CardioMEMS™ HF SYSTEM

Clinical Compendium:
Pulmonary Artery (PA) Pressure-Guided Therapy for Heart Failure Management

The CardioMEMS™ HF System is the first and only FDA-approved heart failure (HF) monitor proven to significantly reduce HF hospital admissions and improve quality of life in NYHA class III patients.1

When used by clinicians to manage HF, the CardioMEMS HF System is:

- **Safe and reliable** – Demonstrated 98.6% freedom from device or system related complications1
- **Clinically proven** – reduced HF admissions by 37%1 and all-cause 30-day readmissions by 58%2
- **Proactive and personalized** – patient management through direct monitoring of PA pressure and titration of medications

Traditional physiologic markers in the development of acute decompensation in patients suffering from HF such as intrathoracic impedance, weight, blood pressure and symptoms are late and unreliable3,4 with only moderate sensitivity and specificity.5-7 Large randomized controlled studies using telemonitoring of these indirect markers have failed to demonstrate a reduction in HF hospitalizations.3,4,8 This clinical compendium summarizes key studies demonstrating the safety and efficacy of the CardioMEMS HF System.
PA PRESSURE-GUIDED THERAPY REDuces HEART FAILURE HOSPITALIZATIONs, REDuces 30-DaY REAdMISSIONs AND IMPROVES QUALITY OF LIFE IN PATIENTs WITH REDuced OR PReSERVED EJECTION FRACTION

The CardioMEMS™ HF System monitors PA pressure measurements from a sensor implanted into the pulmonary artery. The safety and accuracy of the CardioMEMS™ PA Sensor has been demonstrated in previous studies. Systolic and diastolic PA pressures were significantly correlated between the CardioMEMS PA Sensor and traditional Swan-Ganz™ catheter measurements, and between the CardioMEMS PA Sensor and standard echocardiography. A feasibility study reported the safe and successful implantation of the CardioMEMS PA Sensor in a clinical setting with no serious device-related events (n = 17). These preliminary studies provided the safety and accuracy data needed for the pivotal CHAMPION clinical trial and subsequent sub-analyses that support the use of the CardioMEMS HF System to proactively guide HF management in NYHA Class III patients with reduced or preserved left ventricular ejection fraction (LVEF).

Wireless Pulmonary Artery Haemodynamic Monitoring in Chronic Heart Failure: A Randomised Controlled Trial

- The aim of this randomized, multicenter, single-blind, controlled study was to evaluate the safety of the system and the efficacy of PA pressure-guided therapy on HF hospitalizations.
- NYHA Class III HF patients irrespective of LVEF and who had been hospitalized for HF within the past 12 months were implanted with the CardioMEMS PA Sensor (n = 550); patients were randomized to either the treatment group (HF management guided by PA pressure measurements, n = 270), or the control group (standard of care management, n = 280).
- Mean follow-up time was 15 months.
- Both primary safety and efficacy endpoints were met:
  - Patients had a 98.6% freedom from device- or system-related complications (95% CI 97.3-99.4) with no pressure-sensor failures (95% CI 99.3-100.0).
  - The rate of HF hospitalizations at 6 months was reduced by 28% in the treatment group (p = 0.0002).
- During the first 6 months of follow-up, compared to the control group, the treatment group had:
  - A greater reduction in PA pressure (-156 vs. 33 mean area under the curve, p < 0.008).
  - Fewer patients admitted to the hospital for HF (20% treatment group vs. 29% control group, p < 0.03).
  - More days alive outside of the hospital (174.4 ± 31.1 vs. 172.1 ± 37.8 days, p < 0.02).
  - Better patient quality of life (45 ± 26 vs. 51 ± 25, p = 0.02 based on Minnesota Living with Heart Failure Questionnaire).

Key takeaways:
- The treatment group required < 1 medication changes per patient per month compared to the control group (9.1 ± 7.4 vs. 3.8 ± 4.5 changes per patient during first 6 months of follow-up, p < 0.0001).
- During the entire follow-up (mean 15 months), PA pressure-guided therapy (treatment group) significantly reduced HF hospitalizations by 37% compared to the control group (p < 0.0001, see Figure 1).
- The treatment group had a lower risk of death or freedom from first HF hospitalization during the entire follow-up period compared to the control group (p = 0.0086).

