

Validation Studies

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Flow measurement by cardiovascular magnetic resonance: a multi-centre multi-vendor study of background phase offset errors that can compromise the accuracy of derived regurgitant or shunt flow measurements

Peer-Review: [https://doi.org/10.1002/jcmr.12111](#)

Journal of Cardiovascular Magnetic Resonance

Study design

- static phantom, no background phase corrections, 12 sites, 3 vendors
- image 3 slices ('Aorta', 'MPA 1', 'MPA 2'), venc = 150 cm/s, no background phase correction

Results

- average: 2.7 cm/s range = 0.4 – 4.9 cm/s
- Diagnostically important:
 - Error of 0.6 cm/s (0.4% of venc) -> 5% error in cardiac output, 10% error in shunt measurement

Accuracy

Eddy current induced phase in PC-SSFP

Courtesy of Sebastian Kozerke, ETH Zurich

Accuracy

Phase correction

fit correction function: $\text{pha}(x,y) = a + bx + cy + dz + \dots$

Den Fleef JE et al. US Patent #4,870,361
Walker PG, et al. JMIR 1993

Courtesy of Sebastian Kozerke, ETH Zurich

Accuracy

Phase correction in PC-SSFP

Courtesy of Sebastian Kozerke, ETH Zurich

MR-Signal Phase | Elastography

Background

- Mechanical stiffness of tissue: affected by disease
Fibrosis & sclerosis in chronic disease, Scar after infarction / injury
- Motion sensitive phase
→ probe stiffness of deep tissue

Displacement is very small (microns)

Concept

- Image mechanical waves in tissue
- **Phase-locking** of motion & gradients
→ Amplify motion in phase images
- Phase images ~ wavelength
→ tissue stiffness

Acoustic Driver

Shear waves propagate through tissue

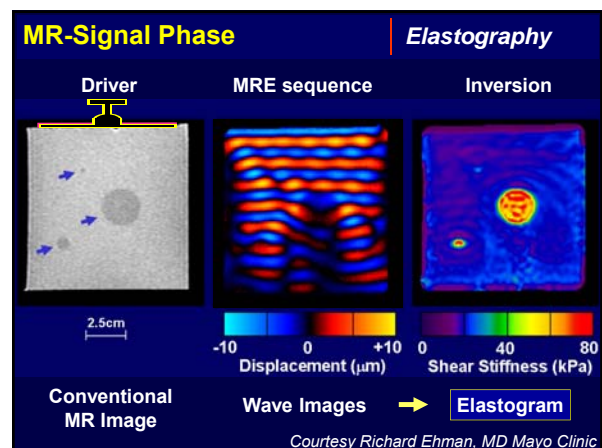
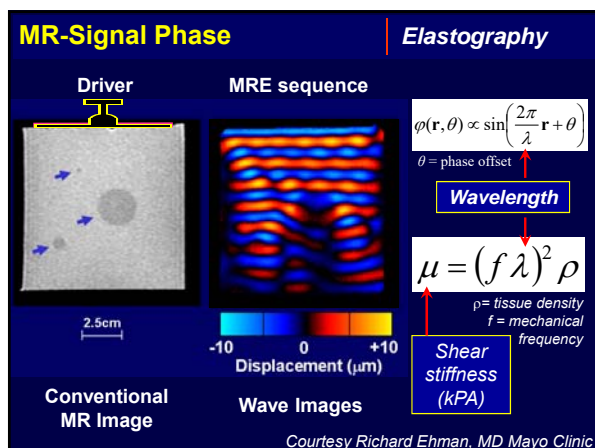
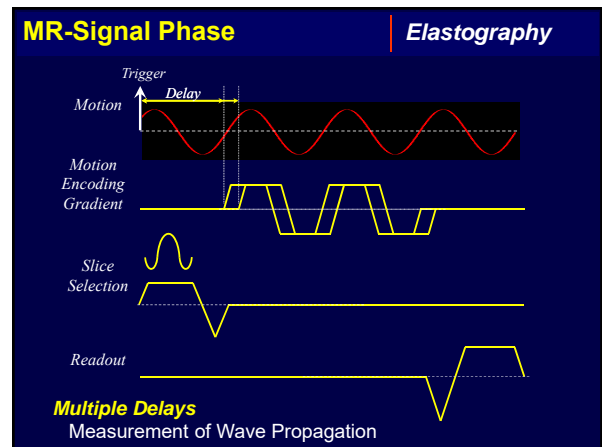
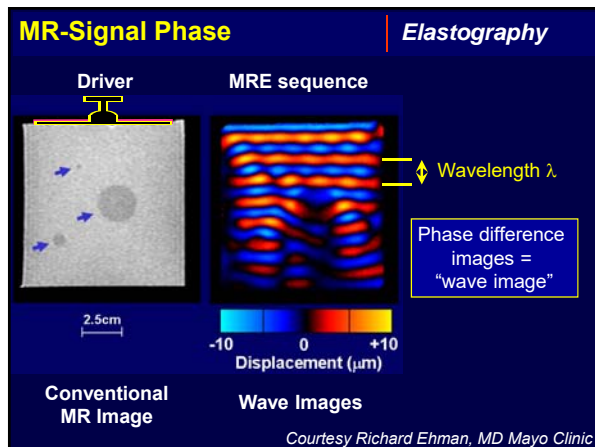
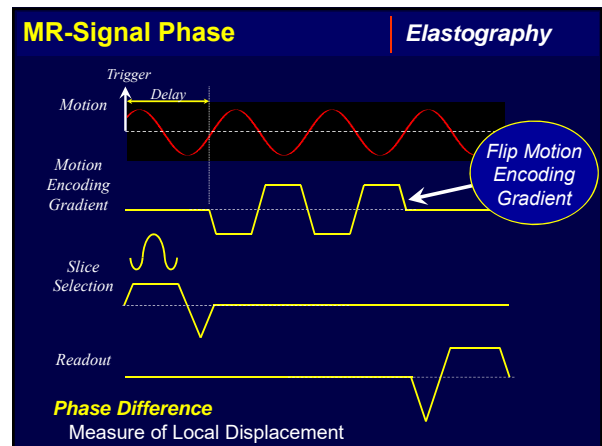
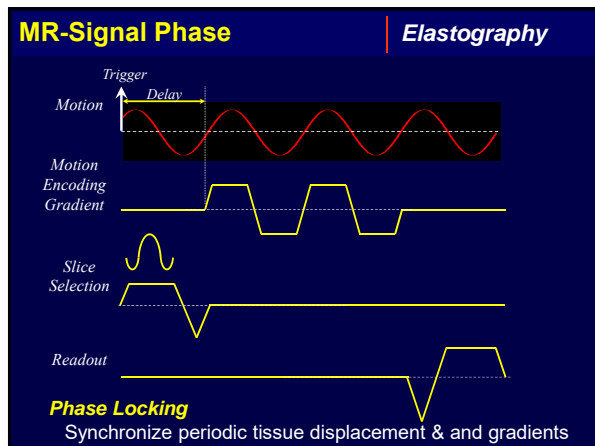
Muthupillai, Ehman et al (Mayo Clinic, Rochester, MN) Science 1995

