microscopy and MicroTester LT compression instrument (spheroids only). Each treatment group is tested at least 3 times to check repeatability and obtain statistical significance within the results.

Results and Discussion

The results indicate a significant softening (up to 50%) of treated spheroids as compared to control group at drug concentrations $\sim 6\text{-}10$ nM. Importantly, Brillouin microscopy is shown to have higher sensitivity to mechanical changes than MicroTester LT instrument, registering a significant softening in cell spheroids at lower concentration of ~ 3 nM. This result can be explained by a higher precision and 3D nature of Brillouin microscopy technique as compared to a standard compression test.

Conclusion

In conclusion, we analysed triple negative cancer cell responses to a standard chemotherapeutic drug, paclitaxel. The study suggests higher sensitivity of Brillouin microscopy technique to detecting small changes in mechanical responses of drug-treated samples compared to the bulk compression testing technique (MicroTester LT). This suggests a pathway to using Brillouin microscopy for assessment of mechanical tumour responses to drug application and pave the way for fast, personalised precision oncology.

References:

¹ Kabakova et al. Brillouin microscopy. *Nature Review Methods Primers* **2024**, 4, 8.

² Filipe et al. Tumor biomechanics alters metastatic dissemination of triple negative breast cancer via rewiring fatty acid metabolism. *Advanced Science* **2024**, 11(23), 2307963.

³ Hilai et al. Mechanical Evolution of Metastatic Cancer Cells in 3D Microenvironment. *Small* **2025**, 21(18), 2403242.

Mechanical characterization of endometrial patients-derived tumor organoids using optical micro-elastography

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Background, Motivation, and Objective

The tumor microenvironment (TME) has been known for several years for playing a key role in cancer development and progression. Several studies have shown that mechanical forces in those pathological tissues are modified during carcinogenesis, which is associated with an overall stiffer tissue than a healthy one. This increasing rigidity is also associated with a poor prognosis for patients. In our study, we are interested in characterizing the stiffness of endometrial cancer biopsy and associated patient-derived tumor organoids (PDTO), to characterize the TME in terms of stiffness, and correlate such stiffness with grades and therapy resistance.

Statement of Contribution/Methods

We used the optical micro-elastography to recover the stiffness of patients' endometrial cancer tissue biopsy and PDTO, a 3D cellular model recapitulating quite accurately the histological and molecular characteristics of the tumor. Briefly, after embedding our samples in agarose gel, we placed a piezoelectric actuator at the gel surface and generated shear waves that can propagate from the gel to the samples. A film recorded with an ultrafast camera and processed using phase tracking algorithms enables the extraction of elastic waves fields. Noise correlation algorithms give an estimation of group velocity and infer the samples' mechanical properties.

Results/Discussion

Our results show that, thanks to optical micro-elastography, it is possible to track elastic waves in biological tissues, such as endometrial cancer tumors and PDTOs. Even more interesting, high-grades PDTOs are found softer than low-grades ones. This finding is consistent with other studies, which have already shown that cancer cells are softer than healthy cells. We are currently investigating mechanical properties within fresh tumor tissue to correlate the value obtained with their PDTOs counterparts. As we used shear waves propagation to estimate the elasticity of our samples, unlike other quasi-static techniques, such as rheometry, optical micro-elastography permits us to have access to 2D mapping of stiffness *in situ*, for a wide range of sample sizes: from few centimeters (biopsy tissue) down to hundreds of micrometers (PDTOs).

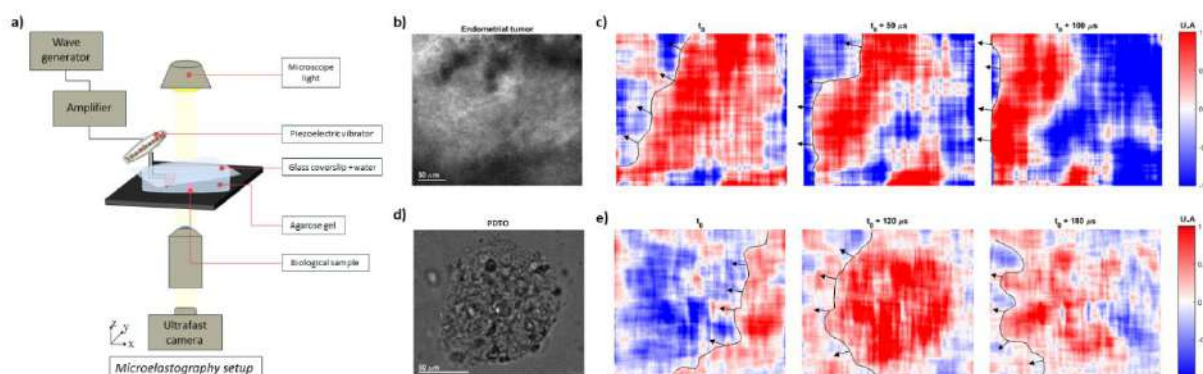


Figure 1: Elastic waves detection using optical micro-elastography in biological samples. **a)** Optical micro-elastography set-up (adapted from: Laloy-Borgna et al. 2020, Gr goire et al., unpublished). **b)** Brightfield image of EC biopsy. **c)** Displacement field from t_0 (arbitrarily defined), $t_0+50 \mu s$ and $t_0+100 \mu s$. **d)** Brightfield image of PDTO derived from the biopsy presented in b). **e)** Displacement field from t_0 (arbitrarily defined), $t_0+120 \mu s$ and $t_0+180 \mu s$.

Conclusions

In conclusion, our objective is to characterize and quantify mechanical properties in EC tumor biopsy to compare them to PDTOs. As we know that mechanics play a key role in carcinogenesis, this work will enable us to develop a mechanically relevant agarose-based platform for PDTOs, recapitulating the overall stiffness of the tumoral tissue.

Optical scanning tomography elastography: first experiences with a novel elastography method

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Background, Motivation and Objective

Elastography noninvasively estimates tissue mechanical properties but depends on accurate internal displacement fields, often limited by noise and imaging constraints. This work introduces a low-cost experimental platform to measure high-resolution 4D displacement fields in soft, transparent phantoms under harmonic loading, enabling improved elastography validation and development.

Statement of Contribution/Methods

This work combines Stationary Optical Scanning Tomography (S-OST) with Digital Volume Correlation (DVC) to measure high-resolution 4D displacement fields in soft, transparent phantoms under harmonic loading. Synchronized volumetric imaging, geometric correction, and optimized 3D DVC with harmonic projection enable robust displacement and strain estimation, followed by nonlinear inversion to reconstruct 3D maps of storage and loss moduli.

Results/Discussion

The Optical Scanning Tomography Elastography (OST-E) framework successfully measured 4D displacement fields in soft, transparent phantoms under harmonic loading, revealing smooth, periodic shear wave patterns. Homogeneous phantoms showed the expected frequency-dependent wave behavior, while heterogeneous phantoms exhibited pronounced wave variations at material interfaces and inclusions, demonstrating sensitivity to mechanical heterogeneities. The NLI-based reconstruction produced accurate 3D maps of shear stiffness and damping ratio, clearly distinguishing homogeneous, layered, and inclusion-containing phantoms.

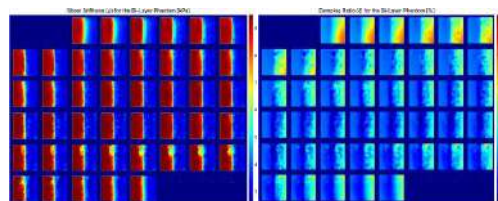


Figure 1. The shear stiffness (a) and damping ratio (b) distributions within a bi-layer phantom from OST-E

Conclusions

Overall, OST-E provides accurate, repeatable displacement measurements consistent with theory, offering a low-cost and flexible platform for validating and advancing elastography methods in complex viscoelastic phantoms.

Quantifying Corneal Biomechanical Alterations in Primate Models of Glaucoma and Form-Deprivation Myopia Using Optical Coherence Elastography

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Background, Motivation and Objectives

Glaucoma and myopia are among the most prevalent causes of irreversible visual impairment worldwide, yet early detection remains challenging because conventional diagnostic methods capture structural and refractive endpoints that emerge only after significant tissue damage has occurred. Emerging evidence implicates the cornea—beyond its refractive role—as an active participant in ocular disease progression through its mechanical coupling to intraocular pressure (IOP) regulation and scleral load distribution. Optical coherence elastography (OCE) offers a non-contact, high-resolution means of mapping tissue mechanical properties in vivo by tracking the propagation of mechanically induced elastic waves. In this study, we leveraged OCE to characterize corneal biomechanical changes in two complementary non-human primate models: experimentally induced ocular hypertension (a surrogate for open-angle glaucoma) and monocular form-deprivation anisometropia (a surrogate for axial myopia).

Statement of Contribution/Methods

Rhesus macaques (*Macaca mulatta*) were used across both studies under IACUC-approved protocols. In the glaucoma cohort, unilateral ocular hypertension was established via selective laser ablation of the trabecular meshwork; contralateral eyes served as within-subject controls. IOP was monitored by rebound tonometry and central corneal thickness (CCT) by optical coherence tomography. A wave-based OCE system delivered air-puff mechanical stimulation and captured elastic wave propagation with phase-sensitive OCT at high spatiotemporal resolution. Group velocity of the elastic wave was used as the primary surrogate for corneal stiffness. In the anisometropia cohort, five macaques with a history of monocular form-deprivation rearing underwent OCE alongside comprehensive ocular biometry (axial length, anterior segment parameters) and IOP measurement. Statistical comparisons were performed using paired t-tests and Pearson correlation, with significance set at $p < 0.05$.

Results/Discussion

Hypertensive glaucomatous eyes demonstrated significantly elevated elastic wave velocities relative to normotensive fellow eyes ($p < 0.01$), consistent with increased corneal stiffness. Importantly, this mechanical distinction persisted even after statistically accounting for IOP differences, suggesting intrinsic extracellular matrix remodeling rather than a purely pressure-driven effect. In the anisometropia cohort, form-deprived eyes with greater axial elongation exhibited higher corneal elastic wave speeds compared to fellow eyes, establishing a positive relationship between axial length and corneal stiffness. Neither IOP ($p = 0.78$) nor CCT ($p = 0.20$) differed significantly between deprived and fellow eyes, reinforcing that the observed mechanical changes are structurally and biomechanically distinct from classical confounders.

Conclusions

OCE-derived elastic wave velocity sensitively detects corneal biomechanical alterations in both glaucoma- and myopia-related primate models, independent of IOP and corneal thickness. These results support a model in which chronic mechanical stress—whether from sustained ocular hypertension or progressive axial elongation—drives collagen fibril reorganization and crosslinking changes in the corneal stroma. OCE therefore holds translational promise as a pre-structural biomarker for disease onset and progression monitoring. Ongoing investigations will pursue longitudinal tracking across disease stages and expanded cohorts to establish normative mechanical reference ranges and clinical decision thresholds.

HIFU-based Elasticity Mapping for Prostate Ablation Treatment

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Background, Motivation and Objective

Ultrasound (US)-guided high intensity focused ultrasound (HIFU) ablation for prostate cancer (PCa) relies on defining accurate tumor margins prior to treatment. Shear wave elastography (SWE) has demonstrated high accuracy in outlining stiff PCa tissue; however, endorectal SWE has a limited effective push depth due to small transducer geometry and lacks integration with clinical HIFU devices. The objective of this study was to evaluate the feasibility of pre-treatment SWE tissue mapping based on HIFU push in tissue-mimicking phantoms.

Statement of Contribution/Methods

Two HIFU-push methods of 2D SWE were implemented using a 1.6 MHz 128-element transrectal HIFU array (Sonic Concepts) integrated with a coaxial US imaging probe (Vermon CLA7.5). The first method used a localized push at HIFU focus, which launched a longitudinal shear wave (LSW) propagating along the HIFU axis and tracked by pulses from the imaging probe. The second method used single-track approach: multiple cylindrically shaped pushes generated laterally propagating shear waves detected at a central imaging ray line. Both methods use normalized cross-correlation of the measured shear wave profiles to obtain shear wave distribution, and were tested in homogenous tissue-mimicking gels (6% to 10% polyvinyl alcohol, 6% Al₂O₃ powder), commercial elastic phantom with cylindrical inclusions (CIRS) and human prostatectomy specimens. The measurements were validated by comparison with a clinical SWE imaging system (SSI Aixplorer).

Results/Discussion

For both push methods, the mean elastic moduli of the homogenous phantoms within the range from 7 to 50 kPa and the stiff inclusion in the commercial elastic phantom agreed well those measured by the clinical SWE system. The single-track method displays better axial resolution than the LSW method, but the LSW method was less susceptible to reverb resulting from the inflated water balloon used for coupling.

Conclusions

The results suggest that both methods of HIFU-based SWE are feasible for quantitative mapping of tissue elasticity preceding endorectal HIFU ablation of prostate cancer. This work was supported by NIH R01CA258581.

In vivo quantification of tensile elasticity and anisotropy of human peripheral nerves using angle-resolved shear wave elastography

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Background, Motivation and Objective

Neuroelectronic devices and tissue-engineered constructs targeting the peripheral nervous system have emerged as promising strategies to restore, replace, or modulate neural function; but require mechanically compliant interfaces to match native nerve tissue. Despite the advent of soft and compliant biomaterials, the in vivo mechanical behavior of anisotropic nerve tissue remains poorly understood.

Statement of Contribution/Methods

Here we combine angle-resolved ultrasound shear wave elastography with a dual-orientation acquisition protocol to non-invasively and non-destructively characterize shear and tensile elasticity and anisotropy of human nerves in vivo. Measurements were conducted on the median nerve of eleven healthy young adults during physiological axial loading (Fig. 1a). Data were acquired using an ultrafast ultrasound scanner (Mach30, Supersonic Imagine) and a 7.5 MHz linear transducer array (SL18-5, 256 elements).

Results/Discussion

We describe the along- and cross-nerve fiber shear and Young's moduli and anisotropy ratios during progressive nerve loading (Fig. 1b-d). We demonstrate that nerves exhibit strongly anisotropic and load-dependent mechanical behavior. The along-nerve shear and tensile moduli increased with nerve loading, whereas cross-fiber moduli remained relatively unchanged. Tensile and shear moduli along-nerve fibers were found to be independent, while cross-nerve fiber moduli exhibited a consistent ratio of 3.9 ± 0.04 . The shear anisotropy was significantly greater than the tensile anisotropy under loading conditions.

Conclusions

These findings provide the most comprehensive in vivo mechanical characterization of human nerves; and demonstrate the value of angle-resolved elastography for quantifying the key elastic mechanical properties relevant to the design of biomimetic materials for neuroregenerative strategies, with potential applications in the clinical diagnosis of peripheral neuropathies and in advancing the understanding of nervous system mechanobiology.

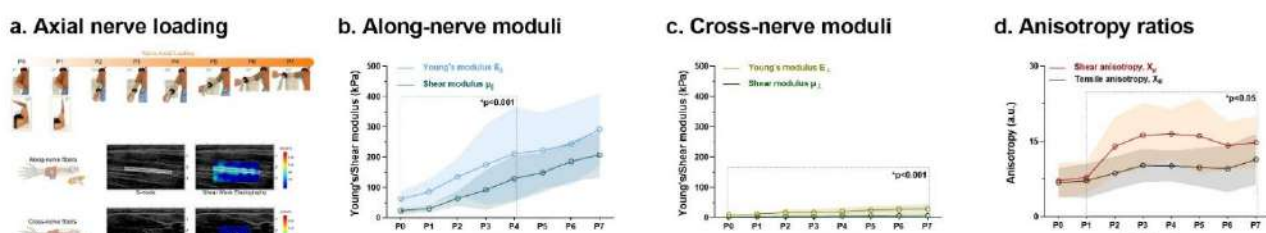


Figure 1. (a) Upper limb positions used for along- and cross-nerve fiber ultrasound acquisitions, with axial nerve loading increasing from P0 to P7; (b, c) shear and Young's moduli measured along and across nerve fibers; (d) tensile and shear anisotropy as a function of axial nerve load.

Multiparametric Ultrasound Time-Harmonic Elastography for Characterization of Focal Liver Lesions

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Background, Motivation and Objective

Tumor malignancy is associated with alterations in tissue mechanical properties. It has been argued that tumor growth and cancer cell motility are promoted by increased viscosity of the tumor environment and reflected by the mechanical heterogeneity of the tumor that reflects the coexisting soft and rigid regions (Sauer et al. Advanced Science 2023). Ultrasound-based time harmonic elastography (THE) enables noninvasive spatially resolved in vivo viscoelastic profiling with large organ coverage and may therefore serve as a diagnostic tool for liver tumor malignancy.

Statement of Contribution/Methods

84 patients with focal liver lesions (41 benign, 39 malignant; 45 women; age range 30–87 years) underwent multiparametric THE. Multifrequency vibrations (27–56 Hz) were induced via a custom portable vibration pillow and data was acquired during a 1 s breath hold. Tumor stiffness (shear wave speed; SWS), viscosity (loss angle; ϕ), and mechanical heterogeneity (SWS-SD) were calculated using k-MDEV inversion (Tzschätzsch et al., Med Imag Anal., 2016) with Andersson gradients (Anderssen and Hegeland, Mathematics of Computation 1999) for improved noise robustness.

Results/Discussion

Malignant tumors exhibited higher mechanical heterogeneity (SWS-SD: 0.41 ± 0.20 vs. 0.28 ± 0.11 m/s) and elevated habitat viscosity (ϕ : 0.76 ± 0.09 vs. 0.71 ± 0.05 rad). Combined, the markers achieve excellent diagnostic accuracy for differentiating tumor malignancy with an AUC=0.88 for tumors ≥ 2.5 cm² and AUC=0.97 for ≥ 6 cm².

Conclusions

Multiparametric THE differentiated malignant from benign liver lesions by measuring elevated viscosity in the surrounding tumor habitat and increased tumor mechanical heterogeneity. THE is a rapid and cost-effective tool for viscoelastic profiling of liver tumors in clinical imaging.

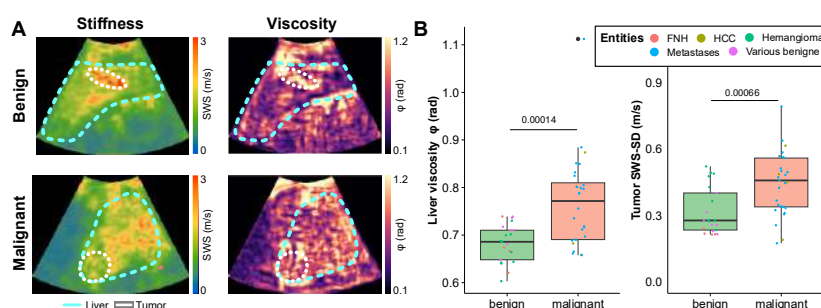


Figure 1: Representative stiffness and viscosity maps for a malignant and benign lesion (A). Boxplots showing the differentiation between malignant and benign tumors by surrounding liver viscosity and tumor stiffness heterogeneity.