Figure 1. Cumulative heart failure hospitalizations during the entire period of follow-up

<table>
<thead>
<tr>
<th>Study Duration</th>
<th>≤ 6 Months</th>
<th>&gt; 6 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>280</td>
<td>267</td>
</tr>
<tr>
<td>Treatment</td>
<td>270</td>
<td>262</td>
</tr>
</tbody>
</table>

Hazard ratio 0.63 (95% CI 0.52-0.77) p < 0.0001

Impact of Introduction of Pulmonary Artery Pressure Monitoring for Heart Failure Management: Longitudinal Results from the CHAMPION Trial


- This CHAMPION clinical trial analysis evaluated the impact on HF hospitalizations of the introduction of PA pressure monitoring in the control group (n = 170) of patients and continued PA monitoring in the treatment group (n = 177) during the open access (OA) phase of the trial.

- Following completion of the randomized access (RA) period (mean follow-up of 18 months), all patients were managed utilizing PA pressure monitoring with the CardioMEMS HF System (mean follow-up of 13 months) and evaluated in a longitudinal analysis.

- New access to PA pressures in the control group resulted in a 48% reduction in HF hospitalization rates (0.36 vs. 0.68, HR 0.52, 95% CI 0.40-0.69, p < 0.0001). See Figure 2.

- The low HF hospitalization rate in the treatment group during the randomized access period was maintained in the open access period (0.45 vs. 0.48, HR 0.93, 95% CI 0.70-1.22, p = 0.5838). See Figure 2.

Key takeaways:
- The longitudinal analysis confirms the effectiveness of the CardioMEMS HF System and supports the findings from the randomized portion of the CHAMPION clinical trial.
- Even after adjustment for longitudinal confounders, new access to PA pressure monitoring for the formerly blinded control group resulted in a significant reduction in HF hospitalizations.

Figure 2. CHAMPION Clinical Trial: Longitudinal Results with Open Access to All Patients Confirm Effectiveness of PA Pressure Monitoring in Reducing HF Hospitalizations
Impact of Wireless Pulmonary Artery Pressure Monitoring on Heart Failure Hospitalizations and 30-Day Readmissions in Medicare-Eligible Patients with NYHA Class III Heart Failure: Results from the CHAMPION Trial

Adamson et al., Circulation 2014.²

- This data analysis from the CHAMPION clinical trial compared 30-day readmissions and HF hospitalizations between Class III HF patients 65 years or older monitored with PA pressure to those managed with standard of care (SOC) over an average of 18 months.
- 245 patient were included in the analysis; 120 in the PA pressure treatment group and 125 in the SOC control group.
- In this analysis, patients managed with PA pressure compared to those managed according to SOC experienced:
  - 58% reduction in all-cause 30-day readmissions (0.07 vs. 0.18, HR 0.42, p = 0.0062)*
  - 78% reduction in HF 30-day readmissions (0.02 vs. 0.10, HR 0.22, p = 0.0027)*
  - 49% reduction in HF hospitalizations (0.34 vs. 0.67, HR 0.51, p < 0.0001)*

*event rates are based on events/patient year

Key takeaways:
- This retrospective analysis of the CHAMPION clinical trial demonstrated that PA pressure-guided management of Medicare-eligible HF patients significantly reduced 30-day readmissions, which may help to alleviate the economic burden associated with HF readmissions.
- This analysis supports results from the CHAMPION clinical trial results demonstrating a 37% reduction in HF hospitalizations and improved quality of life with PA pressure-guided HF management in NYHA Class III HF patients irrespective of Medicare eligibility.¹

CardioMEMS Heart Sensor Allows Monitoring of Pressures to Improve Outcomes in NYHA Class III Heart Failure Patients (CHAMPION) Trial: Impact of Hemodynamic Guided Care on Patients with Preserved Ejection Fraction


- This sub-analysis of the CHAMPION clinical trial evaluated the effect of PA pressure-guided therapy with the CardioMEMS™ HF System in NYHA Class III patients with preserved ejection fraction (HFpEF).
- Of the HFpEF patients (n = 115), 59 were randomized to the treatment group (PA pressure-guided therapy) and 56 to the control group (standard of care).

Key takeaway:
- PA pressure-guided therapy significantly reduced HF hospitalizations for HFpEF patients in the treatment group by 50% and 60% compared to those patients in the control group at 6 and 15 months, respectively (p < 0.0001 and p < 0.0004, respectively).

