Cardiac Magnetic Resonance Elastography

Toward the Diagnosis of Abnormal Myocardial Relaxation

Thomas Elgeti, MD, Mark Beling, MD,† Bernd Hamm, MD,* Jürgen Braun, PhD,‡ and Ingolf Sack, PhD**

Aim: To assess the potential of cardiac magnetic resonance elastography (MRE) for elasticity-based detection of abnormal left ventricular (LV) relaxation.

Materials and Methods: Cardiac MRE was performed in 3 groups: young volunteers (n = 11; mean age, 31.7 years), older volunteers (n = 5; mean age, 54.8 years), and a group with relaxation abnormalities (n = 11; mean age, 58 years) identified by transthoracic echocardiography. Cine MR imaging served to measure LV volumes and global LV systolic function. Wave-amplitude-sensitive electrocardiograph-gated steady-state MRE was performed using an extended piston driver attached to the anterior chest wall. Phase contrast shear wave images were acquired in all 3 Cartesian components and combined to generate amplitude maps. This was done using the time-gradient operator for linear high-pass filtering and phase unwrapping followed by temporal Fourier transformation for extracting externally induced 24.13-Hz shear oscillations from intrinsic motion and blood flow. Amplitudes were evaluated in the left ventricle and normalized by wave amplitudes outside the heart, adjacent to the right ventricle.

Results: One patient and 1 young volunteer had to be excluded from final analysis because of considerable body movement during the acquisition of the MRE scans. Mean wave amplitudes in the remaining subjects were 0.22 ± 0.05 mm in young volunteers, 0.23 ± 0.09 in older volunteers, and 0.14 ± 0.03 mm in patients. The mean ratio of amplitudes inside the ventricle to the anterior chest wall was 0.62 ± 0.15 for young volunteers, 0.50 ± 0.09 for older volunteers, and 0.33 ± 0.08 for patients.

Conclusion: MRE identifies significantly reduced LV shear wave amplitudes in patients with mild relaxation abnormality. Thus, cardiac MRE provides a promising modality for an elasticity-based diagnosis of dysfunctional myocardial relaxation.

Key Words: cardiac MR elastography, relaxation abnormalities, diastolic dysfunction

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Heart failure is associated with a significant morbidity, mortality, and financial burden to the health services.[1] About 50% of cases of cardiac failure mainly involve the diastolic part of the cardiac cycle.[2] In clinical routine, diastolic function is assessed using transthoracic echocardiography.[3] Patients with diastolic dysfunction have increased myocardial stiffness, which is suggested by theoretical considerations and confirmed by observations in vivo and in vitro.[4,5] Careful and definite diagnosis of diastolic dysfunction requires the measurement of pressure time curves[6] because routine assessment of diastolic filling by measurement of mitral flow can miss about 30% of the patients with diastolic dysfunction.[3] A more practical approach is to determine tissue Doppler-derived indices, which are less prone to errors.[7] Nevertheless, echocardiography can be challenging in obese patients or patients with a poor acoustic window.[8] All current noninvasive imaging techniques may provide images with excellent spatial and temporal resolution but provide no direct measure of intramyocardial forces determined by the alteration of the heart's shear modulus. Cardiac magnetic resonance elastography (MRE) is a relatively new method to measure the time-varying cardiac shear modulus, a measure of cardiac stiffness, by application of low-frequency acoustic waves. Until now, this method has only been performed in animals and healthy volunteers.[9–11]

The aim of the current study was to investigate the technical feasibility of cardiac MRE in patients with mild diastolic dysfunction diagnosed by transthoracic echocardiography and tissue Doppler-derived indices and compare the findings with those in a group of healthy volunteers.

We hypothesized that myocardial shear wave amplitude, a measure for the elastic shear modulus,[11] is lower in patients with diastolic dysfunction than in normal volunteers.

MATERIALS AND METHODS

Subjects

The study was approved by the local ethics committee (EA 1/055/07–4), and written informed consent was obtained from all subjects. A total of 11 patients with echocardiographically proven relaxation abnormalities (the criteria for diastolic dysfunction are defined in the following sections) were examined by standard cardiac magnetic resonance imaging (MRI) using a cine steady-state free precession sequence and cardiac MRE. Echocardiography, MRI, and MRE were also used in 16 controls (11 young and 5 older ones) with normal values for systolic and diastolic function and without a history of cardiac dysfunction.

Echocardiography

Transthoracic echocardiography was performed using standard methodology according to the recommendations of the American Society of Echocardiography (using Vivid 7 ultrasound system with an M3S transducer [1.5–4.0 MHz], GE Vingmed, Horton, Norway). The following echo variables were measured or derived: left ventricular (LV) dimensions, volumes, ejection fraction, left atrial dimensions, peak transmitral valve (MV) early diastolic (E) velocity, the average of septal and lateral myocardial annular tissue velocity (E'), the E/E' ratio, and the MV E/A ratio, where A is peak late diastolic transmitral velocity. Peak early and late diastolic transmitral velocities were measured using the pulsed Doppler technique, with the sample volume placed at level of the mitral leaflet tips during diastole in the apical 4-chamber view. The septal and lateral myocardial annular tissue velocities were recorded with the pulsed Doppler sample volumes positioned within 1 cm of the septal and lateral insertion sites of the mitral leaflets. Diastolic function was classified according to the criteria proposed by Nagueh

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From the Departments of *Radiology and †Cardiology, Angiology, and Pulmonology, Charité–Universitätsmedizin Berlin, Campus Mitte, Berlin, Germany; and ‡Institute of Medical Informatics, Charité–Universitätsmedizin Berlin, Campus Benjamin Franklin, Berlin, Germany.
Thomas Elgeti and Mark Beling contributed equally to this manuscript.
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Reprints: Thomas Elgeti, MD, Department of Radiology, Charité–Universitätsmedizin Berlin, Campus Mitte, Charitéplatz 1, 10117 Berlin, Germany. E-mail: thomas.elgeti@charite.de.

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