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The mechanical and hemodynamic effects of left ventricular pacing in heart failure with preserved ejection fraction and left bundle branch block

Daniel J. Friedman, MD^a, Kasper Emerek, MD^{b,c}, Peter Søgaard, MD^b, Maryam Vejdani-Jahromi, MD, PhD^d, Joseph Kisslo, MD^c, Brett D. Atwater, MD^a

^aDivision of Electrophysiology, Duke University Hospital, Durham, NC

^bDepartment of Cardiology and Clinical Medicine, Aalborg University Hospital, Aalborg, Denmark

^cDivision of Cardiology, Duke University Hospital, Durham, NC

^dDepartment of Biomedical Engineering, Duke University, Durham, NC

Abstract

Cardiac resynchronization therapy (CRT) has revolutionized the care of patients with heart failure with reduced ejection fraction (HFrEF) and left bundle branch block (LBBB); some hypothesize that electrical resynchronization may also benefit patients with heart failure with preserved ejection fraction (HFpEF) and LBBB. We assessed the acute hemodynamic and mechanical impact of temporary LV pacing in 2 patients with HFpEF and LBBB and a “classic” pattern of echocardiographic dyssynchrony. LV pacing facilitated electrical resynchronization with acute resolution of mechanical dyssynchrony and improvements in invasively and non-invasively measured global cardiac function, due in part to shortening of the isovolumetric contraction period.

Keywords

Cardiac resynchronization therapy; left bundle branch block; heart failure with preserved ejection fraction

Introduction

Cardiac resynchronization therapy (CRT) improves systolic and diastolic function among patients with heart failure with reduced ejection fraction (HFrEF) and left bundle branch block (LBBB)(1) and has transformed the care of this subset of heart failure (HF) patients. Given the interrelatedness between systolic and diastolic function, some have hypothesized that CRT may provide benefit for HF with preserved ejection fraction (HFpEF) patients.(2) This topic is of substantial clinical importance based on estimates that at least 10% (3, 4) of

Corresponding Author: Brett D. Atwater, MD. Division of Electrophysiology, Duke University Hospital, 2301 Erwin Road, Durham, NC, 27710. brett.atwater@duke.edu phone: (919) 681-6020, fax: (919) 681-9260.

Declaration of Interest: None

HFpEF patients have comorbid LBBB. We report 2 cases that illustrate the acute mechanical and hemodynamic effects of AV sequential LV pacing in patients with HFpEF and LBBB, demonstrating a physiologic rationale for how CRT may be beneficial for selected HFpEF patients.

Material and Methods

We prospectively enrolled 2 patients with LBBB and HFpEF who were scheduled to undergo invasive electrophysiology procedures in an institutional review board approved protocol. A 0.014" pressure wire (Volcano Corporation) and Pentarray mapping catheter (Biosense Webster) were inserted into the left ventricle (LV) via transseptal access. With proximal coronary sinus (CS) pacing faster than the intrinsic sinus rate, we assessed: LV activation with Confidense mapping (CARTO 3, Biosense Webster) with offline manual point annotation; continuous LV and LA pressure monitoring; and global and regional LV mechanical function with echocardiography. Assessments were then repeated with AV sequential LV only endocardial pacing and a 120 ms paced AV delay to provide QRS fusion. Echocardiography was performed with a Vivid E-95 console and G5S probe and analyzed offline using EchoPac PC Version 201 (GE Healthcare). Longitudinal strain was measured as previously reported.(5) Myocardial performance index (MPI) was measured using tissue Doppler imaging(6) and defined as total isovolumetric time divided by ejection time, with lower numbers corresponding to improved cardiac performance and outcomes in HFpEF.(7)

Results

Two patients (1 female) with strict LBBB and HFpEF were enrolled and completed the study protocol (Table 1). Compared to AAI pacing, AV sequential LV pacing abolished the echocardiographic pattern of classic dyssynchrony and improved the MPI and dp/dt_{max} in both patients (Table 2). Figure 1 visually depicts LV pacing induced narrowing of the QRS and normalization of dyssynchrony via changes in electrical activation in patient 1. Figure 2 demonstrates similar findings for patient 2. Figure 3 visually depicts how LV pacing shortened isovolumetric times thereby increasing diastolic filling times in patient 1; again, similar findings were observed in patient 2.

Discussion

This report demonstrates that LBBB in the setting of HFpEF can be associated with "classic" mechanical dyssynchrony despite a normal EF. LV only pacing in HFpEF and LBBB with "classic" dyssynchrony appears to be capable of facilitating electrical resynchronization with acute resolution of mechanical dyssynchrony and improvements in invasively and non-invasively measured global cardiac function, due in part to shortening of the isovolumetric contraction period. Importantly, this report demonstrates a physiologically plausible mechanism by which a device based treatment targeted at systolic function has the capacity to improve diastolic function.

