Validity and Reliability of Magnetic Resonance Elastography for Staging Hepatic Fibrosis in Patients with Chronic Hepatitis B

Shintaro ICHIKAWA1, Utaroh MOTOSUGI1,4*, Hiroyuki MORISAKA1, Katsuhiro SANO1, Tomoaki ICHIKAWA1, Nobuyuki ENOMOTO2, Masanori MATSUDA3, Hideki FUJI3, and Hiroshi ONISHI1

1Department of Radiology, University of Yamanashi
1110 Shimokato, Chuoshi, Yamanashi 409–3898, Japan
2First Department of Internal Medicine, University of Yamanashi
3First Department of Surgery, University of Yamanashi
4Department of Radiology, University of Wisconsin, Madison, WI, USA

(Received December 18, 2014; Accepted January 28, 2015; published online May 19, 2015)

Purpose: We evaluated the validity and reliability of magnetic resonance elastography (MRE) for staging hepatic fibrosis in patients with chronic hepatitis B.

Methods: The study included 73 patients with chronic hepatitis B and confirmed stages of pathological fibrosis. Two radiologists measured liver stiffness using MRE in all cases. We compared the area under the receiver operating characteristic (ROC) curve (Az) for distinguishing stages of fibrosis compared with MRE liver stiffness measurements and serum fibrosis markers. We used intraclass correlation coefficients to analyze interobserver agreement for measurements of liver stiffness and 2 one-sided t-tests to test the equivalence of the measurements by the 2 observers.

Results: ROC analyses revealed the significantly superior discrimination abilities of MRE for liver fibrosis staging (Az = 0.945 to 0.978 [Observer 1] and 0.936 to 0.967 [Observer 2]) to those of serum fibrosis markers (0.491 to 0.742) for both observers (P < 0.0004). The intraclass correlation coefficient between the 2 observers was excellent (\( \rho = 0.971 \)), and the measurements of liver stiffness by the 2 observers were statistically equivalent within a 0.1-kPa difference (P = 0.0157)

Conclusion: MRE is a valid and reliable technique for discriminating the stage of hepatic fibrosis in patients with chronic hepatitis B.

Keywords: chronic hepatitis B, hepatic fibrosis, liver stiffness, magnetic resonance elastography, serum fibrosis marker

Introduction

Accurate staging of hepatic fibrosis is important in the management of chronic liver disease because the stage of fibrosis is closely related to prognosis and risk of hepatocarcinogenesis.1,2 The management of chronic hepatitis B (CHB) depends on the degree of fibrosis as well as preserved liver function and presence of hepatocellular carcinoma. Cirrhosis is believed to be irreversable, but increasing evidence indicates that mild fibrosis and cirrhosis in patients with CHB are reversible when properly treated.3,4

The staging of liver fibrosis commonly involves liver biopsy followed by histopathological assessment. However, biopsy can cause such complications as hemorrhage and infection, and its inherent drawbacks include sampling error, high interobserver variability, and low patient compliance.5–7 Consequently, noninvasive methods have been developed for assessing hepatic fibrosis that include the assessment of several proposed serum fibrosis markers, including the ratio of aspartate aminotransferase (AST) to alanine aminotransferase (ALT) (AAR),6 the AST-to-platelet ratio index (APRI),7

*Corresponding author. Phone: +81-55-273-1111, Fax: +81-55-273-6744, E-mail: umotosugi@uwhealth.org
the fibrosis-4 (FIB-4) index, and the fibrosis quotient (FibroQ). Magnetic resonance elastography (MRE), a modified phase-contrast technique developed to characterize the elasticity of tissues, is a new technique employed for staging noninvasive liver fibrosis. Recent studies have indicated MRE as a promising, highly reproducible tool with advanced diagnostic capacity for the noninvasive staging of hepatic fibrosis.

