Real-time tissue elastography is an emerging diagnostic tool that uses ultrasound to differentiate between hard and soft tissue. Typically, gentle freehand compression is used to apply stress to tissue and the resulting strain or displacement, is displayed as a colour overlay on a conventional B-mode ultrasound image. Elastography has the potential to increase examination specificity and thus reduce the need for diagnostic invasive procedures.

Second generation technology, which quantifies strain characteristics, is bringing further improvements in diagnostic accuracy. Real-time tissue elastography has proven applications in breast, prostate, thyroid and pancreatic disease and where diagnostic biopsy is indicated, elastography allows more accurate localisation and targeting of lesions. This paper briefly reviews the underlying principles of the technique and outlines the current clinical applications.

**Keywords:** Elastography, SonoeLASTography, Real-time Tissue Elastography, Elasticity Imaging

**Introduction**

Elastography is rooted in the practice of palpation, one of the oldest concepts in medicine and first described by Hippocrates in Ancient Greece more than 2000 years ago. An important characteristic of tissue is its plasticity, or elasticity, which changes through pathophysiological processes, in particular, chronic or acute inflammation, malignancy and aging processes all of which affect the elastic nature of tissues. When an abnormal focal mass is discovered, an important aspect of the initial clinical examination is physical palpation of the mass to assess its ‘stiffness’. Unfortunately, manual palpation is subjective and also lacks sensitivity particularly for small or deeply located lesions, improving sensitivity and specificity could have a significant impact on disease prognosis.

Real-time tissue elastography is an emerging diagnostic tool that uses ultrasound to differentiate between hard and soft tissue. The technique is used to measure tissue response to stress, calculate ‘strain’ values and typically, display this information as a colour overlay on a conventional B-mode ultrasound image (Fig. 1). For example, the more ‘stiff’ structures can be displayed as blue whilst the more easily deformed tissues are displayed as red, green indicating an ‘average’ value for strain (Fig. 2).

**Physical Principles**

The underlying principle of elastography utilizes the process of tissue compression (stressing force) to produce strain (displacement in response to stress) within the tissue. Strain is smaller in hard tissue and larger in soft tissue (Fig. 3), thus for example, fatty tissue is more easily compressed than a malignant tumour. By measuring the strain induced by tissue compression, it is possible to estimate tissue hardness and this can be useful when attempting to differentiate benign from malignant lesions.

Unique high-speed algorithms can be employed to measure strain distribution in real-time and thus enable rapid and accurate detection of axial tissue displacement. Such a technique requires gentle freehand compression on the skin’s surface with a standard transducer, capture of the returning echo signals and subsequent analysis of the radiofrequency (RF) data along each vector (Fig. 4). This information is then compared between successive frames to compile a ‘strain map’ of comparative elasticity. The resultant strain values throughout the tissue are colour coded according to magnitude and transluently superimposed onto a conventional B-mode image, the simultaneous display enabling viewers to appreciate the anatomical correlation of tissue elasticity and spatial location (Fig. 5).

Cysts, irrespective of their anatomical location, typically display a three-layered pattern of blue, green and red, the BGR sign (Figs. 6 and 7), and are easily identifiable. This pattern arises due to an artefact because of the low echo intensity inside the cyst.

**Second Generation Elastography**

To date, elastography has involved the display of relative tissue strain; quantitative assessment of strain information offers increased potential for improving the clinical diagnostic capability of the technique. Second generation real-time tissue elastography software incorporates a ‘strain ratio’ measurement which provides an objective quantification of strain within a lesion compared to that of surrounding normal tissue (Fig. 8). The strain ratio is obtained by dividing the mean
strain within the lesion by the mean strain from the subcutaneous fat (Fig. 9). This new information opens up opportunities for further research into tissue characterization with preliminary results showing benefits to using strain ratio data compared to the elastography score for classifying breast lesions.1

Clinical Applications

Breast

Where conventional B-mode imaging of the breast produces poor contrast between the tumour and the surrounding tissue, detecting cancerous breast tumours requires a high degree of operator skill. By offering additional information about tissue stiffness, real-time tissue elastography can improve visualisation of tumours and facilitate differentiation between benign and malignant disease. Breast elastography appearances have been classified into five imaging patterns, the Tsukuba elasticity score,2 according to the distribution and degree of strain induced by light compression (Fig. 10). The possibility of malignancy increases when the score is higher. Sensitivity and specificity are the highest when the 3/4 score interval is

Figure 2. Elastography colour spectrum.

Figure 3. An example of elasticity coefficient values between different types of breast tissue.

Figure 4. Hard and soft tissue behaviour under compression. Using the same applied pressure, soft tissue will deform more than hard tissue.

Figure 5. The simultaneous display enables an instant correlation between B-mode and elastography images.

