The Growth and Growth of Cardiac Ultrasound for the Evaluation of Myocardial Function

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Over 50 years ago, the initial ultrasound pictures of the heart identified structural changes in the mitral valve and pericardium. Very rapidly, however, it became apparent that echocardiography had much to offer than just the evaluation of cardiac anatomy or pathology (1). The subsequent development of blood flow Doppler permitted detailed evaluation of cardiac valves, hemodynamics, and diastolic function. These advances have changed the face of cardiology, with investigations that were performed by invasive catheterization only 2 decades ago now being routinely and almost exclusively investigated by Doppler echocardiography.

This issue of *JACC* highlights 2 important papers regarding the use of cardiac ultrasound to investigate cardiac function. The development of tissue Doppler and more recently speckle tracking to interrogate myocardial function represents a series of advances that have followed the initial achievements in assessment of gross anatomy and pathology and blood flow (Table 1). The initial forays into myocardial imaging with ultrasound, now 15 years old, initially led to the rediscovery and quantification of the longitudinal function of the left ventricle (2). Measurement of myocardial e’ velocity is not only a robust technique for the identification of subclinical left ventricular (LV) dysfunction, but in combination with the transmitral E velocity, is a marker of the ventricular filling pressure (3). The therapeutic implications of this finding are obvious, and in combination with the prognostic findings, this simple measurement has an established role in mainstream cardiology with a central role in the assessment of diastolic heart failure (4). The related ability to quantify longitudinal systolic function of both ventricles has not only offered a simple means of measuring right ventricular function (which is otherwise hard to quantify) but has also shed light upon the subclinical impairment of systolic function in patients with heart failure and preserved ejection fraction (5). The next step in the evolution of these parameters was to measure not only the magnitude of contraction, but also its synchrony. However, the variations of timing measurements led to some prominent negative studies, and constitute the only disappointments in an otherwise satisfactory series of applications of these myocardial imaging techniques (6,7).

The understanding of myocardial behavior has been advanced by the evolution of deformation measurements—initially from tissue velocity (8) and more recently from grayscale imaging (9). This provided the ability to not only quantify longitudinal myocardial function, but to do this on a site-specific basis and allow interrogation of individual myocardial segments. In turn, this led to applications for the assessment of myocardial viability as well as the stress response (10). The technique has been used for tissue characterization, e.g., in infiltrative cardiomyopathies (11) and early myocardial disease due to metabolic disturbances (12). In these situations, the detection of subclinical disease may permit the appropriate selection of apparently healthy subjects for initiation of therapy to prevent disease progression, while sequential measurement may identify treatment response and guide therapy. Potentially, these steps could open up opportunities to better understand stage A and B heart failure (13). The development of speckle-tracking techniques has not only simplified the tissue velocity assessment...
of deformation, improving feasibility and decreasing noise, but also permitted the assessment of radial and circumferential function in the short axis, which could not be performed comprehensively using tissue Doppler because of the angle-dependence of the latter technique (14).

The speckle-tracking applications related to the assessment of myocardial mechanics published in this issue of *JACC* represent the most recent evolution of these myocardial imaging techniques. The paper by Burns et al. (15) confirms that the association of LV untwist with LV suction (the initial component of LV filling) in humans is analogous to that demonstrated in animals (16). This is an important finding as much of the previous work on echocardiographic assessment of diastolic dysfunction examined LV compliance more than relaxation and early filling. Whether the echocardiographic measurement of LV untwist turns into a clinical tool remains to be seen. Unlike the assessment of LV torsion, which was limited by problems in discerning torsion length, apical twist can be measured in a single dimension. However, the current temporal resolution of 2-dimensional strain measurement is insufficient to confidently measure the rate of untwist (note the association of untwist rather than untwist rate with suction in the paper of Burns et al. [15]).

The second, and perhaps more important, observation concerns the evaluation of the time course of myocardial contraction and relaxation in the different myocardial layers (17). The transmyocardial distribution of contractility has already been demonstrated as useful for delineating the transmural extent of scar (18). This work extends these previous observations, to the extent that the reliable assessment of subendocardial ischemia and scar appears feasible.

Ultrasound imaging of the myocardium offers high temporal resolution, as well as excellent spatial resolution, especially in the axis of the ultrasound beam. Three-dimensional approaches are currently at an early phase but will surely progress. This combination of high temporal and spatial resolution contrasts with the attributes of other imaging modalities, and is potentially a competitive benefit of ultrasound for the assessment of myocardial function. The future clinical applications of these sophisticated analyses will include diagnosis, as well as the selection and monitoring of treatment. These applications will require steps to enhance reproducibility, particularly controlling test–retest variability. The applications of these ultrasound tools in the assessment of cardiac function will remain an exciting frontier in the development of cardiac ultrasound in years to come.

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**REFERENCES**


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**Table 1. Applications and Significance of Myocardial Imaging**

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<thead>
<tr>
<th>Application</th>
<th>Significance</th>
<th>Relevance</th>
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<tr>
<td>e' and s'</td>
<td>Disturbance of longitudinal function</td>
<td>Prognosis, therapeutic guidance, RV function</td>
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<tr>
<td>E/e'</td>
<td>Filling pressure</td>
<td>Prognosis, therapeutic guidance</td>
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<td>Synchrony</td>
<td>Mechanical dysynchrony</td>
<td>?substrate of CRT response, prognosis</td>
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<tr>
<td>Strain, SR</td>
<td>Systolic deformation</td>
<td>Regional quantitation, subclinical disease</td>
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<tr>
<td>Torsion</td>
<td>Myocardial mechanics</td>
<td>Mechanistic lessons, ?applications</td>
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CRT = cardiac resynchronization therapy; RV = right ventricular; SR = strain rate.