Non-Invasive Electromechanical Wave Velocity Mapping for Functional Substrate Characterization in Ischemic and Non-Ischemic Cardiomyopathy

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Background, Motivation and Objective

Electromechanical Wave Imaging (EWI) enables noninvasive mapping of cardiac electromechanical (EM) activation from high-frame-rate ultrasound. While EWI provides activation isochrones, it does not directly estimate EM wave propagation velocity. Conduction slowing within fibrotic myocardial (scar tissue) is a key mechanism underlying ventricular tachycardia and is currently assessed invasively via EM mapping. The objective of this study is to develop a framework for estimating EM wave velocity from EWI activation maps and quantify spatial variations in myocardial propagation.

Statement of Contribution/Methods

Transthoracic high-frame-rate ultrasound acquisitions were performed using a diverging wave sequence (2.5 MHz, 2000 fps) across four apical views. Radiofrequency data were beamformed using delay-and-sum. Axial displacement was estimated via 1D cross-correlation (10 λ window, 90% overlap), followed by least-squares incremental strain estimation (5 mm kernel). EM activation times were defined as manually selected zero-crossings of axial strain and multi-view activation maps were co-registered to generate rendered isochrones. Local electromechanical wave velocity was estimated by fitting second-order polynomial surfaces to activation times within a 5 $\times$ 5 $\times$ 5 voxel neighborhood. Velocity vectors were derived from the spatial gradients, and wave speed magnitude was computed from averaged overlapping estimates, constrained by fit quality ($R^2 \geq 0.8$, root mean square error ≤ 5 ms). Gaussian Mixture Modeling (GMM) was applied to the velocity distribution to identify distinct propagation regimes.

Results/Discussion

The study included ischemic cardiomyopathy (ICM, n=3, age 76.0 ± 5.2 years), non-ischemic cardiomyopathy (NICM, n=2, age 54.5 ± 6.4 years), and one healthy control (age 27 years). Mean velocities for core scar (CS), border zone (BZ), and healthy myocardium (HM) were 0.27 ± 0.01 m/s, 0.65 ± 0.01 m/s, and 1.52 ± 0.10 m/s, respectively ($p < 0.001$). GMM identified two velocity components (0.48 m/s and 1.33 m/s), with a separation threshold at 0.795 m/s. Reduced velocity regions were consistently observed in patients with structural heart disease, while the healthy control exhibited predominantly higher velocity values.

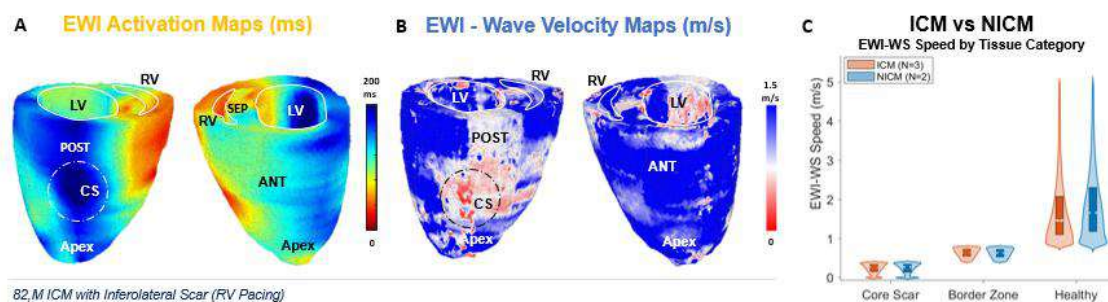


Figure 1. Electromechanical wave velocity mapping. (A) EWI activation maps (ms). (B) Corresponding wave velocity maps (m/s). (C) Velocity distributions showing separation of core scar, border zone, and healthy myocardium across ischemic and non-ischemic cardiomyopathy.

Conclusions

Electromechanical wave velocity estimated from EWI provides spatially resolved propagation and identifies reduced-velocity regions corresponding to scar and border zone, enabling noninvasive substrate characterization.

Recent advances in high-speed volumetric optical coherence elastography: full-field and point-scanning techniques

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Background, Motivation and Objective

Optical coherence elastography (OCE) provides micrometer-scale mechanical contrast for detecting pathological tissue changes but remains limited by slow volumetric imaging, restricting its use within intraoperative time constraints. Here, we present recent progress in full-field and point-scanning approaches, highlighting their potential for rapid volumetric imaging in time-critical clinical applications.

Statement of Contribution/Methods

We present two high-speed volumetric compression OCE approaches: a full-field swept-source OCT technique and a point-scanning OCT system based on a Fourier domain mode locked (FDML) laser. Both approaches measure sample deformation between volumetric scans and use phase-sensitive detection to quantify strain, demonstrating complementary strategies to improve imaging speed while maintaining high sensitivity.

Results/Discussion

Both approaches demonstrate volumetric strain imaging at several volumes per second, representing an order-of-magnitude improvement over previous OCE systems. Displacement sensitivity is maintained through parallel detection in the full-field approach and through high-speed, phase-stable acquisition in the FDML-based system. Strain sensitivity is comparable to state-of-the-art point-scanning systems operating at significantly slower speeds. Mechanical contrast is demonstrated in structured silicone phantoms and *ex vivo* human tissue, showing clear mechanical contrast between healthy and diseased regions, validated by histology.

Conclusions

Recent advances demonstrate that high-speed volumetric optical coherence elastography can be achieved using both full-field and FDML-based point-scanning approaches. These methods overcome key limitations in imaging speed while preserving displacement and strain sensitivity, enabling volumetric biomechanical imaging within clinically relevant timeframes.

Resolving the mechanics of the tumor boundary using optical multifrequency elastography in colorectal liver metastasis

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Background

The tumor boundary, and particularly its mechanics, is a fundamental yet often underestimated feature of cancer. Here, we analyze the mechanical tumor boundary in colorectal liver metastasis (CRLM). Clinical elastography (USE, MRE) reliably captures bulk tumor mechanics but lacks the resolution to resolve the boundary, while microscale techniques (AFM, OCE, Brillouin microscopy and optical techniques; Zorgani et al. PMB, 2019, Flé et al., PNAS, 2023) are not directly comparable to clinical elastography due to significant conceptual differences. In contrast, the recently introduced optical multifrequency time-harmonic elastography (OMTHE; Jordan et al., Advanced Science, 2025) utilizes the same time harmonic shear waves as MRE and reaches histological resolutions. However, OMTHE has not been applied to tissue.

Methods

To remedy this issue, we introduce tissue OMTHE to map tumor boundary mechanics in CRLM at a cellular resolution while maintaining inter-modality comparability to clinical elastography and resolving local soft and stiff regions. Measurements are validated with tabletop MRE, AFM, and histology.

Results

OMTHE resolved the marked biomechanical heterogeneity of the tumor boundary in CRLM.

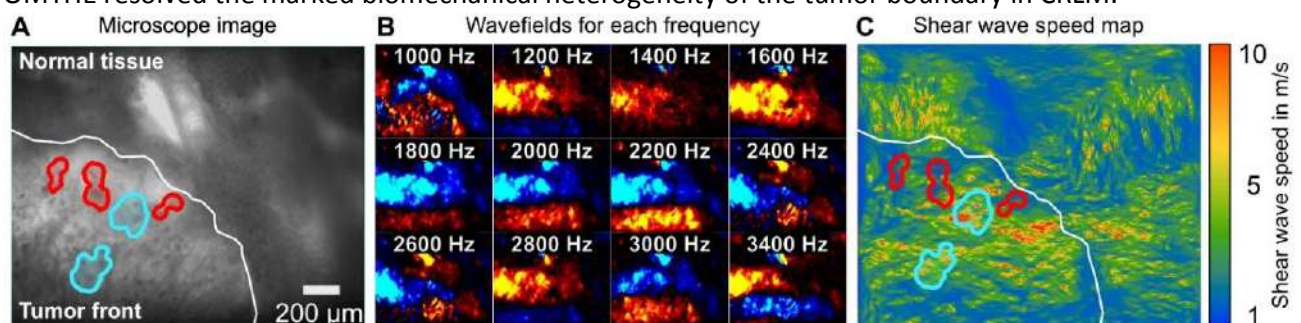


Figure 1. (A) Microscope image (transmission mode) of normal liver tissue on the top right and CRLM on the bottom left. (B) OMTHE wavefields across the measured frequency spectrum. (C) Shear wave speed map, with stiffer tumor front and softer liver tissue. Soft and stiff cells within the tumor front are highlighted in red and light blue, respectively.

Conclusions

OMTHE enables mechanical characterization of tumor boundaries and links boundary mechanics to local tissue state, providing a new framework to study the physics of the tumor front.

Solid stress is a marker of the non-proliferative cirrhotic liver disease

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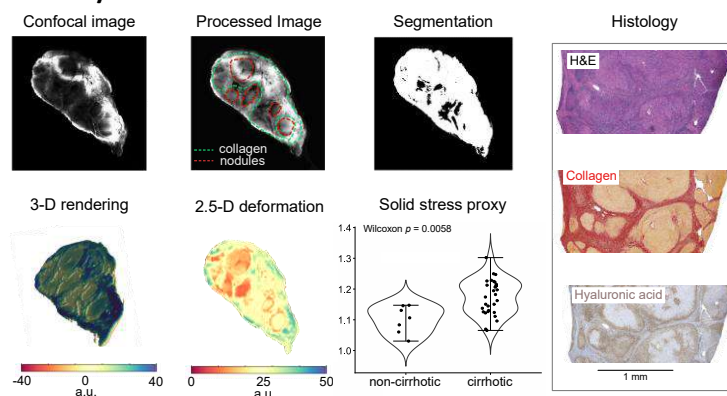
Background, Motivation and Objective

Solid stress arises from residual mechanical forces generated by pathological matrix remodeling by stiffening, cellular proliferation, and metabolic-osmotic dysregulation, and is a hallmark of hepatocellular carcinoma (HCC)[1, 2]. Given the histopathological and mechanical similarities between the HCC extracellular matrix and its preceding, non-proliferative stage, cirrhosis, we investigated whether cirrhotic liver tissue constitutes a microenvironment that supports the accumulation of solid stress.

Statement of Contribution/Methods

Forty-five human liver samples (cirrhotic=30, non-cirrhotic=7) were collected after surgical resection. Tissue sections (300µm) were sliced using a vibratome, embedded in 1% agarose, fixed, stained with DAPI, and imaged by confocal microscopy. Solid stress-induced deformations were quantified as surface elevations relative to a mid-plane after 3D reconstructions from confocal image stacks. Elevations were normalized to the total tissue area. Measurements are reported in arbitrary units. Histological staining was performed.

Results/Discussion



Cirrhotic tissues exhibited higher and more irregular surface elevations compared to the smooth and non-elevated surfaces of non-cirrhotic tissues, indicating increased solid stress. The spatially heterogeneous elevations showed greater magnitudes colocalized with fibrous septae and areas of hyaluronic acid deposition as shown by histology. This suggests that solid stress in cirrhotic tissues predominantly accumulates in the fibrotic septae of the tissue.

Conclusions

Cirrhotic livers exhibit substantial solid stress accumulation, predominantly within the fibrous septae, suggesting that fibrosis is a major driver of solid stress buildup in non-malignant liver cirrhosis.

[1] H.T. Nia *et al*, Nat Biomed Eng 1 (2016)

[2] Y. Boucher *et al*, Cancer research 52(18) (1992) 5110-5114.

Reconstruction of All Three Elastic Moduli in Skin from Phase Velocities of Rayleigh Waves: Data Processing and Optimization Algorithms

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Background, Motivation and Objective

Skin is an anisotropic organ, where a local collagen fiber orientation defines its stiffness. A nearly incompressible transverse isotropic (NITI) model is a good approximation of the local elasticity in skin. As such, 3 independent elastic constants G , μ and δ (contrary to a single shear modulus μ for isotropic tissue) should be determined to define skin's deformational properties. Transient optical coherence elastography (OCE) uses the sensitivity of phase to motion to detect propagating mechanical waves. This noncontact technique offers stiffness measurements in anterior organs such as skin and ocular tissues. Rayleigh waves offer a significant advantage: their angular anisotropy is intrinsically determined by all three elastic moduli of the NITI medium. However, this introduces additional complexity in the inverse reconstruction problem, requiring careful optimization strategies.

Statement of Contribution/Methods

Here we consider step-by-step data processing from phase-sensitive OCT data to angular dependence of Rayleigh wave phase speed. Then three computational methods (a simplex algorithm, a genetic algorithm, and a neural network approach) for retrieving NITI mechanical properties from Rayleigh wave speed angular anisotropy are considered.

Results/Discussion

These algorithms were tested comprehensively on simulated data sets with variable Gaussian noise and on experimental data sets from isotropic and NITI gel samples, and human skin at different skin sites in healthy volunteers *in vivo*. Our results demonstrate that the reconstruction accuracy varies significantly between parameters. The modulus μ , representing the stiffness of the medium across collagen fibers, can be estimated with high accuracy with all the optimization methods even under high noise conditions. Reconstructing shear anisotropy G/μ is slightly less accurate but remains robust across the methods. However, the tensile anisotropy E_L/E_T is least accurate, especially for high noise levels.

Conclusion

Comparing different approaches, we conclude that the simplex method provides the optimal balance between accuracy and computational efficiency. The genetic algorithm provides the most accurate inversion, but it is much slower and its advantage over the simplex method, with properly chosen initial parameters is minimal. Neural network-based optimization offers a promising real-time alternative (10^5 times faster than the simplex approach, although achieving high accuracy for tensile anisotropy remains challenging. Future work will focus on improving the accuracy and reliability of NN-based reconstructions.

Regime-Dependent Optimization of Shear Wave Generation in Harmonic Elastography

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Background, Motivation and Objective

Harmonic shear wave elastography (HSWE) is expanding across modalities. Maximizing shear wave energy while suppressing compressional artifacts remains a critical challenge. This study addresses the optimization of shear-to-compressional ratio through the analysis of an elastic bounded region and identifying the source configurations that minimize compressional wave interference.

Statement of Contribution/Methods

This work characterizes the shear wave components produced by a single spherical source across three physical regimes: quasistatic, modal, and free-space propagation. Using a homogeneous gelatin-agar phantom, we categorize the field regime through dimensionless parameters linking frequency, geometry, and attenuation: size-to-wavelength and attenuation-depth. Four source-transducer configurations were evaluated with results validated against the Carstensen-Oestreicher (C-O) model. A performance metric, the slow-to-fast (S/F) ratio was computed to quantify shear wave dominance.

Results/Discussion

Standing modes at low frequencies and dominant free-space propagation at higher frequencies was confirmed by spatial and spectral analyses. The C-O model accurately predicts shear wave behavior in the free-space regime, despite limitations in bounded conditions. Theoretical and experimental analyses show strong configuration-dependent behavior, with configuration A maximizing shear content and configuration D achieving comparable displacement and SNR in practice. The slow-to-fast (S/F) ratio and SNR decrease with frequency due to attenuation, highlighting a trade-off between resolution and signal quality.

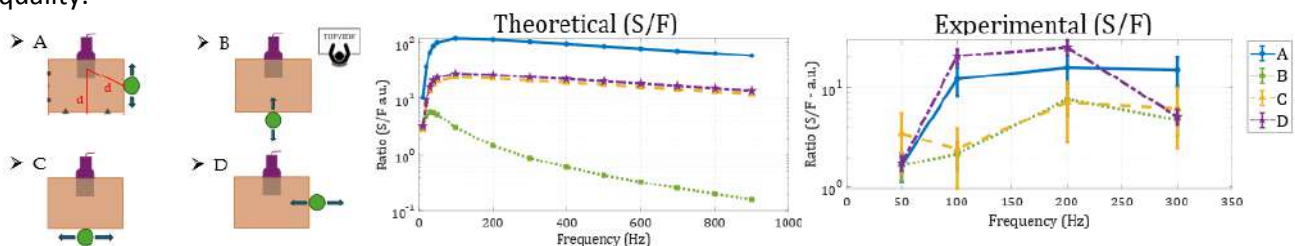


Figure 1. Theoretical and experimental calculation of slow to fast wave amplitude ratio (S/F, arbitrary units). Four source-transducer configurations (A-D) were analyzed across 50 - 900 Hz.

Conclusions

Optimal shear wave dominance is regime-dependent, requiring tailored frequency and source configurations for accurate elastography. This framework provides a physics-based foundation for improving robustness, resolution, and application-specific acquisition strategies.

Shear Wave Elastography For Quantifying the Mechanical Response of the Respiratory Muscles to Functional Electrical Stimulation

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Background, Motivation and Objective

Functional electrical stimulation (FES) of respiratory muscles in the intensive care unit (ICU) is a promising strategy to limit muscle atrophy and reducing complications associated with mechanical ventilation. However, quantifying the effective contraction induced by FES remains challenging. Electromyography (EMG) does directly quantify the mechanical response to stimulation and is strongly contaminated by stimulation artifacts, which limits its usefulness during FES. Ultrasound shear wave elastography (SWE), by measuring shear wave propagation, could provide a direct assessment of stimulation-induced changes in muscle mechanical properties. However, implementing SWE to monitor rapid and repetitive changes in muscle stiffness remains technically challenging.

Statement of Contribution/Methods

We have developed a real-time SWE sequence for dynamic monitoring of muscle shear modulus (μ) using a 192-element linear array transducer (SL10-2) driven by an ultrafast ultrasound scanner (Aixplorer, Supersonic Imagine). The sequence was constituted in two steps: a 300 μ s pushing beam followed by an ultrafast imaging acquisition at 6 kHz. The sequence consisted of two steps: a 300 μ s acoustic radiation force push followed by ultrafast imaging at 6 kHz. A dedicated processing pipeline was implemented, including denoising and time-of-flight estimation, to reconstruct stiffness maps. A region of interest (ROI) was defined within the selected muscle, and spatial averaging was applied to extract a robust stiffness signal. This protocol was applied in mechanically ventilated patients receiving FES of the abdominal muscles. Muscle shear modulus was continuously measured using SWE, together with airway flow and pressure.

Results/Discussion

Data were acquired during six FES sessions in ICU patients. Changes in muscle shear modulus induced by FES were reliably tracked ($\Delta\mu = 8.1$ kPa/cycle [3.5-25.4], $\mu_{\min} = 6.4$ kPa [3.7-8.1], $\mu_{\max} = 14.5$ kPa [8.4-31.2]).

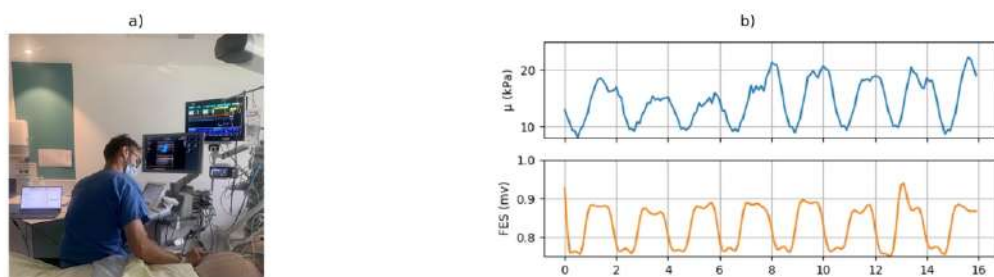


Figure 1. Setup and recording. a) Overview of the experimental setup. b) Typical recording in one participant.

Conclusions

Real-time SWE enables quantitative monitoring of the mechanical response of respiratory muscles to FES in ICU patients. It complements EMG by providing a direct measurement of stimulation-induced changes in muscle stiffness. This paves the way for improved quantification and individualization of FES protocols.

