CardioMEMS™ HF System

PA Sensor and Delivery System

Model CM2000

User's Manual

ST. JUDE MEDICAL

- Do not attempt to use the device before also reading and fully understanding the System Guide.
- Carefully inspect all product packaging for damage or defects prior to use. Do not use product if you see any indication of damage or breach of the sterile barrier.
- This device is supplied sterile for single use only. After use, dispose of the Delivery System. Do not resterilize.
- Caution: Federal (U.S.) law restricts this device to sale by or on the order of a physician.

Contents

Description

The CardioMEMS™ HF System provides pulmonary artery (PA) hemodynamic data used for the monitoring and management of heart failure (HF) patients. The system measures changes in PA pressure which physicians use to initiate or modify heart failure treatment.

The system includes the following components:

- Implantable wireless sensor with delivery catheter
- Patient or Hospital Electronics System
- Patient database

The wireless sensor is designed for permanent implantation into the distal pulmonary artery. Once implanted, the CardioMEMS PA Sensor provides non-invasive hemodynamic data that is collected in the physician's office, clinic, hospital, or the patient's home. The data provided by the system includes:

- PA pressure waveform
- Systolic, Diastolic, and Mean PA pressure
- Heart Rate

This hemodynamic data is transmitted to a secure website that serves as the patient database so that PA monitoring information is available at all times through the Internet. Changes in PA pressure can be used in conjunction with heart failure signs and symptoms to guide adjustments to medications.

For information on the operation of the CardioMEMS HF System, please refer to the System Guide. For information on operation of the patient database, please refer to the Merlin.net™ Patient Care Network Heart Failure Management Application Help manual. For clinical study information, please refer to that section of this guide.

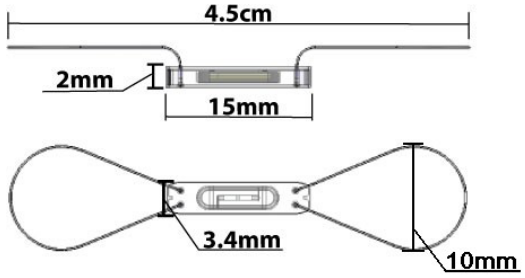


Figure 1. PA Sensor

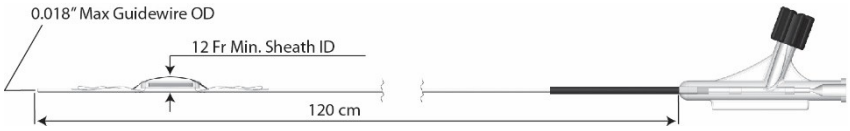


Figure 2. PA sensor and delivery system

Table 1. Device model numbers

Device	Model number
PA Sensor and Delivery System	CM2000
Patient Electronics System	CM1100
Hospital Electronics System	CM3000

Indications

The CardioMEMS™ HF System is indicated for wirelessly measuring and monitoring pulmonary artery pressure and heart rate in NYHA Class II or III heart failure patients who either have been hospitalized for heart failure in the previous year and/or have elevated natriuretic peptides. The hemodynamic data are used by physicians for heart failure management with the goal of controlling pulmonary artery pressures and reducing heart failure hospitalizations.

Contraindications

The CardioMEMS™ HF System is contraindicated for patients with an inability to take dual antiplatelet or anticoagulants for one month post implant.

Clinical Considerations for Patient Selection

An elevated natriuretic peptide level is defined as an NT-proBNP level ≥ 1000 pg/ml or a BNP level ≥ 250 pg/ml. Thresholds are dependent on left ventricular ejection fraction and body mass index, using a 4%[1] reduction per BMI unit over 25 kg/m², as listed in the table below.

