Elastography with breast US

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Elastography

Imaging technique that maps elastic properties of soft tissue: an extension of clinical palpation

Allows us to “see” lesion stiffness
BI-RADS 5th Ed – Lexicon Overview

- Shape
- Orientation
- Margin
- Echo pattern
- Posterior features
- Calcifications

- Associated features:
  - Architectural distortion
  - Duct changes
  - Skin changes
  - Edema
  - Vascularity
  - Elasticity assessment
BI-RADS

• Elasticity Assessment
  • Stiffness as a feature of masses and surrounding tissue
  • Emphasis on SHAPE, MARGIN, ECHOGENICITY more predictive of malignancy
  • Always check color scale
BI-RADS – Elasticity Descriptors

- SOFT    most likely benign
- INTERMEDIATE
- HARD    most likely cancer
Exceptions

• Hard benign masses
  • Hyalinized fibroadenomas
  • Fat necrosis

• Soft malignant masses
  • Medullary
  • Mucinous
  • Papillary
  • Necrotic IDC
Quantifying stiffness: Young’s Modulus (elasticity)

Young’s Modulus = \frac{\text{Applied Stress}}{\text{Induced Strain}}

Hard tissues have higher Young’s Modulus
2 Main Elastography Techniques

Strain
Shear-wave
### Strain & Shear-wave

<table>
<thead>
<tr>
<th>Stress</th>
<th>Strain</th>
<th>Shear-wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>compression</td>
<td>and respirations</td>
<td></td>
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<tr>
<td>Measurement</td>
<td>Qualitative and semi-quantitative</td>
<td>Qualitative and quantitative</td>
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</tbody>
</table>
Strain Elastography

- Standard breast ultrasound transducer
- Measures axial displacement of tissue caused by mechanical stress
- Stress
  - Manual compression (with transducer)
  - Cardiovascular pulsation
  - Respiration
Strain Elastography

- Semi-quantifiable diagnostic assessment
  - Elasticity scores (Tsukuba score, strain pattern)
  - EI/B ratio (length ratio, area ratio)
  - Strain ratio (lesion to fat ratio (LFR))
Strain Elastography – Semi-quantification
Tsukuba score, strain pattern

1. Even strain
2. Strain in most of lesion
3. Strain at periphery
4. No strain in entire lesion
5. No strain in entire lesion or surrounding area
Strain Elastography – Semi-quantification
EI/B ratio & Strain ratio

• EI/B ratio (length ratio, area ratio)
  • Ratio of lesion size on elastography to B-mode
  • Lesion measured in same position on both elastogram and B-mode

• Strain ratio (lesion to fat ratio (LFR))
  • Two manually selected ROIs – one in lesion and other in fat
  • How many times stiffer target area is to fat
Strain Elastography
Characteristic patterns of cysts

• "Bull’s-Eye" Artifact
  • Siemens and Philips
  • Simple and complicated cysts
  • White central spot
  • Black outer ring
  • Bright posterior spot

• “BGR” artifact
  • Hitatchi strain
  • Blue, green, red layers
• Materials and Methods
  • 111 women (mean age 49.4 years, age range 27-91 years)
  • 111 masses
  • B-mode first and BI-RADS 2-5 category determined
  • Elasticity images
  • AUC and cutoff point (obtained by receiver operating characteristic curve analysis) used to assess diagnostic performance

Itoh et al. Strain Elastography Study

• Results
  • 59 benign and 52 malignant masses
  • Elasticity scores significantly higher for malignant lesions
  • 45/52 (86%) malignant lesions scored 4 or 5
  • 40/59 (68%) benign lesions scored 1 or 2

Itoh et al. Strain Elastography Study

<table>
<thead>
<tr>
<th></th>
<th>Mean Elasticity Score</th>
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<tbody>
<tr>
<td>Malignant</td>
<td>4.2 ± 0.9</td>
</tr>
<tr>
<td>Benign</td>
<td>2.1 ± 1.0</td>
</tr>
</tbody>
</table>

P < .001

Itoh et al. Strain Elastography Study

• Conclusion
  • Elastography can complement conventional US, thereby making it easier to diagnose breast lesions.
Shear-wave Elastography
Shear-wave Elastography

\textbf{SW} propagates faster in harder tissue

\textbf{SW} propagates slower in softer tissue

\textbf{SW} does not propagate through fluid
Multinational Study investigated whether adding shear-wave elastographic features could improve accuracy of US assessment of breast masses

Shear-wave BE1 Multinational Study

- Materials and Methods
  - 16 centers and 32 investigators in United States and Europe
  - 9/2008 – 9/2010
  - 939 masses
  - B-mode final category assessment recorded – then evaluated with SW
  - Cat 3 and Cat 4a masses reclassified AFTER elastogram
Shear-wave BE1 Multinational Study

- Materials and Methods
  Qualitative SW features studied
  - $E_{sha}$: lesion shape
  - $E_{homo}$: homogeneity of the elasticity
  - $E_{col}$: maximum elasticity on a six-point color scale
Shear-wave BE1 Multinational Study

- Materials and Methods

Quantitative SW features studied

- $E_{\text{arat}}$: ratio of mass area on SW to mass area on B-mode
- $E_{\text{drat}}$: ratio of mass diameter on SW to mass diameter on B-mode
- $E_{\text{min}}$: minimum value of elasticity
- $E_{\text{rat}}$: ratio of stiffest portion of mass to similar region of interest in fat
- $E_{\text{mean}}$: median of three mean elasticity values
- $E_{\text{max}}$: maximum value of elasticity
Why Cat 3 and Cat 4a masses?

Most management dilemmas occur for low suspicion masses.

