MR Elastography:
Assessment of Diffuse Liver Disease

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Disclosure:
The Mayo Clinic and the presenter have patent rights and a relevant financial interest.

Assurance:
Compliant with oversight by the Mayo Clinic Conflict of Interest Review Board.
Importance of Chronic Liver Disease, Fibrosis, Cirrhosis

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

Progression of Liver Disease

- Normal
- Fibrosis
- Cirrhosis
  - Reversible
  - Silent
  - Irreversible
  - High mortality

Liver Biopsy

- Standard Diagnostic Procedure to rule-out Fibrosis
  - Risk of Complications
  - Potential Sampling Errors
  - Subjective Histology Grading
Noninvasive Tests

- Serum Biomarkers
  - Direct and Indirect
- Conventional Imaging
  - MRI, US, CT
- US Elastography
  - Fibroscan
  - ARFI
- MRI Techniques
  - Contrast enhanced
  - Diffusion-weighted
- MR Elastography

MR Elastography

1. Driver
   (30-500 Hz)

2. MRE Sequence

3. Inversion

Tissue-simulating gel phantom with stiff inclusions

Conventional MR Image

Wave Images → Elastogram
Acoustic Driver System for MRE

Conventional MRI exam of Abdomen: ~ 45 min

MR Elastography:
adds ~ 5 min (15 second scan)
Liver Fibrosis

Biopsy: Stage F1

Biopsy: Stage F2

Biopsy: Stage F3

Biopsy: Stage F4

Normal

2.1 kPa

3.1 kPa

3.5 kPa

4.8 kPa

10.8 kPa

MRE-Assessed Liver Stiffness

<table>
<thead>
<tr>
<th>Fibrosis Stage</th>
<th>No.</th>
<th>Mean</th>
<th>Std Dev</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>109</td>
<td>2.77</td>
<td>0.97</td>
<td>(2.59, 2.96)</td>
</tr>
<tr>
<td>1</td>
<td>76</td>
<td>3.01</td>
<td>0.87</td>
<td>(2.81, 3.21)</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>3.68</td>
<td>1.52</td>
<td>(3.32, 4.04)</td>
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<tr>
<td>3</td>
<td>89</td>
<td>4.32</td>
<td>1.93</td>
<td>(3.92, 4.73)</td>
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<tr>
<td>4</td>
<td>94</td>
<td>5.78</td>
<td>2.26</td>
<td>(5.31, 6.24)</td>
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</table>
Sensitivity and Specificity of MRE for Hepatic Fibrosis


Comparability to Transient Ultrasound Elastography


Reproducibility


Safety

Diagnostic Performance: APRI, UTE, & MRE


100% Correct ➔ 1.0

Area under ROC Curve

Worthless ➔ 0.5

Fibrosis Stage

94%
84%

Technical Success

AST to platelet ratio index

MRE
UTE
APRI

Technical Success

Biopsy: No fibrosis

41 yo Patient – Fatty Liver Disease

Biopsy: No fibrosis

2.3

Shear Stiffness (kPa)
69 yo Patient - Fatty Liver Disease

• Biopsy: Stg. 3 fibrosis

Shear Stiffness (kPa)

8

Steatosis Does Not Affect Liver Stiffness

Steatosis

Fat / Water Ratio

0.68

Stage 0

Stage 1

Stage 2

Stage 3

Stage 4

Liver Stiffness (kPa)

Lever Patient

Normal
How Early Can MRE Demonstrate NASH in Patients with Fatty Liver Disease?

Liver stiffness measurement (kPa)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Shear Stiffness (kPa)</th>
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<tbody>
<tr>
<td>cp685</td>
<td>2.02</td>
</tr>
<tr>
<td>cp910</td>
<td>2.05</td>
</tr>
<tr>
<td>cp484</td>
<td>4.38</td>
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<td>cp765</td>
<td>3.59</td>
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<tr>
<td>cp478</td>
<td>10.24</td>
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<tr>
<td>cp958</td>
<td>7.52</td>
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Liver biopsy findings

<table>
<thead>
<tr>
<th>Fibrosis Stage</th>
<th>Inflamm Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Detection of Steatohepatitis before the onset of Fibrosis

55 yo Patient – Chronic Hepatitis C

• Biopsy: Not performed

Shear Stiffness (kPa)
59 yo Patient – Alcohol

• Biopsy: Stg. 4 fibrosis

76 yo Patient - Alcohol

Abstinent
9 months later
47 yo female with Autoimmune Hepatitis

8/14/07 6/18/09

Mean Liver Stiffness: 4.0 kPa
Liver Biopsy Score = F2

Mean Liver Stiffness: 2.9 kPa
Liver Biopsy Score = F0

MR Elastography

- Emerging as a reliable non-invasive method for diagnosing hepatic fibrosis
- Safer, less expensive, and less affected by sampling error than liver biopsy
- Other potential applications (heart, lung, pancreas, breast) are being explored