Reliability assessment of vibration-based shear wave elastography using signal energy

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Background, Motivation and Objective

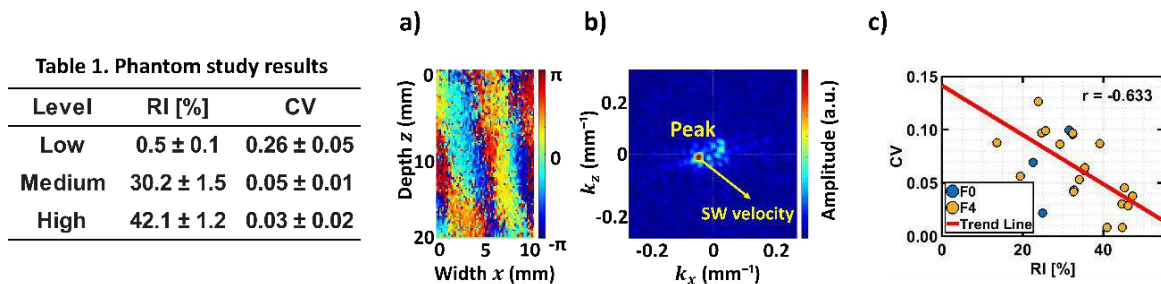
Vibration-based shear wave elastography with an external vibrator offers sufficient penetration for liver fibrosis staging; however, physiological noise (ex., heart pulse) can impair the detection of vibration-induced components. To address this issue, we herein propose a reliability index (RI) based on frequency spectrum analysis of IQ signals to quantify the dominance of vibration-induced components.

Statement of Contribution/Methods

Shear waves (SWs) were generated at 80 Hz by a vibrator. IQ data were acquired from a 10-kPa phantom using a LOGIQ E10 system (GE HealthCare) and a 3-MHz convex probe. Phase maps and wavenumber spectra were reconstructed from the IQ data. Then, SW velocities were estimated using a previously proposed method (T. Naoki et al., IEEE IUS, 2025). Here, RI was defined as the percentage of pixels whose SW energy ratio exceeded a threshold. Clinical validation was also performed on 8 patients (F0 and F4).

Results/Discussion

In the phantom study, RI showed a negative correlation with the coefficient of variation (CV), ranging from 0.5 to 42.1% as CV decreased from 0.26 to 0.03. Clinical data showed a similar negative correlation between RI and CV ($r = -0.633$), indicating that RI quantitatively reflects SW propagation quality. These



findings suggest that RI can be used to select high-quality data for stable elasticity evaluation.

Figure 1. a) Phase map and b) two-dimensional wavenumber spectrum in phantom; c) clinical RI–CV scatter plot ($r = -0.633$).

Conclusions

The reliability index provides a robust metric for objective data selection in C-SWE. Future studies should focus on optimizing the threshold and expanding the dataset to further validate its clinical utility.

Two-Point Model-Free Estimation of Shear Wave Attenuation in Ultrasound Elastography

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Background, Motivation and Objective

Shear wave (SW) attenuation, provides additional diagnostic information, yet accurate estimation remains challenging due to noise and model assumptions in existing techniques. This study proposes a model-free, two-point attenuation estimation method that combines time-frequency analysis with the Kullback-Leibler divergence, enabling robust performance under limited data conditions and low SNR.

Statement of Contribution/Methods

This work proposes a model-free two-point method for estimating the SW attenuation coefficient α_0 from ultrasound particle velocity measurements acquired at two lateral positions. The method identifies peak arrival times, extracts time-frequency amplitude spectra using a continuous wavelet transform and quantifies spectral differences via the Kullback-Leibler divergence. The attenuation coefficient is then estimated from a closed-form relationship linking the divergence to the propagation distance and spectral weighting.

Results/Discussion

Results from noise-free analytical phantoms (Fig. 1a) validated the proposed method, yielding attenuation estimates consistent with those from the Frequency Shift (2P-FSP) technique. While both methods were stable under ideal conditions, clear differences emerged in low-SNR tissue-mimicking phantom experiments (Figs. 1b, 1c). At reduced ARF push/detection voltages (15-25 V), 2P-FSP showed increased sensitivity to spectral model mismatch, leading to biased estimates and limited spatial coverage, whereas the proposed method provided stable attenuation estimates across all phantoms.

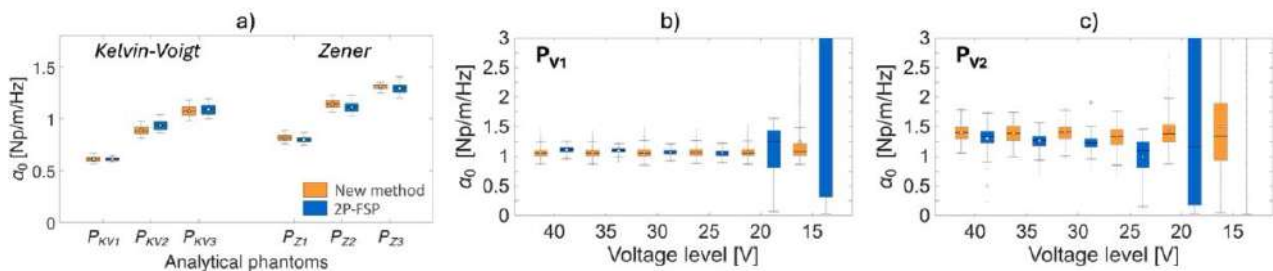


Figure 1. Boxplots of SW attenuation coefficient estimates, α_0 , obtained using the proposed method (orange) and the 2P-FSP technique (blue) for: a) analytical Kelvin-Voigt and Zener viscoelastic phantoms; b), c) two custom-made viscoelastic phantoms evaluated at different push/detection voltage levels.

Conclusions

The proposed method demonstrates markedly improved robustness under low signal-to-noise ratio conditions compared with the conventional two-point Frequency Shift technique.

Single-breathhold 3D MR elastography in the liver, with simultaneous R2* and PDFF mapping

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Background

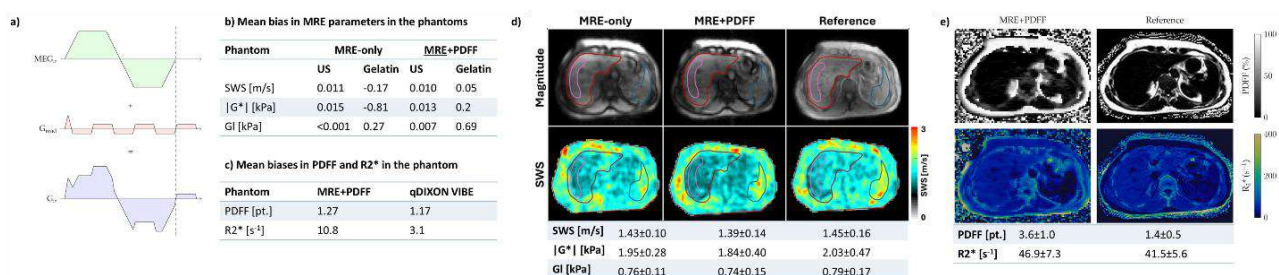
Metabolic dysfunction-associated steatotic liver disease (MASLD) is a prevalent disease. MRI enables non-invasive assessment of fibrosis and inflammation using MR elastography (MRE), and fat and iron via proton-density fat fraction (PDFF) and R2* mapping. However, these are typically acquired separately, increasing breath-holds (BH) and risking spatial misalignment. We propose MRE with a multi-echo readout, to simultaneously acquire PDFF, R2*, and viscoelastic parameters in the liver in a single BH.

Methods

The 3D MRE sequence with interleaved motion encoding uses a six-echo bipolar GRE readout for PDFF and R2* mapping. Acceleration used incoherent Poisson-disk undersampling with across wave offsets. Compressed sensing with temporal regularisation was used for MRE reconstruction. Viscoelastic parameters are derived using curl-based inversion. PDFF and R2* are estimated from combined reference data using a multi-step fitting approach. Validation used three phantoms and eight healthy volunteers. Two versions of the sequence were tested: single-echo (MRE-only), and six-echo (MRE+PDFF), each was compared with a conventional sequence (Ristretto MRE and qDixon VIBE).

Results

Phantom measurements of all viscoelastic parameters, PDFF, and R2* corresponded closely with reference measurements. Average liver tissue parameter values are shown in the figure below.



Discussion and Conclusion

Good agreement with established methods was observed in phantoms and healthy volunteers. The sequence enables comprehensive MASLD assessment in a single breathhold, warranting further evaluation in patients.

Spatially resolved compact tabletop magnetic resonance elastography for mapping biomechanical heterogeneity

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Background, Motivation and Objective

Compact, cost-effective tabletop magnetic resonance elastography (ttMRE) is an emerging research tool for assessing bulk soft tissue biomechanical properties. Current implementations rely on Bessel-function fitting, which provides bulk viscoelastic parameters but still lacks spatial resolution for imaging the viscoelastic properties of heterogeneous specimens like tumors.

Statement of Contribution/Methods

Spatially resolved ttMRE was developed using adaptive bandpass filters constrained by Bessel-fit priors for wave field processing. Maps of shear wave speed c and penetration rate a were reconstructed as surrogates of stiffness and inverse attenuation. The framework was validated in simulations and phantoms, and applied to 34 human colorectal liver metastasis (CRLM) specimens after chemotherapy. Intratumoral biomechanical heterogeneity was quantified using the product of $IQR(c)$ and $IQR(a)$, and joint Shannon entropy $H(c, a)$.

Results/Discussion

Accurate viscoelastic mapping was achieved in simulations and phantoms. In CRLM, maps revealed distinct patterns of biomechanical heterogeneity separating responders from non-responders.

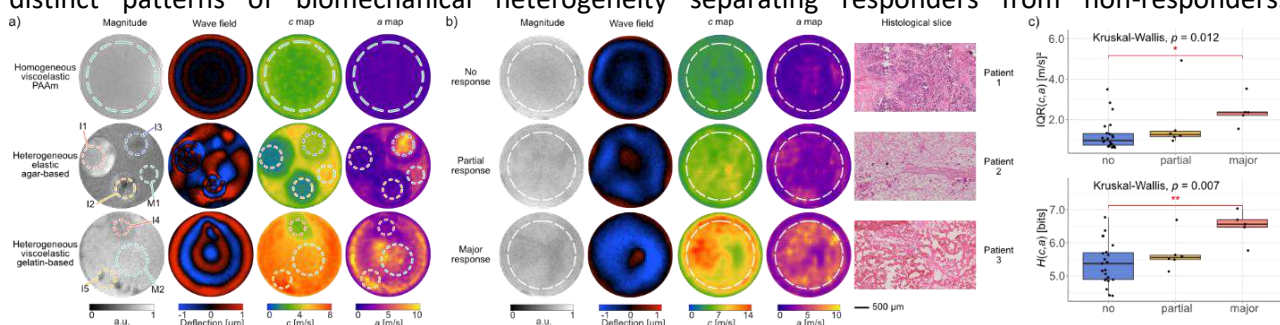


Figure 1. a) Phantom validation of spatially resolved viscoelastic mapping (I: inclusion; M: matrix); b) Viscoelastic mapping in three CRLM tumor specimens; c) Intratumoral biomechanical heterogeneity in CRLM across treatment response groups (* $p < 0.05$, ** $p < 0.01$).

Conclusions

Spatially resolved ttMRE enables mapping of tumor biomechanics. Heterogeneity metrics derived from c and a correlated with response of CRLM to chemotherapy, suggesting ttMRE as a biomarker of tumor viability.

The Prognostic Characterization Of Breast Cancer Tissue Biomechanics With Magnetic Resonance Elastography

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Background, Motivation and Objective

Magnetic resonance elastography (MRE) provides quantitative assessment of tissue mechanical properties and is a promising technique for characterizing pathological changes in tissue microstructure. The objective of this study was to quantify breast cancer stiffness relative to healthy breast tissue and to evaluate spatial variations in stiffness across tumor, peritumoral, and healthy breast regions using MRE.

Statement of Contribution/Methods

Fifteen patients with biopsy-confirmed breast cancer (invasive ductal carcinoma, invasive lobular carcinoma, ductal carcinoma in situ) underwent diagnostic breast MRI with integrated 40 Hz breast MRE. Stiffness maps were reconstructed using 3-D multiple-model direct inversion (MMDI). Tumor and breast ROIs were segmented on dynamic contrast-enhanced (DCE) T1-w images and co-registered to MRE space using 3D Slicer. Voxel-wise stiffness values were extracted from elastograms for each region, and per-patient differences between tumor and healthy tissue were computed.

Results/Discussion

Tumor stiffness (Mean = 3.66 kPa) was elevated relative to contralateral healthy breast tissue (Mean = 1.962 kPa, $p = 0.0004$), with predominantly positive per-patient differences. Regional analysis demonstrated stiffness differences across tissue compartments, with tumor regions exhibiting higher stiffness compared to peritumoral and non-tumoral breast tissue.

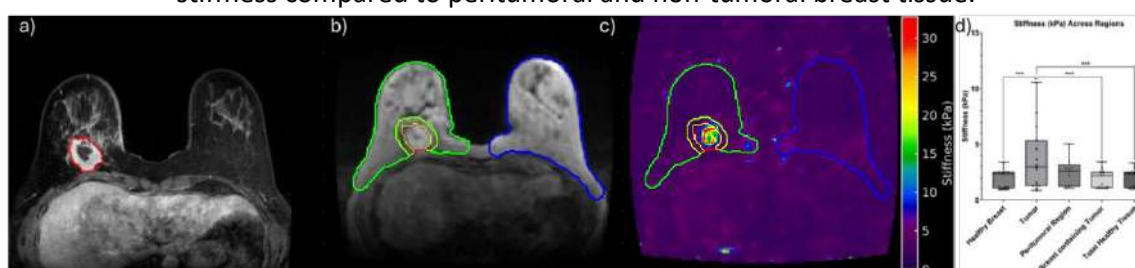


Figure 1. MRE processing and analysis pipeline. a) Tumor segmentation on DCE T1-w; b) delineation of ROIs on MRE magnitude images; c) segmentations on MMDI-derived elastograms for stiffness quantification; d) region-wise stiffness estimates

Conclusions

Breast MRE using MMDI inversion demonstrated increased tumor stiffness and regional variation, supporting its role in quantitative tissue characterization. Ongoing work will define stiffness signatures linked to pathology and clinical outcomes, positioning breast MRE as a prognostic biomarker.

Sensitivity of multifrequency brain MRE to acute caffeine intake

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Background, Motivation and Objective

Brain magnetic resonance elastography (MRE) quantitatively maps the brain's viscoelastic properties, yet their responsiveness to physiological modulation remains incompletely understood. This study investigated whether caffeine intake induces measurable changes in brain tissue mechanics using MRE.

Statement of Contribution/Methods

In a prospective study, 16 healthy adults were scanned pre and post oral intake of 200 mg caffeine on a single 3 T MRI system (Siemens MAGNETOM Cima.X) using multifrequency MRE (20, 25, 30, and 35 Hz). Shear wave speed (SWS) and penetration rate (PR) were reconstructed and normalized to MNI152 space. Atlas-based analysis covered major brain regions. Caffeine-induced changes were assessed using the symmetric relative difference (SRD) and related to physiological markers including blood pressure.

Results/Discussion

Caffeine ingestion induced tissue-specific reductions in SWS, with significant decreases in cortical gray (p < 0.001) but not in subcortical gray matter (p = 0.633) and white matter (p = 0.662). Mean SRDs were -1.65, -0.74, and -0.20 % in cortical, subcortical gray matter and white matter. PR showed no significant changes. SWS in cortical gray matter correlated inverse with systolic blood pressure (p = 0.021).

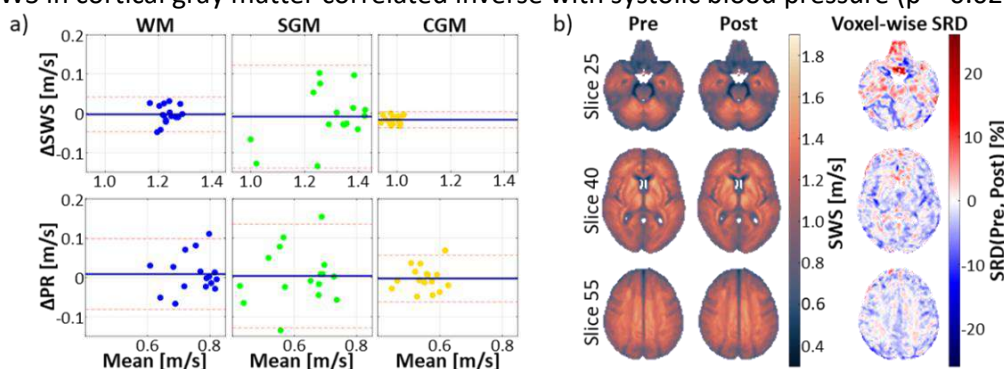


Figure 1. a) Bland-Altman plots of changes of SWS and PR after caffeine intake across brain regions; b) Subject-averaged SWS maps pre and post caffeine intake, and voxel-wise SRD maps for selected slices. *Abbreviations:* SWS, shear wave speed; PR, penetration rate; SRD, symmetric relative difference; WM, white matter; SGM, subcortical gray matter; CGM, cortical gray matter.

Conclusions

Caffeine induces small but statistically significant region-specific reductions in brain tissue SWS.

Analytical Investigation of Pressure-Stiffness Uncoupling during Shear Wave Elastography of Interstitially Pressurized Organs

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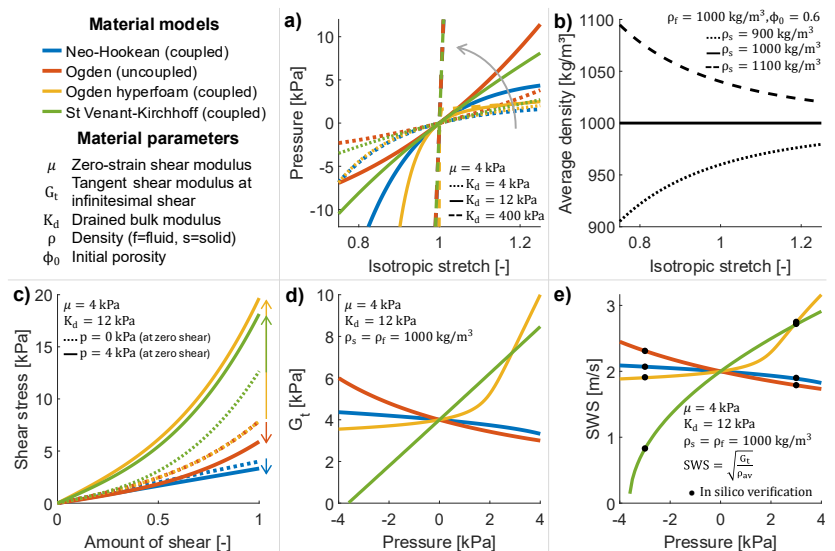
² KU Leuven, Department of Cardiovascular Sciences, Leuven, Belgium

Background, Motivation and Objective

In biological tissue, shear wave speed (SWS) measured by shear wave elastography (SWE) reflects not only intrinsic stiffness, but also functional stiffness effects from interstitial fluid pressure. The latter may enable non-invasive pressure assessment and support diagnosis of hepatic and renal disorders, amongst others. We develop an analytical model to identify conditions in poroelastic materials under which pressure can be decoupled from intrinsic stiffness in SWS measurements.

