An atlas of breast sonoelastography
Abstract:
Elastography is a new adjunct to high resolution USG in characterizing intermediate breast lesions. By using the STRAIN Ratio, the elasticity of the lesion provides comparative values, which will give the tissue stiffness. The length (SIZE) compare tool is also used to compare the ratio of length of the lesion on gray scale with that on elastography. Thus, it helps in avoiding unnecessary FNAC’s and biopsies and a good toll for follow up of those lesions. Elastography is a tool used to compare relative stiffness of a lesion with that of surrounding tissue. Breast elastography looks at mechanical properties of tissues (relative stiffness.) Stiffness is defined only for tissue. Fluid structures show characteristic noise patterns in elastography that may be used as key identifying.

Introduction: What is elastography
➢ The principle of elastography is that tissue compression produces strain (displacement) within the tissue and that the strain is smaller in harder tissue than in softer tissue. Therefore, by measuring the tissue strain induced by compression, we can estimate tissue hardness which may be useful in characterising breast lesions.
➢ Elastography can be used to differentiate between benign v/s malignant lesions.
➢ Elastography helps to determine as to which lesions require further diagnostic intervention like FNA or biopsy or not.
➢ Strain Elastography – performed on Small Parts Advanced Breast TSI, using high frequency transducers on Philips premium color doppler systems – is characterized by:
  • Multiple elastogram grey scale and colour maps.
  • Colors assigned represent the amount of tissue deformation, with stiffer areas represented by the bottom colour and softer areas represented by the top colour.

Color elastography map showing the gradations of stiffness relative to the surrounding tissues in this mass with suspicious characteristics blue on the scale is extremely hard consistency with red being soft lesion and green and yellow are intermediate consistency.

Breast Cyst
The AI (anechoic imaging) mode allows clear depiction of the simple cyst.

Tissue Type Differentiation
Note the distance differences in tissue stiffness relative to the other areas of this image. Dark blue depicts the stiffest areas in the image. (Fig 1)

Fibroadenoma
Quickly and easily assess the size of the lesion on the elastogram relative to the size of the lesion on 2D using the size compare feature.
**Interpretation**

- Comparison of BIRADS grading system of US imaging with strain ratio of elasticity of lesion.
- For elasticity score, the mean standard deviation was 3-4.5 +/- 0.9 for malignant lesions exceptions being intraductal carcinomas with varying degree of cellularity necrosis where in the range can be as lower as 2-2.5 and 2.5 +/- 1.0 for benign lesions (P < .001) except high cellular lesions like phyllodes and angiomas which have strain ratio of 3-3.5.
- When a cutoff point of between 2.5 and 4 was used, elastography had 86.5% sensitivity, 89.8% specificity and 88.3% accuracy.
- When a best cutoff point of between 4 and 5 was used, conventional US had 71.2% sensitivity, 96.6% specificity, and 84.7% accuracy.

**Clinical Diagnosis**

An elasticity score of 5, which shows no strain in the entire hypoechoic lesion, and the surrounding area at B-mode US indicates infiltration of cancer cells into the interstitial tissues (e.g. in scirrhous carcinomas) or into an intraductal component (e.g. in DCIS), both of which are characteristics of carcinoma.

An elasticity score of 4, which indicates no strain in the entire hypoechoic lesion, seems to be characteristic of tumors such as solid tubular carcinomas that are circumscribed and homogeneously harder than the adjacent normal breast tissue.

An elasticity score of 3, which indicates strain at the periphery of the hypoechoic lesion, was mainly found in benign lesions, including intraductal papillomas. The importance of strain at the periphery is unclear at present and requires further investigation.

Note: It is recommended that all lesions with elasticity scores of 3 or higher be examined by means of aspiration cytology or needle biopsy.

