

Left bundle-branch block: The relationship between electrocardiogram electrical activation and echocardiography mechanical contraction

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Background The relationship between myocardial electrical activation by electrocardiogram (ECG) and mechanical contraction by echocardiography in left bundle-branch block (LBBB) has never been clearly demonstrated. New strict criteria for LBBB based on a fundamental understanding of physiology have recently been independently published for both ECG and echocardiography. The relationship between the 2 modalities and the relation to cardiac resynchronization therapy (CRT) response was investigated.

Methods Sixty-six patients with LBBB by conventional criteria had a standard 12-lead ECG and 2-dimensional strain echocardiography performed before CRT implantation. Criteria for LBBB by echocardiography included early termination of contraction in one wall and prestretch and late contraction in opposing wall(s). New strict criteria by ECG included QRS duration ≥ 140 ms (men) or 130 ms (women), QS or rS in leads V₁ and V₂, and mid-QRS notching or slurring in ≥ 2 of leads V₁, V₂, V₅, V₆, I, and aVL. Response was defined as $>15\%$ decrease in left ventricular end-systolic volume after 6 months.

Results In 64 of 66 patients, ECG analysis was possible. Echo and ECG readings for LBBB presence were concordant in 54 (84%) of 64. Thirty-seven (82%) of 45 patients with LBBB by strict ECG criteria responded to CRT, whereas only 4 (21%) of the 19 patients without LBBB responded (sensitivity 90% and specificity 65%). Thirty-six (95%) of 38 patients with concordance for the presence of LBBB responded to CRT. In patients with concordance for the absence of LBBB, 15 (94%) of 16 did not respond.

Conclusion For the first time, a close relation has been demonstrated between electrical activation by ECG and mechanical contraction by echocardiography. These findings may help identify CRT candidates. (Am Heart J 2013;166:340-8.)

Cardiac resynchronization therapy (CRT) has been an established treatment for patients with symptomatic severe heart failure and QRS ≥ 120 ms as a surrogate measure of an activation delay in the left ventricle (LV).^{1,2} It has become obvious, however, that these criteria are imperfect because one-third of qualifying patients do not have optimal response to treatment. Those with QRS duration <150 ms respond with variable degrees of

success,^{3,4} and those with non-left bundle-branch block (LBBB) QRS morphology respond quite poorly.^{4,6} These findings have now been incorporated in recent guidelines.^{7,8}

An LBBB is considered the hallmark conduction abnormality for CRT, but not all LBBB appearances are the same when determined by echo or electrocardiogram (ECG).^{9,10} Studies indicate that CRT may fail in some patients because the current qualifying criteria are inadequate in identifying the LV activation delay of a true LBBB. A better understanding of how common diagnostic methods reflect the culprit pathophysiology of activation delay-induced heart failure is necessary for improved patient selection.

Separate groups, working independently from each other, recently published studies based on a common fundamental understanding of LBBB physiology, which may provide improved insight of the relationships between the electrical and mechanical manifestations of LBBB. Strauss et al¹⁰ defined more strict ECG criteria for

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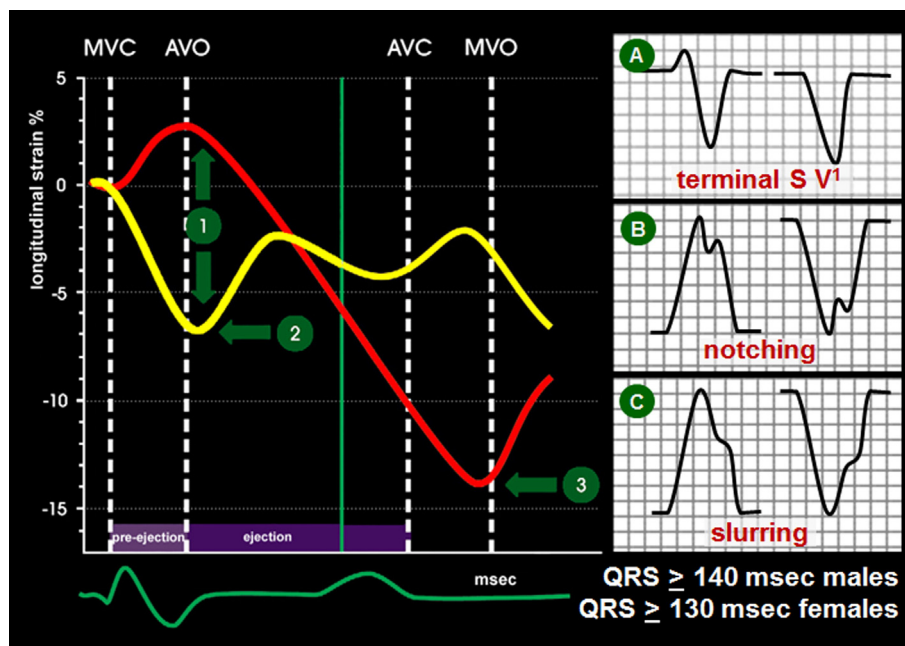
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Figure 1