Table 2. NT-proBNP and BNP Thresholds According to LVEF and BMI

BMI (kg/m²)	NT-proBNP Threshold (pg/ml)		BNP Threshold (pg/ml)	
	LVEF ≤ 40%	LVEF > 40%	LVEF ≤ 40%	LVEF > 40%
≤ 25	1000	700	250	175
26	955	668	238	167
27	911	638	227	159
28	870	608	216	151
29	830	581	206	144
30	792	554	197	137
31	756	529	187	130
32	722	504	178	124
33	689	481	170	118
34	657	459	162	112
35	627	438	154	107
36	599	418	147	101
37	571	399	140	96
38	545	380	133	92
39	520	363	126	87
40	496	346	120	83
41	473	330	114	79
42	452	315	109	75
43	431	300	103	71
44	411	286	98	67
45	392	273	94	64
46	374	260	89	60
47	357	248	84	57
48	340	236	80	54
49	324	225	76	51
50	309	215	72	49

The following patients may not be appropriate for implantation of the CardioMEMS™ HF System:

- Patients with an active infection.
- Patients with a history of recurrent (>1) pulmonary embolism or deep vein thrombosis
- Patients unable to tolerate a right heart catheterization (RHC).
- Patients with a Glomerular Filtration Rate (GFR) <25 ml/min who are non-responsive to diuretic therapy or who are on chronic renal dialysis.
- Patients with congenital heart disease or mechanical right heart valve(s)
- Patients with known coagulation disorders.
- Patients with a hypersensitivity or allergy to aspirin, and/or clopidogrel.
- Patients who have undergone implantation of a Cardiac Resynchronization Device (CRT) within the past 3 months.
- If the patient's BMI is greater than 35, measure the patient's chest circumference at the axillary level. If the chest circumference is >165 cm, sensor implantation should not occur.

1. Frankenstein L, Remppis A, Nelles M, Schaelling B, Schellberg D, Katus H, et al. Relation of N-terminal pro- brain natriuretic peptide levels and their prognostic power in chronic stable heart failure to obesity status. Eur Heart J. 2008;29(21):2634-40.

Warnings

Before use of the system, read and understand the instructions for use contained in this manual and in the System Guide.

- Read this manual thoroughly before using the system to avoid potential patient injury or death.
- Only trained personnel should use this product.
- The implant procedure must be performed by personnel with the appropriate clinical skills and infrastructure to support right heart catheterizations and endovascular device placement and deployment over a guidewire.
- The PA Sensor and Delivery System is for single use only. Do not reuse, reprocess, or resterilize. Reuse, reprocessing, or resterilization may compromise the structural integrity of the device and/or lead to device failure which, in turn, may result in patient injury, illness, or death. Reuse, reprocessing, or resterilization may also create a risk of contamination of the device and/or cause patient infection or cross-infection, including, but not limited to, the transmission of infectious disease(s) from one patient to another. Contamination of the device may lead to injury, illness, or death of the patient.
- The implant procedure must be performed under fluoroscopic guidance.
- Do not use a guidewire with a preformed J-shaped tip for sensor delivery. The preformed J-shaped tip may pull the sensor proximally during guidewire retraction.
- The patient's PA vessel inner diameter must be >7 mm at the site of device implant.
- Following device implantation, all subsequent right heart catheterizations must be performed under fluoroscopic guidance. Without fluoroscopy, there could be inadvertent entanglement between the pulmonary artery catheter and the device.

Precautions

- Only authorized personnel should use this device.
- The delivery system should only be used with a guidewire. Do not aspirate or infuse through the delivery system guidewire lumen during use.
- Follow standard procedure for catheterization of patients receiving anticoagulation therapy. An INR of <1.5 is recommended prior to RHC (Right Heart Catheterization) and implant if patient is on anticoagulant therapy.
- Protect the sensor from surface contamination once removed from the sterile package. Ensure that either talc-less gloves are used for the implantation procedure or rinse all talc from the gloves with sterile saline prior to handling.
- If the hub detaches from the catheter during removal, retract the catheter by holding the shaft.
- Accuracy of the CardioMEMS™ HF System is affected by a change in body temperature (-1 mm Hg/ΔºC).
- Accuracy of the CardioMEMS HF System is slightly affected by large changes in elevation between the initial baseline calibration and subsequent measurements. (+2 mmHg/305 meters elevation change).
- An accurate right heart catheterization is required to set system baseline (mean pressure).
- If a patient has a sensor implanted and another member of the same household is scheduled to have a sensor implanted, contact Technical Support prior to the second patient's implant procedure.
- The mean pressure measurement accuracy of the system may be affected by various factors. Mean pressure measurement error has been observed when the sensor was deployed in a vessel which had an inner diameter of less than 7 mm, and in cases where there was an acute bend in the vessel of >30 degrees at the location of the sensor. Signs of mean pressure measurement error include the following:
  - Gradual mean pressure changes without a corresponding proportional change in the pulse pressure (systolic-diastolic pressure)
  - Negative mean pressures