Statement of Contribution/Methods

We consider pressurized poro(hyper)elastic materials subjected to simple shear using the strain energy densities of coupled Neo-Hookean (NHC), uncoupled Ogden (OGU), coupled Ogden hyperfoam (OGC), and coupled St. Venant-Kirchhoff (SVK) models. SWS is calculated from the analytically derived average density and tangent shear modulus at infinitesimal shear. We verify the method against finite element (FE) models of acoustically induced shear waves.



Results/Discussion

The selected material model and drained bulk modulus govern the strength of the pressure-stretch coupling (Fig. a), and the resulting dilatation can affect the average density (Fig. b). A 4 kPa pressure increase shifts the shear stress-strain curve (Fig. c) downward for NHC and OGU and upward for OGC and SVK. Figs. d and e show how pressure affects the tangent modulus at infinitesimal shear and SWS. Over -4 - 4 kPa, SWS decreases by 0.27 and 0.72 m/s for NHC and OGU, and increases by 1.28 and 2.77 m/s for OGC and SVK. FE simulations confirmed these analytical results.

Conclusions

We introduced an analytical framework to estimate SWS in pressurized porohyperelastic materials. This can be used to uncouple pressure and intrinsic stiffness, by combining SWS with volume or strain measurements across multiple pressure states, e.g. via a drinking protocol. Results of the forward analysis demonstrate that SWS sensitivity to pressure strongly depends on selected material models and parameters. Of the models examined, only SVK and OGC follow the positive SWS-pressure trend observed experimentally in *ex vivo* livers and breast. This highlights the need for future work on experimental calibration and validation.

Shear Excitation Differentially Modulates 3D Tumour Spheroids

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Background, Motivation and Objective

Frequency-dependent effects of shear mechanical stimulation on cancer cells are well documented, yet their characterisation in 3D spheroid models remains limited. This study represents the first experimental step of SWiM-Therapy, a project aimed at developing a shear-wave mechanotherapy for pancreatic cancer, combining a custom bioreactor with dynamic micro-elastography for contact-free mapping of viscoelasticity and stress fields within living tumoroids.

Statement of Contribution/Methods

MG-63 osteosarcoma spheroids — selected as a tractable model prior to translation to pancreatic cancer stem cells (PCSCs) — were cultured in low-adhesion conditions (37°C, 5% CO₂) for five days under sinusoidal shear excitation via whole-plate lateral oscillation (Fig. 1a) at low-frequency (LF, 15–60 Hz) and high-frequency (HF, 150–300 Hz) regimes, alongside a static control and a Day 1 baseline. Proliferation was quantified by DAPI fluorescence intensity (a.u.) and proliferation ratio; spheroid integrity was assessed by brightfield microscopy.

Results/Discussion

LF and HF shear excitation elicited divergent proliferative responses (Fig. 1b,c): HF trended towards reduced proliferation ratio (~16.2) relative to control (~18.2) and LF (~19.5), with partial spheroid structural disruption, while LF trended towards increased proliferation with preserved morphology. These contrasting observations suggest that excitation frequency is a potential determinant of spheroid mechanobiological response. Given the limited replicates and non-pancreatic model, findings are strictly preliminary; pathway attribution requires molecular validation. PCSC results will be presented at the congress.

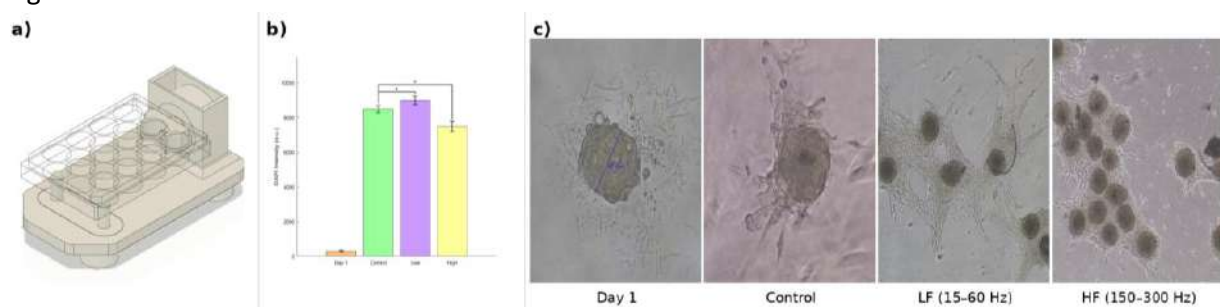


Figure 1. a) CAD of the shear-wave bioreactor under development. b) DAPI fluorescence intensity and proliferation ratio across groups. c) Brightfield micrographs (scale bar = 100 μm): Day 1, Control, LF (15–60Hz), HF (150–300Hz).

Conclusions

Sinusoidal shear excitation shows frequency-dependent effects on 3D spheroid proliferation and morphology, supporting the rationale for shear-wave mechanotherapy. These preliminary results motivate the development of a spectrally controlled bioreactor with integrated micro-elastography, all currently underway within SWiM-Therapy alongside translation to PCSC models.

Ultrasound Micro Time-Harmonic Elastography for *In Vivo* Viscoelasticity Mapping in Preclinical Research

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Background, Motivation and Objective

Small animal models are indispensable for preclinical research. While Magnetic Resonance Elastography (MRE) is the gold standard for full-organ viscoelasticity mapping (Jordan et al., MRM, 2020), prolonged acquisition imposes anesthesia burden and limits throughput, imaging hardware is limited for *in vivo* elastography of small animal models such as zebrafish. Existing approaches using ultrasound scanners require ultra-fast acquisition sequences which are often not supported by conventional scanners. We therefore propose micro Time-Harmonic Elastography (μ THE) leveraging conventional small animal ultrasound scanners to rapidly and safely assess tissue viscoelasticity *in vivo*.

Statement of Contribution/Methods

We developed bandpass-sequential, prime-number-spaced multi-frequency vibration sequences enabling conflict-free stroboscopic sampling at conventional ultrasound framerates (200 Hz) within a 5-second acquisition (VisualSonics Vevo 2100/3100). Custom 3D-printed actuators covering the required frequency range (200-2000 Hz) were tailored to small animal dimensions (Figure 1A, C). Wave fields were reconstructed into quantitative viscoelastic maps using k-MDEV (Tzschätzsch et al., Med Imag Anal., 2016).

Results/Discussion

Following successful validation on agarose phantoms, *in vivo* mouse experiments demonstrated high sensitivity, accurately differentiating tumor lesions from healthy liver tissue. Crucially, μ THE successfully mapped *in vivo* viscoelasticity of neuroblastoma tumor tissue in zebrafish showing strong alignment with *ex vivo* MRE reference data.

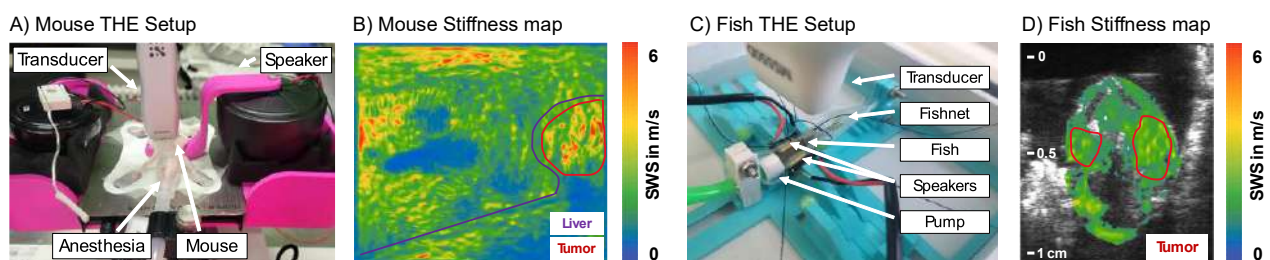


Figure 1: THE setups for mouse (A) and fish (C). Representative stiffness maps depicting (B) a mouse liver (purple) with tumor (red) as well as a (D) zebrafish with lateral tumor (red).

Conclusions

To our knowledge, μ THE allowed first in-vivo elastography in living zebrafish and established a robust method for full-organ in vivo viscoelasticity assessment of mouse abdominal organs with short acquisition times and minimized anesthesia burden. Delivering MRE-comparable contrast across species, μ THE represents a versatile and accessible tool for preclinical oncology and beyond.

Longitudinal Shear Wave Elastography Monitors Response to Combined Radiation and Immunotherapy in a Murine Model of Pancreatic Ductal Adenocarcinoma

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Background, Motivation, and Objective

Pancreatic ductal adenocarcinoma (PDAC) is characterized by a dense desmoplastic stroma that elevates solid stress, impairs drug delivery, and promotes treatment resistance. Conventional imaging monitors tumor size, but size changes lag the biological response to therapy. Because treatment alters the composition and architecture of the extracellular matrix (ECM), the mechanical properties of tumors may serve as earlier and more specific biomarkers of treatment efficacy. Shear wave elastography (SWE) can quantify both the elastic (shear wave speed, SWS) and viscous (shear wave attenuation, SWA) components of tissue viscoelasticity non-invasively. The objective of this study was to determine whether longitudinal SWE can detect and differentiate the mechanical response of PDAC tumors to radiation, immunotherapy, and combination therapy in vivo.

Statement of Contribution/Methods

KP2.1 pancreatic tumor cells were injected orthotopically into the pancreatic tail of C57BL/6J mice. Animals were randomized into four groups: Control (untreated), SBRT (stereotactic body radiation therapy, Days 5–8), IL-12 (interleukin-12 microspheres, Day 10), and SBRT+IL-12 (combination). B-mode ultrasound and SWE imaging were performed longitudinally at eight time points from Day 14 to Day 42 post-injection. Mean SWS and SWA were computed within manually delineated tumor boundaries at each session. Animals were sacrificed at Day 43 for histological analysis, including H&E staining, Masson's trichrome staining for collagen quantification, and grey-level co-occurrence matrix (GLCM) texture analysis of both SWS maps and histological sections.

Results/Discussion

A treatment-dependent dose-response hierarchy was observed in the SWS data. SBRT+IL-12 produced the earliest (Day 23), strongest, and most sustained significant separation from Control ($p < 0.001$ at Days 27–42). SBRT alone achieved late separation (Day 27+), while IL-12 alone showed intermittent mid-study significance. SWA exhibited a concordant but less sensitive pattern, with SBRT+IL-12 separating from Control at Days 27–42. Treated tumors were consistently softer than untreated Controls. Histological analysis revealed that SBRT+IL-12 produced complete tumor eradication, with normal pancreatic acini replacing the tumor bed. Masson's trichrome staining showed significantly higher collagen density in the SBRT+IL-12 group ($p < 0.0001$ vs. Control), while GLCM texture analysis of H&E sections revealed higher energy and homogeneity in the combination group, indicating organized tissue replacement. Notably, GLCM analysis of SWS maps showed no inter-group differences, highlighting a resolution gap between elastographic and histological scales.

Conclusions

Longitudinal SWE detected treatment-induced mechanical remodeling of PDAC tumors in vivo, with combination SBRT+IL-12 therapy producing the most pronounced response.

Cardiac time harmonic elastography: validation against invasive left ventricular pressure in patients

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Background, Motivation and Objective

Diastolic dysfunction is a leading cause of heart failure, yet noninvasive detection remains challenging. While invasive left ventricular pressure catheterization is the diagnostic gold standard, it imposes patient risks and is unsuitable for routine use. Cardiac time harmonic elastography (THE) enables noninvasive full-field-of-view left ventricular (LV) myocardial stiffness mapping using externally induced vibrations and conventional ultrasound (Meyer & Wellge et al. JASE 2025). We present catheter-based validation of cardiac THE and introduce quality maps for quasi-real-time acquisition feedback.

Statement of Contribution/Methods

Six patients undergoing clinically indicated left heart catheterization were examined by cardiac THE. Multifrequency vibrations were induced via a custom vibration pillow. 4s RF loops were reconstructed into diastolic shear wave speed (SWS) maps using k-MDEV (Tzschätzsch et al., Med Imag Anal., 2016). A composite quality score map was derived from the displacement estimation correlation coefficient, wave amplitude, z-score, and its coefficient of variation.

Results/Discussion

Cardiac THE-derived myocardial stiffness correlated significantly with invasive diastolic ($r=0.83$, $p<0.05$; Fig. 2), but not with systolic LV pressure, indicating specificity of cardiac THE towards diastolic myocardial function. Quality maps successfully enabled exclusion of unreliable acquisitions to improve diagnostic consistency.

Conclusions

Cardiac THE correlates with invasive diastolic pressure measurements, supporting its potential as a noninvasive diagnostic tool for diastolic dysfunction. Quality maps enhance reliability, advancing cardiac THE towards robust clinical application.

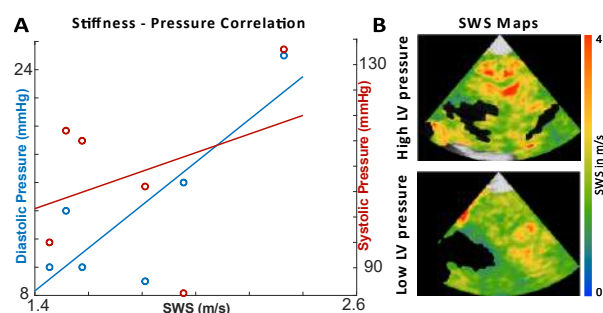


Figure 1: Stiffness (SWS in m/s) correlation with systolic and diastolic pressure in the left ventricle (A). Representative SWS maps at high (upper)

Effect of Transmit Voltage and Vibration Amplitude on Shear Wave Speed Estimates in Phase-Gradient Elastography

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Background, Motivation and Objective

Tissue characterization with ultrasound shear wave elastography (SWE) depends on accurate tissue-motion tracking and imaging quality, which are influenced by ultrasound signal to noise ratio (SNR), and the amplitude of the induced shear wave motion. The effect of systematically varying these parameters is not fully established in a controlled setting with a phantom. This study aims to provide a systematic assessment that how transducer voltage and vibration amplitudes affect elastography outputs.

Methods

In this study, ultrasound SNR and frequency, and vibration amplitude were treated as controlled parameters, allowing their effects to be examined separately and together with a homogeneous phantom made with 2% Agar. Data was acquired with an ultrasound research system Vantage 128 and two linear array probes with center frequencies of 7.5 MHz and 28 MHz (Verasonics, WA, USA). The ultrasound excitation voltage varied from 15 V to 30 V and a mini shaker (2007E, PCB Piezotronics, NY, USA) with excitation voltage from 0.5 V to 2.5 V generated continuous 700 Hz shear waves.

Results/Discussion

Increasing transmit voltage improved B-mode SNR for both probes. Increasing shaker voltage improved the visibility and coherence of the measured displacement and phase maps, indicating stronger shear wave response under higher excitation. Although the phase maps showed consistent shear-wave wavelengths across the tested conditions, the estimated shear wave speed changed with both transducer and shaker excitation voltages for a fixed region of interest (ROI), with an example shown in Fig. 1

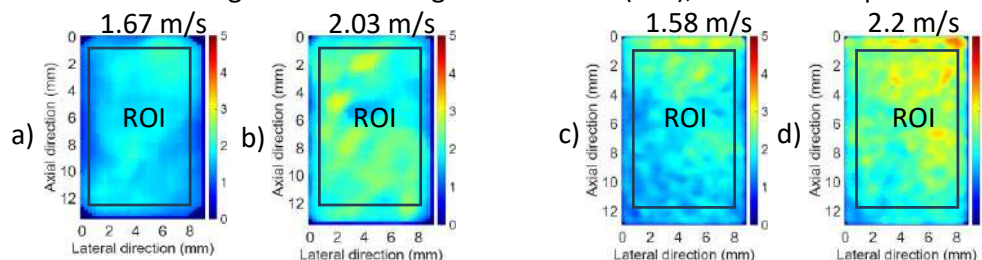


Figure 1. Shear wave speed maps for (a–b) 7.5 MHz and (c–d) 28 MHz transducers at 30 V excitation. (a, c) shaker voltage 1.18 V; (b, d) shaker voltage 2.5 V.

Conclusions

Different transducer and mechanical shaker settings can produce different shear wave speed estimates in the same phantom, even when the shear wave frequency is kept constant. This suggests that SWE performance is governed by the combined effect of imaging and excitation settings, and that careful selection of these parameters is necessary for accurate shear wave speed estimation.

Median Nerve Stiffness Assessment in Carpal Tunnel Syndrome Using Time-Harmonic Elastography: a pilot study

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Background, Motivation and Objective

Carpal tunnel syndrome (CTS) is the most common peripheral nerve entrapment neuropathy, affecting 3-4% of the general population and causing significant functional disability. The gold standard nerve conduction study (NCS) for diagnosing CTS is often painful and has variable diagnostic accuracy. In recent years, ultrasound shear wave elastography has attracted growing interest for CTS assessment, demonstrating consistently elevated median nerve stiffness in patients compared to healthy controls. In this pilot study, we evaluate the feasibility of time-harmonic elastography (THE) as a fast, flexible, and cost-efficient approach for this application. We assess THE sensitivity to position-dependent stiffness changes in the carpal tunnel of healthy volunteers under graded wrist extension, establishing a normative basis for a follow-up clinical study.

Statement of Contribution / Methods

Twelve asymptomatic volunteers (6 females, 6 males; age 24.8 ± 10.1 years; BMI 23.2 ± 3.5 kg/m²) were enrolled. Multi-frequency THE (320-340 Hz) was applied over the carpal tunnel in three standardized positions: neutral wrist (rest), 40°, and 60° extension of the wrist. The ultrasound central frequency was 14 MHz, and the frame rate was 100 Hz (three aliasing wraps corrected during the post-processing). Mean shear wave speed (SWS) of the median nerve was compared across conditions using repeated-measures ANOVA with Greenhouse-Geisser correction and Bonferroni-corrected post-hoc tests.

Results / Discussion

SWS increased monotonically with wrist extension angle in all participants (Fig. 1). Mean SWS rose from 2.82 ± 0.15 m/s at rest to 3.21 ± 0.12 m/s at 40° ($+14.0 \pm 4.4\%$) and 3.47 ± 0.14 m/s at 60° ($+23.4 \pm 8.0\%$), with all pairwise contrasts significant after Bonferroni correction ($p < 0.001$; Cohen's $d = 2.83, 4.40$, and 1.98 , respectively; partial $\eta^2 = 0.91$). At 60°, males exhibited significantly higher SWS than females (3.57 ± 0.09 vs. 3.36 ± 0.10 m/s; $p = 0.004$), indicating that sex should be considered as a covariate in future studies.

