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Real-Time 3-Dimensional Echocardiographic Assessment of Left Ventricular Dyssynchrony

Pitfalls in Patients With Dilated Cardiomyopathy

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OBJECTIVES This study sought to establish normal values for real-time 3-dimensional echocardiography (RT3DE)–derived left ventricular (LV) dyssynchrony index (LVDI) and determine its age dependency, and to compare dyssynchrony in patients with normal LV function and patients with dilated cardiomyopathy (DCM), with and without left bundle branch block (LBBB).

BACKGROUND Cardiac resynchronization therapy is known to be ineffective in one-third of patients with heart failure, highlighting the need for alternative techniques to assess LV dyssynchrony.

METHODS Datasets from RT3DE were analyzed to calculate LVDI using 16- and 17-segment models. First, 135 normal subjects were studied to establish LVDI abnormality threshold (mean + 2 SD) and to study the relationship with age. Then, 3 groups of patients (N = 16 each: DCM with and without LBBB, normal LV function with LBBB) were compared with 50 age-matched normal control subjects.

RESULTS In normal subjects, the 16-segment model resulted in a lower LVDI abnormality threshold than the 17-segment model (4.0% vs. 4.5%). In patients with normal LV function, LVDI was significantly lower than in those with DCM, irrespective of LBBB. Although LBBB resulted in a nearly 2-fold increase in LVDI in patients with normal LV function, its effects were nonsignificant in DCM. All patients with DCM and ejection fraction <35% had abnormally high LVDI, likely as a result of low signal-to-noise ratio in low-amplitude regional volume curves hampering accurate determination of regional ejection time.

CONCLUSIONS Normal values established in this study resulted in indiscriminate diagnosis of abnormal dyssynchrony in all patients with reduced LV function. The value of RT3DE-derived LVDI in the evaluation of dyssynchrony in patients with reduced LV function needs to be critically reassessed because of the inability to accurately detect end-ejection in low-amplitude regional volume curves. Alternative indices of dyssynchrony need to be developed to address this limitation. (J Am Coll Cardiol Img 2009;2:802–12) © 2009 by the American College of Cardiology Foundation

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Although cardiac resynchronization therapy (CRT) is known to benefit most patients with heart failure (HF), the inability to show a positive response in up to one-third of the patients in whom CRT is indicated has highlighted the need for redefining the selection criteria for CRT (1) and triggered a search for alternative approaches. Currently, a prolonged QRS complex on 12-lead electrocardiogram (ECG) is a prerequisite to select patients for CRT, in addition to left ventricular (LV) ejection fraction (LVEF) under 35% and severe HF (New York Heart Association functional class III/IV) (2–5). However, several recent studies have shown that QRS width is a poor predictor of response to CRT (6–10). Importantly, because LV dyssynchrony was shown to be a predictor of severe cardiac events, independent of QRS width and LVEF (7), the search for alternative echocardiographic methods to evaluate mechanical LV dyssynchrony has gained increasing attention.

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Tissue Doppler imaging (TDI) assessment of LV dyssynchrony is considered the standard technique for selection of patients for CRT. Despite its excellent temporal resolution, this technique has several limitations, including the inability to assess multiple myocardial segments simultaneously, angle dependency that limits the evaluation of the timing of motion in the longitudinal direction only, and the inability to reliably quantify apical wall motion. In addition, no single echocardiographic measure of dyssynchrony is currently recommended to improve patient selection for CRT beyond current guidelines (11,12).

Real-time 3-dimensional echocardiography (RT3DE) is a simple and reproducible method for measuring LV dyssynchrony (6), free of the above limitations of TDI. This technique is capable of capturing the 3D dynamics of the entire LV, including the timing of wall motion, independent of its direction. Accordingly, it has been postulated that this technique may prove useful in the selection of patients for CRT. However, because a certain level of dyssynchrony is present even in normal ventricles, the RT3DE diagnosis of abnormally increased dyssynchrony in individual patients relies on the availability of normal values for quantitative indexes of dyssynchrony, which have yet to be established. Moreover, an important question in this regard is whether LV dyssynchrony is age dependent and whether its normal range needs to be age adjusted for individual patients.

Although it has been shown that RT3DE-derived LV dyssynchrony is inversely related to ejection fraction (EF), it is not known whether RT3DE-derived measures of LV dyssynchrony are sufficiently sensitive to quantify the impact of left bundle branch block (LBBB) or whether the effects of LBBB on LV dyssynchrony are different in patients with normal versus abnormal ventricular volumes and EF. This information is crucial as part of the evaluation of the RT3DE-based technique as an alternative method to improve the criteria for selection of patients for CRT.

In addition, in previous RT3DE studies (6,13–16), the LV dyssynchrony index (LVDI) was calculated using a 16-segment model that included 4 apical segments, each containing one-fourth of the apical cap. It is not known how the use of the current American Heart Association–recommended standard 17-segment model, in which the apical cap is treated as a separate segment, would affect LVDI.

Accordingly, the aims of this study were: 1) to establish normal values for LVDI, calculated using both the 16- and 17-segment models, and to determine whether this index is age- and/or sex-dependent; and 2) to compare the degree of LV dyssynchrony, as assessed by RT3DE in patients with normal LV function and dilated cardiomyopathy (DCM), and understand the effects of LBBB in these patients.

ABBREVIATIONS AND ACRONYMS

CRT = cardiac resynchronization therapy
DCM = dilated cardiomyopathy
ECG = electrocardiogram/electrocardiography
EDV = end-diastolic volume
EF = ejection fraction
ESV = end-systolic volume
HF = heart failure
LBBB = left bundle branch block
LV = left ventricle/ventricular
LVDI = left ventricular dyssynchrony index
LVEF = left ventricular ejection fraction
RT3DE = real-time 3-dimensional echocardiography
TDI = Tissue Doppler imaging

METHODS

Study design and population. A total of 183 subjects were studied prospectively in 2 separate protocols. Protocol 1 was designed to address aim 1 and included 135 normal subjects over a wide range of ages who had normal blood pressure, no history of heart disease, were not taking any cardiac medications, and had no 2-dimensional echocardiographic evidence of cardiac abnormality. Protocol 2 was designed to address aim 2 listed previously and included 48 additional patients: 32 patients with DCM (group 1 with 16 consecutive patients with LBBB and group 2 with 16 consecutive patients without LBBB) and 16 consecutive patients with