  If either feature is observed, temporarily suspend use of the pressure information for management of the patient and contact Technical Support for further assistance. A right heart catheterization may be needed to recalibrate the Baseline (mean pressure) in order to continue use of the system.
- Patients who are currently on chronic anticoagulant therapy should restart treatment after sensor implantation. Patients who are not currently being treated with chronic anticoagulant therapy should be placed on aspirin (81 mg or 325 mg) and clopidogrel (75 mg) daily for one month following the procedure. After one month, the patient should continue aspirin therapy.
- Patients with a reduced ejection fraction should be on stable AHA/ACC guidelines based medical therapy prior to implant.
- The PA Sensor is a permanent implant. The sensor does not have any batteries that require replacement or any components that will wear or fail over time. Removal after implantation is not recommended. No circumstances where the sensor needs to be removed have been identified and no sensors were removed during the CHAMPION trial, the CardioMEMS US Post-Approval Study, or the GUIDE HF trial. The sensor should be retrieved by using standard intra-vascular and surgical procedures as would be used for other vascular implants if required.
- If there is evidence of a change in device performance, contact Technical Support for additional information.
- PA Sensor function is unaffected after temporary exposure up to 2 Atmospheres Absolute (ATA) pressure. Follow the contact process under Technical Support for additional information if the patient will have hyperbaric chamber exposure or is planning to scuba dive.
- Pacemakers, ICDs, and Ventricular Assist Devices (VADs) can work in conjunction with the PA Sensor and will

not affect the performance of the system. Several medical procedures can also be performed while the sensor is implanted if precaution is taken to avoid direct contact with the sensor. These procedures include radio-frequency ablation, ionizing radiation, and diagnostic ultrasound. The effects of therapeutic ultrasound have not been determined. If therapeutic ultrasound is required, avoid contact with the sensor.

MRI Information

MR Conditional

Non-clinical testing demonstrated that the sensor is MR Conditional. A patient with this device can be scanned safely immediately after implantation under the following conditions:

- Static magnetic field of 1.5 or 3.0 Tesla
- Maximum spatial gradient magnetic field of 720-Gauss/cm (7200-mT/m) or less

In non-clinical testing, the CardioMEMS™ PA Sensor produced the temperatures in the table below during MRI performed for 15 minutes of scanning (per pulse sequence) in the 1.5-Tesla/64-MHz[1] and 3-Tesla/128-MHz[2] MR systems. These temperature changes will not pose a hazard to the patient under the conditions indicated.

Table 3. MRI Related Heating

	1.5-Tesla	**3-Tesla**
MR system reported whole body averaged SAR	2.9-W/kg	2.9-W/kg
Calorimetry measured values, whole body averaged SAR	2.1-W/kg	2.7-W/kg
Highest temperature change	1.9°C	2.3°C

MR image quality may be compromised if the area of interest is in the same area or relatively close to the position of the sensor. Selecting optimal MR imaging parameters to compensate for the presence of the sensor may be necessary. The maximum artifact size (as seen on the gradient echo pulse sequence) extends approximately 5 mm relative to the size and shape of the sensor.

Table 4. Artifact Information

Pulse sequence	**T1-SE**	**T1-SE**	**GRE**	**GRE**
Signal void size	305-mm^2	34-mm^2	645-mm^2	101-mm^2
Plane orientation	Parallel	Perpendicular	Parallel	Perpendicular

Explant and Disposal

The sensor does not require removal before cremation. Do not implant an explanted sensor in another patient as sterility, functionality, and reliability cannot be ensured.