Cat 2 – benign

**Cat 3 – probably benign** (**≤ 2%**)

**Cat 4a – low suspicion** (**> 2% to ≤ 10%**)

Cat 4b – intermediate suspicion (**> 10% to ≤ 50%**)

Cat 4c – moderate suspicion (**>50% to <95%**)

Cat 5 – highly suggestive of malignancy (**> 95%**)
Shear-wave BE1 Multinational Study

• Results
  • Any of SW features increases the AUC compared to B-mode alone
  • Excellent correlation between $E_{col}$ and $E_{max}$

• $E_{col}$: best performing qualitative feature
  - AUC increased from 0.940 to 0.971

• $E_{max}$: best performing quantitative feature
  - AUC increased from 0.940 to 0.962
Shear-wave BE1 Multinational Study
Upgrade stiff cat 3 & downgrade soft cat 4a

Specificity & Sensitivity

B-mode alone
61.1% 397/650
97.2% 281/289

Conservative
Black to dark blue
70.3% 457/650

Aggressive
Black to dark blue to light blue
78.5% 510/650

96.2% 278/289

96.9%
280/289

University Hospitals
Case Western Reserve University School of Medicine
Shear-wave BE1 Multinational Study
Upgrade stiff cat 3 & downgrade soft cat 4a

Positive Predictive Value

<table>
<thead>
<tr>
<th>Method</th>
<th>Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-mode alone</td>
<td>9.3%</td>
</tr>
<tr>
<td>Black to dark blue</td>
<td>18/193</td>
</tr>
<tr>
<td>Conservative</td>
<td>17.9%</td>
</tr>
<tr>
<td>Black to dark blue</td>
<td>25/140</td>
</tr>
<tr>
<td>Aggressive</td>
<td>26%</td>
</tr>
<tr>
<td>Black to dark blue to light blue</td>
<td>22/84</td>
</tr>
</tbody>
</table>
Shear-wave BE1 Multinational Study

• Conclusion
  • Adding consideration of SW features could reduce unnecessary biopsies for Cat 4a masses
  • Could help ID oval circumscribed (Cat 3) malignancies
  • Increased specificity without loss of sensitivity
Addition of Shear-wave Elastography during Second-look

Investigated if adding SW to second-look US after MR helps find or target lesions

• Patients are initially scanned with B-mode US by a registered sonographer technologist

• If a B mode US correlate was found to the MRI lesion, shear wave elastography (SWE) was used to map tissue stiffness

• If lesion was not found, or subtle questionable lesion was found with B mode, radiologist scanned with real-time SWE in the area of MRI concern.

  • Looked for areas of stiffness
  • Evaluated if isoechoic or subtle lesions could be detected with SWE
  • Evaluated if subtle or questionable lesions were more confidently seen with SWE
Recorded the maximum stiffness of each lesion found with US

6 Point color scale

Did not have quantitative values
• 72 women with 96 lesions
• All lesions underwent biopsy with US or MRI guidance
• Avg largest diameter of lesion
  • DCE MRI = 1.25 cm +/- 1.6 cm (range = 0.4–7.1 cm)
  • US = 0.94 +/- 0.57 cm (range = 0.4 – 2.7)
84 (87.5%) of DCE MRI detected lesions were masses
  48 (57%) were found on US
12 (12.5%) were non mass enhancement
  2 (17%) were found on US
DCIS
  invasive ductal carcinoma
US was statistically more likely to find mass enhancement (p=0.012)
96 Category 4 or 5 MRI detected lesions

50 (52%) lesions seen with second look US
- 22 (44%) Malignant lesions
  - 2 (9%) DCIS
  - 20 (91%) Invasive (1 non breast malignancy)
- 28 (56%) Benign lesions
  - 6 (20%) High Risk
  - 22 (80%) Benign

46 (48%) lesions seen on MRI only
- 7 (15%) Malignant lesions
  - 3 (43%) DCIS
  - 4 (57%) Invasive
- 39 (85%) Benign lesions
  - 8 (21%) High Risk
  - 31 (79%) Benign
## Elastography Scale

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Elastography scale 1, 2, 3 (softer lesions)</th>
<th>Elastography scale 4, 5, 6 (stiffer lesions)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>20 (true -)</td>
<td>8 (false +)</td>
<td>28</td>
</tr>
<tr>
<td>Malignant</td>
<td>1 (false -)</td>
<td>21 (true +)</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>29</td>
<td>50</td>
</tr>
</tbody>
</table>

- **Pearson's chi²(1) = 22.62, p<0.001**
- **Sensitivity = 95%**
- **Specificity = 71%**
- **PPV = 72%**
- **NPV = 95%**
• Real time SWE helped find 5 of the 50 lesions detected on second look US
• All 5 were invasive cancer (4 IDC, 1 ILC)

• SWE increased number of cancers undergoing biopsy with second look US by 29%
<table>
<thead>
<tr>
<th>Modality</th>
<th>Number of cancer cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI only</td>
<td>7</td>
<td>24%</td>
</tr>
<tr>
<td>US: B-mode only</td>
<td>17</td>
<td>57%</td>
</tr>
<tr>
<td>US: B-mode and SWE</td>
<td>22</td>
<td>76%</td>
</tr>
<tr>
<td>Total # cancers</td>
<td>29</td>
<td>100%</td>
</tr>
</tbody>
</table>
Real-time SWE with second look US after DCE MRI

- Increase confidence of lesion detection (decrease biopsy threshold of subtle lesions)
- Help target lesion
- Find isoechoic or subtle lesions that are not seen on B mode scanning
- Increase confidence of concordance with benign pathology result
References


Real-time SWE with second look US after DCE MRI

• Increase confidence of lesion detection (decrease biopsy threshold of subtle lesions)
• Help target lesion
• Find isoechoic or subtle lesions that are not seen on B mode scanning
• Increase confidence of concordance with benign pathology result