In general, different causes of liver disease produce dissimilar patterns of fibrosis that may affect the stiffness value. For example, pericellular fibrosis is a characteristic feature of alcoholic hepatitis, whereas perportal degeneration and fibrosis appear to be more prominent in chronic hepatitis C (CHC). It is believed that CHB has a tendency to involve more advanced focal necrosis and inflammatory cell infiltration than CHC. Unfortunately, the number of MRE studies is limited for groups with a single etiology, such as CHC, CHB, alcoholic hepatitis, nonalcoholic steatohepatitis (NASH), and Gaucher disease. Accordingly, it appears that more evidence would have to be collected using subjects with single-etiologic liver disease to establish the use of MRE in clinical settings.

One criticism raised for MRE is that inhomogeneity on a stiffness map might lead to varying measurements depending on the placement of the region of interest (ROI). To provide consistency in ROI measurements, a confidence map has been proposed that is based on the correlation coefficient of polynomial fits during application of an inversion algorithm. However, such a map might exclude the best area for ROI measurement because the algorithm is performed without knowledge of the anatomy. An alternative means to achieve consistent measurements is to follow predetermined rules using an MRE phase image as well as a stiffness map. On the MRE phase images, the presence of a parallel wave form without interference is a hallmark of well propagating elastic waves in the liver. Consequently, it would make sense to place ROIs on phase images in areas in which straight elastic waves are visualized. Although previous results indicated high repeatability of MRE, little is know about interobserver agreement according to the placement of ROIs.

Hence, we evaluated the accuracy and reliability of MRE for staging liver fibrosis in patients with chronic hepatitis B by comparing the diagnostic ability between MRE and serum fibrosis markers, and we secondarily assessed agreement between 2 observers.

Materials and Methods

Patients

This retrospective study was performed in accordance with the principles outlined in the Declaration of Helsinki, and was approved by the relevant institutional review board. Between January 2010 and May 2014, 1516 consecutive patients underwent MRE for liver investigations. Patients were included in the study with type B chronic hepatitis, available MRE data, histopathological determination (METAVIR scoring system) of hepatic fibrosis stage available within 6 months of MRE, and laboratory test results available within one week of MRE. We excluded 3 patients because the associated gradient echo-based MRE sequences did not provide a measurable stiffness map due to severe iron deposits, 3 patients with insufficient amounts of liver tissue from tissue biopsy to assess the stage of fibrosis, 3 patients with both CHC and CHB (n = 3), and one patient with both CHB and alcoholic hepatitis. After applying the inclusion criteria, we enrolled 73 patients (57 men, 16 women; aged 39 to 82 years, mean age 62.8 ± 9.6 years) in the study (Fig. 1).

Liver specimens were obtained by liver biopsy in...
30 patients and resection in 43. One of 3 pathologists with 12 to 18 years of experience who was blinded to the MRE results reviewed all specimens by evaluating hematoxylin and eosin staining and Masson trichrome staining to determine the stage of fibrosis using the META VIR scoring system. According to the scoring system, F0 indicated no fibrosis (n = 0); F1, portal fibrosis without septa (n = 13); F2, portal fibrosis with a few septa (n = 17); F3, numerous septa without cirrhosis (n = 16); and F4, cirrhosis (n = 27).

**Serum fibrosis markers**

The values for the serum fibrosis markers, AAR, APRI, FIB-4 index, and FibroQ, were calculated using the following formulas, where ULN denoted the upper limit of normal AST levels, PLT referred to the platelet count, and PT-INR signified the prothrombin time-international normalized ratio:

\[
AAR = \frac{AST[U/L]}{ALT[U/L]};\quad APRI = \frac{AST[U/L]/ULN}{PLT[10^9/L]} \times 100;
\]

\[
Fib-4\ index = \frac{age[years] \times AST[U/L]}{PLT[10^9/L] \times ALT^{1/2}[U/L]},\quad \text{and}
\]

\[
FibroQ = \frac{10 \times age[years] \times AST[U/L] \times PT-INR}{PLT[10^9/L] \times ALT[U/L]}.
\]