Potential Adverse Events

Potential adverse events associated with the implantation procedure include, but are not limited to the following:

- Air embolism
- Allergic reaction due to device component materials or procedure related
- Infection
  - Upper respiratory infection
  - Bronchitis
  - Pneumonia
  - Acute Bronchitis
  - Groin abscess
  - Methicillin-resistant staphylococcal aureus infection
  - Pulmonary Infiltration
  - Sepsis
- Delayed wound healing
- Arrhythmias
  - Ventricular tachycardia
  - Atrial fibrillation
  - Ventricular arrhythmia

1. Magnetom, Siemens Medical Solutions, Malvern, PA. Software Numaris/4, Version Syngo MR 2002B DHHS Active-shielded, horizontal field scanner
2. Excite, HDx, Software 14X.M5, General Electric Healthcare, Milwaukee, WI

    - Ventricular fibrillation
    - Atrial fibrillation with rapid ventricular response
    - Atrial flutter
    - Cardiac dysrhythmias
    - Tachycardia
    - Wide complex tachycardia
    - Atrial dysrhythmia
- Bleeding
    - Epistaxis/Nose bleeds
    - GI bleed
    - Bleeding – Other
    - Blood in stool
    - Catheter site bleeding
    - Catheter site ecchymosis
    - Hematuria
- Hemoptysis
- Hematoma (Bruising)
- Hematoma
    - Catheter site hematoma
    - Vessel puncture site hematoma
- Nausea
- Cerebrovascular accident
    - Stroke/Transient ischemic attack
- Thrombus
    - Arterial thrombosis (limbs)
    - Blood clot
- Cardiovascular Injury
    - Valve damage
    - Pseudoaneurysm formation
    - AV Fistula
    - Pulmonary artery injury
- Myocardial infarction (Heart attack)
- Death
- Embolism
    - Pulmonary infarct
    - Pulmonary embolism
    - Device embolization
- Thermal Burn
- Cardiac Perforation
- Pneumothorax, thoracic duct injury, or hemothorax

Instructions for Use

Personnel Training

Implanting physicians are required to have successfully completed additional training in the use of the PA Sensor and Delivery System prior to implant.

Accessories

The accessories required to implant the device and set the sensor's PA pressure baseline are listed in the following table. These accessories are not packaged with the device.

Table 5. Accessories

Item	Specifications
Vascular Access Kit	12 Fr Introducer sheath and dilators with access guidewire
PA Catheter	110 cm length

Sensor Delivery Guidewire	0.018” x 260-300 cm fixed core guidewire with straight or angled tip (no J-tip)

In addition to the specified accessories, the following catheter lab equipment and supplies are required to implant and set the sensor’s PA pressure baseline:

- Fluoroscope with digital angiography capabilities and ability to record and recall images (C-arm or fixed)
- Blood pressure monitoring equipment for a right heart catheterization procedure
- Saline solution
- Radiopaque contrast media

Package Inspection

Inspect the package carefully before opening and check the Use By date on the product label. Implant of the sensor is not recommended after its expiration date. If the integrity of the sterile package has been compromised, or the product or package is defective, do not use the product and contact Technical Support.

Package Contents

The sensor is packaged separately and supplied sterile. Packages contain:

- 1 PA Sensor and Delivery System
- 1 USB flash drive
- 1 temporary patient implant card
- Product documentation

Sterilization

The package contents have been sterilized with ethylene oxide before shipment. The system is for single use and is not intended to be resterilized. If the sterile package has been compromised, contact Technical Support.

Pre- and Post-Procedure Antiplatelet Regimen

Patients who are currently on anticoagulant therapy, or those in which chronic anticoagulant therapy is indicated for heart failure treatment, will restart treatment after sensor implantation. An INR of <1.5 is recommended prior to sensor implant for patients who were previously on anticoagulant therapy. Patients should discontinue use of anticoagulant therapy 1-2 days prior to sensor placement. The standard of care as bridge therapy to sensor placement should be used in patients who were on anticoagulant therapy.