**Elasticity Scoring:**

<table>
<thead>
<tr>
<th>Elastosonographic Score</th>
<th>Typical B-mode image</th>
<th>Chromatic code</th>
<th>Typical elastosonographic image</th>
<th>Classification standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elasticity Score 1:</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td>Strain is seen in the entire hypoechoic area (the entire lesion is shown in green similar to the surrounding tissue).</td>
</tr>
<tr>
<td>Prevalently in benign lesions as well as in the simple cysts.</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td>A tri-stratified pattern of blue, green and red (BGR sign) which is a typical artifact seen in a cystic lesion.</td>
</tr>
<tr>
<td><strong>Elasticity Score 2:</strong></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></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>
</tr>
<tr>
<td>Prevalently in benign forms</td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
<td>Strain appears only in the periphery with no strain in the center of the lesion (the centre of the lesion is shown as blue with the periphery in green).</td>
</tr>
<tr>
<td><strong>Elasticity Score 3:</strong></td>
<td><img src="image13.png" alt="Image" /></td>
<td><img src="image14.png" alt="Image" /></td>
<td><img src="image15.png" alt="Image" /></td>
<td>No strain is measured within the lesion (the entire lesion is shown in blue).</td>
</tr>
<tr>
<td>Probably benign.</td>
<td><img src="image16.png" alt="Image" /></td>
<td><img src="image17.png" alt="Image" /></td>
<td><img src="image18.png" alt="Image" /></td>
<td>No strain is measured within the lesion nor in the surrounding tissues (the entire lesion and the surrounding tissue are blue).</td>
</tr>
<tr>
<td><strong>Elasticity Score 4:</strong></td>
<td><img src="image19.png" alt="Image" /></td>
<td><img src="image20.png" alt="Image" /></td>
<td><img src="image21.png" alt="Image" /></td>
<td>Probably malignant.</td>
</tr>
<tr>
<td><strong>Elasticity Score 5:</strong></td>
<td><img src="image22.png" alt="Image" /></td>
<td><img src="image23.png" alt="Image" /></td>
<td><img src="image24.png" alt="Image" /></td>
<td>Prevalently in malignant forms.</td>
</tr>
</tbody>
</table>

*Fig. 2. Categories of breast lesions on the B-mode US and RTE according to the modified classification introduced by Italian MultiCenter Team of Study [Quoted from Smajlovic et al. [3]]*
Recently, elasticity scores were classified into three categories: [5]

- A score of 1 (even strain across the entire lesion) as negative,
- Scores of 2 and 3 (uneven strain in the lesion) as equivocal, and
- Scores of 4 and 5 (no strain across the entire lesion) as positive results.

A specific bull’s eye artifact on black-and-white images or an aliasing artifact that appears as a blue-green-red (BGR) pattern on color-coded images (Fig. 2B) can be observed in simple cysts.

Practical Tips for Data Acquisition of US Elastography:

1) For adequate data acquisition, the probe should be placed vertically on the skin to correctly compress the tissue using light pressure and the chest wall should be parallel to the lesion.

2) Generous amounts of contact jelly should be used and the range of ROI should be adjusted to exclude the skin and chest wall layers to reduce artifacts.

3) Adjust the range of the region of interest to include a sufficient amount of adjacent normal tissue and the lesion; however, do not include the skin and chest wall.

4) Light repetitive compression is needed for strain elastography while managing to avoid allowing the probe to slip.

5) Try to minimize the artifacts that might appear during elastography.

Practical tips for the interpretation of breast ultrasound elastography:

1) Recognize the learning curve for interpretation; it is important to reduce the interobserver variability during the interpretation of elastograms by practicing and forming a consensus with experts.

2) Detect the true signal of a lesion, distinguishable from artifacts, and compare it with that of normal subcutaneous fat or glands.

3) Always assess the image quality of the elastogram and determine the diagnostic value of the image. High quality images showed better diagnostic performance in differentiating benign from malignant breast masses than did poor quality images.

4) Practice combining elastographic results with B-mode Ultrasound Breast Imaging Reporting and Data System using various cases.
Fig. 4. Representative good and poor quality elastographic images.
A. Good quality images on SE can be defined by a high signal-to-noise ratio in the region of interest.
B. Poor quality images were acquired due to probe slipping (left) and a deeply located lesion or thick breast (right) on strain elastography.
Case Study 1: Complex fibroadenoma

35 year old female presented with multiple lumps in both breasts.

On HRUSG there were multiple illdefined hypoechoic soft tissue mass lesions with varying vascularity on color Doppler. On elastography strain ratio was 2.9, suggesting firm consistency lesions.

FNAC proved it to be fibroadenomas with high cellularity

Clinical Note:
Fibroadenomas are benign tumors composed of stromal and epithelial elements. The typical presentation is in a woman of reproductive age with a mobile palpable breast lump. The lesions are well defined and well circumscribed clinically and the overlying skin is normal. The lesions are not fixed to the surrounding parenchyma and slip around under the palpating hand, hence the colloquial term a breast "mouse". On USG, they are typically seen as a well-circumscribed, round to ovoid, or macrolobulated mass with generally uniform hypoechogenicity. Intralesional sonographically detectable calcification may be seen in 10% of cases. Sometimes a thin echogenic rim - pseudocapsule may be seen sonographically.
Case Study 2: Ductal Papilloma

54 yr old female presented with spontaneous serosanguinous left nipple discharge on and off since six months.

HRUSG reveals few dilated ducts with clear internal echoes. But one of the ducts showed a mildly hypoechoic peripheral moderately vascular soft tissue.

On elastography it had strain ratio of 1.8. Hence FNAC performed and revealed ductal papilloma with severe dysplasia.