Effect of CRT on Heart Failure Related Hospitalizations in Patients with Reduced EF Utilizing Remote Pulmonary Artery Pressures in the CHAMPION Trial


- This sub-analysis of the CHAMPION clinical trial evaluated the effect of PA pressure-guided therapy with the CardioMEMS HF System in patients with reduced ejection fraction (rEF < 40%, n = 430) with and without a cardiac resynchronization therapy (CRT) device.
  - 40% (171 of 430) of rEF patients had CRT devices; of this cohort, 82 patients were in the treatment and 89 in the control group.
  - 60% (259 of 430) of rEF patients did not have CRT devices; of this cohort, 126 patients were in the treatment group and 42 in the control group.

Key takeaways:
- Remote PA pressure data in the treatment group resulted in similar reductions in HF hospitalization in patients with and without a CRT device, suggesting that HF management guided by PA pressures may provide additive benefits to CRT therapy.
  - For patients in the rEF-CRT group, those who received PA pressure-guided therapy had significantly fewer HF hospitalizations (RRR = 24%, p = 0.0264).
  - For patients in the rEF-no CRT group, PA pressure-guided therapy resulted in an RRR = 23%.
Targeting Pulmonary Artery Pressures in the Treatment of Chronic Heart Failure: Insights from the CHAMPION Trial

- This CHAMPION clinical trial sub-analysis determined if remote access to PA pressure data may provide a method to identify and treat high filling pressures in HF patients at increased risk for decompensation (n = 550).
- At implant, the mean PA pressure was similar in both control and treatment groups (31.8 ± 10.7 and 31.3 ± 11.1 mmHg, respectively).
- Average PA pressures increased during the 6 weeks prior to HF hospitalizations in both groups (p < 0.0001) and decreased significantly after successful in-hospital decongestion (p < 0.0001).
- Treatment patients with HF hospitalizations had lower pressures compared to control patients with HF hospitalizations at all timepoints prior to hospitalization.
- Treatment patients also had lower PA pressures compared to the control patients regardless of hospitalization type (HF-related or non-HF related).

Key takeaways:
- Higher PA pressures and increases in PA pressure were both associated with increased risk for HF hospitalizations.
- HF treatment strategies that target both high PA pressure and increases in PA pressures may be effective strategies for lowering the risk of decompensation in chronic HF patients.

Benefits of Pulmonary Artery Pressure Monitoring Extend to Reduction of All-Cause Rehospitalizations

- In this CHAMPION clinical trial sub-analysis, the impact of other causes of rehospitalizations was evaluated.
- Total all-cause rehospitalizations were significantly reduced with the CardioMEMS HF System for patients in the treatment group compared to patients in the control group (554 vs. 672, p < 0.0032).
  - 38% of the rehospitalizations were for a primary HF diagnosis.
  - The number needed to treat (NNT) to prevent 1 event per year was 4.
- Death or all-cause rehospitalizations were significantly reduced for patients in the treatment group compared to patients in the control group (604 vs. 736, p = 0.0017).

Key takeaway:
- PA pressure-guided HF management not only reduces HF rehospitalizations, but also reduces all-cause rehospitalizations.

The Malignant Effect of Acute Decompensation in Patients with Chronic Heart Failure: Insights from the CHAMPION Trial

- This CHAMPION clinical trial sub-study reports on the impact of obtaining remote PA pressure data and the effect on patient.
- This CHAMPION clinical trial sub-study reports on the impact of obtaining remote PA pressure data and the effect on patient mortality and quality of life (n = 550).
- Patients in both treatment (n = 270) and control (n = 280) groups who did not experience a HF hospitalization had a 66% reduction in mortality (HR 0.34, 95% CI 0.22-0.54, p < 0.0001).
- The treatment group had a significant 27% reduction in the risk of HF hospitalization or death (HR 0.73, 95% CI 0.57-0.94, p = 0.015).
- Among patients who did not experience a HF hospitalization, those in the treatment group had an improved quality of life compared to those in the control group (Minnesota Living with Heart Failure Questionnaire, 43.2 vs. 48.9, p = 0.0377).

Key takeaway:
- The PA pressure monitoring system may reduce the risk of HF hospitalization and mortality while improving a patient’s quality of life.
PA PRESSURE-GUIDED THERAPY REDUCES HEART FAILURE HOSPITALIZATIONS AND IMPROVES SURVIVAL IN HF REDUCED EF PATIENTS ON GUIDELINE-DIRECTED MEDICAL THERAPY

The CHAMPION clinical trial demonstrated a significant reduction in HF hospitalizations and a trend toward better survival when patients were managed in the treatment group with the CardioMEMS™ HF System. In retrospective data analysis specific patient populations, however, significant reductions in both HF hospitalizations and mortality were observed.