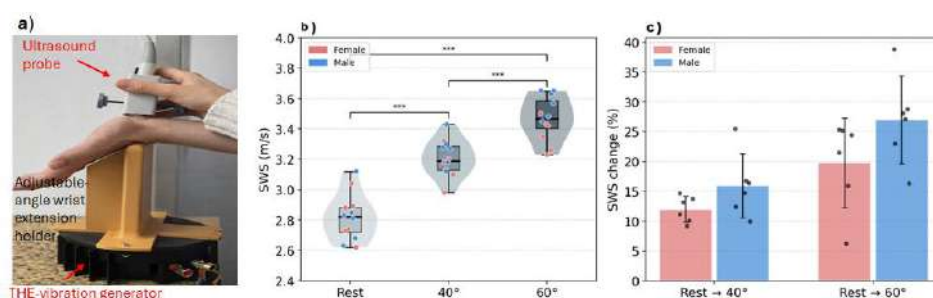


Figure 1. (a) Measurement setup. (b) Carpal tunnel SWS distributions across group. Violin shapes show the kernel density estimate; boxes indicate the median and interquartile range (** $p < 0.001$). (c) Percentage change in SWS relative to rest at 40° and 60° dorsiflexion, stratified by sex. Bars show group mean $\pm$ SD.

Conclusions

THE reliably detected position-dependent stiffness changes in the carpal tunnel under graded dorsiflexion, with large effect sizes consistent across all participants. These findings establish a normative mechanical reference and motivate a follow-up case-control study to evaluate THE as a non-invasive tool in CTS diagnosis.

Sensitivity of Ultrasound Time-Harmonic Elastography to Mechanical Changes in the Multifidus Muscle

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Background, Motivation and Objective

Low back pain (LBP) is one of the leading causes of global disability, with multifidus muscle dysfunction playing a central role in lumbar spine instability. Reliable non-invasive quantification of paraspinal muscle mechanical properties under different loading conditions is therefore clinically important. We investigated whether ultrasound time-harmonic elastography (THE), as a fast, flexible and cost effective elastography, can sensitively detect stiffness and viscosity changes in the multifidus. In this pilot study, we compared tissue properties across resting and active conditions, as a basis for future diagnostic use in patients.

Statement of Contribution / Methods

Eight young healthy adults (19.4 ± 2.8 yr; 4 men, 4 women) underwent multi-frequency THE (60-80 Hz, frame rate: 100 Hz) while lying prone in two conditions: (1) rest and (2) upper trunk lifted off the table. Continuous mechanical vibrations were delivered via a custom pillow-driver beneath the lumbar region (Fig. 1a). Also, a linear ultrasound transducer (5-11 MHz) was positioned over the multifidus centered at the L3 level. The k-MDEV algorithm extracted shear wave speed (SWS, elastic stiffness proxy) and penetration rate (PR, viscosity proxy) maps from the steady-state wavefield. Differences between conditions were assessed calculating standardized mean differences (Cohen's d).

Results / Discussion

As shown in Fig. 1b, SWS largely increased from rest (1.89 ± 0.27 m/s) to trunk extension (2.48 ± 0.31 m/s; Cohen's d = 3.38), confirming a huge and consistent mechanical stiffening response across all volunteers. PR (Fig. 1c) showed a corresponding decrease from rest (1.92 ± 0.35 m/s) to trunk extension (1.57 ± 0.35 m/s; Cohen's d = -0.84), indicating increased viscous energy dissipation during muscle contraction, albeit with greater inter-individual variability.

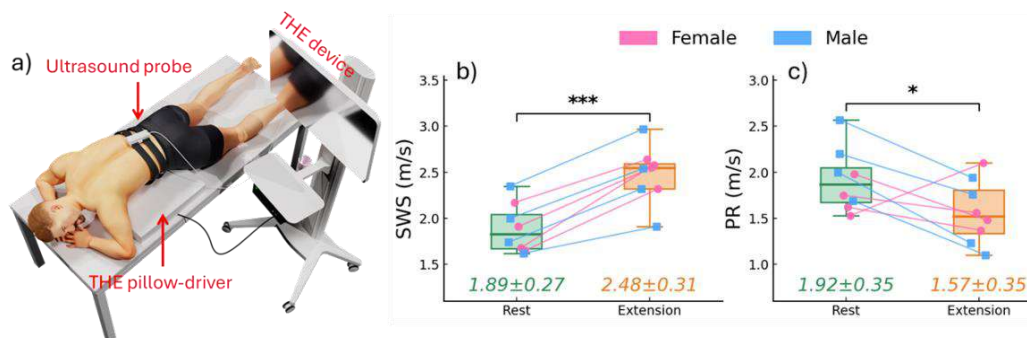


Fig. 1. (a) Measurement setup. (b) SWS, and (c) PR in rest and back extension conditions. Box plots show median, IQR, and 1.5×IQR whiskers (**p < 0.001, * p = 0.050).

Conclusions

THE reliably detects load-dependent mechanical changes in multifidus stiffness and viscosity, supporting its use as a non-invasive tool for paraspinal muscle assessment. SWS showed a large and consistent stiffening response to back extension, while PR demonstrated a moderate but more variable decrease in energy dissipation. These pilot results provide an empirical foundation for a larger study comparing multifidus mechanics in individuals with and without LBP.

Toward a Renal Digital Twin: Dispersion-Based 3D Ultrasound Elastography for Early Detection and Spatial Characterization of Chronic Kidney Disease

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Background, Motivation and Objective

Chronic kidney disease (CKD) induces fibrosis-driven viscoelastic remodeling. Current elastography relies on linear stiffness and 2D ROI models, limiting sensitivity and ignoring spatial heterogeneity. This work develops a dispersion-based 3D FEM framework with lesion modeling for spatially resolved and early CKD detection.

Statement of Contribution/Methods

A 3D ARFI-based FEM framework (COMSOL) was developed to simulate renal shear wave propagation. ARFI excitation (200 μ s, FOCUS-validated) generated 0.1–30 μ m displacements, with tissue modeled as Kelvin–Voigt (E , η) for CKD staging. TOF (85 probes, 0.25 mm) estimated speed, while k–f analysis with inverse fitting (100–500 Hz) quantified dispersion and viscosity (DSI). A spherical lesion enabled spatial heterogeneity beyond 2D SWE.

Results/Discussion

TOF showed linear propagation ($c = 1.397$ m/s). Lesion velocity increased (1.605 m/s) vs pre (1.223 m/s) and post (1.210 m/s), indicating localized stiffening. At $E = 3.5$ kPa, TOF changed <4% (1.07–1.11 m/s), while dispersion increased >120%. At $E = 12.75$ kPa, TOF varied <0.5% but dispersion retained ~40% sensitivity. Thus, TOF reflects stiffness, while dispersion sensitively captures viscosity-driven early CKD changes.

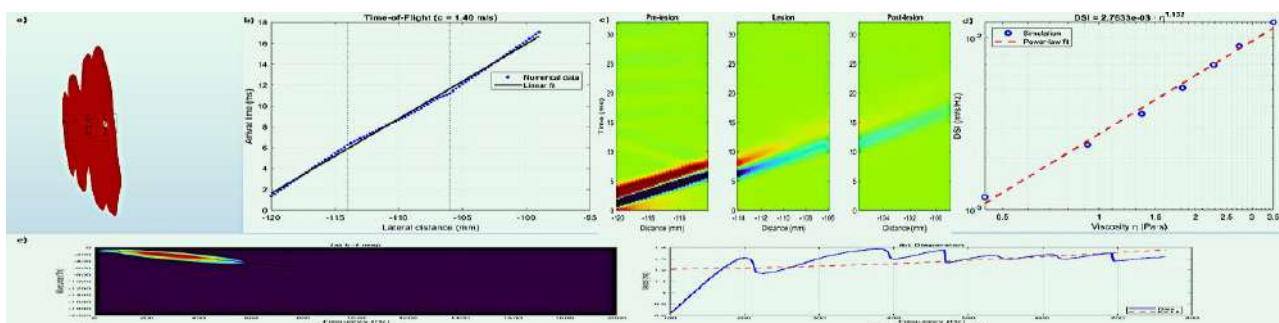


Figure 1. (a–d) Shear wave propagation, TOF, and dispersion (k–f, DSI) with Kelvin–Voigt fitting. Dispersion reveals viscosity changes beyond TOF stiffness.

Conclusions

3D FEM ARFI enables full-field modeling for early CKD detection. Dispersion (DSI) captures viscosity beyond TOF stiffness, supporting advanced renal models.

High-Efficiency Quasi-Static Displacement Estimation in B-mode Ultrasound via Structured Deep Learning

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Background, Motivation and Objective

Accurate displacement estimation is fundamental to ultrasound elastography, yet speckle noise and resolution anisotropy-particularly in the lateral direction- hinder motion tracking. This work presents a deep learning model designed to estimate dense displacement fields from pre- and post-compression B-mode images.

Methods

We propose a multiscale architecture that sequentially estimates axial displacement via 1D correlation, followed by lateral displacement and incompressibility constraints. The displacement field is refined using a coarse-to-fine strategy that compares reference and warped deformed images. The model was trained in a supervised manner using Field II simulated datasets.

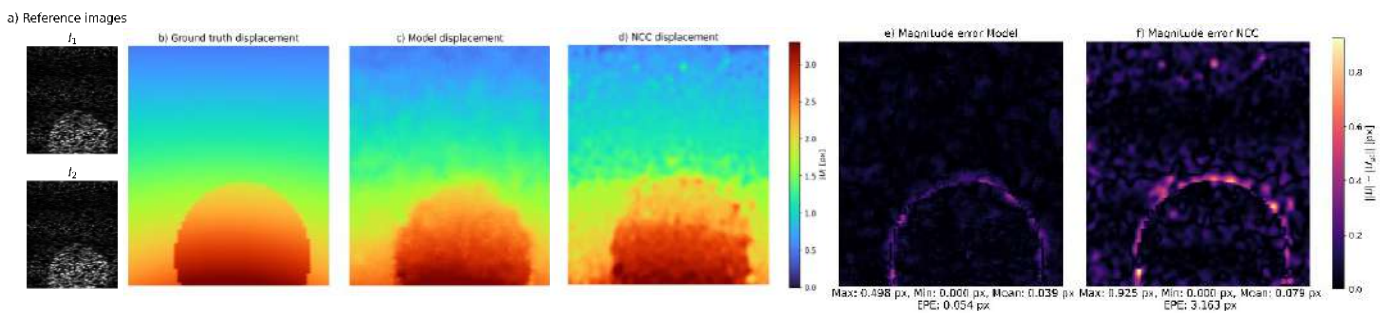


Figure 1. Example of quasi-static displacement estimation in simulated B-mode ultrasound data. a) Reference B-mode images, b) Ground truth displacement magnitude, c) Displacement magnitude estimated, d) Displacement magnitude estimated using normalized cross-correlation (NCC), e) Absolute error map between predicted and ground truth displacement fields, and f) Absolute error map between predicted displacement and NCC displacement fields.

Results and Conclusions

Preliminary results demonstrate that the model produces spatially coherent displacement fields with superior stability. Notably, the proposed approach significantly outperforms Normalized Cross-Correlation (NCC), achieving a much lower End-Point Error (0.054 px vs. 3.163 px) and a rapid execution time of 23ms, versus 17sec for NCC in this example. This structured deep learning strategy offers a robust, high-speed alternative for efficient quasi-static displacement estimation in ultrasound imaging.

Momentum equation-based regularization and image registration for two-dimensional ultrasound elasticity imaging

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Background, Motivation and Objective

Displacement estimation from ultrasound images is an important and challenging problem encountered in ultrasound elastography. Most of the available displacement estimation algorithms are only able to precisely estimate the displacement component along the direction of sound propagation due to the anisotropic ultrasound point spread function (PSF). This makes it difficult to efficiently solve the inverse problem for the mechanical properties. The goal of this work is to develop a displacement estimation algorithm that can reconstruct precise estimates of the full displacement vector field from ultrasound images.

Statement of Contribution/Methods

We develop four different optimization formulations for the image registration problem: two formulations are implementations of existing methods proposed in literature, and the last two add a regularization term that constrains the displacements to satisfy the conservation of momentum equations for a 2D elastic solid undergoing quasi-static plane stress and plane strain deformations. Simulated ultrasound images will be created using a finite element model, with physiological boundary conditions and known displacement fields, and an approximate ultrasound PSF. Experimental ultrasound image sequences will also be acquired of manufactured tissue mimicking phantoms with known material properties and controlled boundary conditions.

Results/Discussion

We apply the displacement estimation algorithm to the simulated image data and experimentally acquired ultrasound data from tissue mimicking phantoms and found that the formulations with momentum-based regularization, particularly under plane stress assumptions, achieved the lowest strain errors and highest strain contrast, even when the underlying tissue deformation violated 2D assumptions. In contrast, strain-based regularization with an incompressibility constraint produced unstable results. We used the displacement fields in an inversion algorithm to efficiently reconstruct the mechanical properties

Conclusions

Momentum-based regularization outperforms strain-based techniques in ultrasound image registration, particularly when used in an optimization framework. This approach improves robustness to noise and model mismatch, offering a promising direction for future displacement-based inversion methods.

Reduction of shear wave phase errors using a single-block scan sequence in continuous shear wave elastography

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Background

Continuous shear wave elastography (C- SWE) uses continuous external vibration to generate shear waves and assess tissue stiffness using Color Doppler-based post-processing without hardware changes or signal synchronization. However, with conventional Color Doppler sequences, small temporal delays between interleaved blocks may cause velocity- estimation errors, particularly under motion disturbances from respiratory, cardiac pulsation, or probe/vibrator movement.

Methods

To reduce block- to- block temporal delays, we developed a single- block acquisition scheme using a multiline sequence. Experiments were performed on a LOGIQ E10 system (GE HealthCare) with a 3 MHz C1- 6- D convex probe. Three tissue- mimicking phantoms (10, 25, 45 kPa; OST) were evaluated under 1 Hz disturbances. Continuous 78 Hz vibration was applied, and RF data were acquired at PRF 623 Hz.

Results

Shear- wave velocity estimates with the conventional method increased from 1.39 ± 0.14 m/s (no disturbance) to 1.66 ± 0.10 m/s under disturbance, whereas the proposed scheme maintained nearly identical values of 1.47 ± 0.12 m/s regardless of disturbance, for the 10kPa tissue phantom.

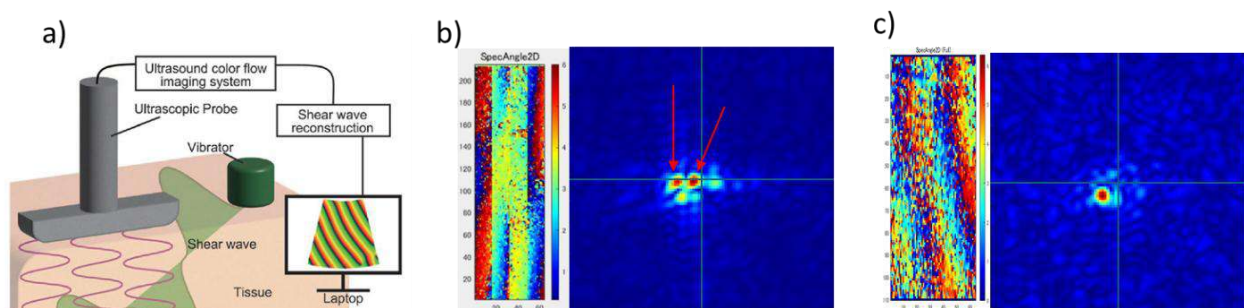


Figure 1. a) C- SWE method. b) 2D wavenumber spectrum in a 10 kPa phantom (multi- block). c) single- block- multiline acquisition, where the false peaks at the red arrows have disappeared.

Conclusions

This single- block acquisition approach improves the stability and reliability in shear- wave velocity estimation, representing a promising advancement toward more accurate and clinically robust C- SWE liver stiffness assessment.

The Impact Of Acoustic Push Duration On Shear Wave Signal Quality

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Background, Motivation and Objective

Active shear wave elastography (SWE) enables non-invasive assessment of myocardial stiffness, but its feasibility depends on the induced vibration characteristics, which is influenced by push wave parameters (e.g., frequency, amplitude, and duration). Reported values vary across studies; therefore, this study systematically evaluated the effect of push duration on shear wave (SW) detectability.

Statement of Contribution/Methods

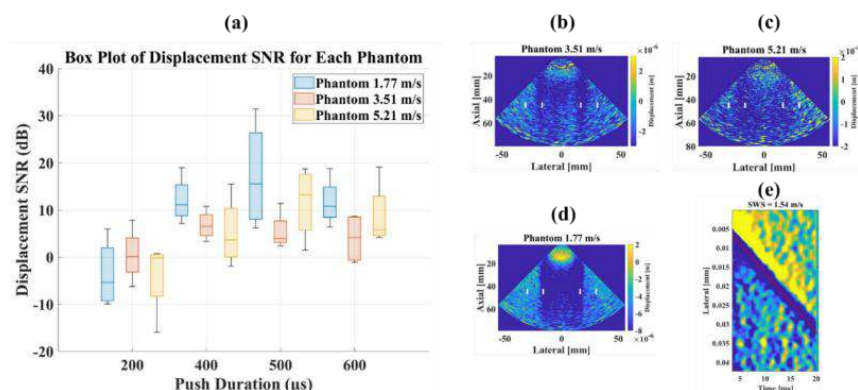
A SWE sequence was implemented on the ULA-OP 256 scanner using a phased-array probe and tested on 3 tissue-mimicking CIRS phantoms with different stiffness. SWs were acoustically generated at a typical cardiac wall depth of 50 mm and imaged using a high-frame-rate sequence (2kHz) with coherent compounding of three tilted diverging waves. Axial displacement was estimated using autocorrelation, and the shear wave speed (SWS) was calculated via Radon transform. The push pulses (3.0 MHz, 60 V) varied from 200 to 600 μ s. Signal-to-noise ratio (SNR) was calculated as the ratio of the average tissue motion of the SW to the background within a rectangular region of interest (white boxes in fig. b-d).

Results and Discussion

Preliminary results indicate that, increasing push duration improves SNR across all phantoms (fig. a), however, each phantom exhibits an optimal push duration beyond which additional gains are limited, i.e. 500 μ s for the stiffest and softest phantom and 400 μ s for the other. Estimated SWS deviated from reference values by 12.4%, 2.3%, and 6.4% for 1.77, 3.51, and 5.21 m/s phantoms, respectively.

Conclusion

Active SWE with the ULA-OP system is feasible for stiffness estimation. Optimizing push duration enhances SNR, but adaptive strategies might be beneficial for in vivo implementation to balance SW SNR with acoustic safety. Ongoing work aims to refine push and imaging strategies to improve SW detectability and reduce variability, ultimately enabling reliable myocardial stiffness estimation in clinical settings.



Mechanical properties of textiles investigated through wave propagation

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Context

Textile-based implant (mesh) treatment is considered as a standard of care for abdominal wall hernia repair but also for the reparation of pelvic tissues after tearing during labor. To characterize the impact of the textiles, the mechanical properties could represent an important marker. However, mechanical properties of medical textiles are difficult to evaluate in situ due to complex interactions with surrounding biological tissues. Accurate prior characterization is therefore essential to isolate intrinsic material behavior before accounting for tissue–textile coupling effects. Elastography techniques that would be used are intrinsically dynamic. We assume that the mechanical characterization of the knitted textiles should be performed using elastic wave propagation.

Objective

The present study aims to investigate the accuracy of the characterizing knitted fabrics using wave propagation. External factors such as tension and air are investigated.

