Shear Wave Elastography Characteristics of Benign and Malignant Breast Masses

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Aims and objectives

Elastography is a non-invasive method combining information obtained from a conventional ultrasound (US) with the assessment of stiffness, analogous to clinical palpation (1). Elastography may be static or transient, quantitative or qualitative, and may use strain or shear wave techniques (2).

The most commonly used elastographic techniques include strain elastography and more recently shear wave elastography (SWE). Strain elastography analyses the deformation of tissue induced by manual compression and the information is coded on a color scale based on the tissue displacement. Strain images give a relative stiffness display of lesions compared with that of surrounding tissue in the form of an elastogram. The main pitfall of this modality is that it does not provide a quantitative assessment of the local stiffness. (3)

SWE is a newer technique of quantitative elastography. Unlike conventional elastography methods, SWE is based on the combination of a radiation force induced in a tissue by an ultrasonic beam and an ultrafast imaging sequence capable of capturing in real time the propagation of the resulting shear waves (4). SWE brings three essential innovations to elastography: being quantitative, having a very high spatial resolution, and providing elasticity maps in real time. SWE is also reproducible with minimal inter-observer variability (5).

Addition of elastography to B-mode US improves the characterization of benign (BM) and malignant (MM) breast masses (6). Elastography is a particularly useful adjunct for the difficult to characterize masses falling under BIRADS categories 3 and 4. It may potentially help reduce the number of unnecessary biopsies in such masses by reducing the number of false positives (7).

The aim of this study is to illustrate the patterns of BM and MM based on qualitative and quantitative SWE parameters and identify the best discriminating SWE parameters. We also tried to assess the adjunct role of SWE to B-mode US in better characterization of difficult to diagnose breast masses.
Methods and materials

A prospective study was carried out on patients presenting with breast lump, pain, nipple discharge or asymptomatic women with imaging diagnoses of breast masses. One-hundred and nineteen patients with BIRADS 3 and 4 masses, diagnosed on B mode US or mammography were included. Institute Ethical Committee approval was obtained and informed written consent was obtained from each patient. Patients having BIRADS 2, 5, or 6 breast masses on B-mode US, patients with breast implants and patients with previous breast conserving surgery in the breast of interest were excluded from the study. Previous excision of a benign lesion 4 cm or more away from the suspected lesion didn't constitute an exclusion criterion. All the patients underwent clinical breast examination followed by B-mode US and SWE.

Clinical Breast Examination:

A detailed history was obtained followed by clinical breast examination including inspection and palpation of breast and axilla, supraclavicular and infraclavicular regions for regional lymph node involvement.

B-mode Ultrasound:

B-mode US was performed using the Aixplorer® ultrasound system (SuperSonic Imagine, Aix en Provence, France), using a 4-15 MHz linear-array transducer (fig. 1). The same machine was used for SWE also. Overlapping scans in transverse and radial planes in an overlapping pattern from the nipple to the periphery was done. The lesion's size, shape, orientation, margins, echotexture, posterior acoustic shadowing/enhancement and depth from the skin surface were assessed.

Ultrasound Elastography:

SWE was performed at the same time as B mode US on the same machine. The tip of the transducer was covered with generous amount of ultrasound gel and placed on the skin, without undue pressure to avoid artefactual stiffness. Simultaneous split view of B-mode and SWE mode was done. The probe was kept still for 10 to 20 seconds during acquisition of the elastography images. After ensuring the image stabilization, a color image of different types of stiffness was obtained. At least two orthogonal elastography images were obtained for each of the lesions.

The ROI (region of interest) of a size from 5 to 10 mm was moved around the elastography colour map with a cursor to allow the measurement of elasticity in the areas of greatest stiffness.

The following elastographic features (fig. 2) were defined:

Qualitative features:
#E sha - Lesion shape (oval, round, irregular).

E homo - Homogeneity of elasticity within the lesion and surrounding tissue (homogenous, inhomogenous, heterogenous).

#E col - colour obtained in the stiffest area in the mass or surrounding tissue using system defaults of blue for soft and red for stiff.

**Quantitative features:**

Elasticity values (Kilopascals)

# E max, E min, E mean (maximum, minimum and mean values).

Elasticity ratios

# E rat (mean elasticity ratio) - ratio of the E mean in the stiffest portion of the lesion to the E mean in a similar region of interest in fat.

