Published in final edited form as:

J Card Fail. 2018 October ; 24(10): 716–718. doi:10.1016/j.cardfail.2018.09.008.

Acute Hemodynamic Effects of Biventricular Pacing After Left Ventricular Assist Device

Joanna M. Joly, MD¹, Deepak Acharya, MD¹, Harish Doppalapudi, MD¹, G. Neal Kay, MD¹, Chee Paul Lin, MA², William R. Maddox, MD¹, H. Thomas McElderry, MD¹, Salpy V. Pamboukian, MD¹, Vance J. Plumb, MD¹, Indranee N. Rajapreyar, MD¹, José A. Tallaj, MD¹, Takumi Yamada, MD¹, and Vineet Kumar, MD¹

¹Division of Cardiovascular Disease, Department of Medicine, University of Alabama, Birmingham, Alabama

²Center for Clinical and Translational Science, University of Alabama, Birmingham, Alabama

Abstract

Background: Despite cardiac resynchronization therapy (CRT), some patients with heart failure progress and undergo left ventricular assist device (LVAD) implantation. Management of CRT after LVAD implantation has not been well studied. The purpose of this study was to determine whether RV pacing or biventricular pacing measurably affects acute hemodynamics in patients with an LVAD and a CRT device.

Methods and Results: Seven patients with CRT and LVAD underwent right heart catheterization. Pressures and oximetry were measured and LVAD parameters were recorded during 3 different conditions: RV pacing alone, biventricular pacing, and intrinsic atrioventricular conduction. Paired *t* tests were used to evaluate changes within subjects. There were no significant changes in right atrial pressure, pulmonary arterial pressures, pulmonary capillary wedge pressure, cardiac index, or any LVAD parameter ($P > .05$).

Conclusions: Our data suggest that CRT probably has no acute hemodynamic effect in patients with LVADs, but further study is needed.

Keywords

Hemodynamics; heart failure; right heart catheterization; biventricular pacing; cardiac resynchronization therapy; left ventricular assist device

Cardiac resynchronization therapy (CRT) is an effective therapy for selected patients with heart failure (HF). Invasive studies and randomized controlled trials have confirmed that CRT provides acute hemodynamic benefits that translate to improved HF outcomes and survival.^{1–3}

jjoly@uabmc.edu (J.M. Joly).

Disclosures

None.

Yet approximately one-third of patients do not respond to CRT.⁴ For many patients with progressive HF, left ventricular assist device (LVAD) therapy is an option. The rate of LVAD implantation is increasing, and survival has improved considerably.^{5,6} Thus, the number of patients with both CRT and LVAD is growing, but there have been no formal studies examining whether continued CRT after LVAD implantation provides clinical benefit.

The purpose of the present study was to determine whether pacing measurably affects acute hemodynamics in patients with both LVAD and CRT devices.

Methods

This protocol was approved by the Institutional Review Board at the University of Alabama, Birmingham. The study population included 21 patients with CRT who subsequently underwent LVAD implantation. Two patients were excluded because of left ventricular (LV) lead capping at the time of implant. Of the remaining patients, 8 underwent right heart catheterization (RHC) during the study period. Each patient was clinically stable at the time of RHC. Indications for RHC included routine hemodynamic assessment per transplant listing protocol and LVAD speed optimization. One patient experienced discomfort during the RHC related to diaphragmatic stimulation with LV pacing and was excluded from the analysis, resulting in a cohort of 7 patients.

RHC was performed with the patients supine and without sedation. The international normalized ratio goal at the time of RHC was 1.8–2.2. Filling pressures and oximetry were measured and LVAD speed, flow, power, and pulsatility index were recorded during 3 separate conditions: RV-only pacing, biventricular pacing, and intrinsic atrioventricular conduction, when present. Hemodynamic data were acquired 5 minutes after initiating each new condition. Spontaneous heart rate during intrinsic conduction was compared with RV and biventricular pacing at similar rates. Average heart rate variation was <4 beats per minute.

Statistical Analysis

Paired *t* tests were used to evaluate hemodynamic and LVAD changes from one condition to the other within patients: namely, RV-only pacing to intrinsic conduction, biventricular pacing to intrinsic conduction, and biventricular pacing to RV-only pacing. A *P* value of <.05 was considered to be statistically significant in 2-tailed statistical tests. All analyses were conducted with the use of SAS 9.4 software (SAS Institute, Cary, North Carolina).