**Magnetic resonance elastography**

MRE was performed using either a 1.5-tesla (T) MR system with a superconducting magnet (Signa Excite HD MR 1.5T, GE Medical Systems, Waukesha, WI, USA) with an 8-channel phased-array coil (n = 57) or a 3T MR system (Discovery 750; GE Medical Systems) with a 32-channel phased-array coil (n = 16). Patients were placed in the supine position, and a cylindrical passive driver was attached to the right chest wall using a rubber belt. A pneumatic vibration was delivered through a plastic cylinder to the driver via a vibrator placed outside the imaging room. The driver then transferred the vibration to the liver via the chest wall.26 The scanning position began above the gallbladder and progressed to below the subphrenic region of the liver. Patients were instructed to hold their breath after expiration to maintain a consistent position during image acquisition at each phase offset.14

Table 1 summarizes the MR sequence parameters. The MR scanners automatically generated liver stiffness maps by processing the acquired propagating shear wave images according to a 2-dimensional (2D) inversion algorithm,27 and shear stiffness of the tissue was translated to a pixel value (kPa).28

On the basis of the stiffness maps, 2 radiologists (S.I., H.M.), each of them had 9 years experiences in abdominal radiology, who were blinded to the histopathological data placed a region of interest (ROI) in the right lobe of the liver of each patient. The latest versions of MRE systems automatically provide confidence maps that indicate areas that are inadequate for measurement as areas of cross-hatching on stiffness maps. However, we stuck with placing ROIs only with wave images and stiffness map for consistent measurement without using confidence maps. We placed ROIs of at least 1.5

---

**Table 1. Sequence parameters of MRE**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1.5T system</th>
<th>3T system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence</td>
<td>Two-dimensional gradient-echo</td>
<td>Two-dimensional gradient-echo</td>
</tr>
<tr>
<td></td>
<td>T1-weighted imaging</td>
<td>T1-weighted imaging</td>
</tr>
<tr>
<td>Plane</td>
<td>Transverse</td>
<td>Transverse</td>
</tr>
<tr>
<td>Repetition time (ms)</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Echo time (ms)</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Matrix</td>
<td>256 × 64</td>
<td>256 × 80</td>
</tr>
<tr>
<td>Field of view (cm)</td>
<td>36 × 27</td>
<td>35 × 35</td>
</tr>
<tr>
<td>Section thickness</td>
<td>10/5</td>
<td>10/5</td>
</tr>
<tr>
<td>Number of signals</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Flip angle (°)</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>Acquisition time (s)</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Frequency of driver (Hz)</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Amplitude (%)</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Axis of motion-sensitizing gradient pulse</td>
<td>z</td>
<td>z</td>
</tr>
</tbody>
</table>

MRE: magnetic resonance elastography
cm² to exclude blood vessels seen on a magnitude image of MRE and the edge of the liver and to include a parallel waveform without interference on the phase images (Fig. 3).

Statistical analysis

We calculated the mean and standard deviation of the serum fibrosis markers and of the liver stiffness values measured by Observers 1 and 2 for each stage of hepatic fibrosis. Spearman’s rank correlation was used to determine significant correlation of the variables with the stage of hepatic fibrosis. The correlation was deemed strong if the absolute value of the coefficient (|ρ|) exceeded 0.7, moderate if the value was greater than 0.4 and less than or equal to 0.7, minimal if the value was greater than 0.2 and less than or equal to 0.4, and not meaningful if the value was 0.2 or less. The discriminative capacities of the serum fibrosis markers and the MRE images were assessed using receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (Az value) and the optimal cutoff value were calculated to differentiate ≥ F2 from ≤ F1, ≥ F3 from ≤ F2, and F4 from ≤ F3. We used the jack knife method to compare the Az values of serum fibrosis markers and MRE measurements determined by each observer to discriminate the stage of fibrosis. We also used intraclass correlation coefficients (ICC) to assess interobserver agreement. Agreement was considered excellent with an ICC value (r) above 0.8, good with a value above 0.6 and less than or equal to 0.8, moderate with a value above 0.4 and less than or equal to 0.6, fair with a value above 0.2 and less than or equal to 0.4, and poor with a value of 0.2 or less.

We analyzed all statistics using JMP software (Ver. 10; SAS Institute, Cary, NC, USA) and employed 2 one-sided t-tests that assumed 0.1 kPa as a clinically acceptable difference between the observers to determine statistical equivalence between the results of the 2 observers. P values < 0.05 were considered statistically significant.