The analysis showed that patients on guideline-directed medical therapy (GDMT) managed with PA pressures had a 43% reduction in HF hospitalizations and 57% reduction in mortality over the patients in the control group managed with standard of care (see Figure 3).

**Key takeaway**

- The data demonstrates that neurohormonal control combined with hemodynamic optimization through PA pressure management led to substantial incremental clinical benefit.

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**Pulmonary Artery Pressure Management in Heart Failure Patients with Reduced Ejection Fraction Significantly Reduces Heart Failure Hospitalizations and Mortality Above and Beyond Background Guideline-Directed Medical Therapy**


- This retrospective data analysis from the CHAMPION clinical trial evaluated whether HFrEF patients on guideline-directed medical therapy (ACE inhibitor or ARB and beta blocker) could benefit from PA pressure management.

- 456 study patients were analyzed and of those 337 met the criteria of GDMT from the treatment and control groups, n = 163 and n = 174, respectively, with an average follow-up of 17 months.

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**Figure 3.** CHAMPION clinical trial sub-analysis: Reduced HF hospitalizations and improved survival in HFrEF patients on GDMT managed with PA pressure

**HFrEF Patients on ACE/ARB and Beta Blocker Prior to Implant**

- **43% Reduction**
  \( \text{HR} 0.57, \text{CI} 0.45-0.74, p = 0.0001 \)

**HFrEF Patients on ACE/ARB and Beta Blocker Prior to Implant**

- **57% Reduction**
  \( \text{HR} 0.43, \text{CI} 0.24-0.76, p = 0.0026 \)
Pulmonary Artery Pressure Management in Heart Failure Patients with Cardiac Resynchronization Therapy or Implantable Cardioverter Defibrillator Devices Significantly Reduces Heart Failure Hospitalizations and Mortality Above and Beyond Background Guideline-Directed Medical Therapy

Abraham W, et al., HRS 2015 Abstract AB37-03.18

- This retrospective data analysis from the CHAMPION clinical trial evaluated whether patients with a CRT or ICD on guideline-directed medical therapy (ACE inhibitor or ARB and beta blocker) could benefit from PA pressure management.

- 275 study patients were analyzed from the treatment and control groups, n = 129 and n = 146, respectively, with an average follow-up of 18 months.

- The analysis showed that patients with a CRT or ICD on guideline-directed medical therapy (GDMT) managed with PA pressures had:
  
  - 43% reduction in HF hospitalizations (HR 0.57, 95% CI 0.44-0.74, p < 0.0001)
  
  - 30% reduction in all-cause hospitalization HR 0.70, 95% CI 0.60-0.82, p < 0.0001)
  
  - 53% reduction in mortality (HR 0.47, 95% CI 0.26-0.87, p = 0.014) over the patients in the control group managed with standard of care (see Figures 4 and 5).

Key takeaways

- This analysis builds on the data presented by Abraham, et al. at ACC 2015, which showed that patients on GDMT benefited from PA pressure monitoring.17 With this new analysis, the data shows that even on top of optimal medical therapy and CRT or ICD devices, PA pressure management still results in additional benefit to decrease HF hospitalizations and reduce mortality.

- These improvements are likely attributable primarily to PA pressure-guided changes in diuretic and vasodilator therapies but possibly also to PA pressure-guided changes in neurohormonal antagonist therapies.

Figure 4. CHAMPION clinical trial sub-analysis: Improved survival in patients with a CRT-D or ICD on GDMT managed with PA pressure

Patients with CRT-D or ICD devices on ACEi/ARB and Beta Blocker Therapy

Abraham W, et al., HRS 2015 Abstract AB37-03
Figure 5. CHAMPION clinical trial sub-analysis: Improved survival in patients with a CRT-D or ICD on GDMT managed with PA pressure.

**Patients with CRT-D or ICD devices on ACEi/ARB and Beta Blocker Therapy**

![Graph showing survival probability over days after PA pressure sensor implant, comparing Guideline-Directed Standard of Care and PA Pressure-Guided HF Management.]

