Assessment of diastolic dysfunction in hypertensive patients using full-cycle cine DENSE
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Target audience: Clinicians and scientists working on assessment of diastolic dysfunction or patients with hypertension.

Introduction: Heart failure with preserved ejection fraction (HF-PeF) resulting primarily from diastolic dysfunction accounts for more than half of all heart failure cases¹. Diastolic dysfunction is independently associated with increased cardiovascular morbidity and mortality². Echocardiographic techniques such as transmitral inflow and tissue Doppler imaging are commonly used to assess diastolic function; however, limited acoustic windows, operator dependence, and the angular dependence of Doppler can limit the accuracy of these techniques. Speckle tracking techniques have been used to assess diastolic strain but robust application of this technique requires high image quality which may not be routinely obtainable in a clinical setting. Strain and strain rate measurement using MRI may be preferable to existing techniques, since they do not have these limitations. Cine Displacement Encoding with Stimulated Echoes (DENSE) has been used to measure systolic displacement, strain³, and strain rate⁴. We previously developed a full-cycle cine DENSE sequence⁵ to image the entire cardiac cycle with sufficient signal-to-noise ratio (SNR) to compute accurate systolic and diastolic displacements, strains, and strain rates. Diastolic dysfunction is known to be present in half of patients with hypertension⁶. In the present study we assess diastolic function in hypertensive patients using the full-cycle cine DENSE sequence by comparing results with healthy volunteers.

Methods: A spiral cine DENSE sequence³ was modified to continually acquire data until the next ECG R wave was detected (fig. 1). Full-cycle DENSE (fig. 1) was designed to detect the ECG R wave, even during the readout period, allowing data to be collected throughout the cardiac cycle. A ramped flip angle, which compensates for the cumulative effect of radio frequency pulses and myocardial T1 decay of the stimulated echo, was used to achieve a more uniform SNR throughout the cardiac cycle. We acquired data in six hypertensive patients and seven healthy volunteers as controls entire cardiac cycle with sufficient SNR.

Using full-cycle cine DENSE. All studies were performed using a 1.5T scanner (Avanto, Siemens, Germany) in accordance with protocols approved by our institutional review board. A single mid-ventricular short-axis section of the left ventricle was acquired. Specific imaging parameters included: field of view = 300-350 mm, matrix = 128 x 128 pixels, slice thickness = 8mm, variable flip angle with last flip angle=14-16⁶, TR = 17 ms, TE = 1.08 ms, and number of spiral interleaves = 6. View sharing was used to achieve an effective temporal resolution of 17 ms, and a two point displacement encoding strategy was used with displacement encoding frequency = 0.1 cycles/mm. Through-plane dephasing (frequency = 0.08 cycles/mm) and 2-point RF phase cycling were used for artifact suppression. Lagrangian displacement and strain were computed offline as described previously⁷. Peak systolic circumferential strain rate (SRₚ), early diastolic strain rate (SRₑ) and atrial systolic strain rate (SRₐ) were computed for each study and were compared between hypertensive subjects and normal controls.

Results: Figure 2 shows example circumferential strain (fig. 2A) and strain rate (fig. 2B) time curves from a hypertensive patient and a healthy volunteer. All phases of diastole can be distinguished from the strain-time curves, including early filling, diastasis and atrial systole. Figure 3 shows a comparison of SRₛ, SRₑ and SRₐ between hypertensive patients and healthy volunteers. The SRₑ was significantly lower in patients compared to volunteers (p<0.01), implying impaired early diastolic relaxation. The SRₐ was significantly higher in patients compared to volunteers (p<0.01), implying an increased filling rate during atrial systole. The SRₐ values were similar in patients and healthy volunteers (p=NS), implying preserved systolic function in these hypertensive subjects. The echocardiography results (transmitral inflow and tissue Doppler imaging) showed that all the patients possessed diastolic dysfunction based on ASE guidelines⁸, which is in agreement with our CMR findings.

Conclusions: Full-cycle cine DENSE detects diastolic dysfunction in hypertensive patients. It enables measurement of strain and strain rate during the entire cardiac cycle, allowing a more comprehensive quantitative assessment of both systolic and diastolic function.


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