Experimental approach

Two set of experiments have been performed: one during tensile testing experiments and one in a vacuum chamber. In the latter, Lycra fabric membranes were clamped between two concentric rings allowing to control the isotropy of the membrane tension by stretching the membrane in various directions along the rings. A high-speed camera (Chronos 1.4, Kron Technologies, Burnaby, Canada) was used to record the longitudinal and transverse waves excited by a K2004E01 vibrator (The Modal Shop Inc., Cincinnati, OH). DIC algorithms were used to process the recorded images and track the wavefronts, then noise correlation algorithms were subsequently employed to derive the dispersion curves of the wave velocities. The physical model of the membrane was further elucidated through an analysis of these wave velocity dispersion curves. Results were then compared to finite-element simulations using COMSOL through the membrane module coupled with fluid-structure interaction.

Viscoelastic characterization of polyacrylamide microbeads: cross-method comparison of atomic force microscopy and optical microelastography

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Background, Motivation and Objective

Reliable micromechanical characterization of soft materials requires methods that are both spatially resolved and frequency-sensitive. Atomic force microscopy (AFM) is widely used for surface stiffness measurements but cannot capture spatially heterogeneous bulk viscoelastic behavior. Optical microelastography (OME) provides full-field viscoelastic maps through elastic wave propagation, yet its agreement with indentation-based approaches across frequency domains remains to be established. Homogeneous polyacrylamide (PAAm) microbeads with tunable mechanical properties were used as a controlled mechanical reference to compare AFM- and OME-based viscoelastic characterization across a wide frequency range.

Statement of Contribution/Methods

Spherical PAAm microbeads (75 μm diameter) were independently characterized using AFM (0.01–80 kHz) and OME (30–60 kHz). OME mapped spatially resolved viscoelasticity using elastic wave propagation processed via a subzone nonlinear inversion (NLI) framework. Storage (G') and loss (G'') moduli were extracted from both methods and compared in terms of frequency-dependent power-law behavior using a fractional dashpot model ($G^*(f) = A(i\omega)^\alpha$).

Results/Discussion

AFM data were best described by a two parallel fractional dashpot model, with a near-elastic element (exponent: 0.01) dominating at lower frequencies, and a viscoelastic element (exponent: 0.45) governing high-frequency dispersion ($R^2 = 0.86$). OME, operating within the high-frequency portion of AFM's range (30–60 kHz), was well-described by a single fractional dashpot (exponent: 0.68; $R^2 = 0.96$). Spatially resolved OME maps showed uniform viscoelastic properties across the bead interior, consistent with the homogeneous composition of PAAm. The comparable power-law exponents at high frequencies, despite fundamentally different operating principles (indentation for AFM and wave propagation for OME), support the validity of OME for quantitative viscoelastic mapping of soft materials.

Conclusions

AFM and OME yield consistent frequency-dependent viscoelastic behavior on homogeneous PAAm microbeads, supporting the validity of wave-based mechanical characterization and establishing these beads as a reliable reference for cross-method comparison. These findings position OME as an effective tool for broadband, microscale viscoelastic characterization of soft materials.

Evaluating Age Related Biomechanical Changes in the Psoas Major Following Spinal Manipulative Therapy Using Magnetic Resonance Elastography

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Background, Motivation and Objective

Magnetic Resonance Elastography (MRE) enables non-invasive quantification of tissue-specific mechanical properties and may provide new insight into how spinal manipulative therapy (SMT) affects deep lumbar musculature. The aim of this case study was therefore to explore biomechanical changes in the psoas major (PM) after a single SMT session in two individuals with low back pain and a large age difference.

Statement of Contribution/Methods

This case study included two male participants with low back pain, aged 72 and 19 years. Both underwent lumbar MRE before and after one SMT session targeting the L3-L5 segments. Multifrequency axial MRE acquisitions were performed at 60-90 Hz, and biomechanical parameters were assessed using shear wave speed (SWS) and loss angle (ϕ), derived through k-MDEV and MDEV inversion. This study contributes with a novel insight into the biomechanical effects of SMT in the PM.

Results/Discussion

Both participants showed lower mean PM stiffness (SWS) after SMT. In the older participant (P1), mean SWS decreased from 1.42 ± 0.07 to 1.25 ± 0.07 m/s post-SMT, whereas in the younger participant (P2), it decreased from 1.60 ± 0.11 to 1.55 ± 0.11 m/s, although this reduction was small relative to the within-participant variability. Frequency-dependent analysis showed the greatest reduction at 60 Hz in P1 and at 90 Hz in P2. Loss angle remained stable.

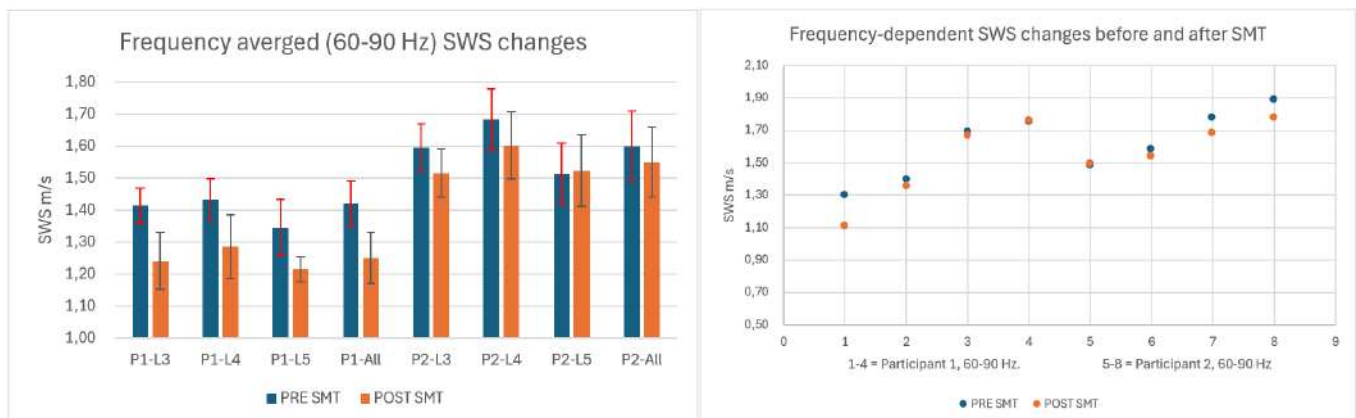


Figure 1. (A) Mean psoas major shear wave speed (SWS) at L3-L5 before and after a single spinal manipulative therapy (SMT) session in two participants. Error bars indicate standard deviation; "All" denotes the average across levels. (B) Frequency-dependent SWS (60-90 Hz) before and after SMT. Points 1-4 represent participant 1 and points 5-8 participant 2. SWS was derived using k-MDEV inversion.

Conclusions

A single session of SMT was associated with lower mean PM stiffness after intervention. These preliminary findings support the potential of MRE as a tool for assessing tissue-specific biomechanical responses to spinal interventions. Further studies in larger and more clinically diverse populations are needed to confirm these findings and clarify their clinical relevance.

Genetic Correlates of Brain Mechanical Properties*Isa Rietveld, Luisa Sophia Seckinger, Tobias Navarro Schröder*

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Background, Motivation and Objective

Brain MRE remains largely in the phase of clinical investigation and translational development (Anderson et al., 2016; Hiscox et al., 2016). Mechanical properties measured with brain MRE show strong associations with various neurological conditions, and growing evidence indicates that distinct biological processes produce characteristic mechanical signatures (Coelho & Sousa, 2022; Hiscox et al., 2016; Bergs et al., 2024; Fløgstad Svensson et al., 2023). These findings suggest a potential role for genetic factors in shaping brain mechanics, yet literature directly linking genetic variation to human brain mechanical properties is extremely limited (Fløgstad Svensson et al., 2023). This study therefore aims to identify the genes most strongly associated with MRE-derived brain mechanical properties. Genetic predictors of MRE-derived mechanics could enable targeted risk profiling and help uncover the biological pathways driving mechanical degeneration.

Methods

Preprocessed and normalized gene-expression data from the Allen Human Brain Atlas (AHBA) (six donors; ~15.000 genes and loci) were mapped to MNI space, yielding 2754 usable samples (ALLEN Human Brain Atlas, 2013). Data was acquired on a Siemens MAGNETOM Terra System at the Norwegian 7T MR Center in Trondheim. Using 32-channel coil and 2 compressed-air actuators at the back of the head, the brain of two healthy subjects were scanned, applying an SE-EPI MRE sequence. The following imaging parameters were set for Scan 1: TE: 70ms; TR: 4700ms; resolution: 2mm isotr., actuator frequencies: 20, 25, 30, 35Hz; and Scan 2: TE: 70ms; TR: 6790ms; resolution: 1x1x2mm³, actuator frequencies: 40, 45, 50, 55Hz). For both scans, the mechanical waves were sampled at 8 phase offsets and in 3 MEG encoding directions. Furthermore, first moment nulling was applied. Multifrequency inversion was performed using the KMDEV scripts from the Elastography Group at the Charité Berlin (Meyer et al. 2022). For each donor, Spearman correlations between gene expression and stiffness values per voxel were computed. Genes showing the highest and most consistent correlations across donors were selected, after which final correlations and FDR corrections were performed using the combined dataset of all six donors.

Preliminary results

Across two independent MRE acquisitions, shown in Figure A and B, ROCK2 emerged as one of the most consistently associated genes with regional brain stiffness. ROCK2 expression showed a reproducible positive correlation with brain stiffness (Figure C and D), with $\rho = 0.186$ ($p = 4.07 \times 10^{-19}$, FDR = 1.28×10^{-16}) in Scan 1 and $\rho = 0.228$ ($p = 3.88 \times 10^{-28}$, FDR = 3.02×10^{-25}) in Scan 2. ROCK2 is a Rho-activated serine/threonine kinase that regulates actin–myosin contractility, stress-fiber formation, and focal adhesion assembly (GeneCards, n.d.).

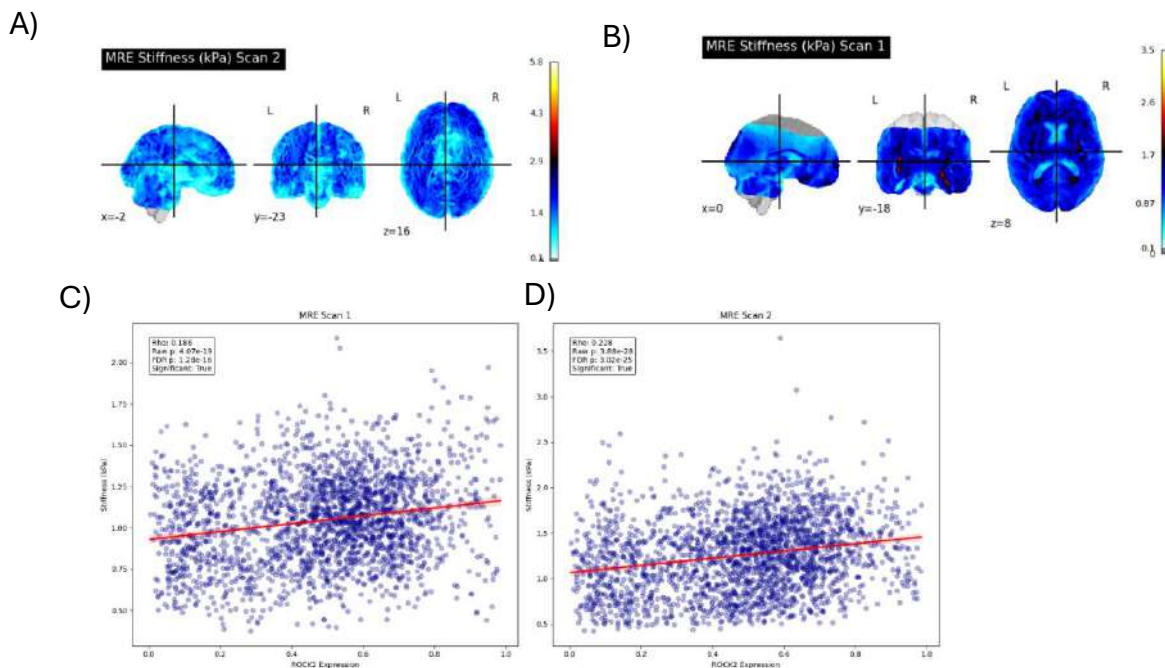


Figure A) and B) show brain maps of tissue stiffness measured with MRE from two independent scans. Figure C) and D) show scatter plots relating ROCK2 gene expression to regional stiffness for each scan.

Conclusions

Preliminary results show that linking regional gene expression to brain stiffness produces consistent patterns across independent datasets, allowing the direct identification of genes that may influence the mechanical properties of cortical tissue. Among these, ROCK2 emerges as a particularly robust and reproducible correlate of stiffness. By regulating cytoskeletal tension and cell adhesion, ROCK2 directly shapes the mechanical behavior of neural tissue, making it a biologically plausible contributor to cortical stiffness. Together, these findings suggest that regional variation in ROCK2 expression may underlie aspects of the mechanical heterogeneity observed in the human cortex and provide a strong foundation for future mechanistic studies.

Repeatability and reproducibility of 2D and 3D MRE at 1.5T and 3T in the liver of healthy volunteers

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Background: There is an unmet clinical need for improved toxicity management in patients treated with systemic anti-cancer therapies (SACT) (E. Lee, Current Oncology, 2023). SACT is known to cause hepatotoxicity, such as steatosis, pseudocirrhosis, and sinusoidal obstruction syndrome (F. Alessandrino, 2017, Clinical Radiology). MRE is established for staging liver fibrosis (Yin, 2016, Radiology), but is not routinely used when assessing toxicity effects from SACT. We aim to investigate MRE in combination with other quantitative MRI techniques for early detection and monitoring of toxicity caused by SACT. This abstract reports initial work to characterise the performance of a gravitational MRE device, which can measure the complex shear modulus (G^*) using 2D or 3D MRE.

Objective: To evaluate the repeatability and reproducibility of MRE using a gravitational MRE device at 1.5T and 3T.

Methods: A short-term repeatability study was performed in 22-exams of healthy volunteers (14/F, median 41.5 years, range 25-59, median BMI 22.3 kg/m², range 19.1-30.7 kg/m²) at 1.5T (n=11) and 3T (n=11) (MAGNETOM Sola and Vida, Siemens Healthcare, Forchheim, Germany). MRE was performed at 60 Hz using a Gravitational Transducer (Runge, 2019, Phys Med Biol) (Quality Electrodynamics, Mayfield OH, USA). Additional 2D MRE images were acquired in volunteers at 1.5T using an Acoustic MRE system (Resoundant, Rochester, MN, USA). A reproducibility study was performed in n=7 healthy volunteers (4/F, median 41 years, range 29-59, median BMI 20.9 kg/m², range 19.1-30.7 kg/m²) where the same participants were scanned on both 1.5T and 3T using the same MRE transducer. The median time between 1.5T and 3T scans was 51 days (range 16-85 days). Technical performance was assessed using Bland-Altman analysis and the Repeatability and Reproducibility Coefficients (RC) with 95% confidence interval (CI).

Results: The repeatability analysis for 3D MRE showed no test-retest bias ($p>0.3$) with RC of 11.3% (95%CI 8.7-16.1%) for $|G^*|$, 13.6% (95%CI 10.6-20.0%) for G' , and 22.9% (95%CI 15.8-29.7%) for G'' . The RC for $|G^*|$ measured by the Acoustic 2D MRE system was 12.9% (95%CI 10.0-18.5%). $|G^*|$ values measured by 3D MRE were 0.2 kPa lower than 2D MRE ($p < 0.01$). The reproducibility analysis showed no bias between 1.5T and 3T for $|G^*|$ measured by 3D MRE ($p>0.4$) with RC of 12.7% (95%CI 9.7-18.1%).

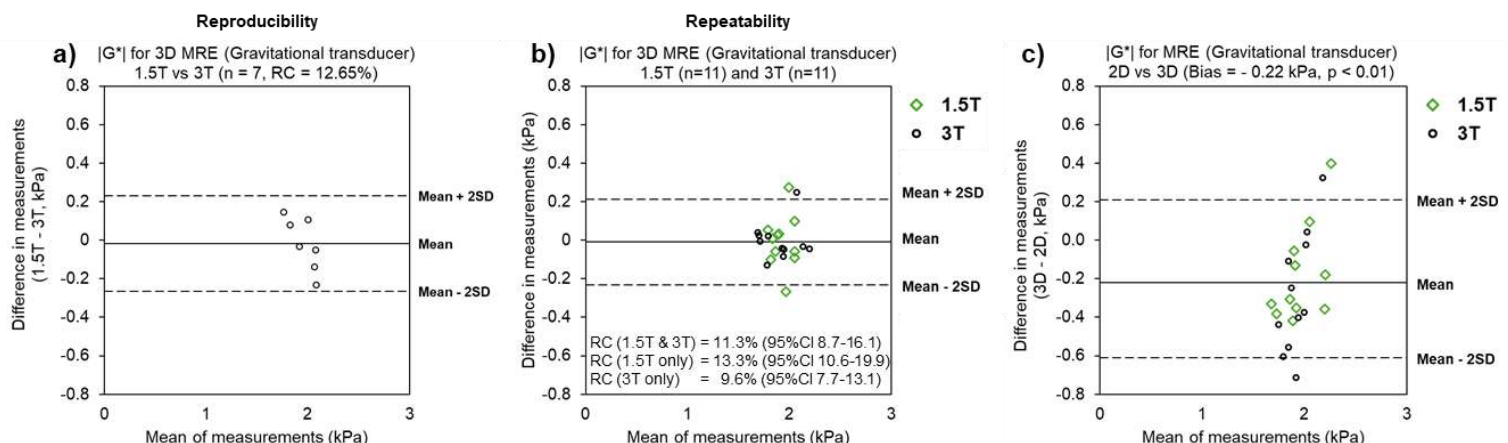


Fig 1: Bland-Altman plots of **a)** 3D $|G^*|$ reproducibility at 1.5T and 3T, **b)** 3D $|G^*|$ repeatability, **c)** 2D and 3D $|G^*|$.

Conclusion: MRE is repeatable in the liver. These preliminary findings suggest that 3D-MRE is feasible and could be used to detect longitudinal biomechanical changes in $|G^*|$. Future studies should evaluate the utility of MRE for the early detection and monitoring of hepatotoxicity, and could explore the 3D vs 2D MRE bias.

Acknowledgements: We gratefully acknowledge QED (Mayfield, OH, USA) for the loan of the research prototype hardware and Software, and also Siemens Healthineers for their technical support and helpful discussions. This was a prospective, single-centre study approved by a national research ethics committee (ClinicalTrials.gov Identifier: NCT05118555). Consent was obtained from all participants. This project represents independent research funded by the National Institute for Health and Care Research (NIHR) Biomedical Research Centre at The Royal Marsden NHS Foundation Trust and The Institute of Cancer Research, London, by the Royal Marsden Cancer Charity, and Cancer Research UK (CRUK) National Cancer Imaging Trials Accelerator (NCITA). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. This work uses data provided by patients and collected by the NHS as part of their care and support.

Thyroid MR Elastography for Small-Organ Viscoelastic Assessment

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Background

Quantitative mapping of thyroid biomechanics may provide clinically relevant information for the evaluation of diffuse and focal thyroid disease. Yet, due to its small size, challenging anatomy, and proximity of tissue-air interfaces, the thyroid has been a challenging target for MR elastography. This work aims to establish quantitative viscoelastic assessment using thyroid MRE.