**53% Reduction**

[HR 0.47, 95% CI 0.26-0.87, p = 0.014]

**Guideline-Directed Standard of Care (Control Group)**

**PA Pressure-Guided HF Management (Treatment Group)**

<table>
<thead>
<tr>
<th># at Risk</th>
<th>Control</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>Days after PA Pressure Sensor Implant</td>
<td>146</td>
<td>129</td>
</tr>
<tr>
<td>0</td>
<td>132</td>
<td>120</td>
</tr>
<tr>
<td>180</td>
<td>110</td>
<td>98</td>
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<td>360</td>
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<td>7</td>
<td>6</td>
</tr>
<tr>
<td>900</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**PA Pressure-Guided HF Management Reduces All-Cause Mortality in CRT-D Population Therapy**

![Graph showing survival probability over days after PA pressure sensor implant, comparing Guideline-Directed Standard of Care and PA Pressure-Guided HF Management.]

**64% Reduction**

[HR 0.36, 95% CI 0.14-0.89, p = 0.028]

**Guideline-Directed Standard of Care (Control Group)**

**PA Pressure-Guided HF Management (Treatment Group)**

<table>
<thead>
<tr>
<th># at Risk</th>
<th>Control</th>
<th>Treatment</th>
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</thead>
<tbody>
<tr>
<td>Days after PA Pressure Sensor Implant</td>
<td>79</td>
<td>63</td>
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<tr>
<td>0</td>
<td>71</td>
<td>56</td>
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<tr>
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<td>3</td>
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<tr>
<td>900</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

Abraham W, et al., HRS 2015 Abstract AB37-03
Cost Effectiveness Assessment of Pulmonary Artery Pressure Monitoring for Heart Failure Management
Adamson P, et al., HRS 2015 Abstract AB36-01.20

- This economic analysis to determine the cost-effectiveness of PA pressure monitoring was based on CHAMPION clinical trial data.
- A Markov cohort simulation model was used to approximate the course of management observed in the CHAMPION clinical trial for the Treatment (PA pressure management) and Control (SOC) groups.
- CHAMPION clinical trial data was used to estimate the event rates, mortality and quality-of-life.
- The base case follow-up period was 5 years and costs related to all-cause comprehensive management were used.
- In this economic analysis PA pressure-guided management of CardioMEMS HF System indicated patients showed:
  - Incremental cost-effectiveness ratio (ICER) of $30,167 comparing comprehensive management over a 5-year time horizon hospitalizations.

Key takeaways:
- This economic analysis showed an ICER of $30,167 per quality adjusted life year (QALY) based on all-cause comprehensive management of HF patients modeled over a 5-year time horizon.
- The ICER of $30,167 is below the US accepted ICER threshold of $50,000 per QALY and well under the World Health Organization threshold of approximately $160,000 for the US (based on GDP).21,22
- Cost effectiveness is attributive to a reduction in HF hospitalization rates.
PA PRESSURE-GUIDED THERAPY HAS BEEN SHOWN TO CONSISTENTLY REDUCE HF HOSPITALIZATIONS IN PATIENTS WITH COMMON HEART FAILURE COMORBIDITIES

HF is often associated with a variety of comorbidities such as respiratory disease, coronary artery disease and atrial fibrillation. These comorbidities contribute to disease progression and may alter the response to treatment. This section highlights additional sub-analyses from the CHAMPION clinical trial that consistently show that PA pressure-guided therapy reduces HF hospitalizations in patients with common HF comorbidities. Table 1 summarizes the rate of HF hospitalizations across the different studies.

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>N size (control)</th>
<th>N size (treatment)</th>
<th>HF hospitalization rate reduction at 15 months in treatment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of myocardial infarction$^{24}$</td>
<td>137</td>
<td>134</td>
<td>46% (p &lt; 0.001 vs. control)</td>
</tr>
<tr>
<td>COPD$^{25,26}$</td>
<td>96</td>
<td>91</td>
<td>41% (p = 0.0009 vs. control)</td>
</tr>
<tr>
<td>Pulmonary hypertension$^{27}$</td>
<td>163</td>
<td>151</td>
<td>36% (p = 0.0002 vs. control)</td>
</tr>
<tr>
<td>AF$^{28}$</td>
<td>135</td>
<td>120</td>
<td>41% (p &lt; 0.0001 vs. control)</td>
</tr>
<tr>
<td>Chronic kidney disease$^{29}$</td>
<td>150</td>
<td>147</td>
<td>42% (p = 0.00001 vs. control)</td>
</tr>
</tbody>
</table>

Table 1. Patients with common HF comorbidities have consistent reduction in HF hospitalizations with PA pressure-guided therapy

Benefits of Pulmonary Artery Pressure Monitoring in Patients with NYHA Class III Heart Failure and Chronic Kidney Disease: Results from the CHAMPION Trial

- This subgroup data analysis from the CHAMPION clinical trial compared heart failure hospitalizations between Class III HF patients with chronic kidney disease (CKD) monitored (mean follow-up of 18 months) with pulmonary artery (PA) pressure (n = 150) to those managed with standard of care SOC (n = 147).
- When CKD patients were managed with PA pressures, heart failure hospitalization rates were significantly reduced (42%) compared to patients with CKD managed according to standard of care (0.48 vs. 0.83, HR 0.58, p < 0.001).
- Changes in CKD indicators (creatinine and GFR) were not adversely affected in the PA pressure monitored group.

