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EDITORIAL

The Stiffer, the Faster: Echocardiographic Evaluation of Myocardial Properties

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High-frame-rate echocardiography is a novel development in diagnostic ultrasound that allows for the evaluation of myocardial stiffness. By measuring the velocity of mechanical waves in the myocardium triggered by cardiac events like valve closure or atrial contraction, myocardial stiffness can be assessed. According to physical laws, assuming other factors remain constant, faster wave propagation indicates a stiffer material. Whereas clinical 2-dimensional echocardiography typically operates at 50 to 100 frames per second (FPS), the assessment of myocardial wave velocities requires at least 800 to 1000 FPS. These wave velocities correlate with various myocardial stiffness parameters.[1,2]

See Article by Benz et al

In this issue of the Journal, Benz et al[3] using tissue Doppler-based echocardiography at 250 FPS, demonstrate that patients with cardiac amyloidosis have higher intrinsic velocity propagation (iVP, previously described as atrial kick wave velocity) compared with both patients with nonadvanced hypertrophic cardiomyopathy (HCM) and healthy subjects. Moreover, patients with advanced cardiac amyloidosis exhibit higher iVP than those in earlier disease stages. Furthermore, they examined 38 patients from 2 cohorts (cardiac amyloidosis and HCM) and 16 healthy subjects. The results confirmed the high feasibility of acquisition and analysis of the iVP, as found by others.[4] The study supports that iVP is a clinically useful parameter for differentiating patients with advanced cardiac amyloidosis from healthy subjects.[5] Importantly, the strong correlation between iVP, as a marker of myocardial stiffness, and conventional measures of interstitial expansion and systolic and diastolic function by cardiac magnetic resonance imaging (MRI) and echocardiography, respectively, is confirmed.[5]

Other similar noninvasive methods have also been used to assess myocardial stiffness. Recently, Meyer et al[6] applied external mechanical vibration to the chest wall to initiate a diastolic shear wave. They found higher wave velocities in patients with wild-type transthyretin amyloidosis as compared with healthy subjects and patients with left ventricular hypertrophy of other etiologies. During follow-up, they reported a reduction in shear wave velocity in the septal and posterior left ventricular wall among patients treated with tafamidis, a drug that reduces amyloid fibril formation.[7] Meyer et al's[6] study emphasizes how noninvasive assessment of myocardial stiffness may be applied for treatment monitoring.

Thus, iVP has the potential to be useful when used in patients with cardiac amyloidosis for the following reasons: (1) As a diagnostic tool, integrating iVP with relevant parameters from multimodality cardiac imaging[8,9]; (2) For disease staging, as iVP increases with disease progression; and (3) For treatment monitoring, particularly interesting with new emerging drugs that have the potential to reduce amyloid deposits and extracellular volume.[7,10] However, iVP is probably not suitable for screening, as it is not increased in mild disease.

Previous studies have shown that cardiac amyloidosis in particular increases mechanical wave velocities,

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exhibiting the highest reported iVP (atrial kick wave velocity).[5,11] The extracellular volume by cardiac MRI is linked to the fraction of noncontractile tissue and is significantly higher in patients with cardiac amyloidosis as compared with those with HCM. In HCM, iVP values by echocardiography are closer to those of healthy subjects, but with greater dispersion. Some patients with HCM exhibit higher myocardial wave velocities, typically having thicker septal walls and a higher amount of fibrosis.[12] Focal fibrosis is expected to be less prevalent in patients with less hypertrophy. It appears that iVP increases when myocardial fibrosis surpasses a certain threshold or when load conditions change significantly. This threshold varies between individuals. Diseases with minor changes in load or myocardial structure may not show a significant iVP increase at the group level; however, individual variations may occur in more advanced cases. We have previously summarized the minimal differences observed in iVP between healthy subjects and various diseases, such as severe mitral regurgitation, HCM, myocardial infarction, and severe aortic stenosis.[4] Moreover, myocardial wave velocities produced by valve closure events seem to be more sensitive for the detection of early-phase pathology, possibly due to the higher velocity of these waves as compared with atrial contraction waves.[4]

