Quantitative MSK US Elastography: Shear Wave Speed Measurements

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Objectives

- Introduce the basic concepts of MSK US Elastography (EUS)
- Discuss shear wave speed as a quantitative biomarker reflecting biomechanical tendon changes
Outline

I. Why MSK US?

II. How can EUS add value?

III. When can EUS be translated into clinical practice?
Dx MSK US Volume

Outpatient Volume Growth Projections
All Providers, by Modality
2012-2022

<table>
<thead>
<tr>
<th>Modality</th>
<th>5 yr growth</th>
<th>10 yr growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>6%</td>
<td>16%</td>
</tr>
<tr>
<td>MRI</td>
<td>10%</td>
<td>19%</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>14%</td>
<td>30%</td>
</tr>
<tr>
<td>Mammography</td>
<td>7%</td>
<td>20%</td>
</tr>
<tr>
<td>X-ray</td>
<td>5%</td>
<td>9%</td>
</tr>
<tr>
<td>PET</td>
<td>22%</td>
<td>52%</td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>3%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Market-specific volume forecasts can be found in The Outpatient Imaging Market Estimator.
Reasons for MSK US Growth

- Improved technology
- Real-time, dynamic capability
- US-guided procedures
- Low cost and portability
Limitations of MSK US

- Diagnostic evaluation
  - Morphologic Δ’s
  - Doppler Δ’s
  - FP (17%) and FN (33%) rate is high\(^1\)
  - Moderate inter-reader correlation\(^2\)

\(^1\)Dirrichs T et al. *Acad Radiol* 2016 Oct; 23:1204
\(^2\)Sunding K et al. *Knee Surg Traumatol Arthrosc* 2016; 47:89
US Δ of Tendinosis

Sag T1w

55F

1 year

calcaneus
US Technical Advances

- Grey scale (1973)
- Doppler (1979)
- Elastography (EUS)
  - Strain EUS
  - Shear wave EUS

[Images of ultrasound scans]
Strain EUS

A >> B
- high strain ratio
- soft mass

A = B
- low strain ratio
- hard mass
Strain (Compression) EUS

Advantages
- Biomechanical info
- Objective biomarker

Disadvantages
- Free hand
- Compression-based
- Not reproducible
- Technique dependent
Shear wave-based EUS

- Focused acoustic beams
  - Supersonic wave imaging
  - ARFI
- Mechanical push
  - Transient EUS
Shear wave EUS (SWE)

B-mode Sequence

Transducer

1
2
3
...
n

Shear Wave Speed Image

Shear Wave EUS (SWE)
Shear Wave EUS (SWE)

- **Advantages**
  - Reproducible!
  - Biomechanical info
  - Objective biomarker
  - Track healing changes
  - Evaluate therapies

- **Disadvantages**
  - The very superficial
  - The very deep
  - Strain dependent
Value of SWE

- Quantitative measure
- Young’s modulus (kPa)
- SW velocity $\propto$ stiffness
MSK Literature Review


Basic Science - SWE

- Using porcine tendon
  - Tear model
  - Tendinosis model
Partial Tear Model – *Ex Vivo* Tendon

Dewall R. *Ultrasound Med Biol* 2014; 40: 158
Clinical Application - SWE

- Tendon
  - Achilles
  - Patellar
  - Humeral epicondyles

- Muscle
Tendon SWE

Asymptomatic Right (35y)

Symptomatic Left

Dirrichs T et al. Acad Radiol 2016 Oct; 23: 1204
Achilles - SWE

Slane LC *Eur Radiol* 2016, May 28, Epub
Muscle SWE

Sag T1w

SST

Rosskopf A et al. Radiology 2016 Feb; 278:465
Translation of SWE

- SWE may be useful in characterizing MSK injuries
  - Quantitative biomechanical info
  - Follow injury healing
  - Evaluate therapies
  - Predict impending tendon injury
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