Methods

32 healthy subjects were examined with thyroid MRE on a clinical 3T MRI system using a dedicated neck mechanical excitation setup. Harmonic shear waves at 40, 50, 60 Hz were encoded with a multi-slice SE-EPI MRE acquisition. Shear wave fields were reconstructed and postprocessed to derive quantitative viscoelastic maps, including shear wave speed (SWS), penetration rate (PR), and loss angle (PHI). Thyroid regions of interest were segmented on anatomical images. Currently only 5 healthy subjects have been evaluated.

Results

The representative anatomical and SWS map demonstrates successful spatially resolved MRE of the thyroid gland. The SWS map shows clear mechanical contrast between the thyroid and the surrounding tissue. Analysis across 5 healthy volunteers is summarized by boxplots of SWS (mean: 1.16 ± 0.17 m/s), PR (mean: 0.52 ± 0.03 m/s), and PHI (mean: 0.69 ± 0.10 rad).

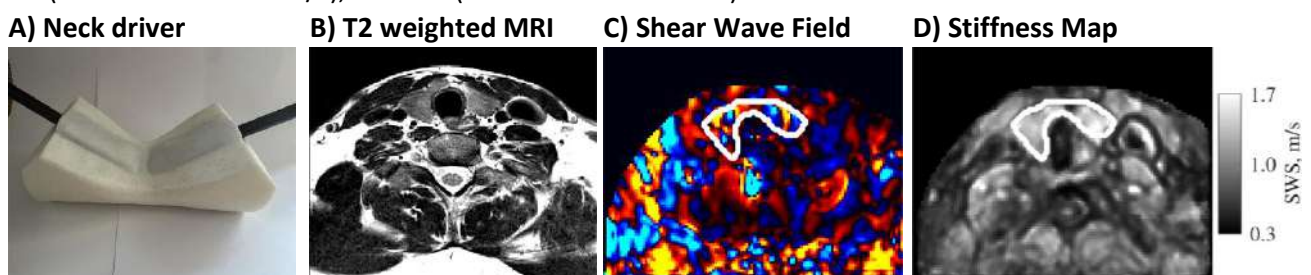


Figure 1

Conclusion

Our results show the technical feasibility of thyroid MRE and indicate stable wave penetration and quantitative viscoelastic assessment in a small-organ application in the head-neck region.

Longitudinal tabletop magnetic resonance elastography in a bioreactor for monitoring tissue mechanics

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Background, Motivation and Objective

Tabletop magnetic resonance elastography (ttMRE) enables compact assessment of soft tissue biomechanics but is currently limited to ex vivo tissue specimens. Longitudinal monitoring of viscoelastic properties of biosystems under physiological conditions, such as during cell culture, remains unexplored. Therefore, we developed an incubator-compatible ttMRE platform for time-resolved biomechanical assessment.

Statement of Contribution/Methods

A custom-designed ttMRE-compatible bioreactor was developed and integrated into a standard heat chamber (37°C, 0.5 ml/min flow rate of cell culture media, 95% O₂ with 5% CO₂ mix gas supply) while maintaining stable mechanical excitation and MR acquisition. A human liver decellularized extracellular matrix (dECM) scaffold was investigated repeatedly over 7 days without cell seeding to assess baseline stability. Shear wave speed c and penetration rate a , representing stiffness and inverse attenuation, were reconstructed to quantify viscoelastic properties over time.

Results/Discussion

The ttMRE bioreactor enabled stable and reproducible measurements under incubator conditions. No significant changes in viscoelastic parameters were observed in the dECM scaffold over 7 days, demonstrating mechanical stability and measurement robustness.

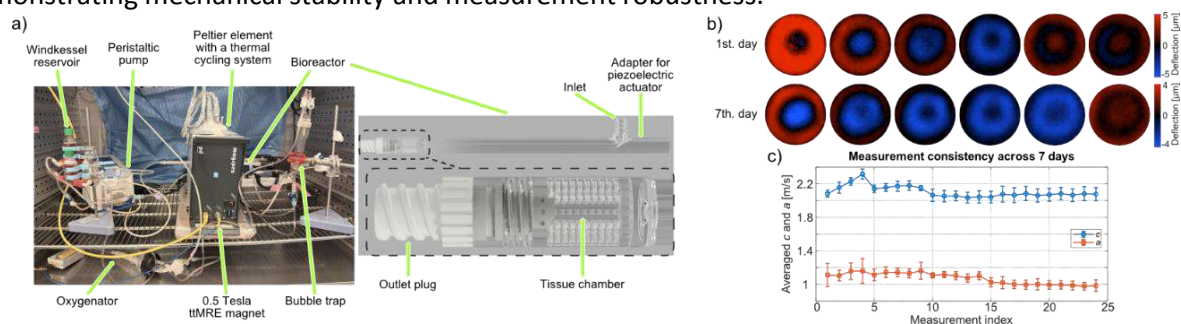


Figure 1. a) ttMRE-compatible bioreactor setup and design; b) Wave fields (700–1200 Hz) on day 1 and day 7; c) Stable viscoelastic parameters of dECM over 7 days (c : shear wave speed, a : penetration rate).

Conclusions

We present a novel bioreactor-integrated ttMRE platform for longitudinal biomechanical monitoring under physiological conditions. Baseline stability of dECM confirms the system's suitability for detecting cell-induced mechanical changes, enabling future studies of tissue remodeling and tumor cell activity.

Inter-scanner reproducibility of multifrequency brain MRE

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Background, Motivation and Objective

Magnetic resonance elastography (MRE) quantitatively maps the brain's viscoelastic properties, yet systematic cross-site data for brain MRE are limited. This study quantified cross-site reproducibility of harmonized multifrequency brain MRE (20, 25, 30, and 35 Hz) across two distinct 3 T MRI platforms.

Statement of Contribution/Methods

In a prospective cross-site test-retest design, 16 healthy adults were scanned at two sites on two 3 T MRI systems (Siemens MAGNETOM Cima.X and Vida) using identical MRE sequences and a standardized vibration driver (Vibro42, THEA-Devices GmbH). Shear wave speed (SWS) and penetration rate (PR) were reconstructed and normalized to MNI152 space. Atlas-based analysis covered major brain regions. Reproducibility was assessed using multiple metrics, including the absolute relative difference (ARD).

Results/Discussion

Brain MRE yielded stable measurements, with region-averaged SWS ARDs of 1.38, 3.43, and 1.52 % and PR ARDs of 3.44, 7.25, and 3.20 % in white matter, subcortical gray matter, and cortical gray matter, respectively. Violin plots showed comparable distributions across scans, with slight mean differences.

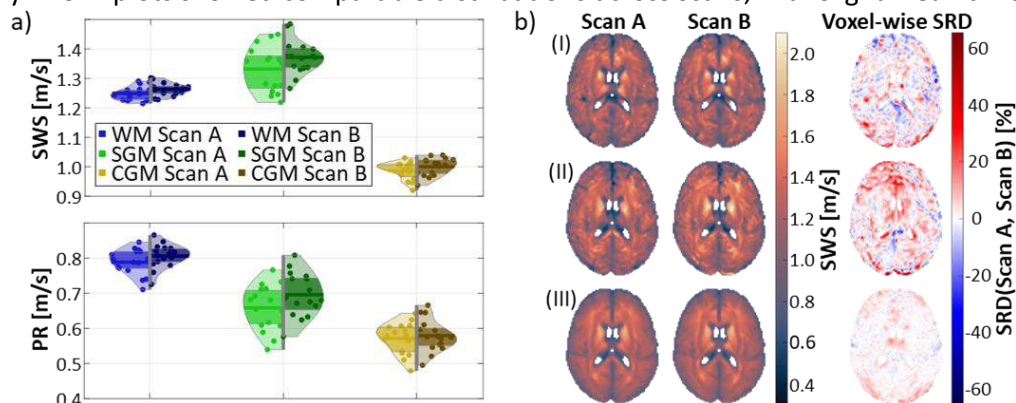


Figure 1. a) Violin plots of SWS and PR across major brain regions; b) SWS and voxel-wise SRD for subject pairs with smallest (I, 0.27 %) and largest (II, 3.00 %) whole brain ARD, and all subjects averaged (III).

Abbreviations: SWS, shear wave speed; PR, penetration rate; SRD, symmetric relative difference; WM, white matter; SGM, subcortical gray matter; CGM, cortical gray matter.

Conclusions

Harmonized multifrequency brain MRE demonstrates robust cross-site reproducibility across platforms.

Applications of Atomic Force Microscopy in Cardiac Micromechanics

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Background

Heart failure remains a major clinical challenge worldwide and is frequently associated with impaired cardiac mechanics. The mechanical properties of the heart are governed both by the dynamic mechanical behavior of living cells as well as the structural properties of the surrounding extracellular matrix (ECM). Atomic force microscopy (AFM) is well suited for probing cell and ECM biomechanical properties at the microscale.

Methods

Beating cardiomyocytes were characterized by AFM microrheology across a frequency range from 10 Hz to 90 Hz. The measurements were analyzed in consecutive 0.1 s windows, within which phase angle and apparent stiffness were calculated to resolve their temporal evolution over the myocytic contraction cycle. The hiPSC-derived cardiac fibroblasts were cultured under baseline or heart failure with preserved ejection fraction (HFpEF)-mimicking conditions. AFM indentation was performed on the cells, the surrounding ECM and the ECM produced by these cells following a decellularization protocol (dECM). Young's modulus was extracted from force-indentation curves and compared between groups.

Results

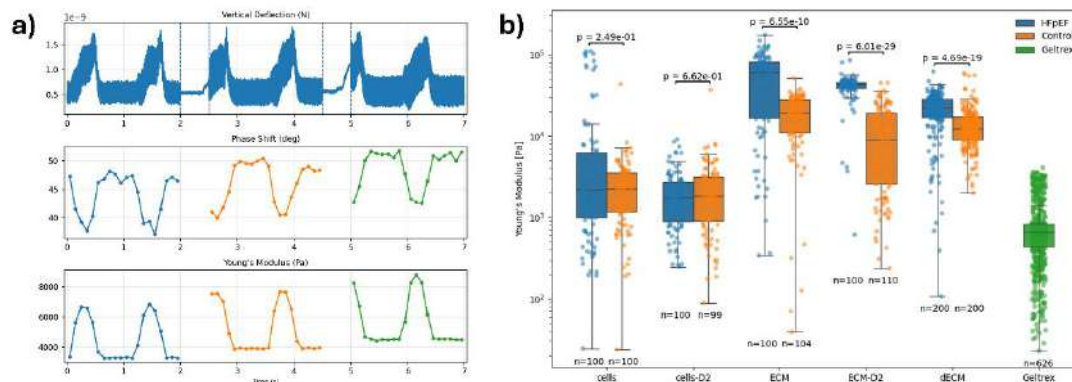


Figure 1. a) force-time curve from microrheology measurements on cardiomyocytes, phase angle and Young's modulus for three myocytic contraction cycles. Dynamic changes of cell viscoelasticity during contraction are well visible; b) Young's modulus of fibroblasts, ECM and dECM between HFpEF and control conditions, with Geltrex as substrate. The ECM in HFpEF is stiffer than in controls while cells do not significantly differ across these conditions.

Conclusion

Using AFM, we characterized the time-dependent viscoelastic behavior of beating cardiomyocytes over the contraction cycle. The same method revealed that ECM under HFpEF conditions is stiffer than in controls, whereas cells do not show significant differences between groups.

LABOU: Iterative Laplace-Based Bi-Level Optimization Phase Unwrapping for MR Elastography

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Background, Motivation and Objective

Phase unwrapping converts wrapped phase contrast MR images to continuous displacement fields, which is a critical preprocessing step in MR elastography (MRE). Standard MRE stiffness reconstruction approaches often rely on a single-pass Laplacian unwrapper¹, which solves the Poisson equation efficiently based on numerical finite difference schemes but over-smooths genuine phase variations near tissue boundaries². We present LABOU, a bi-level optimization framework that addresses these limitations, and evaluate its downstream impact on wave-number based multi-inversions (k-MDEV¹) stiffness estimation in brain MRE.

Statement of Contribution / Methods

LABOU decomposed phase unwrapping into two coupled levels. The lower level solved the Poisson equation on an iteratively refined wrapped residual via discrete cosine transformation (DCT), yielding a continuous phase estimate. The upper level then utilised a greedy local search which minimised data-fidelity while enforcing piecewise constancy, balancing the two criteria by an appropriate weight like the MRI magnitude, to generate a pixelwise integer phase-offset map. Adaptive SNR-weighted Gaussian smoothing further stabilised the DCT-solve in low-SNR regions. The method was evaluated on 3,800 brain MRE phase images acquired in a frequency range from 5 to 50 Hz against manually corrected reference images, and its effect on k-MDEV shear wave speed (SWS) maps was assessed.

Results / Discussion

The proposed method had a median residual error of 0, coinciding with the reference in 3759 out of 3800 images while the Laplace unwrapper resulted in a median residual error of 1.3879 and 0 matches with the reference. Fig. 1 further showed that replacing single-pass Laplacian unwrapping with LABOU markedly improved the quality of SWS maps: Anatomical boundary sharpness increased, and fine structural detail in cortical and subcortical regions became clearly visible (red arrows in Fig. 1). These gains were consistent with the propagation of unwrapping errors into spatial phase gradients on which k-MDEV depends.

Conclusions

LABOU substantially outperforms standard Laplacian unwrapping in accuracy, and its integration into the k-MDEV pipeline yields SWS maps with improved spatial resolution and reduced artefacts. Future work includes the extension of LABOU to abdominal MRE and higher-field acquisitions, where the accuracy gains are expected to translate directly into improved viscoelastic parameter estimation.

References: [1] Heiko Tzschätzsch et al., 2016 Medical Image Analysis
[2] Robinson et al., 2017 NMR in Biomedicine

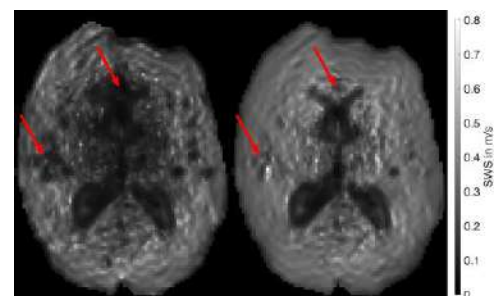


Fig. 1: Representative SWS maps with standard Laplacian unwrapping (left) and LABOU (right).

Improved Full-Waveform Inversion in Time-Harmonic Elastography

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Background, Motivation and Objective

In time-harmonic elastography (THE), shear waves are induced into the tissue and measured using pulse-echo ultrasound or magnetic resonance [1]. When estimating shear-wave velocity, physics-based methods can handle multidirectional propagation without degradation associated with directional filtering. Full-waveform inversion (FWI) further improves this, iteratively fitting a forward model to the data [2], without requiring spatial differentiation as in direct inversion. However, FWI relies on accurate modeling, particularly of source and boundary conditions. We seek to mitigate these FWI limitations.

Statement of Contribution/Methods

We demonstrate a novel FWI framework in THE, integrating source/boundary condition estimation. The goal is to achieve improved inversion with a forward model accounting for source and reflection effects originating outside the image window. This boundary estimation is done along the image edges, capturing excitation, reflection, and absorbing-boundary effects. We also propose a total variation (TV) regularization, promoting convergence toward piecewise-constant shear-wave speed maps.

Results/Discussion

We apply the novel strategies to phantom data (CRIS Phantom 049, inclusion IV) acquired with pulse-echo ultrasound and a 150 Hz actuator. We show FWI: assuming fixed source (Fig. 1a); assuming fixed source, with TV (b); TV with boundary estimation (c). The novel strategy gives smoother maps, clearer inclusion contrast, significantly fewer artifacts near the source, and improved data fitting (d).

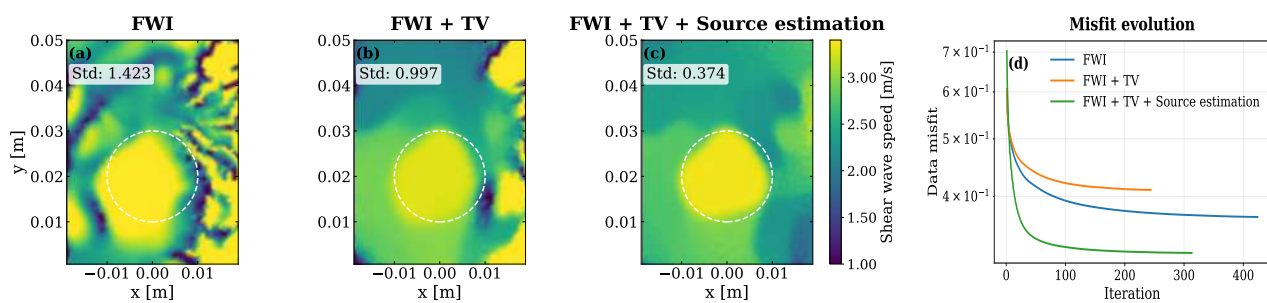


Figure 1. FWI shear-wave speed reconstruction, with the source on the right of the image. (a) Fixed source, (b) fixed source with TV regularization, and (c) TV with source estimation. (d) Misfit evolution.

Conclusions

The proposed strategies improve the FWI inversion, thereby opening for using it in on in-vivo data.

[1] H. Tzschtzsch et al., "Two-Dimensional Time-Harmonic Elastography of the Human Liver and Spleen," *Ultrasound in Medicine & Biology*, vol. 42, pp. 2562–2571, 2016. [2] M. A. Boukraq et al. "Proof of Concept for Full-Waveform Inversion in Ultrasound Time-Harmonic Shear-Wave Elastography," *Physics in Medicine & Biology*, *Revised paper in review*, 2026

Physics-Informed Deep Learning for Rapid MR Elastography

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Background, Motivation, and Objective

Magnetic Resonance Elastography (MRE) quantifies tissue biomechanical properties by encoding shear waves into the MR image phase, but suffers from slow data acquisition and an ill-posed wave inversion. We address these challenges with physics-informed deep learning reconstruction methods for highly accelerated MRE, targeting robust shear wave speed (SWS) estimation from undersampled k -space data.

Statement of Contribution/Methods

Instead of relying on handcrafted image priors, we propose data-driven reconstruction frameworks with regularization tailored to the MRE quantification task. Here, we integrate the k -MDEV inversion method into a model-based reconstruction pipeline that alternates between CNN and data consistency layers, enabling task-specific end-to-end optimization from k -space to SWS maps and exploiting spatio-temporal correlations across vibration phase offsets. The method is visualized in Figure 1a.

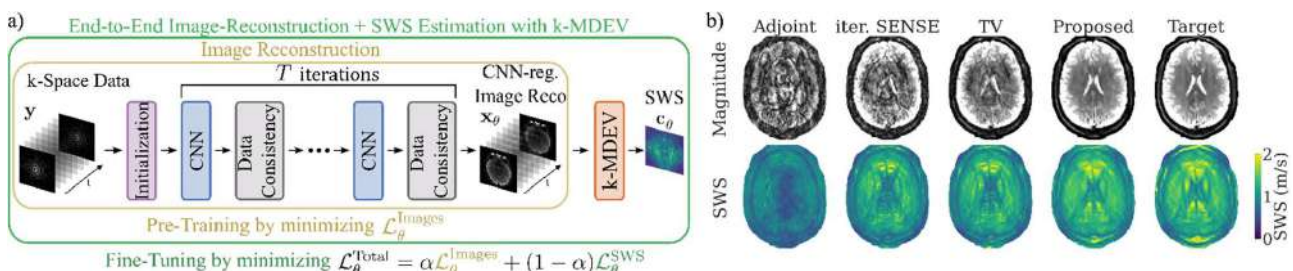


Figure 1. End-to-end supervised method. a) Schematics of the end-to-end method.

b) Results of retrospectively undersampled single-spiral data, reconstructed with different methods.