Figure 6. The ‘BGR sign’: a three-layered pattern of blue, green and red, an anomaly which arises due to the low level of echoes inside the cyst.
established as the cutoff point between benign and malignant tumours. In the breast, elastography has a complementary diagnostic role alongside conventional B-mode imaging. Breast elastography is easy to perform, is not time-consuming and the elastographic scores have been demonstrated accurate and reproducible in multicentre studies. Whilst the sensitivity of conventional breast ultrasound is considered to be directly related to lesion size, elastography has high diagnostic accuracy for identifying and characterizing nodular breast lesions particularly when smaller than 2 cm diameter. With the increased specificity afforded by the addition of new benign criteria, elastography has the potential to eliminate unnecessary diagnostic procedures, and thus reduce the emotional burden of invasive procedures. Where intervention is indicated, elastography techniques offer more accurate localization for precise targeting of lesions.

Prostate

Prostate cancer has a higher cell density than surrounding normal tissue and this increased density alters tissue elasticity; such changes can be measured and displayed by elastography under real-time conditions (Fig. 11). Elastography techniques have revolutionized the detection and visualization of prostate cancer, improving assessment of tumour location for precise targeting of lesions.

Thyroid

The additional information offered by elastography imaging of the thyroid gland helps in tumour diagnosis and choice of therapy. With follicular lesions, elastography shows distinct differences in tissue elasticity between the peripheral zone and the lesion centre. The detection of clinically important associated disease, e.g. lymph node metastases in papillary thyroid cancer, has been reported. The high specificity of the technique makes elastography very effective for targeting a specific nodule for biopsy, especially in patients with multinodular goitre (Fig. 12); high true positive rates have been achieved.

Endoscopic Ultrasound

Endoscopic elastography allows characterization and differentiation of benign and malignant lymph nodes with a high sensitivity, specificity and accuracy. The technique offers complementary information to that obtained with conventional endoscopic ultrasound (EUS) imaging and allows better targeting for fine needle aspiration (FNA) procedures in patients with multiple enlarged lymph nodes (Fig. 13). Mapping of tissue elasticity distribution can provide additional information that helps differentiate focal pancreatic masses (Fig. 14). EUS tissue elastography is performed with conventional EUS probes and does not require additional instrumentation, compression being achieved through physiological processes such as vascular pulsation and respiratory motion.

Musculoskeletal

Real-time elastography is emerging as a promising technique for diagnosis of acute muscle injury and quantification of elasticity of muscle fibres (Fig. 15). Studies have shown improvement in discrimination of acute injury and that it is a faster, more accessible and ultimately a more economical diagnostic tool than alternative diagnostic investigations.

Conclusions

Real-time tissue elastography is an exciting development in ultrasound imaging: it is a simple, non-invasive technique that improves the differentiation of benign and malignant disease. A highly accurate diagnosis can be expected where elastography is used in combination with conventional ultrasound. Incorporating elastography into the ultrasound investigation adds new benign criteria; this potentially increases the specificity of the examination and can significantly reduce the number, and thus the emotional and financial burden, of diagnostic biopsies performed for benign disease. Where diagnostic intervention is indicated, elastography allows more accurate localization for precise targeting of lesions.
The technique is easy and rapid to perform and is reproducible. Clinical applications are expanding: the technique is developing an established role for evaluating focal disease in the breast, prostate, thyroid and pancreas, and it has been shown to be useful for assessing local lymphatic spread in malignant disease. Second generation technology is allowing quantification of the strain characteristics of tissue, bringing further associated improvements in diagnostic accuracy.

### Table: *Image Classification*

<table>
<thead>
<tr>
<th>Score</th>
<th>Classification</th>
<th>Typical Image</th>
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<tbody>
<tr>
<td>SC1</td>
<td>An elasticity score of 1 indicates uniform strain throughout the whole lesion, evenly shaded as green, as is the surrounding breast tissue.</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>SC2</td>
<td>A score of 2 indicates strain in most of the hypoechoic lesion with some areas of no strain exhibiting a mosaic pattern of green and blue.</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>SC3</td>
<td>A score of 3 indicates strain at the periphery of the lesion shown as green, with sparing of the central area shown as blue.</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>SC4</td>
<td>A score of 4 indicates no strain in the entire lesion shown as blue.</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>SC5</td>
<td>No strain within the lesion or in the surrounding tissues ie both the lesion and surrounding area shown as blue.</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Score 1 – 3 Typical benign pattern  Score 4 – 5 Typical malignant pattern

**Figure 10.** The Tsukuba elasticity score for classification of breast lesions.

**Figure 11.** Prostate cancer as detected with elastography within the right side of the prostate gland. The capsule cannot be visualized as seen by the missing ‘soft rim’ sign. Histopathology verified extracapsular disease.

**Figure 12.** A follicular carcinoma in the left thyroid lobe displaying a typical appearance on the elastogram of a hard rim with a softer central area.
Further Information

Clinical abstracts are available on all of the above applications through Hitachi Medical Systems (http://www.hitachi-medical-systems.co.uk or telephone: 0844 800 4294).

References


Figure 13. EUS elastography illustrates the malignant nature of this large upper mediastinal lymph node in a patient with oesophageal carcinoma, depicting mainly ‘stiff’ areas when compared with the surrounding tissue.

Figure 14. EUS elastography demonstrates a mixed pattern of hard and soft areas in this patient with chronic pseudotumoural pancreatitis indicating variable stiffness throughout the mass.

Figure 15. Musculoskeletal elastography: a complex appearance of a resolving tear, 2 months old, in the left pectoral muscle.