Results

Relationships between stage of fibrosis, liver stiffness, and serum fibrosis markers

Table 2 summarizes serum fibrosis marker and liver stiffness data. Mean liver stiffness values determined by MRE increased with the stage of fibrosis (Fig. 2a, b), and interobserver correlations were strong (Observer 1, ρ = 0.9029, P < 0.0001; Observer 2, ρ = 0.8855, P < 0.0001).

There was a moderate positive correlation between APRI and stage of fibrosis (ρ = 0.4051, P = 0.0004) but only minimal correlation between FibroQ and fibrosis stage (ρ = 0.2195, P = 0.0620) (Fig. 2c, f). No significant correlations were observed between Fib-4 index and stage of fibrosis (ρ = 0.1831, P = 0.1211; Fig. 2d) and AAR and stage of fibrosis (ρ = −0.0087, P = 0.9420; Fig. 2e). Figure 3 details the clinical cases.

Diagnostic values of serum fibrosis markers and MRE

The discrimination ability of MRE and serum fibrosis markers are shown in Table 3 (Observer 1) and Table 4 (Observer 2). According to ROC analysis, the MRE Az values determined by Observers 1 and 2 for the diagnosis of each stage of fibrosis were significantly higher than the fibrosis marker values. The cutoff values for Observer 1

<table>
<thead>
<tr>
<th>Table 2. Comparison between liver stiffness and serum fibrosis markers for each fibrosis stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>liver stiffness (kPa)</td>
</tr>
<tr>
<td>(observer 1)</td>
</tr>
<tr>
<td>liver stiffness (kPa)</td>
</tr>
<tr>
<td>(observer 2)</td>
</tr>
<tr>
<td>APRI</td>
</tr>
<tr>
<td>Fib-4 index</td>
</tr>
<tr>
<td>AAR</td>
</tr>
<tr>
<td>FibroQ</td>
</tr>
</tbody>
</table>

Statistical analysis was performed using the Spearman’s correlation analysis. Data are presented as mean ± standard deviation.

ρ means Spearman’s correlation coefficient.

APRI, aspartate aminotransferase (AST)-to-platelet ratio index; AAR, AST/alanine aminotransferase (ALT) ratio; FibroQ, fibrosis quotient.

* Liver stiffness and APRI increased as the liver fibrosis stage progressed (p < 0.05).
were ≥ F2, 3.0 kPa; ≥ F3, 3.4 kPa; and F4, 4.5 kPa. Those for Observer 2 were ≥ F2, 3.1 kPa; ≥ F3, 3.4 kPa; and F4, 4.0 kPa.

Interobserver agreement of MRE
The interobserver ICC was excellent for Observers 1 and 2 (0.971; 95% CI, 0.955 to 0.982). Figure 4 shows scatter plots generated to visualize correlations and Bland-Altman plots created to visualize the dispersion of liver stiffness measurements of the 2 observers. The average (95% CI) difference in liver stiffness between the observers was 0.0178 (−0.0568 to 0.0924). Liver stiffness measured by both observers was statistically equivalent within ±0.1 kPa, which suggested that the mean difference in measurements by the 2 observers was less than 0.1 kPa (P = 0.0157).

Discussion
Our results revealed the superior discriminative ability of MRE to serum fibrosis markers for determining the stage of hepatic fibrosis in patients with CHB, indicated high interobserver agreement for MRE-based measurements of liver stiffness measurements.

The results of the current study were in accord with findings of previous reports that showed the superiority of MRE with regard to discriminative ability for staging liver fibrosis compared to serum fibrosis markers. It has been reported that assessments of serum fibrosis markers are simple and rel-
Fig. 3. Magnetic resonance elastography (MRE) images of 2 patients, (a–c) a 62-year-old man with mild fibrosis (F1) and (d–f) a 58-year-old man with cirrhosis (F4). (a & d) Phase images; (b & e) portions of the elastogram that correspond with theLiver superimposed on conventional MR images; (c & f) magnitude images. A region of interest (ROI) was placed in the right lobe of the liver (circle) based on the criteria that the ROI was at least 1.5 cm², excluded blood vessels seen on the magnitude image of MRE, excluded the edge of the liver, and included a parallel wave form without interference on the phase images. The mean liver stiffness values increased with the progression of the stage of fibrosis.

