Introduction

Many diseases markedly affect the mechanical properties of tissues. This accounts for the efficacy of palpation, a centuries-old technique of clinical medicine. MR Elastography (MRE) is an emerging diagnostic imaging technique for quantitatively assessing the mechanical properties of tissue [1]. It is a three-step process, involving: (i) generating mechanical waves within the tissues of interest, (ii) imaging the micron-level displacements caused by propagating waves using a special MR imaging technique with oscillating motion-sensitizing gradients, and (iii) processing the wave images using an “inversion” algorithm to generate quantitative maps of mechanical properties.

MRE has been applied to assess a variety of tissues, ranging in stiffness from lung to cartilage. Human studies have demonstrated that it is feasible to quantitatively image the mechanical properties of skeletal muscles, gray and white matter in the brain, thyroid, kidney, liver, and skin. Studies of volunteers and patients have demonstrated the feasibility of imaging normal breast anatomy with MRE and delineating breast cancer.

The most advanced current application of MRE is for diagnosing hepatic fibrosis [2-6]. Chronic liver disease is a serious worldwide problem, and hepatic fibrosis is the most important consequence, which if not detected and treated, eventually leads to cirrhosis which is irreversible and associated with high mortality. Currently, needle biopsy is the accepted method for detecting and quantifying hepatic fibrosis. Biopsy is invasive, expensive, and affected by sampling error.

MR Elastography – Technique

MRE can be readily implemented on a standard MRI system. The requirements are (i) a device for generating mechanical vibration in the liver under MRI scanner control, (ii) a special MRE pulse sequence, and (iii) processing software to generate the diagnostic MRE images, which are called “elastograms”.

In a typical implementation, a simple, drum-like “passive” acoustic driver is placed over the right anterior chest wall and coupled to a source of low frequency sound wave by a flexible tube. Vibrations at 40-90 Hz are generated in the abdomen with this device. The waves are imaged with a modified phase contrast MRI pulse sequence. Imaging time is approximately 15 seconds, using parallel acquisition techniques and is done during suspended respiration. Because the incremental imaging time is so small, MRE can readily added to standard abdominal MR imaging protocols. The MRE data are processed with a special inversion algorithm to generate a quantitative image showing the elasticity of the liver and other tissues in the upper abdomen.
Clinical MRE of the Liver

Clinical studies by multiple investigators have now established that MRE is an accurate method for diagnosing hepatic fibrosis [2-5] (Figure 1). MRE-measured hepatic stiffness increases systematically with fibrosis stage. In a recent published study, encompassing 50 patients with biopsy-proven liver disease and 35 normal volunteers, ROC analysis showed that, with a shear stiffness cut-off value of 2.93 kPa, the predicted sensitivity and specificity for detecting liver fibrosis is 98% and 99%, respectively [5]. ROC analysis also provided evidence that MR elastography can discriminate between patients with moderate and severe fibrosis (grades 2–4) and those with mild fibrosis (sensitivity, 86%; specificity, 85%). Importantly, hepatic stiffness is not systematically influenced by the presence of steatosis.

In studies of patients with chronic liver disease, there has been a very strong correlation between the measured stiffness of the spleen and the biopsy-proven grade of hepatic fibrosis. There is some evidence that this may reflect the presence of portal venous hypertension, with the spleen becoming stiffer as pulp pressure increases. If true, this points to the possibility that MRE may be useful for estimating portal venous pressure.

Emerging experience in over 360 liver MRE exams performed for clinical purposes at Mayo Clinic suggests that MRE also has promise for characterizing focal liver lesions. Benign focal liver masses, including cavernous hemangioma, hepatic adenoma, and focal nodular hyperplasia have typical stiffness values in the 3 kPa range, slightly stiffer than normal liver parenchyma. Malignant focal masses of the liver, including hepatocellular carcinoma, metastases, and cholangiocarcinoma are much stiffer than normal liver tissue (Figure 2). In a series of 44 liver masses (31 malignant and 13 benign), a threshold of 5 kPa was very effective in differentiating malignant from benign masses [6].

Preliminary results indicate that it is feasible to apply MRE to visualize the mechanical properties of other abdominal and pelvic structures including the spleen, gastric wall, adrenal glands, pancreas, bowel, kidneys, and bladder wall.
**Figure 2:** Left: Conventional MR image shows a mass in the liver. Center: Mechanical waves are imaged in the liver, using an MRE sequence. Right: The wave information is processed to generate an elastogram, which indicates that the mass (arrow) is very hard, consistent with a malignant tumor (hepatocellular carcinoma). The elastogram also shows that the surrounding liver is much stiffer than the normal value of 2 kPa, indicating this patient has moderately advanced hepatic fibrosis.

**Conclusion**

Multiple studies have now established that MRE is a reliable method for diagnosing hepatic fibrosis. MRE is intrinsically safer, less expensive, and probably more accurate than biopsy in this regard. Other abdominal applications are likely to emerge.

**References**


