



## Peer-Reviewed Case Series

# CardioMEMS™ in LVAD Patients: A Case Series

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## Abstract

Patients with a left ventricular assist device (LVAD) commonly encounter issues with volume status post-implant. Volume overload can result from incomplete compensation of left ventricular failure or from right ventricular failure. The CardioMEMS™ intracardiac hemodynamic monitoring device is an area of growing interest regarding the management of chronic congestive heart failure, however, its utility has not been serially investigated in patients with an LVAD. We present a case series of patients with ventricular assist devices care for at our institution in which the CardioMEMS™ device aided in the management of volume status and pump performance.

**Keywords:** CardioMEMS, remote hemodynamic monitoring, ventricular assist device, heart failure

## Introduction

As decompensated heart failure (HF) represents a leading cause for hospitalization and carries a high readmission rate, it imposes high economic burdens on health care organizations. As such, prediction of decompensation has been a surging area of interest. Patients randomized to treatment guided by pulmonary artery pressure data from the CardioMEMS™ (St. Jude Medical, Inc., St. Paul, MN) device reduced their HF-related hospitalizations at six months, garnering much enthusiasm regarding intracardiac hemodynamic monitoring<sup>1</sup>.

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The utility of the CardioMEMS™ device, however, has not been investigated in patients with a left ventricular assist device (LVAD), a population which also carries a high readmission rate after implantation. Hospital readmissions in LVAD patients occur at a rate of 1.5-2.5 per patient year of support with HF representing a leading cause<sup>2-4</sup>. Persistent heart failure after LVAD implantation is common, occurring in up to 25% of patients<sup>5</sup>. Such persistence of HF may result from incomplete compensation of left ventricular (LV) failure or from right ventricular (RV) failure.

Given the lack of available data, we retrospectively reviewed the LVAD patient population managed at our institution who had a CardioMEMS™ device implanted. We present a case series of four patients whose volume status we managed by relying on the information made available by the CardioMEMS™ device. None of the patients had any complications related to the CardioMEMS™ device implantation procedure

### **Case Series**

#### **Patient 1**

A 52-year-old male had multiple admissions after implantation of a HeartWare LVAD in the beginning of 2014 for nonischemic cardiomyopathy. He never had any serious complications of the LVAD (such as infections or bleeding) but was admitted nearly monthly (16 admissions over 2 years). The majority of admissions related to complaints of weight gain, increased abdominal girth, and peripheral edema. His volume status was difficult to evaluate clinically as the patient was morbidly obese with a body mass index of 43. After implantation of the CardioMEMS™ device, he was admitted twice over an eight month follow-up period with no admissions in the latter six months. There were a total of 22 adjustments in his diuretic dose after CardioMEMS™ implantation. Prior to CardioMEMS™, the patient was taking bumetanide 2 mg/day with metolazone as needed. At the time when data was collected for this report, his dose was bumetanide 4 mg/day and metolazone 5 mg/day. The patient serum creatinine improved from 2.8 mg/dL to 1.3 mg/dL. His pump speed was also adjusted several times and ultimately increased from 2900 revolutions per minute (rpms) before CardioMEMS™ implantation, to 3000 rpms currently. There was no significant change in his pulmonary artery pressures.

#### **Patient 2**

A 52-year-old male with nonischemic cardiomyopathy had a HeartMate II LVAD in place for five months before a CardioMEMS™ was implanted. In the four months after CardioMEMS™ implantation, his pulmonary arterial pressures decreased from 38/20 mmHg to 32/16 mmHg. There were 18 diuretic dose adjustments. The patient's baseline dose was torsemide 40 mg/day while his current dose is



torseamide 40 mg/day with metolazone 5 mg/day. His pump speed was increased from 9600 rpms to 9800 rpms. Serum creatine decreased from 2.4 mg/dL to 1.6 mg/dL. Nevertheless, the patient continued to have marked peripheral edema, likely related to right ventricular failure, and is currently listed for heart transplantation.

#### Patient 3

A 66-year-old male with nonischemic cardiomyopathy was implanted with a CardioMEMS™ device after seven months of HeartMate II LVAD support. Prior to this, the patient had four admissions related to either gastrointestinal bleeding or volume overload. While on CardioMEMS™ monitoring over four months, he was admitted once. His pulmonary arterial pressures were near normal over this period of time. His diuretic dose, however, was adjusted six times, changing from torsemide 80 mg/day to torsemide 40 mg/day. His serum creatinine has slowly trended down from 2.98 mg/dL to 2.88 mg/dL.

#### Patient 4

A 60-year-old male was implanted with a HeartMate II LVAD in the spring of 2015. Within 11 months, the patient had 3 admissions, 2 of which primarily related to gastrointestinal bleeding. However, his function status remained limited and symptoms were consistent with either volume overload (edema, weight gain) or with volume depletion (dizziness). He subsequently underwent CardioMEMS™ implantation and in the following five months, there was only one admission. His pulmonary arterial pressure decreased from 40/20 mmHg to 37/16 mmHg. A total of 11 diuretic adjustments were made. His torsemide dose was gradually decreased from 40 mg/day to 20 mg every other day along with metolazone 2.5 mg. Serum creatinine improved from 2.1 mg/dL to 1.7 mg/dL.

A summary of the 4 patients along with important clinical and hemodynamic trends can be found in Tables 1 and 2.