We are only aware of 1 other report(8) on the use of CRT in a patient with HFpEF and LBBB. In this case, permanent CRT improved dp/dt_{max} , dp/dt_{min} , pressure volume loop

assessed LV dyssynchrony, and exercise capacity. Our report builds on this provocative literature by describing the mechanical substrate (“classic pattern” of dyssynchrony) in HFpEF that may respond to CRT and demonstrating how augmentation of systolic performance (through treatment of dyssynchrony) can translate into longer diastolic filling times and improved diastolic performance.

In summary, we demonstrate that temporary AV sequential LV pacing in HFpEF and LBBB successfully treated electrical and mechanical dyssynchrony, thereby augmenting systolic and diastolic cardiac performance. This report suggests further study is required to determine whether LV pacing may be a viable treatment strategy for patients with HFpEF and LBBB.

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Figure 1.

Patient 1: With AAI pacing the ECG (25mm/s) demonstrated the baseline LBBB (a), electroanatomic map (RAO on left, LAO on right) demonstrated earliest LV activation at the apical septum with late activation at the basolateral wall (b), and longitudinal strain imaging demonstrates a “classic pattern” of LV dyssynchrony with early septal contraction (blue arrow), early lateral wall stretch (yellow arrow), and delayed lateral wall peak contraction (red arrow) after aortic valve closure (green line)(c). With AV sequential basolateral LV only pacing, the ECG demonstrates wavefront fusion (positive in I and V1) with a narrowed QRS (d), electroanatomic map (RAO on left, LAO on right) demonstrates earliest activation at mid and apical septum and inferolateral wall (site of LV pacing) (e), and longitudinal strain demonstrates resolution of the “classic pattern” of LV dyssynchrony with near simultaneous contraction of all opposing walls (f).

Figure 2.

Patient 2: With AAI pacing, the ECG (25mm/s) demonstrated the baseline LBBB (a), electroanatomic map (RAO on left, LAO on right) demonstrated earliest LV activation at the apical septum with late activation at the anterolateral wall (b), and longitudinal strain imaging demonstrates a “classic pattern” of LV dyssynchrony with early septal contraction (blue arrow), early lateral wall stretch (yellow arrow), and delayed lateral wall peak contraction (red arrow) after aortic valve closure (green line)(c). With AV sequential anterolateral LV only pacing, the ECG demonstrates wavefront fusion (positive in I and V1) with a narrowed QRS (d), electroanatomic map (RAO on left, LAO on right) demonstrates earliest activation at the anterolateral wall (site of LV pacing) followed by the apical septum and inferolateral wall (e), and longitudinal strain demonstrates resolution of the “classic pattern” of LV dyssynchrony with near simultaneous contraction of all opposing walls (f).

Figure 3.

Schematic diagram depicting changes in the timing of the cardiac cycle with baseline AAI pacing and with CRT pacing in Patient 1. CRT pacing decreased the isovolumetric contraction time by 51% allowing for a 15% increase in the diastolic filling time. Intervals were measured using tissue Doppler imaging with a frame rate of 125 frames per second. Findings were similar in Patient 2: isovolumetric contraction decreased from 99ms to 78ms, isovolumetric relaxation decreased from 142ms to 103ms, and overall diastolic filling increased from 434ms to 518ms.

Table 1.

Baseline characteristics of the study participants

Characteristics	Patient 1	Patient 2
Age in years	81	69
Sex	Female	Male
QRS characteristics	Strict LBBB, 154ms	Strict LBBB, 146ms
LVEF	>55%	51%
LVH	No	No
NYHA Class	II/III	II

LBBB = left bundle branch block, LVEF = left ventricular ejection fraction, LVH = left ventricular hypertrophy, NYHA = New York Heart Association

Table 2.

Baseline (AAI) versus CRT (AV sequential LV pacing) changes in cardiac structure and function

Parameter	Patient 1		Patient 2	
	AAI	CRT	AAI	CRT
LVEF, %	>55	>55	51	52
Strain pattern	Classic	Normal	Classic	Normal
MPI	0.58	0.45	0.75	0.57
dP/dt _{max} , mmHg/ms	1.1	1.3	1.0	1.2
dP/dt _{min} , mmHg/ms	-0.8	-1.0	-1.1	-1.1
Tau, ms	70.6	68.4	67	69.3
LA pressure, mmHg	12	10	15	14
V-waves, mmHg	25	17	26	25
LVEDP, mmHg	21.0	20.4	11.0	11.3

CRT = cardiac resynchronization therapy, LA = left atrial, LV = left ventricular, LVEDP = left ventricular end diastolic pressure, LVEF = left ventricular ejection fraction, MPI = myocardial performance index