Elastography

- Elastography is a novel imaging method that evaluates tissue stiffness and presents data in color-coded displays.
- Elastography can be performed with ultrasound, using manual pressure or low frequency sonic waves, or by MR elastography imaging.
- Elastography is a promising technique for several purposes, including identification and localization of prostate cancer for biopsy and therapy, and for staging of liver fibrosis.

Ever since Hippocrates, physicians have used palpation to detect differences in tissue stiffness as an aid to diagnosis. Elastography depends on the same differences in mechanical properties between healthy and abnormal tissues but uses imaging to detect these differences at depths not reachable by manual palpation. Elastography techniques have been developed for both ultrasound and MR imaging.

Ultrasound elastography depends on reproducible differences in backscattered ultrasound signals that result from compression of tissues of varying stiffness. In the technique known as sonoeLASTography, first described 20 years ago, compression is achieved manually by putting pressure (stress) on the tissue being imaged. The degree of tissue distortion (strain) is assessed in real-time ultrasound imaging and depicted as color-coded images (Figure 1). A more recently developed ultrasound technique, shear wave elastography, uses focused beams of ultrasound energy from conventional transducers to produce movement on the order of several microns at depths of up to 6 cm beneath the ultrasound transducer. This technique results in low-frequency shear waves in a plane perpendicular to tissue displacement, much like the ripples in a pond that appear after a stone is thrown in the water. The speed of shear wave propagation is directly proportional to tissue elasticity, with faster speeds in stiffer tissues. Detection is accomplished by ultrafast real-time ultrasound imaging, and the data are displayed in kilopascals (kPa) on color-coded elasticity maps (Figure 2). This method has the advantage of being quantitative, reproducible, and operator independent. It is therefore suitable for monitoring changes over time.

MR elastography is another quantitative method that relies on shear pressure waves and elastic displacement of tissue. In this case, a pneumatic driver (Figure 3) is activated by a special MR elastography pulse sequence that performs velocity encoding through phase sensitization. This pulse sequence is sensitive to the transmission of waves through tissue, and the data from the troughs and peaks is mathematically converted into parametric images that display tissue elasticity in kPa (Figure 4).
Ultrasound Elastography for Prostate Cancer Detection

Conventional ultrasound has a low sensitivity for prostate cancer detection. Prostate cancer may be observed as a hypoechoic region in conventional ultrasound, but up to 40% of cancers are isoechoic. Moreover, hypoechoic regions are also found in benign processes such as prostatitis or focal atrophy. Because there is no effective way of detecting prostate cancer with current imaging techniques, systematic ultrasound-guided biopsy is used to detect prostate cancer in patients with elevated prostate specific antigen (PSA) levels. However, sampling errors are common, and many patients have repeat biopsies before the cancer is detected.

Prostate carcinoma is significantly stiffer than normal prostate tissue. In vitro assessment has confirmed that sonoelastography can distinguish between normal and cancerous prostate tissue. There is increasing evidence that sonoelastography may be an effective tool for detecting areas suspicious for cancer and for guiding the selection of sites for biopsy. Using sonoelastography to target biopsy sites has the potential to allow prostate cancer detection with fewer biopsy cores than systematic biopsy.

Elastography for Monitoring Liver Fibrosis

Chronic infection with the hepatitis C virus is an important cause of cirrhosis, and precise estimation of fibrosis is essential for optimal care. Other conditions that are associated with an increased risk of fibrosis include non-alcoholic steatohepatitis and a previous liver transplant. Liver biopsy is the current standard method of evaluating fibrosis. However, its accuracy is limited due to sampling error and observer variability and it is associated with patient discomfort and the risk, albeit small, of serious complications. Several studies have provided evidence that elastography is a promising method for non-invasively assessing fibrosis and steatohepatitis.

In clinical studies, shear wave elastography ultrasound and MR elastography are being used at our institution in a prospective cross-sectional study to quantitatively measure liver elasticity in patients with hepatitis of viral etiologies who have been referred for liver fibrosis staging by non-focal liver biopsy.

Previous studies have shown that tissue elasticity values derived from shear wave elastography ultrasound are highly correlated with METAVIR stage. Shear wave elastography measurements take approximately 15 minutes and are painless. Multiple measurements are obtained from the liver. Data are post-processed to yield quantitative estimates of shear wave velocity and liver stiffness (Figure 2).
Figure 3. Acoustic Driver System for MRE - A remote acoustic driver pumps air into a pneumatic device strapped onto the patient’s body, eliciting tissue displacement, which is measured by MR elastography and used to derive images showing tissue stiffness. Images courtesy of Richard L. Ehman, MD, Mayo Clinic, Rochester, MN.

Figure 4. MR Elastography - (A) An elastogram of a healthy liver showing a post processed value of 1.98 kPa corresponding to normal tissue stiffness. (B) An elastogram of the liver of a patient with Grade 3 fibrosis, with a shear stiffness value of 6.95 kPa. Images courtesy of Richard L. Ehman, MD, Mayo Clinic, Rochester, MN.

For MR elastography, a pneumatic driver device is strapped onto the patient over the rib cage (Figure 3), centered over the mid-point of the liver, beneath the MRI coil. When the pneumatic device is activated, the patient will feel vibrations in the rib cage due to the pressure waves. Each MR elastography examination takes about 30 seconds, in addition to the standard 35-40 minute MRI examination. The MR elastography image shows the shear-wave displacement patterns for the entire liver (Figure 3, 4). Therefore the data are not subject to sampling error, as are ultrasound-based shear wave elastography images and biopsies. However, it should be noted that shear wave elastography samples a much larger region of tissue than is possible with biopsy.
Further Information

Elastography is not yet FDA approved for clinical care and is, therefore, available only for clinical investigational purposes at this time.

IRB-approved research protocols for sonoelastography of the prostate gland, liver, and thyroid are currently active at Mass General. In addition, shear-wave ultrasound and MR elastography of the liver is IRB approved as a protocol for patients with hepatitis of viral etiology. IRB applications are underway for assessing post-transplant patients with accelerated fibrosis, patients with suspected steatohepatitis (as part of a comprehensive examination assessing liver fat, fibrosis and elasticity), and patients with known liver disease who refuse biopsy. In the approved protocol, patients who will be undergoing a non-focal liver biopsy will receive a shear wave elastography ultrasound examination and an MRI examination with an additional MR elastography sequence. MR elastography is currently performed at Mass General Imaging, Chelsea. US elastography is currently performed on the main campus on White 2.

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References