**Table 1: Summary of patients with LVAD after CardioMEMS™ implantation**

Patient and Device	Age	Months between LVAD implantation and CardioMEMS™	Months of data collection with CardioMEMS™	Number of diuretic adjustments with CardioMEMS™
Patient 1 - HeartWare	52	23	7	22
Patient 2 - HeartMate II	52	5	4	18
Patient 3 - HeartMate II	66	7	4	6
Patient 4 - HeartMate II	60	11	5	11



**Table 2: Hemodynamic and clinical changes before and after CardioMEMS™ implantation**

Patient	Mean PASP (mmHg)		Mean PADP (mmHg)		Serum creatinine (mg/dL)		Pump speed (rpms)		Number of admissions/month		Diuretic dose (mg/day)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Patient 1	41.4 ± 5.2	42.1 ± 3.8	21.7 ± 1.8	21.8 ± 2.5	2.8	1.3	2900	3000	0.7	0.3	Bumex 2 + metolazone 5	Bumex 4 + metolazone 5
Patient 2	38.1 ± 3.0	32 ± 2.6*	19.7 ± 1.9	<b>15.6 ± 1.6*</b>	2.43	1.64	9600	9800	0.8	0.5	Torseamide 40	Torseamide 40 + metolazone 5
Patient 3	34.9 ± 4.6	35.5 ± 3.0	14.4 ± 2.9	<b>13.2 ± 1.3***</b>	2.98	2.88	9600	9600	0.6	0.25	Torseamide 40	Torseamide 20
Patient 4	40.5 ± 5.6	37.5 ± 7.4	20.1 ± 3.3	<b>16.3 ± 3.5**</b>	2.1	1.7	9200	9200	0.27	0.2	Torseamide 40	Torseamide 10 + metolazone 1.25

PASP - pulmonary artery systolic pressure, PADP - pulmonary artery diastolic pressure, RPMS - revolutions per minute

\*p < 0.0001, \*\*p = 0.0009, \*\*\*p = 0.047

## Discussion

Left ventricular assist devices improve hemodynamics in advanced HF by increasing LV output. Nevertheless, as many as 20-25% of patients may have HF after LVAD implantation, due to either incomplete compensation of LV failure or from the presence of RV failure<sup>5</sup>. Persistent fluid retention, in either the pulmonary or systemic circulation (or both), requires diuretics. In fact, it has been our experience that roughly half of the patients on LVAD support continue taking loop diuretics, even if it is on an as needed basis.

Right heart catheterization in LVAD patients revealed that only 43% of patients had a normal central venous pressure and pulmonary capillary wedge pressure. Optimization of pump parameters under hemodynamic control results in significant improvement in both cardiac output and wedge pressure and achieved nearly normal hemodynamics in 56% of patients<sup>6</sup>. Not surprisingly, several abstracts at the 2016 International Society for Heart and Lung Transplant meeting presented novel ways to diagnose fluid overload in patients on LVAD support. Specifically, Grinstein et al found that that analyzing the ventricular phase slope in a HeartWare device can determine elevated pulmonary capillary wedge pressure and decreased cardiac output<sup>7</sup>. Moss et al discovered that changes in LV pacing lead impedance also correlated with changes in wedge pressure during hemodynamic ramp tests<sup>8</sup>.

At our institution, we believe that utilizing already existing technology for remote hemodynamic monitoring, namely CardioMEMS™, affords several advantages. Not only is there easy access to key hemodynamic parameters on a regular basis,



but less time and effort are needed to perform echocardiogram ramp tests or placement of a Swan-Ganz catheter.

In our small case series, we demonstrated that in three out of four patients, pulmonary arterial diastolic pressures significantly decreased after just a few months of post-implant monitoring. This is particularly remarkable, because due to financial regulation, the CardioMEMS™ device is typically not implanted when the patient is already admitted for fluid overload. In fact, the device is implanted when subjects are in a stable status, i.e. in the outpatient setting. As a result, pulmonary arterial pressures are near normal to begin with and further reduction was difficult to achieve. Likewise, conveying statistical significance is impossible with a mere four cases, however all patients invariably had fewer admissions after CardioMEMS™ implantation. As important is the fact that all four patients experienced some improvement in serum creatinine.

Volume status with LVAD patients can be controlled by changing loop diuretic dose and/or adjusting pump speed. Analysis of the CHAMPION trial demonstrated that diuretics were adjusted many more times in patients with CardioMEMS™ when providers had access to hemodynamic data as compared to a control group<sup>1</sup>. We made multiple adjustments of diuretics in our patients. Unfortunately, the documentation of changes was not as thorough before CardioMEMS™ implantation and a comparison of the number of changes was not feasible. Finally, one of the patients in our case series failed to improve with remote hemodynamic monitoring because of severe RV failure. Pulmonary arterial pressured measured by the CardioMEMS™ device reflects the degree of LV failure. Elevations in central venous pressure, the hallmark of RV failure, cannot be detected. As such, the evaluation of RV failure requires a different means of diagnosis.

Future studies regarding the role of the CardioMEMS™ device in LVAD patients should focus on collecting and analyzing the following several pieces of data. Hemodynamic parameters of right heart catheterization before LVAD implantation and before subsequent CardioMEMS™ implantation would be particularly beneficial as it allows for two sets of invasive hemodynamics (in steady state and during volume overload). Second, the number and magnitude of pump speed adjustments before and after CardioMEMS™ implantation should be tracked. Also, the number of diuretic adjustments (agents and doses) should be characterized before and after CardioMEMS™ implantation. Lastly, the number and causes of hospitalizations before and after CardioMEMS™ implantation should be described.

## **Conclusion**

Our case series of patients on long-term LVAD support with concomitant remote hemodynamic monitoring using the CardioMEMS™ device demonstrated favorable profiles including a decrease in pulmonary artery diastolic pressures, improvement in serum creatinine levels, and a trend to fewer hospital readmissions. An observational study with a larger cohort and longer follow-up



period, but especially a randomized, controlled trial would be necessary to validate the utility of remote hemodynamic monitoring with the CardioMEMS™ device in this unique patient population.

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