Clinical Note:
Intraductal papilloma is a benign breast lesion. Papillomas are the most common intraductal mass lesions of the breast. Patients typically report a bloody or clear (serosanguinous) nipple discharge of less than 6 months duration. The bloody nipple discharge is thought to be due to twisting of the papilloma on its fibrovascular pedicle, leading to necrosis, ischaemia, and intraductal bleeding. Intraductal papillomas are broadly classified into central and peripheral types with central ones usually being solitary and subareolar in location within a major duct, whilst peripheral types tending to be multiple within the terminal duct lobular unit. The peripheral types have greater incidence of atypia or malignancy. On USG, papilloma may be seen as a well-defined solid nodule or intraductal mass which may either fill a duct or be partially outlined by fluid - either within a duct or by forming a cyst. Colour doppler will demonstrate a vascular stalk. A dilated duct can be frequently visible sonographically. According to a consensus committee of the College of American Pathologists, women with this lesion have a relative risk of 1.5-2 times for developing invasive breast carcinoma in their lifetime.
Case Study 3: Intraductal Carcinoma

Intraductal mass in young lady who presented with hard lump in left breast with pain.

**Elastography strain ratio of 4** raised high suspicion in favour of atypical malignant mass rather than inflammatory lesion. HP proven **high grade ductal carcinoma**.

**Clinical Note:**

Ductal carcinoma in situ (DCIS) refers to a breast carcinoma limited to the ducts with no extension beyond the basement membrane, as a result of which the disease has not infiltrated the parenchyma of the breast and the lymphatics and cannot therefore metastasise. DCIS (also known as intraductal carcinoma) is considered non-invasive or pre-invasive breast cancer and it accounts for approximately 15-20% of all detected breast cancers. It can be broadly divided into two types:

- **comedo - large cell:** more aggressive form; also referred to as comedocarcinoma
- **non-comedo - small cell:** less aggressive; can be further divided into - cribriform, micropapillary and solid

A microlobulated mild hypo echoic mass with ductal extension, and normal acoustic transmission is considered the most common feature in sonographically detected DCIS. This disease is likely the precursor of IDC at a stage of the disease when the therapy is potentially curable.

Treatment options for ductal carcinoma in situ include mastectomy, lumpectomy with breast irradiation, or, for patients with small lesions (<1-2 cm) of low-grade ductal carcinoma in situ, lumpectomy alone.

*Fig 7: Intraductal Mass with irregular border definition shows high strain values in Elastography.*
Case Study 4: High Grade Adenocarcinoma

53 yr old female presented with **painless hard lump** in left breast since 6 months.

HRUSG showed a characteristic **illdefined lobulated hypoechoic** mass in outer quadrant with three hypoechoic **axillary lymph nodes** with loss of hilum and focal cortical asymmetrical thickening.

**Size Compare on Elastography** showed a **length larger than that on gray scale** and **strain ratio of 4-5.5** consistent with features of **malignant mass** and metastatic axillary lymph node deposits.

**FNAC suggestive of adenocarcinoma**

**Clinical Note:**

An adenocarcinoma refers to a type of carcinoma that begins in the ducts and lobules of the breast. Adenocarcinoma: accounts for 99% of breast cancer. They are classified as –

A) Ductal:
- Ductal carcinoma in situ (DCIS): 10%
- comedo type: ~60% of DCIS
- non comedo type: ~40% of DCIS papillary
- Invasive ductal carcinoma
- Invasive ductal carcinoma not otherwise specified (NOS): ~65%
- tubular carcinoma of breast: ~7-8%

B) Lobular:
- lobular carcinoma in situ (LCIS)
- invasive lobular carcinoma: ~10%

Breast cancer is the most common of all cancers and is the leading cause of cancer deaths in women worldwide, accounting for >1.6% of deaths and case fatality rates are highest in low-resource countries. A recent study of breast cancer risk in India revealed that 1 in 28 women develop breast cancer during her lifetime.

Strain Elastography shows well defined margins of the mass, especially the posterior margins, which were ill-defined on the gray scale imaging.

Strain elastography also highlights the extent of the lesion into the surrounding parenchyma. This additional information is highly valuable from surgical point of view.
Case Study 5: Sarcoma

45 yr old female presented with lump in left breast which had rapidly increased in size over a period of 6 months.

On HRUSG—there was a large well defined characteristically hyperechoic lesion with high internal and peripheral vascularity on color Doppler.

On elastography lesion was larger in length than on gray scale. Strain ratio was 4–5.5 consistent with malignant mass.

