ARFI
Acoustic Radiation Force Impulse

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Innovative u/s elastographic application

Determines the local mechanical properties of tissue

SIEMENS
- eSie Touch™ elasticity imaging
- Virtual Touch™ tissue imaging
- Virtual Touch™ tissue quantification

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Applications and Technologies

1. Tissue Strain Analytics

2. Acoustic (ARFI) → Manual (Compression)

3. Virtual Touch Tissue Imaging* → Virtual Touch Tissue Quantification* → eSie Touch Elasticity Imaging
In this method we are using sound to both compress and interrogate tissue.
Conventional elastography requires manual compression in order to provide relative displacement between the mass and the surrounding structures and therefore an assessment of strain. This can be difficult to apply to abdominal structures because of the presence of the ribs and abdominal wall. Not true quantification of stiffness.

Where manual compression is not possible or is ineffective to create tissue displacement.
Additional challenges - Chronic Liver Disease

- Among the ten major causes of death in the United States
- Chronic hepatitis and cirrhosis progress over several decades
- Fibrosis staging is the key factor in determining liver health in these patients
- Staging is currently accomplished by a single core needle biopsy
  - Not well tolerated
  - Small sample size from a focal area
  - Misdiagnosis of stage occurs in 20-40% of cases

Which is the better description: cirrhosis or “6”?

Late stage Cirrhosis
Transmission of longitudinal acoustic pulse leads to tissue displacement which results in a shear-wave propagation away from the region of excitation.

The shear-wave velocity is measured within a defined region of interest (ROI) by using ultrasound tracking beams laterally adjacent to the single push beam.

(ARFI): promising technique that measures hepatic elasticity and enables real-time sonographic assessment of the liver.
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Real-time ARFI imaging measurement in the liver with fibrosis stage F3

ROI= region of interest
(5mm axial by 4mm width)
ARFI can create a localized displacement of a few microns in the ultrasound axial direction, which decays in a few ms.

Sufficient force for this purpose can be generated with a standard ultrasound scanner at depths of many centimeters by a sequence of rapid bursts of long focused ultrasound pulses.

Fig. (a) ARFI image (right) demonstrates a liver metastasis with higher contrast and clearer boundaries than on the B-mode image (left), despite the ascites.

(b), (c), (d) gelatin phantom containing a stiff inclusion in a soft background.
Virtual Touch Tissue Imaging - VTi

Large displacement for soft tissue
Low displacement for hard tissue
Virtual Touch Tissue Imaging - VTi

VTi is a **qualitative** grayscale map of relative stiffness

- Large displacement for soft tissue
- Low displacement for hard tissue

- colored map
### Ueno Classification System

<table>
<thead>
<tr>
<th>Score</th>
<th>Classification Standard</th>
<th>Typical Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strain is seen in the entire hypoechoic area (the entire lesion is shown in green similar to the surrounding tissue)</td>
<td><img src="image1.jpg" alt="Image" /></td>
</tr>
<tr>
<td>1*</td>
<td>BGR (blue-green-red) 3 layer pattern – typical artefact seen in a cystic lesion</td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
<tr>
<td>2</td>
<td>Strain is seen within most of the hypoechoic area but some areas show no strain (the lesion is a mixture of green and blue)</td>
<td><img src="image3.jpg" alt="Image" /></td>
</tr>
<tr>
<td>3</td>
<td>Strain appears only in the periphery with no strain in the centre of the lesion (the centre of the lesion is shown as blue with the periphery in green)</td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
<tr>
<td>4</td>
<td>No strain is measured within the lesion (the entire lesion is shown in blue)</td>
<td><img src="image5.jpg" alt="Image" /></td>
</tr>
<tr>
<td>5</td>
<td>No strain is measured within the lesion nor in the surrounding tissues (the lesion and the surrounding tissues are blue)</td>
<td><img src="image6.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

**Benign** (score 1, 2, 3)  
**Malignant** (score 4, 5)
Virtual Touch Tissue Quantification - VTq

Shear waves are induced by the displacement of tissue

- The shear waves travel perpendicular to the path of the acoustic push pulse

- The *speed* of shear wave propagation is related to tissue stiffness:
  The greater a shear wave's velocity, the more stiff the tissue through which it travels
Virtual Touch Tissue Quantification