Results/Discussion

Evaluated on retrospectively undersampled brain MRE data (see Figure 1b), the end-to-end method with SWS targets reduced NRMSE by 30% at 19-fold acceleration compared to total variation (0.14 ± 0.033 vs. 0.20 ± 0.041 for SWS maps) and by 5% over image-only pre-training. Further, the method generalized successfully to prospective in vivo acquisitions, demonstrating the potential for clinical deployment.

Conclusions

We present a physics-informed end-to-end framework for accelerated MRE that significantly outperforms conventional reconstruction methods and generalizes to prospective in vivo acquisitions, enabling accurate SWS estimation at 19-fold acceleration and stiffness mapping at frame rates up to 18 Hz for dynamic physiological studies and clinical diagnostics, with a reconstruction time < 1 s. When training data are unavailable, a complementary zero-shot self-supervised strategy offers an alternative.

System Identification for Magnetic Resonance Elastography

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Background, Motivation and Objective

Inversion algorithms in magnetic resonance elastography (MRE) rely on user-supplied models of tissue dynamics, which encode a set of assumptions. Depending on the configuration, this may generate significant differences in predictions. Thus, being able to identify how appropriate a model is, given a set of data, may serve as an evaluation of both model and data quality. In this abstract, we discuss HetSI, a system identification (SI) method for data-driven model discovery, which can be used with MRE.

Statement of Contribution/Methods

HetSI is an algorithm for data-driven PDE discovery which allows for spatially varying parameters. The algorithm selects a sparse linear combination of explanatory bases from a user-defined library. Unlike similar algorithms, such as PDE-FIND and SINDy, HetSI identifies a parameter field which allows for the identification of the gradients of the parameters. These gradients can be incorporated into the explanatory bases, enabling discovery of terms relevant for heterogenous media.

Results/Discussion

We applied HetSI to the four-insert phantom measurement from BIOQIC (<https://bioqic-apps.charite.de/>), using the library $\{\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial u}{\partial z}, \nabla \times u, \nabla \cdot u, \nabla^2 u + 2\varepsilon \cdot \nabla \gamma_i, \nabla(\nabla \cdot u) + \nabla \gamma_j(\nabla \cdot u), \text{Constant}\}$, where γ_i, γ_j were the predicted parameters of that basis, and u was the measured displacement, both at a given voxel, assuming an isotropic and frequency-independent prediction. Fig. 1a and 1b show that the data primarily adhered to the spatial heterogeneous shear wave equation (1a), with small to negligible longitudinal contribution (1b). Small contributions from spatial gradients (Fig. 1c and 1d) may indicate that some regions are not fully explained by shear wave propagation, the data quality is insufficient, or another set of algorithm settings is required.

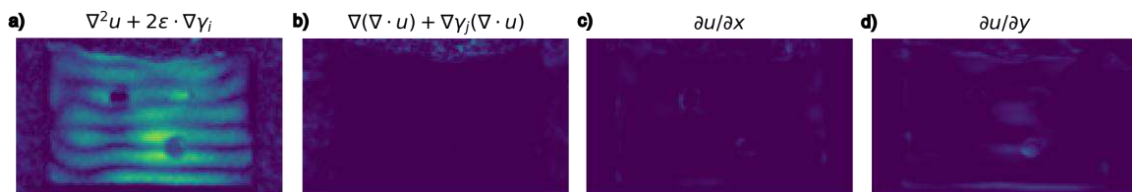


Figure 1: Magnitude of predicted contributions to normalized acceleration field for example operators in z-direction, at 100Hz, at the 10th z-slice. Other components generally showed low contribution.

Conclusions

HetSI enables the use of SI in MRE to identify both heterogeneous parameter fields, as well as governing models from data. The method can potentially be used to infer data quality by testing if the correct model is supported by data, or to explore the suitability of new models.

Open-Source FEM Framework - MRE Phantom Simulations

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Background, Motivation and Objective

Brain MRE shows promise as a future clinical tool. To facilitate the development of brain MRE inversion methods, this project aims to provide an open-source FEM framework, to allow groups to transparently validate their inversion.

Statement of Contribution/Methods

An isotropic linear viscoelastic model in the frequency domain has been implemented using DOLFINx. Validation against COMSOL and a mesh convergence study has been conducted. Hexahedral elements along with quadratic and linear base-functions were utilized for the displacement and material field respectively.

Results/Discussion

The validation of the model showed a <1% difference between the implemented model in DOLFINx and the corresponding COMSOL implementation for different material fields and frequencies. An example of a simulated forward field can be seen in Figure 1 (b). The mesh convergence study showed a less than 5% error for simulations with nodes per wavelength (NPW) of ≥ 15 , as shown in Figure 1 (c).

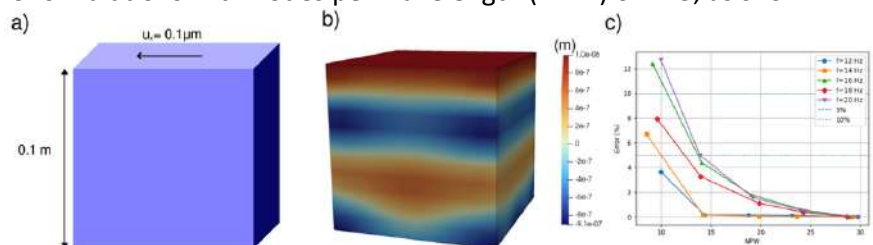


Figure 1. (a) The geometry of a typical phantom along with boundary condition on top. (b) A typical simulated displacement field, here shown real x-displacement in meters. (c) The difference of the absolute value of the displacement at one of the bottom corners of the cube normalized with the value for the highest NPW, shown in % for different frequencies (12-20 Hz).

Conclusions

The constructed framework shows good performance for the implemented model. Future work will focus on implementing a perfectly matched layer along the traction free faces to mitigate boundary effects, and more flexibility in solver configurations to allow for larger geometries.

Viscoelastic tissue characterization using shear-wave focal spot imaging: numerical experiments

Goulven Le Moign¹, Romain Brossier¹, Michel Campillo¹, Ludovic Métivier^{1,2}

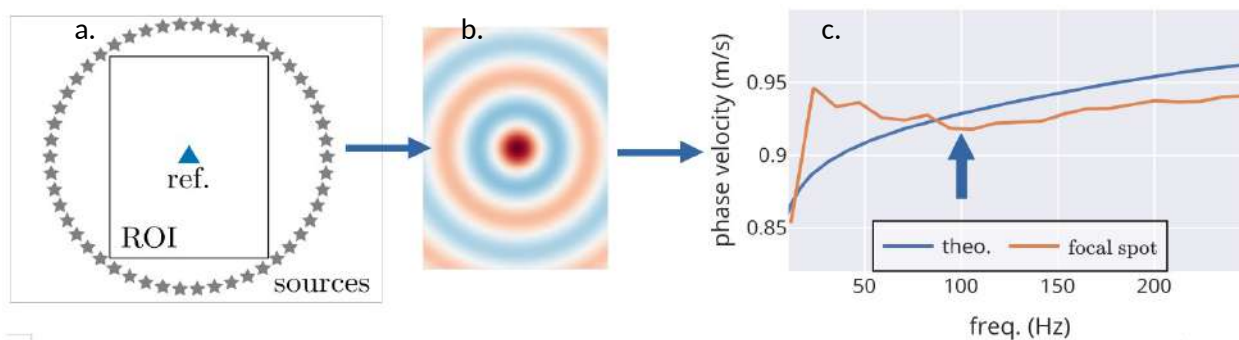
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Background, Motivation and Objective: When ambient noise correlation is applied to a diffuse wave field, a focal spot emerges and contains information about the media [1]. The term “focal spot imaging” first appeared in seismology [2], where it has been applied to Rayleigh-wave to characterize the Earth sub-surface structure. While the focal spot is used in many ways for passive elastography [3], the methodology of the focal spot imaging could be a suitable option in this latter context. We aim to adapt the focal spot imaging for a diffuse shear-wave field to characterize the elasticity and viscosity of a soft tissue.

Statement of Contribution/Methods: The work is based on simulated data, provided by a software used in full waveform inversion for seismic exploration [4]. This gives us the opportunity to simulate a 3D wavefield for either an elastic or viscoelastic medium with high accuracy. We then construct focal spots where the noise structure can be adapted. The focal spot imaging is applied to characterize the soft tissue.

Results/Discussion: Applying the focal spot imaging on shear-wave makes it possible to retrieve the shear-wave phase velocity for a homogeneous viscoelastic media. Phase velocity in the lowest frequencies (under 100 Hz) exhibits values under theoretical values; several reasons might lower the estimation, as for example the size of the region of interest that could be limited regarding the wavelength. In contrary in higher frequencies, the phase velocity increases regarding to theoretical prediction, with a maximum of 2% relative error.

Conclusions: The focal spot imaging can be applied for shear-wave in soft tissues to measure the dispersion using simulation.



a) configuration showing the region of interest (ROI) of the displacement field, the targeted point for the focal spot (ref.) and sources surrounding the ROI. b) narrowband focal spot around 100 Hz. c) shear-wave phase velocity compared to theoretical prediction

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Histology-inspired reconstruction and analysis of microscopic tissue structure using sonography: SonoHisto

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Background, Motivation and Objective

Ultrasound elastography characterizes tissue mechanical properties at the mesoscopic scale. However, the microstructural basis of altered stiffness, such as fibrosis, inflammation, or tumor infiltration, is only accessible by histology, which requires biopsy. A method that directly images microscopic tissue architecture from acoustic data would bridge elastographic maps with their underlying microstructure.

Statement of Contribution/Methods

Our novel SonoHisto method reconstructs the position and intensity of ultrasound scatterers from standard B-mode acquisitions. This yields direct information about tissue microstructure. We solve the reconstruction problem using ADMM with an anisotropic total variation regularizer (to preserve sharp scatterer boundaries), a Gaussian noise fidelity term, and amplitude bound constraints. We validated the resolution and reconstruction quality using Field II simulations and agar-based phantoms with known scatterer density and signal-to-noise ratio (SNR) properties.

Results/Discussion

Simulations showed that SonoHisto can accurately reconstruct scatterers at densities ranging from 5 to 80 scatterers per mm² with an SNR greater than 26 dB (Figure 1). Spatial resolution as fine as 19 $\mu\text{m} \times 78 \mu\text{m}$ was demonstrated, which is substantially below the acoustic diffraction limit. Preliminary phantom reconstructions are consistent with the predicted performance of the simulations.

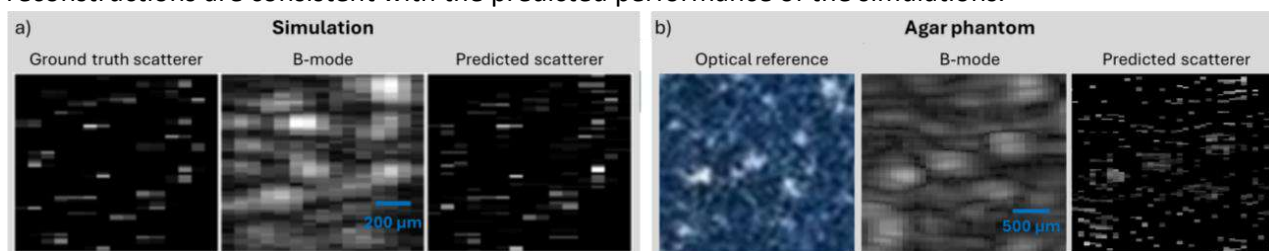


Figure 1. Quality of reconstructed scatterers by SonoHisto. a) simulation-based phantom (40 scatterers per mm² and SNR = 26 dB); b) agar-based phantom (3 scatterers per mm² and SNR = 26 dB).

Conclusions

SonoHisto provides noninvasive access to tissue microstructure from standard ultrasound acquisitions. By resolving the microscopic tissue architecture that governs mechanical properties, SonoHisto offers a complementary diagnostic layer and bridges elastography with its underlying microstructure.

Bubble dynamics in soft matter driven by Bjerknes forces generate shear waves

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Background, Motivation and Objective

The dynamics of oscillating bubbles in complex soft media is of strong interest in rheology and mechanobiology, as bubble oscillation phenomena can provide insight into the mechanical properties of the surrounding medium. However, interactions between two bubbles subjected to secondary Bjerknes forces in elastoviscoplastic media remain poorly understood.

Statement of Contribution/Methods

Precise observations of the interaction regimes of cavitation bubbles subjected to secondary Bjerknes forces in elastoviscoplastic media provide a basis for validating theoretical models. Bubbles with a diameter of 100 μm are generated by laser cavitation in Carbopol, a very soft elastoviscoplastic medium with a shear modulus of $\sim \text{kPa}$ and a yield stress of a few Pa. The two bubbles are set into oscillation under a stationary ultrasonic field in the kilohertz frequency range and observed using fast imaging.

Results/Discussion

Distinct interaction regimes were observed, including attraction leading to contact or coalescence and stable oscillatory dynamics in which the bubbles remain separated. In the coalescence regime, bubble merging occurs on a timescale of a few acoustic cycles (~ 200 cycles), while in the stable equilibrium separation is maintained throughout the oscillation. The transition between regimes appears to be governed by the competition between the secondary Bjerknes force and the yield-stress resistance of the Carbopol gel.

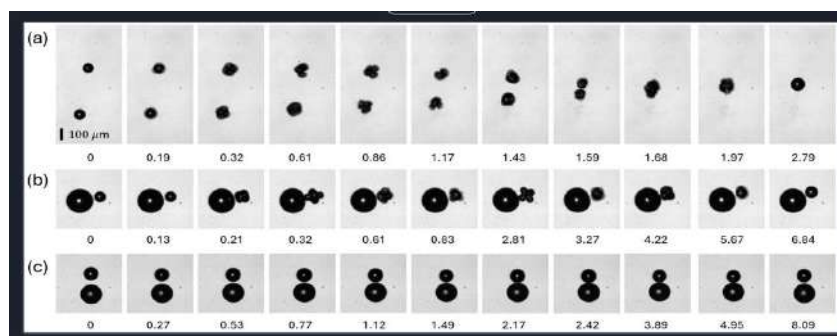


Figure 1. Snapshots of two bubbles oscillating under an acoustic pressure field in an elastoviscoplastic fluid in different regimes.

Conclusions

A proper understanding of bubble dynamics allows controlled displacements to be imposed by acoustic forces, inducing oscillation or coalescence. This generates harmonic or nonlinear shear waves, paving the way for elastography in complex and biological media.

Experimental Detection of Tumor-Like Inclusions in Soft Tissue Using Torsional Wave Elastography

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Background, Motivation and Objective

Early detection of localized pathological changes in soft tissues remains a challenge in non-invasive diagnostics, particularly for skin cancer. Conventional elastographic methods often rely on full-field imaging or complex inverse models, limiting clinical applicability. Torsional wave elastography (TWE) offers a promising alternative by enabling localized and sensitive mechanical assessment. This work aims to experimentally evaluate the detectability of tumor-like inclusions in tissue-mimicking phantoms using simple, sensor-based features, with validation through ultrafast ultrasound imaging.

Statement of Contribution/Methods

A purely experimental framework is proposed using a phantom with a controlled tumor-like inclusion. Torsional wave measurements were acquired over 400 Hz–1 kHz at locations near and far from the inclusion. Time- and frequency-domain features (peak-to-peak and FFT amplitude) were extracted and evaluated using ROC analysis on a quality-controlled dataset. Ultrafast imaging was used for independent validation.

Results/Discussion

Clear discrimination between inclusion and non-inclusion measurements was observed, with performance strongly dependent on frequency. FFT-based features outperformed time-domain features, achieving near-perfect classification above 800 Hz. Ultrafast imaging confirmed localized differences in wave propagation, supporting the sensor-based findings.

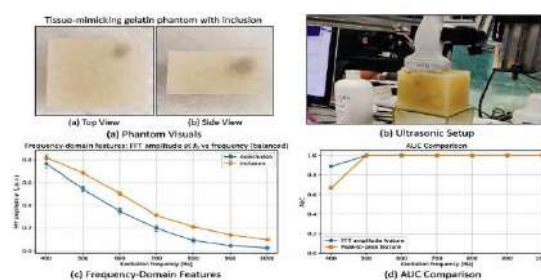


Figure 1. Tumor detection using torsional wave elastography: (a) phantom, (b) imaging setup, (c) FFT separation, (d) ROC-based detectability.

Conclusions

Tumor-like inclusions can be reliably detected using torsional wave elastography with simple sensor-based features. Detection improves with frequency, achieving near-perfect performance at high frequencies. The agreement with imaging validation supports the method's robustness and potential for practical diagnostic applications.

Transverse Oscillation based Displacement Estimation in Ultrasound Time Harmonic Elastography

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Background, Motivation and Objective

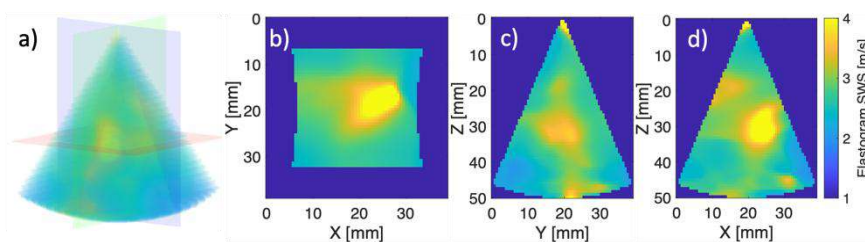
Due to the nature of time harmonic elastography (THE), shear waves can propagate in multiple directions, forming a complex 3D wave field to be characterized. Capturing the complete wave dynamics requires access to the full 3D displacement field. Modern 3D volumetric ultrasound imaging, combined with the transverse oscillation (TO) technique, enables estimation of the complete 3D displacement field. In this work, we demonstrate the feasibility of employing TO as a 3D displacement vector estimator in a THE processing pipeline.

Statement of Contribution/Methods

A harmonic excitation at 100 Hz was applied to a CIRS Elasticity Phantom 049, and pulse-echo data were acquired using a 4Vc-D probe at 400 Hz volume rate. 3D motion estimation was achieved by combining transverse oscillations for both lateral and elevation estimation with a 3D phase-based motion estimator. See [1] for further details on this displacement estimation approach. The resulting vector field was then used to estimate the 3D shear wave speed (SWS) using the autocorrelation-based method of [2].

Results/Discussion

Panel a) shows the resulting 3D SWS estimate based on the TO-derived displacement vector. Panels b)-d) display three planes in this volume. These results demonstrate that the proposed approach can estimate 3D displacement vectors in THE, and that the reconstructed SWS map detects the phantom inclusion.



Conclusion

This work provides a first proof-of-concept for incorporating TO-based 3D displacement vector estimation with THE. Our initial result support the potential of TO as a promising improvement for THE processing.

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