Pre operative core biopsy confirmed it as high grade sarcoma

Clinical Note:

Breast sarcomas are rare, histologically heterogeneous nonepithelial malignancies that arise from the connective tissue within the breast and can include: angiosarcoma, pleomorphic sarcoma, fibrosarcoma, myxofibrosarcoma, leiomyosarcoma and primary osteosarcoma - of the breast

They can develop de novo (primary), after radiation therapy (RT), or in the setting of chronic lymphedema of the arm or breast (therapy related, secondary). Although the clinical features of breast sarcoma mimic those of breast carcinoma in some ways, therapy and prognosis differ dramatically. As a sub group they comprises 0.5–1% of all breast neoplasms. They tend to present at a younger age than ductal or lobular carcinomas (mean 45 years). They characteristically show haematogenous metastases with nodes metastases being rather rare

Fig 9: Breast Mass with hyperechoic appearance consistent with hypercellularity and increased vascularity and irregular border. It shows high strain ratio
Case Study 6: Phylloides

37 yr old young lady presented with a large mass in right breast dramatically increasing in size since 2 years.

On HRUSG: there was a well-defined mixed hypo to isoechoic mass in right breast with an adjacent similar character smaller lesion in different quadrants. Both lesions had peripheral and mild internal vascularity on color doppler.

Since on elastography strain ratio was 4-4.5, FNAC was performed and revealed features typical of phylloides.

Clinical Note:
Phyllodes tumors of the breast are rare, accounting for less than 1% of all breast tumors. The name "phyllodes," which is taken from the Greek language and means "leaflike," refers to that fact that the tumor cells grow in a leaflike pattern. They are also named as cystosarcoma phyllodes. Phyllodes tumors tend to grow quickly, but they rarely spread outside the breast. Although most phyllodes tumors are benign, some can be malignant or borderline. All three kinds of phyllodes tumors tend to grow quickly, and they require surgery to reduce the risk of local recurrence. Phyllodes tumors can occur at any age, but are usually seen when a woman is in her 40s. Benign phyllodes tumors are usually diagnosed at a younger age than malignant phyllodes tumors. Phyllodes tumors are extremely rare in men.
Case Studies

Case Study 7: Post chemotherapy tumor recurrence

54 yr old lady with large painless lump with histopathologically proven k/c/o adenocarcinoma underwent debulking with chemotherapy for tumor reduction and came for follow up.

HRUSG showed a primary heterogeneous hyperechoic mass with central calcific foci and another synchronous lesion with multiple hypoechoic vascular lymph nodes in axilla.

On elastography strain ratio was 3.5-4 suggesting hard mass.

Fig 11
Case Studies

Case Study 8: Fibroepithelial tumor

A young 32 yr old lady had a painless lump in left breast since 3 years.

On HRUSG it had appearance of atypical fibroadenoma. But elastography strain ratio was 3-4.

Hence FNAC was performed histopathological diagnosis was fibroepithelial tumor.

![Image](Fig 12)

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Case Study 9: Fat lesions

57 yr old lady underwent body massage and detected a painful lump that evening in left breast.

On HRUSG there was homogeneous fatty echoappearance of both breasts. Except a well defined hypoechoic area in mid parenchyma with surrounding edema and minimal parenchymal vascularity on color doppler.

On elastography strain ratio within this lesion was 0.3

A diagnosis of fat necrosis was made.

![Image](Fig 13)
Other interesting Cases

Postoperative scar

*Fig 14:* Scars tend to be softer, with strain ratio of less than 0.5 and within length as compared to gray scale.

Superficial Lesions in Breast

*Fig 15:* Subcutaneous lesion has elastography strain ratio of 3.5 suggesting high cellularity lesion. FNAC suggested angioma.
Conclusion

- ELASTOGRAPHY IS AN EXCELLENT TOOL FOR CHARACTERISING INDETERMINATE BREAST LESIONS.
- HELPS IN AVOIDING UNINDICATED NEEDLE FNAC AND BIOPSIES.
- HELPS IN DECIDING WHICH LESION NEEDS INTERVENTION / FOLLOW UP
- GOOD TOOL FOR FOLLOW UP OF BENIGN LESIONS.
- LOW TECHNICAL FAILURE RATE.
- HOWEVER, ELASTOGRAPHY IS LESS SPECIFIC IN DIFFUSE INFILTRATING LESIONS

Although it has high sensitivity and less specificity, but still it is a valuable adjunct to HRUSG and mammography in differentiating benign versus malignant lesions.

Reference


3. The Egyptian Journal of Radiology and Nuclear Medicine, Volume 45, Issue 2, June 2014, Pages 605–618, Incremental value of real-time ultrasound elastography in differentiating breast masses. Rania E. Mohamed, Khalid A. Abo-Dewan Radiodiagnosis Department, Tanta University, Tanta, Egypt.


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