# E arat (area ratio) - ratio of mass area on the B mode image to the mass area on the SWE image.

# E drat (diameter ratio) - ratio of mass diameter on the B mode image to the mass diameter on the SWE image.

**Gold standard:**

All the patients were subjected to image (US) guided core biopsy from the mass. Histopathology was considered the gold standard.
Images for this section:

Fig. 1

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Fig. 2: Elastography color map depicting qualitative and quantitative SWE parameters

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Results

1. One hundred and nineteen patients with single breast mass each and mean age 42.3±13.6 years, were enrolled.

2. On histopathology, 57 were BM and 62 MM (figs. 3, 4). Those with malignant breast mass (MM) were older (48.8±11.9 years), had larger sized mass (mean 2.9±1.32 cm) with shorter duration of symptoms (4±2.2months) as compared to patients with a benign mass (BM), whose had mean age 35.2±11.7 years, mean mass size of 2.5±1.5cm and longer duration of symptoms (7.2±6.4 months, p 0.001).

3. SWE characteristics of the two categories of masses were significantly different (Table 1, 3). BM (figs. 5-7) were oval (50.8%), homogenous (66.7%) and blue color (77.1%) while MM (figs. 8-10) were irregular (93.6%), inhomogenous (92.1%) and red/orange (90.5%) in color.

4. Best differentiating qualitative parameter was Ecolor [specificity 84.2% and sensitivity 91.9%, (p <0.001)] (table 2).

5. Elasticity of BM (fig. 11) were low (Emax=72.6+/−60.6 kPa, Emean=47.9+/−44 kPa, Emin=28.5+/−33.4 kPa) while that of MM (fig. 12) were significantly higher (Emax=215+/−64.1 kPa, Emean=163+/−51.6 kPa, Emin=99+/−48.7 kPa, p 0.001). E ratio was also higher for MM (14.7+/−8 vs 5.8+/−5.1, p 0.001) (table 3).

6. Emax (cut-off of 140kPa) and Emean (cut-off of 102kPa) emerged as the best quantitative parameters (table 4).

7. We attempted a modified BI-RADS' (table 5) with the incorporation of SWE parameters to B-mode US. BI-RADS 3 and 4a masses were upgrade or downgraded (figs. 13-15) based on whether they showed malignant or benign features on SWE.

8. Modified BI-RADS' using SWE parameters yielded best results with - Ecolor (improved specificity from 70.2% to 78.9%), Emean and Emax (enhancing specificity from 70.2% to 75.4%) (see tables 6, 7).

9. Limitations of our study:

Masses with indeterminate elasticity values (Emax 72-140kPa) were less in number and spectrum- no valid conclusion could be made regarding these masses (figs. 16, 17).

We had only a small number of BIRADS 4a masses (n=10) in our study.

We expect statistical significance with larger sample size of 4 a masses as 5 out of 10 4 a masses could be accurately downgraded by SWE (table8).
**Fig. 3:** Histopathology of benign masses (n=57).

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Fig. 4: Histopathology of malignant masses (n=62).

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Fig. 5: SWE image (a) showing oval mass with homogeneous blue color. Dual image with B mode US (b) showing a well circumscribed hypoechoic mass (BI-RADS 3). Histopathological examination (HPE) revealed fibroadenoma.

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Fig. 6: SWE image of a 36 year old lady (a) shows homogenous blue color. B mode US (b) shows a well defined intraductal soft tissue mass. HPE suggestive of benign ductal papilloma.

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Fig. 7: B mode US(a) of a 35 year old lady shows an ill-defined hypoechoic lesion with posterior acoustic shadowing -BIRADS 4c. SWE image (b) shows homogenous blue color suggesting a benign etiology. HPE was Sclerosing adenosis.
Fig. 8: SWE image(a) shows irregular shape, hard areas (red color) and inhomogenous SWE pattern suggesting malignancy. B mode US (lb) shows hypoechoic irregular mass HPE diagnosis was Infiltrating Ductal Carcinoma (IDC).

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Fig. 9: SWE image of a 55 years old lady (a) shows the eccentric cystic component as color void and the peripheral solid area as hard (red color) with an Emax of 300kPa. B mode US (b) shows a complex, heteroechoic mass with ill defined and angulated margins (BIRADS 4c). HPE diagnosis was mucinous carcinoma.

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Fig. 10: B mode US (a) of a 37 year old woman shows hypoechoic mass with echogenic rim (BIRADS 4c). SWE image(b) shows hard areas (red color), inhomogenous SWE pattern and an Emax of 260.8kPa suggesting malignancy. HPE diagnosis was IDC.

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Table 1: Table showing qualitative differences between BM and MM. Most of the BM are oval/round, dark blue/light blue and homogeneous, while most of the MM are irregular, red and inhomogeneous. The results were statistically significant. (BM - benign masses, MM - malignant masses)

<table>
<thead>
<tr>
<th>Description</th>
<th>Count (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Blue</td>
<td>25 (43.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Light Blue</td>
<td>19 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>53 (85.5)</td>
<td></td>
</tr>
<tr>
<td>Oval</td>
<td>29 (50.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Irregular</td>
<td>59 (95.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Homogeneous</td>
<td>38 (66.7)</td>
<td></td>
</tr>
<tr>
<td>Inhomogeneous</td>
<td>58 (93.5)</td>
<td></td>
</tr>
</tbody>
</table>

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### Table 2: Table showing the diagnostic accuracy of various qualitative parameters. Ecolor (combination of red and orange color) emerged as the best qualitative parameter in our study with a high sensitivity of 91.9% and specificity of 84.2% for diagnosing malignancy.