Results

Average age was 50.4 ± 15.5 among the 7 patients at the time of RHC. The etiology was nonischemic cardiomyopathy in 6 patients. Twelve-lead electrocardiography (ECG) before CRT was available for 5 patients; In all 5, the QRS interval prolonged with the use of biventricular pacing (Table 1). Biventricular pacing had been abandoned in patients 1, 5, and 6 owing to worsening electrical dyssynchrony on 12-lead ECG. There were no significant hemodynamic differences in right atrial pressure, pulmonary arterial pressures, pulmonary

capillary wedge pressure, cardiac index, or any LVAD parameter, regardless of pacing mode comparison ($P > .05$; Table 2).

Discussion

Biventricular Pacing

Our findings suggest that patients who fail to respond to CRT are unlikely to derive hemodynamic benefit from CRT after an LVAD is implanted. This may be because powerful unloading of the LV may significantly alter conditions relevant to CRT. In addition, ineffective CRT because of sub-optimal lead position or lack of dyssynchrony is unlikely to be positively influenced by LVAD implantation.

Though there is concern that LV pacing can trigger ventricular arrhythmias, a retrospective study found no significant difference in ventricular arrhythmia burden between those with CRT with defibrillator versus implantable cardioverter-defibrillator alone.⁷ Ventricular arrhythmias before LVAD implantation is the strongest predictor of recurrence after LVAD implantation.^{8,9}

Right Ventricular Pacing

RV dysfunction is an independent predictor of poor response to CRT.¹⁰ Similarly, RV dysfunction after LVAD poses one of the greatest risks for death.⁵ Poor RV systolic function and ventricular interdependence impede adequate filling of the LV and perpetuate unmitigated neurohormonal activation.¹⁰ We have had anecdotal success managing patients with RV dysfunction after LVAD by deactivating the LV lead and forcing atrioventricular-synchronous RV pacing at a rate higher than baseline to promote left-sided filling and improve hemodynamics.

Conclusion

In every patient with CRT, pacing strategy should be individualized after LVAD implantation. Our sample size here is small, which limits the strength of conclusions that can be drawn, but our data suggest that deactivating the LV lead probably does not affect hemodynamics acutely. Further study is warranted to better understand the impact of CRT after LVAD implantation.

Acknowledgments

Statistical analysis reported in this publication was partially supported by the National Center for Advancing Translational Sciences of the National Institutes of Health, under award number UL1TR001417.

References

1. Leclercq C, Cazeau S, le Breton H, Ritter P, Mabo P, Gras D, Pavin D, et al. Acute hemodynamic effects of biventricular DDD pacing in patients with end-stage heart failure. *J Am Coll Cardiol* 1998;32:1825–31. [PubMed: 9857858]
2. Moss AJ, Hall WJ, Cannom DS, Klein H, Brown MW, Daubert JP. MADIT-CRT Trial Investigators. Cardiac-resynchronization therapy for the prevention of heart-failure events. *N Engl J Med* 2009;361:1329–38. [PubMed: 19723701]