Vs = 2.79 m/s
Depth: 2.9 cm
ARFI

- **Probes**: 6C1HD, 9L4 (previously on abdominal probes only)
- **velocity m/s** (quantitative tissue stiffness measurement)
  velocity to pressure: formula that uses Poisson’s ratio
- **measurements**: average of 5 tumour/surrounding normal tissue
  It is recommended 10 as a guide/ the user gains experience this can sometimes be reduced
- **Speed** appears higher (≈×2) in malignant tumours/normal tissue
  > 2 cm/s in malignant tissue
  < 2 cm/s in benign lesion/surrounding tissue
- **Speed measurement** is best acquired with breath-hold
- **No Pressure** (speed values can potentially be influenced by the pressure applied on the probe)
- **ARFI technology** could allow a better “compression” of deep lesion than manual compression

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**Poisson’s ratio**, named after Siméon Poisson, is the negative ratio of transverse to axial strain. When a material is compressed in one direction, it usually tends to expand in the other two directions perpendicular to the direction of compression. This phenomenon is called the Poisson effect. Poisson's ratio \( \nu \) is a measure of this effect.

A wave is described by \( y = (2.08 \text{ cm}) \sin(kx -\omega t) \), where \( k = 2.01 \text{ rad/m} \), \( \omega = 3.56 \text{ rad/s} \), \( x \) is in meters, and \( t \) is in seconds. Determine the amplitude, wavelength, frequency, and speed of the wave.
Propagation velocity of the shear wave is around 1.1 m/s and is clearly raised in a patient with chronic hepatitis C.

maximum displayable values:
5.5 m/s on the curved transducers
8.4 m/s on the 9L4

10 measurements for each location
Position of ROI

- right lobe: intercostal approach near the mid-axial line.
- ROI: no closer than 2 cm from the liver capsule and that vessels or other areas like the gallbladder wall be avoided.
- The liver capsule and VTq line should be perpendicular to each other.
- patient: stop breathing. Avoid deep inspiration as this can sometimes have an effect on the liver stiffness.
cut-offs

- of 1.21-1.34 m/s predict significant fibrosis (F>2)
- of 1.55-2 m/s cirrhosis
- best cut-offs for F4
  - Friedrich-Rust (Radiology 2009): 1.75 m/s
  - Fierbinteanu-Braticevici C (World J Gastroenterol 2009): 1.94 m/s
  - Lupasor (J Gastrointest Liver Dis 2009): 2.00 m/s
  - Takahashi (Liver Intern 2010): 1.80 m/s
  - Piscaglia (Ultraschall in Med 2011): 1.77 m/s
  - Rizzo (Am J Gastro 2011): 2.00 m/s
clinical experience: spleen
prediction of liver cirrhosis and portal hypertension
spleen stiffness
ARFI
Advantages- Disadvantages

Advantages
- Good US imaging and ROI guidance
- Acceptable US visible Elastography quality indicator
- Absolute elasticity quantification (m/sec)
- Stiffness assessment of surrounding tissue as well as lesions

Disadvantages
- Important Intra-Inter Observer variability
- Statistical analysis on static (frame) data
- Dependence on frequency of probe
- Single-value / non-real-time elasticity measurements
ARFI technology: Conclusions

early diagnosis and follow-up of the Chronic Liver Disease
estimation moderate - severe liver fibrosis- cirrhosis- portal hypertension

☐ Provides non-invasive quantification of tissue stiffness - Improves diagnostic accuracy

☐ Allows tissue stiffness of different areas within an organ to be compared, e.g., heterogeneous livers, identifying areas of greatest stiffness

☐ Can reduce the number of biopsies by confirming the stiffest areas and so enhancing biopsy site selection

☐ Can allow monitoring of disease or timing of intervention through use of serial measurements to assess response to therapies or speed of disease progression

☐ Reliable quantification in high BMI – ascites

☐ “one-probe solution”

☐ Breast or Thyroid
(ARFI) technology

• 1st commercially available application for evaluation of deep tissues not accessible by superficial compression elastography.

• Strain imaging can help clinicians “see” the relative stiffness of a particular area that they may not be able to feel.
References

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Thank you for your attention