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Fig. 11: Figure depicting SWE quantitative parameters of BM. SWE image (a) showing oval homogeneous blue color with an Emax value of 12.8kPa. B mode US(b) showing a well circumscribed hypoechoic mass (BI-RADS 3). HPE diagnosis - fibroadenoma.

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Fig. 12: Figure depicting SWE quantitative parameters of MM. SWE image of a 45 year old lady (a) shows mass with hard areas predominantly in the periphery with an Emax of 134.6 kPa. B mode US (b) shows a hypoechoic mass with ill defined margins (BIRADS 4c). HPE diagnosis DCIS.

Table 3: Table showing differences of SWE Quantitative parameters in BM and MM. The elasticity values were significantly different for BM and MM. (BM- benign masses, MM- malignant masses).

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Table 4: Among the 4 quantitative SWE parameters studied, Emax and Emean emerged as the best parameters with high diagnostic accuracy. Emean showed a higher sensitivity than Emax (93.4% vs 88.9%) whereas its specificity was marginally lower than that of Emax (88.9% vs 89.5%).

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Table 5: Modified BI-RADS': SWE parameters added to B mode US-for BI-RADS 3 and 4A categories.

<table>
<thead>
<tr>
<th>B mode US + Eshape</th>
<th>B mode US + Ehomog</th>
<th>BmodeUS + Ecolor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Sensitivity</td>
<td>96.8 CI (88.8-99.6%)</td>
<td>96.8 CI (88.8-99.6%)</td>
</tr>
<tr>
<td>Overall Specificity 70.2 CI (56.6-81.6%)</td>
<td>70.2 CI (56.6-81.6%)</td>
<td>78.95 CI (66.1-88.6%)</td>
</tr>
<tr>
<td>PPV 77.9 CI (67.0-88.6%)</td>
<td>78.5 CI (67.8-86.9%)</td>
<td>83.3 CI (72.7-91.1%)</td>
</tr>
<tr>
<td>NPV 95.2 CI (83.8-99.4%)</td>
<td>100 CI (91.2-100.0%)</td>
<td>95.7 CI (85.5-99.5%)</td>
</tr>
</tbody>
</table>

Table 6: Modified BI- RADS' vs BI-RADS on US (Comparison of qualitative SWE parameters): Each qualitative parameter was added to the B-mode US to derive modified BI-RADS' and their diagnostic accuracy was compared with BI-RADS on B-mode US.

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Table 7: Modified BI-RADS’ vs BI-RADS on US (Comparison of quantitative SWE parameters): Each quantitative parameter was added to the B-mode US to derive modified BI-RADS’ and their diagnostic accuracy was compared with BI-RADS on B-mode US.

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Fig. 13: Correct downgrading by Emax on SWE: Mass has an Emax of 24.7 kPa. Although mass is BI-RADS 4 A on B-mode US, it is BI-RADS 3' based on SWE. Histopathology was fibroadenoma.

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**Fig. 14:** Correct upgrading by Emax on SWE: Mass has an Emax of 211.0 kPa on SWE. Although mass is BI-RADS 3 on B-mode US, it is BI-RADS 4A' based on SWE. Histopathology was invasive ductal carcinoma.

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Fig. 15: Incorrect downgrading by Ecolor on SWE: Mass is BI-RADS 4A on B-mode US, but BI-RADS 3’ on SWE based on Ecolor. However histopathology in this case revealed ductal carcinoma in situ.

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Table 8: Table depicts the results of Modified BI-RADS’. Biopsy could have been avoided in 5 out of 10 BIRADS 4 A masses. Two malignancies amongst 42 BI-RADS 3 were correctly diagnosed.

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Fig. 16: Limitation of B-mode US and SWE (False positive on both): Based on the B-mode US and SWE characteristics, lesion would be categorized as BI-RADS 5. However the histopathology in this case revealed chronic mastitis.

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Fig. 17: Limitation of SWE: The mass on B-mode US was categorized as BI-RADS 4A. However on SWE, the mass showed intermediate hardness with an Emax of 105.4 kPa and remained indeterminate. Histopathology revealed invasive ductal carcinoma in this case.

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Conclusion

Benign and malignant breast masses have distinct demographic profile and shear wave elastographic characteristics. Ecolor emerged as the best qualitative parameter and Emean and Emax as the best quantitative SWE parameter for characterizing breast masses. SWE can serve as a useful adjunct tool to B mode US for characterization of breast masses, particularly BI-RADS 3 and 4a masses.
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References