Key takeaways:
- Chronic kidney disease in patients with HF is a frequent comorbidity that is associated with worse clinical outcomes, including higher HF hospitalization rates.
- For HF patients with CKD, pulmonary artery (PA) pressure monitoring reduced heart failure hospitalizations by 42% compared to standard of care HF management.
- Intensified HF medical therapy as a result of PA pressure monitoring was safe and did not adversely affect renal function.

The Utility of Remote Wireless Pulmonary Artery Pressure Monitoring in Patients with or without a History of Myocardial Infarction: Experience from the CHAMPION Trial
Strickland WL, et al. JACC 2011.$^{24}$

- This sub-analysis of the CHAMPION clinical trial determined if PA pressure monitoring affected the clinical outcomes of patients with and without a history of myocardial infarction (MI).
- 271 of the 550 NYHA Class III HF patients enrolled in the CHAMPION clinical trial had a history of MI and were randomized to either the control (n = 137) or treatment (n = 134) groups.
- At 6 months, there was a 2.2-day benefit of days alive outside the hospital for patients in the treatment group; at 15 months, this increased to 30.1 days.

Key takeaway:
- At 6 months and for the full study duration (mean 15 months), remote PA pressure monitoring had a significant reduction in HF hospitalizations for patients with and without a history of MI in the treatment group versus control (see Table 2).

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>RRR at 6 months for treatment group</th>
<th>RRR at 15 months for treatment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of MI</td>
<td>30% (p &lt; 0.0039 vs. control)</td>
<td>46% (p &lt; 0.0001 vs. control)</td>
</tr>
<tr>
<td>No MI</td>
<td>25% (p = 0.016 vs. control)</td>
<td>23% (p = 0.021 vs. control)</td>
</tr>
</tbody>
</table>

Table 2. Relative Risk Reduction of HF Hospitalizations
Impact of Wireless Implanted Pulmonary Artery Pressure Monitoring System in Heart Failure Patients with Comorbid Chronic Obstructive Pulmonary Disease


- The purpose of this CHAMPION clinical trial sub-analysis was to evaluate if PA pressure-guided therapy reduced HF hospitalizations in a cohort of patients with comorbid chronic obstructive pulmonary disease (COPD, n = 187).
- Reductions in PA pressure were analyzed using an area under the curve (AUC) methodology.
- There was an overall reduction in PA pressures: patients in the treatment group (n = 91) had an average AUC reduction of 202 mmHg days compared to the increase of 107 mmHg days in the control group (n = 96, p = 0.03).

Key takeaway:
- At 15 months, there was a 41% reduction in HF hospitalization rates in the treatment group vs. control (0.55 vs. 0.96, HR 0.59, 95% CI 0.44-0.81, p = 0.0009).

Respiratory Event Hospitalizations are Reduced in Heart Failure Patients with Comorbid Chronic Obstructive Pulmonary Disease Using a Wireless Implanted Pulmonary Artery Pressure Monitoring System


- This study determined if PA pressure monitoring impacts the number of respiratory event hospitalizations (REH) in HF patients with a medical history of COPD (n = 187).

Key takeaway:
- At 15 months, patients in the treatment group (n = 91) had a 62% reduction in REH (0.12 vs. 0.31, HR 0.38, 95% CI 0.21-0.71, p = 0.0023).

Heart Failure Hospitalizations are Reduced in Heart Failure Patients with Comorbid Pulmonary Hypertension Using a Wireless Implanted Pulmonary Artery Pressure Monitoring System


- This CHAMPION clinical trial sub-analysis evaluated the effect of PA pressure monitoring in HF patients with comorbid pulmonary hypertension (PHTN, mean PA pressure > 25 mmHg).
- A total of 314 out of the 550 patients from the CHAMPION clinical trial also exhibited PHTN.
- Patients in the PHTN cohort were further stratified by transpulmonary gradient (TPG) and pulmonary vascular resistance (PVR).
- 67% (213/314) of PHTN patents had a TPG ≤ 15.