3. Cleland JG, Daubert JC, Erdmann E, Freemantle N, Gras D, Kappenberger L, Tavazzi L. Cardiac Resynchronization—Heart Failure (CARE-HF) Study Investigators. The effect of cardiac resynchronization on morbidity and mortality in heart failure. *N Engl J Med* 2005;352:1539–49. [PubMed: 15753115]
4. Galli E, Leclercq C, Donal E. Mechanical dyssynchrony in heart failure: still a valid concept for optimizing treatment? *Arch Cardiovasc Dis* 2017;110:60–8. [PubMed: 28065446]
5. Kirklin JK, Pagani FD, Kormos RL, Stevenson LW, Blume ED, Myers SL, et al. Eighth annual INTERMACS report: special focus on framing the impact of adverse events. *J Heart Lung Transplant* 2017;36:1080–6. [PubMed: 28942782]
6. Kirklin JK, Naftel DC, Stevenson LW, Kormos RL, Pagani FD, Miller MA, et al. INTERMACS database for durable devices for circulatory support: first annual report. *J Heart Lung Transplant* 2008;27:1065–72. [PubMed: 18926395]
7. Gopinathannair R, Birks EJ, Trivedi JR, McCants KC, Sutton BS, Deam AG, et al. Impact of cardiac resynchronization therapy on clinical outcomes in patients with continuous-flow left ventricular assist devices. *J Card Fail* 2015;21:226–32. [PubMed: 25528199]
8. Schleifer JW, Mookadam F, Kransdorf EP, Nanda U, Adams JC, Cha S, et al. Effect of continued cardiac resynchronization therapy on ventricular arrhythmias after left ventricular assist device implantation. *Am J Cardiol* 2016;118:556–9. [PubMed: 27328958]
9. Garan AR, Yuzefpolskaya M, Colombo PC, Morrow JP, Te-Frey R, Dano D, et al. Ventricular arrhythmias and implantable cardioverter-defibrillator therapy in patients with continuous-flow left ventricular assist devices: need for primary prevention? *J Am Coll Cardiol* 2013;61:2542–50. [PubMed: 23643502]
10. Tabereaux PB, Doppalapudi H, Kay GN, McElderry HT, Plumb VJ, Epstein AE. Limited response to cardiac resynchronization therapy in patients with concomitant right ventricular dysfunction. *J Cardiovasc Electrophysiol* 2010;21:431–5. 10.1016/j.cardfail.2018.09.008 [PubMed: 19845815]

Table 1.

Patient Characteristics

ID	Age (y)	HF Etiology	Before CRT			After CRT		
			QRS Morphology	QRS Interval	QRS Interval	Time to LVAD (y)	VAD Strategy	Time to RHC (y)
1	54	NICM—Familial	LBBB	128	180	4.6	DT	2.5
2	34	NICM—Myocarditis	RBBB	142	154	1.7	BTT	1.1
3	78	Ischemic cardiomyopathy	ND	ND	114	2.6	DT	7.0
4	58	NICM—NOS	ND	ND	136	1.0	BTT	0.8
5	34	NICM—Peripartum	LBBB	160	206	1.9	DT	2.4
6	52	NICM—Noncompaction	IVCD	180	216	2.5	BTT	0.2
7	42	NICM—NOS	IVCD	184	186	5.5	BTT	0.9

BTT, bridge to transplantation; CRT, cardiac resynchronization therapy; DT, destination therapy; IVCD, interventricular conduction delay; LBBB, left bundle branch block; ND, no documentation; NICM, nonischemic cardiomyopathy; NOS, not otherwise specified; RBBB, right bundle branch block; RHC, right heart catheterization.

Table 2.

Mean Hemodynamic and LVAD Changes Between Each Pacing Mode Comparison

Variable	n	RV-Only to Intrinsic	SD	Effect Size	P Value	n	BiV to Intrinsic	SD	Effect Size	P Value	n	BiV to RV-only	SD	Effect Size	P Value
RAP (mm Hg)	5	-0.20	0.45	0.03	.37	5	-1.00	0.71	0.16	.23	7	-0.71	1.50	0.11	.25
PAMP (mm Hg)	5	0.60	2.41	0.07	.61	5	-0.20	2.49	0.03	.87	7	-0.14	3.89	0.02	.93
PCWP (mm Hg)	5	-0.60	1.52	0.08	.43	5	-2.20	3.56	0.31	.24	7	-0.86	2.27	0.13	.36
CI Fick (L/min-m ²)	5	-0.03	0.09	0.08	.56	5	-0.07	0.07	0.21	.09	7	0.01	0.17	0.03	.90
CI Thermo (L/min-m ²)	5	-0.12	0.19	0.25	.22	5	-0.06	0.21	0.12	.58	7	0.05	0.20	0.10	.54
LVAD flow (L/min)	5	0.06	0.54	0.11	.81	5	0.32	0.28	0.91	.06	7	0.16	0.64	0.24	.54
LVAD PI	5	0.20	0.47	0.09	.39	5	0.16	1.14	0.07	.77	7	0.00	1.01	0.00	1.00

BiV, biventricular; CI, cardiac index; LVAD, left ventricular assist device; PAMP, pulmonary arterial mean pressure; PCWP, pulmonary capillary wedge pressure; PI, pulsatility index RAP, right atrial pressure; RV, right ventricular; Thermo, thermomodulation.