Patients who are not being treated with chronic anticoagulant therapy should be placed on aspirin (81 mg or 325 mg) and clopidogrel (75 mg) daily for one month following sensor placement. After one month, the patient should continue with aspirin therapy only. It is important to resume or initiate antiplatelet or anticoagulant therapy following sensor implantation to reduce the likelihood of thrombotic events.

For patients at risk for gastrointestinal bleeding during the period in which dual antiplatelet therapy is given, the physician should consider a proton pump inhibitor. Patients at risk include the elderly or those with a history of gastroduodenal ulcers, GERD, esophagitis, intestinal polyps or cancer. Patients who smoke or who are using steroids or non-steroidal anti-inflammatory drugs may also be at risk.

Implantation Procedure

Hospital Electronics System Setup

To set up the Hospital Electronics System:

- Mount the external system on an IV pole.
- Position the IV pole near the head of the patient and on the same side as the implant site.
- Plug the power cord into a wall outlet.
- Insert the USB flash drive that came with the PA Sensor and Deliver System.
- Turn on the power to the system.
- Select New Implant.
- Either select or enter the patient information.
- Confirm that the sensor serial number displayed on the screen matches the number on the sensor product.
- Place the right and left ECG electrodes high on the shoulders and place the reference electrode below the chest. The leads should be routed away from the chest. ECG leads draped near the antenna or antenna cable can reduce sensor signal strength.

Right Heart Catheterization and Sensor Implant Procedure

- Gain percutaneous access to the left or right femoral vein or internal jugular vein.
- Introduce 12 Fr introducer sheath over a 0.035 mm guidewire.
- Remove the dilator and guidewire.

- Insert and advance the pulmonary artery (PA) catheter, with balloon inflated, until it reaches a wedge position in the lower lobe region of the left or right pulmonary artery.
- Measure PA and PA wedge pressure.
- Measure cardiac output (optional).
- Identify target implant site by angiogram through the PA catheter distal lumen (5 cc hand injection of radiographic contrast) with the balloon inflated. Care should be taken to verify balloon location and lack of over-wedging prior to contrast injection.

Target implant site criteria:

- Target implant vessel is within the lower lobe of either lung and the vessel is directed towards the feet and back.
- Vessel diameter is >7 mm and has <30 degree angulation where body of Sensor will be placed.
- Vessel diameter is 5–8 mm where the distal loop of Sensor will be placed. See the figure below.

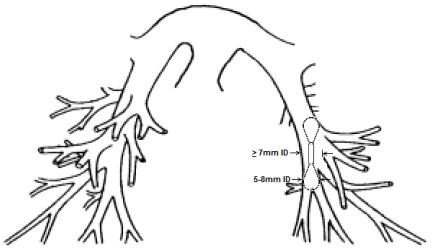


Figure 3. Target implant site

- Insert the sensor delivery guidewire through the PA catheter, across the target implant site.
- Retract and remove the PA catheter while maintaining the guidewire position.
- Remove the sensor from the package and flush the guidewire lumen with saline.
- Carefully swirl the distal end of the catheter (at least 20 cm from the tip) in a bowl of saline to activate the hydrophilic coating.
- Introduce the sensor delivery catheter over the guidewire through the sheath and into the deployment position at the target implant site.
- Release the sensor: Unscrew the cap on the delivery catheter hub, then retract and remove the wires from the catheter.
- Under fluoroscopic monitoring, slowly and gently retract and remove the delivery catheter while maintaining guidewire and sensor position. If resistance is encountered, do not forcibly retract the hub or catheter shaft.
- Insert the PA catheter over the guidewire into the main PA.
- Slowly remove the guidewire while maintaining sensor position.
- Position the PA catheter tip approximately 5-10 cm proximal to the sensor or within the opposite lung and measure PA pressure.
- Acquire the sensor signal using the Hospital Electronics System antenna placed under the patient's back, centered under the sensor position.
- Set Mean PA Pressure Baseline: Once a valid PA pressure waveform is observed on both the PA catheter and Hospital Electronics System displays, press the Set Pressure Baseline button on the Hospital Electronics System. Enter the mean PA pressure value measured by the PA catheter.
- Set Cardiac Output Baseline: Press the Set CO Baseline button on the Hospital Electronics System. Enter the Cardiac Output value which was measured by the PA catheter. (Optional)
- Press the Take Reading button to capture baseline reading(s).
- Remove antenna from under patient's back.
- Remove pulmonary artery catheter and introducer sheath.
- Close venous access site per standard of care.