Despite methodological differences and the small number of healthy subjects included in the study by Benz et al[4] it is reassuring that the iVP values align with those reported previously. The more homogenous iVP found in healthy subjects and early HCM, as compared with the highly heterogeneous values in cardiac amyloidosis, underscores that patients with more severe pathology have a higher variability in mechanical wave velocity than healthy subjects.[3,4] The greater heterogeneity and higher wave velocities in patients with severe myocardial disease are probably due to advanced alterations in myocardial material properties and load, both of which have been demonstrated to influence the mechanical wave velocities.[13]

Interestingly, iVP is associated with both measures of load changes (NT-proBNP [N-terminal pro-B-type natriuretic peptide], E/e′ [relation between early diastolic transmitral velocity and peak early diastolic annular plane velocity], and systolic pressure in the pulmonary artery) by echocardiography, as well as structural myocardial changes, including left ventricular mass and extracellular volume from cardiac MRI and amyloid burden from nuclear medical imaging. Furthermore, iVP excels in predicting extracellular volume and amyloid burden compared with conventional echocardiographic measures of systolic function and filling pressures.[3] These findings underscore the potential of estimating myocardial stiffness by echocardiography, which allows for the assessment of not only extracellular changes or amyloid fibril quantity but also provides insight into how the heart adapts to these changes.

The frame rates reported in the Benz study are low, although sufficient to demonstrate a meaningful difference between populations, concordant with previous reports.[5] The highest wave velocity for a cardiac amyloidosis patient was reportedly close to 8 m/s. With 250 FPS, the wave would propagate >3 cm/frame, meaning that in the septum, only 2 observations of the wave will be available if the examined septal wall is <6 cm. If iVP exceeds 3 to 4 m/s, the wave velocity is likely to be high, but precise velocity estimates are difficult to obtain. Thus, the current consensus is that frame rates should exceed 800 to 1000 FPS for this type of investigation.[1,2]

Furthermore, the tissue velocity-curved anatomic M-mode map can occasionally be noisy. This may be overcome by using timing based on pulsed-wave Doppler or ECG to ensure that the desired event is accurately captured (Figure). Moreover, since the velocity slopes are prone to noise and gain adjustments,[4] the quality of the iVP measurement should be reported. Unfortunately, there is no consensus on whether the wave front, mid, or end should be measured. However, since all cases in the Benz study were evaluated using the same approach, this should not affect the main results.

Evaluation of mechanical wave velocities, specifically iVP, can potentially be applied in 2 key clinical scenarios for heart failure. First, if load is expected to be constant, changes in iVP indicate changing myocardial properties, adding value in the management of valvular heart disease, cardiomyopathies, or cardio-oncology and other serial follow-up. Second, during a hospital stay, changes in iVP can evaluate load changes and inform treatment strategy, If myocardial properties are assumed to be constant (eg, not in acute myocardial infarction or myocarditis). The future of mechanical wave imaging, including iVP estimation, appears promising. Prospective trials are, however, needed to determine the added clinical value of

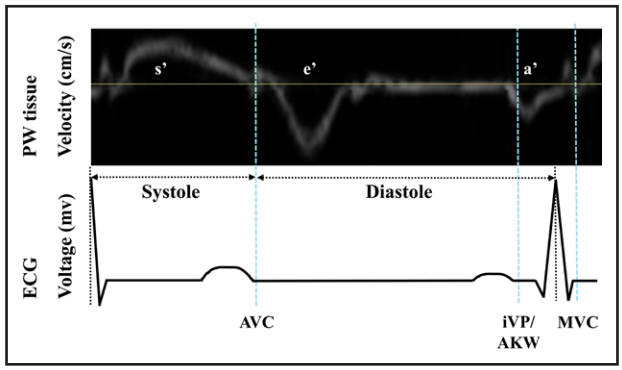

Figure. One cardiac cycle is depicted from 1 QRS peak to the next.

The pulsed-wave (PW) tissue Doppler and the ECG is used to time the initiating natural event. Systolic shortening (s′) and early (e′) and late (a′) diastolic lengthening of the left ventricle are indicated in the figure. AKW indicates atrial kick wave; AVC, aortic valve closure; iVP, intrinsic velocity propagation of myocardial stretch; and MVC, mitral valve closure.

this technique across various patient categories, including cardiac amyloidosis and HCM.[8,9,14] However, it is likely that cardiac MRI and nuclear medicine will continue to play a crucial role in managing these patients.

ARTICLE INFORMATION

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Disclosures

None.

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