New criteria for LBBB by echo and ECG. Left: LBBB pattern by 2D strain echocardiography. 1. A nadir of contraction of at least 1 basal or midventricular segment of the septal (inferoseptal or antero-septal) wall (yellow curve) and early stretching of at least 1 basal or midventricular segment of the opposing (postero-)lateral wall (red curve) that ends during the LV ejection phase. 2. The nadir of septal contraction occurs within 70% of the ejection phase (green line). When there are 2 nadirs, the first nadir is considered. 3. The nadir of contraction of the (postero-)lateral wall occurs after aortic valve closure that defines the end of the LV ejection phase. Right: LBBB strict criteria by ECG, QRS duration ≥ 140 ms (men) or ≥ 130 ms (women) and QS or rS in leads V_1 and V_2 , and mid-QRS slurring or notching in ≥ 2 contiguous leads of V_1 , V_2 , V_5 , V_6 , I, and aVL.

true LBBB based on the electrophysiology of its altered LV activation sequence. Risum et al⁹ demonstrated by 2-dimensional (2D) strain echocardiography that a specific true LBBB contraction pattern exists within the multitude of mechanical delays detected by common time-to-peak dyssynchrony analysis and that this is highly amenable to CRT.

A clear correlation between ECG electrical activation and echocardiography mechanical contraction has never previously been demonstrated. This study was based on the assumption that stricter defined methods thought to reflect a true LBBB activation delay would, in fact, correlate and be of value in the selection of CRT candidates. Accordingly, it was hypothesized that (1) refined ECG and echo strain-determined patterns of electrical/mechanical delay based on the fundamental understanding of LBBB physiology would be reasonably well correlated and (2) that agreement between refined methods would be related to CRT outcome.

Methods

Study patients

This study was performed in the same patient cohort in which we have previously shown the predictive ability of LBBB-related

contraction patterns.⁹ A total of 66 consecutive patients were included. Before CRT implantation, all patients had an LV ejection fraction $\leq 35\%$, QRS ≥ 120 ms, and LBBB according to conventional ECG criteria¹¹ and New York Heart Association functional class II or III, despite optimal medical treatment. Patients were excluded if they had significant primary valve disease, atrial fibrillation, acute coronary syndrome, or revascularization within 3 months of the baseline echocardiography or during the study period. The study was approved by local ethical committee, and all patients gave informed consent.

Electrocardiographic analysis

All patients had standard 12-lead ECGs (10 mm/mV and 25 mm/s) recorded and baseline echocardiography the day before CRT implant.

All ECG analyses were performed independently by 3 observers blinded to all clinical and echocardiographic data, except for gender. A complete LBBB was defined as QRS duration ≥ 140 ms (men) or ≥ 130 ms (women) and QS or rS in leads V_1 and V_2 , and mid-QRS slurring or notching in ≥ 2 contiguous leads of V_1 , V_2 , V_5 , V_6 , I, and aVL¹⁰ (Figure 1). Electrocardiogram studies deemed inadequate were excluded from analysis. In instances of disagreement, consensus was attained in conference among the 3 observers. Patients were divided into groups with and without LBBB according to these criteria.

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