Key takeaways:
- At 15 months, patients in the treatment group had a 51% reduction in HF hospitalization vs. control (0.60 vs. 0.94, HR = 0.64, 95% CI 0.51-0.81, p = 0.0002).
- PHTN patients in the treatment group with TPG > 15 had 30% reduction in HF hospitalization vs. control (p = 0.08).
Limitations of Right Heart Catheterization in the Diagnosis and Risk Stratification of Patients with Pulmonary Hypertension: Insights from the CHAMPION Trial

- This CHAMPION sub-study compared the use of the CardioMEMS HF System with right heart catheterization (RHC) to diagnose and stratify risk in patients with pulmonary hypertension (PH).
- RHC identified 320 patients with PH (defined as mean PA pressure > 25 mmHg) and among these patients mean PA pressure obtained from RHC was similar to the CardioMEMS HF System’s first week PA pressure.
- RHC also identified 217 patients without PH (defined as mean PA pressure readings ≤ 25 mmHg) and 51% of them met this definition according to data obtained from the CardioMEMS HF System (18.5 for the RHC vs. 18.4 for the CardioMEMS HF System, p = 0.9208).
- The other 49% of patients identified by RHC as not having PH had first week mean PA pressure readings > 25 mmHg with the CardioMEMS HF System, indicating PH.
- Among the 217 patients using the CardioMEMS HF System diagnosed by RHC as non-PH, the 49% with first week mean PA pressure reading > 25 mph had significantly higher HFH rates than the 51% of patients with readings ≤ 25 mmHg (0/49 vs. 0.25/yr., p = < 0.0001).

Key takeaways:
- This analysis suggests that using RHC alone may result in PH underdiagnoses in patients with HF.
- In this study, the more frequent PA pressure monitoring with the CardioMEMS HF System provided better diagnostic and risk stratification compared with single RHC.

Impact of Remote, Wireless Pulmonary Artery Hemodynamic Monitoring in Patients with Atrial Fibrillation and Chronic Heart Failure: Insights from the CHAMPION Trial
Miller AB, et al. JACC, 2012.28

- This CHAMPION clinical trial sub-analysis compared the baseline characteristics and impact of PA pressure-guided therapy on hospitalization rate in patients with a history of atrial fibrillation (AF, n = 255) compared to those with normal sinus rhythm (n = 200).
- The AF cohort had significant baseline differences compared to the sinus rhythm cohort (older: 65 vs. 59, more often male: 80% vs. 66%, more frequently had CRT or CRT-D devices: 44% vs. 27%, higher mean PA pressures: 30.2 vs. 28.5 mmHg, etc.).

Key takeaways:
- AF patients in the treatment group had a significantly lower HF hospitalization rate than those in the control group at 6 months (37%, p = 0.0004) and 15 months (41%, p < 0.0001).
- AF patients had a 57% higher HF hospitalization rate vs. non-AF patients (0.47 vs. 0.30 events/patient, p < 0.0001).

A Wireless Hemodynamic Pressure Sensor Before and After Ventricular Assist Device Placement: A Sub-Study of the CHAMPION Trial

- This sub-analysis of the CHAMPION clinical trial evaluated the effect of PA pressure-guided therapy on optimizing medications, pump parameters and timing of ventricular assist device (VAD) intervention and transplantation in patients receiving a left ventricular assist device (LVAD) (n = 27).

Key takeaway:
- LVAD patients who received PA pressure-guided therapy (15/27 patients) had significantly shorter times to VAD intervention (p = 0.001), more changes to medical therapy based on hemodynamic information (p = 0.025), and shorter times between VAD intervention and heart transplantation (p = 0.001).
PA PRESSURE MONITORING ENABLES PROACTIVE AND PERSONALIZED GUIDANCE OF MEDICATION MANAGEMENT IN HF PATIENTS

Medication management is a challenging aspect in the overall treatment strategy for chronic HF patients. The range of effective medication doses for each patient varies widely and may change frequently over the course of treatment. The following sub-analyses show that PA pressure monitoring may provide early and reliable assessment of volume status and feedback on treatment response, enabling clinicians to tailor optimal medication strategies for patients suffering from chronic HF.