Table 3. Comparison between MRE measured by observer 1 and serum fibrosis markers

<table>
<thead>
<tr>
<th>Variable</th>
<th>MRE (observer 1)</th>
<th>APRI</th>
<th>Fib-4 index</th>
<th>AAR</th>
<th>FibroQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 vs F2–4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Az value (95%CI)</td>
<td>0.945 (0.862–0.979)</td>
<td>0.668 (0.505–0.799)</td>
<td>0.523 (0.345–0.695)</td>
<td>0.583 (0.383–0.760)</td>
<td>0.496 (0.318–0.676)</td>
</tr>
<tr>
<td>P value (vs MRE)</td>
<td>—</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>F1–2 vs F3–4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Az value (95%CI)</td>
<td>0.974 (0.928–0.991)</td>
<td>0.697 (0.562–0.991)</td>
<td>0.595 (0.459–0.719)</td>
<td>0.491 (0.355–0.629)</td>
<td>0.632 (0.494–0.751)</td>
</tr>
<tr>
<td>P value (vs MRE)</td>
<td>—</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>F1–3 vs F4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Az value (95%CI)</td>
<td>0.978 (0.927–0.994)</td>
<td>0.742 (0.602–0.845)</td>
<td>0.647 (0.511–0.764)</td>
<td>0.519 (0.383–0.653)</td>
<td>0.649 (0.512–0.765)</td>
</tr>
<tr>
<td>P value (vs MRE)</td>
<td>—</td>
<td>0.0003</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

PPV, positive predictive value; NPV, negative predictive value.
APRI, aspartate aminotransferase (AST)-to-platelet ratio index; AAR, AST alanine aminotransferase (ALT) ratio; FibroQ, fibrosis quotient.
Az values are shown with 95% confidence interval.
Az values of MRE and serum fibrosis markers for discriminating the fibrosis stages were compared using jackknife method.

Magnetic Resonance in Medical Sciences
atively reliable methods for estimating stage of fibrosis. Conversely, serum markers are associated with limited discriminative ability for staging liver fibrosis. Further, their validity decreases when patients have no underlying liver disease or when serum AST levels are normal.

Previous systemic reviews of the performance of serum fibrosis markers revealed that the median Az values for discriminating stages of liver fibrosis ranged from 0.73 to 0.88 for ≥ F2 and from 0.73 to 0.94 for discriminating F4. However, in the current and previous reports, the capacity to discriminate stages of liver fibrosis was consistently higher for MRE than fibrosis markers.

Our cut-off values in subjects were in accord with those reported by Venkatesh and associates but lower than the values reported by Shi’s group, even though both studies involved CHB patients. Hepatitis activity may be a confounder of liver stiffness measurement during liver fibrosis staging using MRE. However, the higher stiffness values observed by Shin and colleagues than ours even
among patients with mild hepatitis suggest that the discrepancy cannot be explained by inflammation alone. We might have to consider other confounding factors, including differences in MR unit/coil or parameters. We observed mean liver stiffness values that were relatively lower (by a margin of 0.2 to 0.8 kPa) than those of other studies conducted in patients with CHC,\textsuperscript{13} and the current mean values were also lower for each stage of fibrosis than those in prior studies involving multiple etiologies.\textsuperscript{38,39} Besides the technical aspects of MRE, the differences might be related to multiple factors, including pattern of pathological fibrosis (micronodular versus macronodular cirrhosis), variation in pathological assessment, and difference in the patient population.\textsuperscript{40,41} Consistency in measurement is critically important for quantitative assessments including MRE.\textsuperscript{10,12,42} Hines’s group revealed only a minor effect of interobserver variability on overall variability of measurements using a linear mixed effect model in which the component sources of variability included day-to-day physiological changes in the subject and examinations were replicated on the same subject on the same day.\textsuperscript{11} In addition, Shin’s group recently reported a very low interobserver difference in stiffness measurements (\(\sim 0.005\) kPa) in healthy subjects.\textsuperscript{43} Although we observed statistically equivalent liver stiffness measurements by the 2 observers (within a difference of 0.1 kPa), the mean of the difference (0.0178 kPa) was relatively higher than values reported by Shin. Our lower interobserver agreement might be attributable to variations in measurements resulting from the heterogeneous fibrosis patterns detected in the liver. However, the difference we observed in interobserver agreement might be acceptable because the value was smaller than the difference between the results of short term (a week, \(\sim 0.05\) kPa) or mid-term (a half year, \(\sim 0.05\) kPa) repetitions of MRE in healthy subjects.\textsuperscript{43}

