In Vivo Abdominal Magnetic Resonance Elastography for the Assessment of Portal Hypertension Before and After Transjugular Intrahepatic Portosystemic Shunt Implantation

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Purpose: The purpose of this study was to investigate the correlation between hepatic venous pressure gradient (HVPG) and in vivo viscoelasticity of the liver and spleen before and after transjugular intrahepatic portosystemic shunt (TIPS) implantation.

Materials and Methods: Ten patients with portal hypertension were examined twice by 3-dimensional multifrequency magnetic resonance elastography as well as prior and subsequent TIPS intervention; HVPG was also measured during TIPS placement. Five harmonic vibrations (25–60 Hz) were transferred to the abdominal region and recorded for the reconstruction of 2 viscoelastic constants, $|G^*|$ and φ, corresponding to the magnitude and the phase angle of the complex shear modulus G^* of the liver and spleen.

Results: All patients had cirrhosis, yielding high $|G^*|$ values in the liver (8.34 ± 2.18 kPa) and spleen (8.44 ± 1.36kPa). In both organs, a decrease of $|G^*|$ after TIPS placement was observed (liver: 8.34 ± 2.18kPa vs 7.02 ± 1.46 kPa, $P = 0.01$; spleen: 8.44 ± 1.36 kPa vs 7.06 ± 1.32 kPa, $P = 0.01$), whereas φ was insensitive to TIPS. Relative changes in $|G^*|$ of the spleen were correlated with the relative change of HVPG ($R^2 = 0.659$, $P = 0.013$).

Conclusions: The observed linear correlation between spleen viscoelasticity HVPG raises the prospect of an image-based noninvasive assessment of portal pressure by magnetic resonance elastography in the follow-up of TIPS placements.

Key Words: magnetic resonance elastography, MRE, liver, spleen, shear viscoelasticity, stiffness, portal hypertension, hepatic venous pressure gradient, TIPS, portosystemic shunt

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Transjugular intrahepatic portosystemic shunt (TIPS) is an effective method for treating patients with portal hypertension. During the TIPS intervention, an artificial channel is established between the portal and hepatic veins to reduce the portal venous pressure (PVP). Hepatic venous pressure gradient (HVPG) is currently considered the criterion standard for assessing the hemodynamic procedural outcome of a TIPS placement; it is also the most important prognostic parameter for decompensation of portal hypertension and the risk for variceal bleeding. However, HVPG measurements are invasive and therefore not suited for follow-up examinations.[1] Noninvasive technique such as Doppler sonography,[2,3] acoustic radiation force impulse (ARFI) imaging,[4] or shear wave elastography[5] were introduced to assess portal hypertension. These methods are operator dependent, and the accuracy is sometimes affected by ascites and obesity.

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Magnetic resonance elastography (MRE) is a unique imaging modality that serves as a noninvasive and quantitative measure of tissue's viscoelastic properties.[6] To date, MRE studies correlating liver and spleen stiffness with portal hypertension were carried out in animal models[7,8] and humans.[9–11] For TIPS intervention, a noninvasive assessment of portal hypertension after the treatment procedure is important for evaluating therapeutic efficiency and long-term follow-up monitoring. A direct comparison of the tissue mechanical properties before and after the TIPS treatment using MRE was reported by Hirsch et al.[11] However, this previous study focused on strain measurements inside the liver, whereas high-resolution maps of the shear viscoelastic properties of abdominal organs could not be obtained. High-resolution MRE refers to a pixel-wise fidelity mapping of the tissue's shear viscoelastic properties without the necessity of masking out regions of unreliable mechanical contrast. High-resolution MRE based on 3-dimensional multifrequency MRE (3DMMRE) in combination with a dual-parameter inversion algorithm was recently introduced[12] and has been demonstrated in the kidney,[13] liver,[14] uterus,[15] and brain.[16] The purposes of this study were to apply this high-resolution MRE technique to patients with portal hypertension and to investigate the response of shear viscoelastic parameters of the liver and the spleen to TIPS placement.

METHODS

Patients

The study was approved by the local institutional review board. Written informed consent was obtained from all patients. Ten patients (age range, 43–70 years; 5 women) with portal hypertension were enrolled. Detailed patient information is collected in Table 1.

TIPS Intervention

Placement of TIPS was performed by a board-certified interventional radiologist (C.A.) under local anesthesia and mild sedation. Six patients received a Nitinol bare metal stent (Luminexx; C.R. Bard GmbH, Karlsruhe, Germany) and 4 patients received a polytetrafluoroethylene-covered stent graft (Gore, Flagstaff, AZ), each with a diameter of 10 mm. The stents and stent grafts were selected on the basis of anatomical information such as size of the liver, shunt position, distance between the main portal vein and right hepatic vein, as well as right-sided heart function. The HVPG was measured during the intervention as the pressure difference between PVP and systemic venous pressure at the level of the superior vena cava (vena cava pressure) via inserted catheters using a pressure transducer located outside the body of the patient before and after TIPS placement, and the values were collected in Table 1.

Magnetic Resonance Elastography

In vivo abdominal MRE was performed twice in each patient: 1 day before the intervention and 48 to 72 hours after the TIPS was implanted. The abdominal MRE setup is the same as described in the