MR-Signal Phase | Elastography

Phase Locking
Motion & Gradients

→ Phase accumulation:
Amplify motion

← Microscopic Motion (μm) →

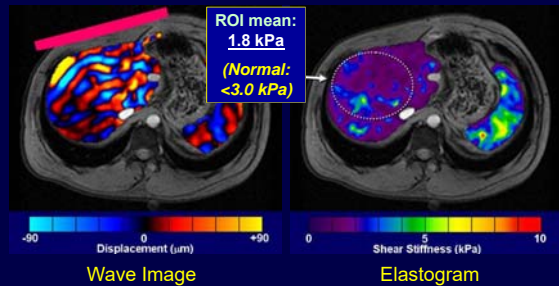


MR-Signal Phase

Elastography

Normal Liver

- Externally applied vibrations (90 Hz), acq. time = 20 - 40s



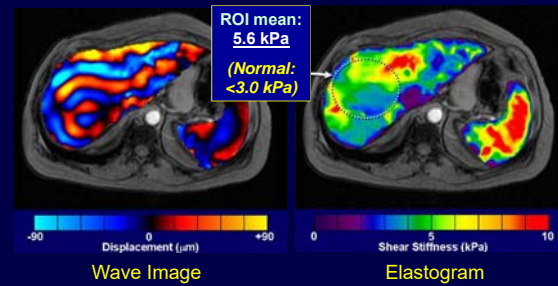
Courtesy Richard Ehman, MD Mayo Clinic

MR-Signal Phase

Elastography

Chronic Liver Disease - Fibrosis

- MR Elastogram Shows Liver Fibrosis



Courtesy Richard Ehman, MD Mayo Clinic

MR-Signal Phase

Elastography

MRE Summary

- Create shear waves in tissue
- Phase lock motion with gradients
 - amplifies phase shifts from microscopic motion
- Phase difference images = "wave image"
- Repeat at different phase offsets
- Invert wave images → Stiffness image
- Numerous important clinical applications