In addition to MRE, several other MR imaging methods have been proposed for staging hepatic fibrosis, including diffusion-weighted imaging, intravoxel incoherent motion, and an uptake index in gadoxetic acid-enhanced hepatocyte-phase imaging.\textsuperscript{44–47} The alternative methods employ such parameters as molecular diffusivity, tissue microperfusion, or hepatocyte function to assess hepatic fibrosis. Although results using these methods correlate well with the stage of fibrosis, comparative studies have suggested the inferior diagnostic capabilities of these methods to the use of serum markers or MRE.\textsuperscript{55,46,48,49} Ultrasound-based elastography, another method used to measure liver stiffness, includes transient elastography (FibroScan\textsuperscript{®}, Echosens\textsuperscript{TM}, Paris, France),\textsuperscript{50} real-time strain elastography (RTE),\textsuperscript{51} acoustic radiation force impulse (ARFI),\textsuperscript{52} and real-time shear wave elastography (SWE).\textsuperscript{53} In previous studies, ultrasound-based elastography performed well in predicting hepatic fibrosis.\textsuperscript{54–66} However, only a limited number of clinical studies have compared the discriminative abilities of MRE and ultrasound-based elastography for staging hepatic fibrosis.\textsuperscript{58–60,66} Two of those revealed the superior ability of MRE to Fibroscan\textsuperscript{®} for distinguishing stages of hepatic fibrosis,\textsuperscript{58,60} and the others revealed the similar diagnostic performance of MRE, Fibroscan\textsuperscript{®}, and SWE for staging hepatic fibrosis.\textsuperscript{59,60} Consequently, it might be concluded that the discriminative ability of MRE for staging hepatic fibrosis is equivalent or superior to that of ultrasound-based elastography. However, no clinical guideline is available for these new techniques for noninvasive assessment of liver fibrosis. Further, a prospective validation study that combines these methods would offer comfortable and low risk management of liver disease.\textsuperscript{67,68}

The current study had some limitations. First, we included no F0 case because of the minimal clinical requirement for performing a biopsy to evaluate fibrosis during early stages of liver disease. Second, we did not analyze necroinflammation (A grade in the METAVIR scoring system); some studies have shown that the grade of hepatitis activity independently affected MRE measurements of liver stiffness. Further, we did not subdivide cases by grade because our patient population was moderate in size. Third, only one histopathological assessment was used to diagnose the stage of fibrosis following either liver biopsy or resection. In addition, subjects underwent scanning on 2 different MR scanners, though the difference in main magnetic field strength or differences in coil channels should not theoretically affect the MRE stiffness measurement.\textsuperscript{59} Neither should MR parameter settings, including repetition time (TR) and echo time (TE), affect the measurement results. However, a recent study suggested that slightly different stiffness values may be obtained using different parameter settings.\textsuperscript{70} Therefore, it would be necessary to show the reproducibility of the MRE results using various field strengths and scanners from different manufacturers to validate the accuracy and reproducibility of MRE.

**Conclusion**

In conclusion, MRE proved to be a reliable tech-
nique for discriminating the stage of hepatic fibrosis in patients with CHB.

Acknowledgements

We thank Richard Ehman and Scott Kruse from Mayo Clinic for providing MRE equipment and Tetsuya Wakayama from GE Healthcare for technical support.

References