Medical Management Guided by Pulmonary Artery Pressures in NYHA Functional Class III Heart Failure Patients

- This CHAMPION clinical trial sub-analysis closely compared the medical management strategy of the treatment and control groups.
- By 6 months, dosage increases of ACE/ARB, beta blockers and nitrates were greater in the treatment group than in the control group (0.11 vs. 0.00 change in fraction of maximal dose for ACE/ARB, p = 0.0042; 0.07 vs. 0.01 change in fraction of maximal dose for beta blockers, p = 0.0481; 17.5 mg vs. 3.7 mg dosage change for nitrates, p = 0.0422).
- Although diuretics were the most frequently adjusted drugs, at 6 months the total diuretic dose was similar between groups (p = 0.1214).

Key takeaways:
- The PA pressure-guided management required < 1 incremental medication changes per patient per month (1.55 vs. 0.65 changes/patient/month, p < 0.0001).
- The decreased HF hospitalization rate in the treatment group may be due to proactive titration of medical therapy guided by PA pressure measurements provided by the CardioMEMS HF System.

Diuretic Use Guided by a Wireless Implanted Pulmonary Artery Pressure Monitoring System in NYHA Class III Heart Failure Patients: Observations from the CHAMPION Trial

- This CHAMPION clinical trial sub-analysis study determined if adjustments to diuretic therapy in response to wireless PA pressure monitoring were associated with reduced HF hospitalization rates (n = 550).
- At baseline, a similar percent of HF patients in control (n = 280) and treatment (n = 270) groups were receiving diuretics (91.9% and 94.2%, respectively).
- At 6 months, diuretics were more frequently adjusted in the treatment group than the control group (1,267 vs. 498 times, p < 0.0001).
- 49.7% (629/1267) of the adjustments in 57.4% (155/270) of the patients resulted from detection of increasing PA pressures.
- 75.4% (107/142) of the changes in 17% (46/270) of those patients occurred after detection of declining PA pressures.
- The 89 treatment patients with increased loop diuretic dose had a lower rate of HF hospitalizations than the 68 control patients with similarly increased diuretic doses (0.32 vs. 0.70, p = 0.0014).
- HF hospitalization rates were similar in the 134 treatment and 173 control patients without diuretic dose changes (0.28 vs. 0.27, p = NS).

Key takeaway:
- Wireless, remote PA pressure monitoring enables physicians to effectively increase and decrease diuretic doses in HF patients, resulting in reduced HF hospitalization rates.
Data analysis from the CHAMPION clinical trial during the 6-month primary endpoint period

- 550 Patients: 270 in the Treatment group and 280 in the Control group.

All interventions for patients in the PA pressure-managed group were characterized prospectively by investigators as triggered primarily by clinical findings OR by changes in PA pressure.

- HF hospitalization rates were lowest in patients for whom all diuretic interventions were triggered by PA pressure (.39 events/patient year), despite this cohort having the highest baseline PA pressure (see Figure 6).

There was a statistically significant 67% relative risk reduction of HF hospitalizations if a patient’s diuretic management therapies were managed by:

- PA pressure only compared to clinical signs (67% reduction), or
- PA pressure and clinical signs compared to clinical signs (46% reduction).

- Heart failure hospitalization rates were most effectively reduced by a management strategy based on PA pressures without reliance upon clinical changes.
- This supports the strategy of early intervention prior to clinical signs to avert clinical decompensation and heart failure readmissions.1,2

**Figure 6.** HF hospitalization Rates by Diuretic Management Strategy

**67% Reduction**

<table>
<thead>
<tr>
<th>Managed Patients vs. Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>(HR 0.33, 95% CI 0.16-0.59, p = 0.0007)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>HF Hospitalization Rate (events/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group (Clinical Triggered Rx Only)</td>
</tr>
<tr>
<td>PAP Managed Patients (Clinical Triggered Rx Only)</td>
</tr>
<tr>
<td>PAP Managed Patients (Clinical and PAP Triggered Rx)</td>
</tr>
<tr>
<td>PAP Managed Patients (PAP Triggered Rx Only)</td>
</tr>
</tbody>
</table>

Baseline PA Mean:
- Control Group = 30.0 mmHg
- PAP Managed Patients = 30.5 mmHg
- PAP Managed Patients = 29.0 mmHg
- PAP Managed Patients = 32.0 mmHg

*p = 0.05 vs. Control Patients (unmonitored)
References


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Rx Only

Brief Summary: Prior to using these devices, please review the Instructions for Use for a complete listing of indications, contraindications, warnings, precautions, potential adverse events and directions for use.

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