Patient Identification Card

A temporary patient identification card is provided in the device packaging and should be given to the patient after implantation. Advise patients to keep this card in their possession at all times. A permanent card will be mailed to the patient within a few weeks after discharge.

Patient Counseling Information

Discuss these topics with patients prior to discharge:

- Signs and symptoms of infection
- Reporting symptoms
- EMI and RF Interference

Clinical Study Information

Introduction

Heart failure (HF) is a life-threatening condition with debilitating symptoms and is a burden to patients and their caregivers. Over 60 million people are estimated to be living with heart failure worldwide. It has been shown that pulmonary artery (PA) pressures begin to increase earlier than signs and symptoms of worsening heart failure (for example, weight gain or shortness of breath) and can provide a physiologic basis for heart failure patient management.

The CardioMEMS™ HF System provides a proven method for measuring PA pressure using a wireless pressure sensor implanted into the pulmonary artery. The CardioMEMS HF System provides clinicians with a patient's PA pressure while the patient is at home, without the need for a procedure or an office visit. This information allows the physician to manage the patient's heart failure proactively with the goal of controlling PA pressures and reducing heart failure hospitalizations.

GUIDE HF Trial – Randomized Arm

The applicant performed a clinical study in the US under IDE#G170258 to establish a reasonable assurance of safety and effectiveness of the CardioMEMS HF System to guide the treatment of patients with New York Heart Association (NYHA) Class II – IV heart failure. Data from this clinical study were the basis for the current PMA supplement approval decision. A summary of the clinical study is presented below.

Study Design

Patients were enrolled from 3/15/2018 to 12/20/2019. The database for the Panel Track Supplement reflected data collected through Jan 18, 2021 and included 1007 patients from 114 U.S. sites and 15 patients at 4 sites in Canada.

The study was a prospective, randomized, controlled, single-blind, multi-center, pivotal clinical trial. The study enrolled subjects with NYHA Class II, III, or IV heart failure and either elevated natriuretic peptides (N-terminal pro-B-type natriuretic peptide [NT-proBNP] or B-type natriuretic peptide [BNP]) and/or a prior HF hospitalization. All enrolled subjects underwent a right heart catheterization and implantation of a CardioMEMS device. Successfully implanted subjects were then randomized 1:1 to either hemodynamic-guided management using information provided by the CardioMEMS HF System (Treatment group) or heart failure management according to the standard of care (Control group). All patients took daily readings from home, but they were blinded to the treatment assignment or PA pressure measurements. Clinicians had access to pulmonary artery pressure information for patients in the Treatment group but not for patients in the Control group. Patient contacts were performed with scripted calls and equalized between two groups.

The study was evaluated for success based on the composite of HF hospitalization, urgent HF visits (emergency department or hospital outpatient visits for intravenous diuretic therapy), and all-cause mortality at 12 months. The study would be considered successful by demonstrating that the hemodynamic-guided HF treatment is superior to the control therapy for heart failure outcomes.

An independent Clinical Events Committee (CEC) provided blinded adjudication for all primary endpoint events. An independent Data Safety Monitoring Board (DSMB) oversaw clinical data and safety.

Clinical Inclusion and Exclusion Criteria

Enrollment in the GUIDE-HF Trial (Randomized Arm) was limited to patients who met the following inclusion criteria:

1. Diagnosis and treatment for HF (regardless of LVEF) for >90 days prior to the date of consent. Subjects should be on stable, optimally titrated medical therapy for at least 30 days, as recommended according to current AHA/American College of Cardiology (ACC) guidelines as standard-of-care for HF therapy in the United States, with any intolerance documented.
2. NYHA Class II, III or IV HF symptoms documented within 30 days prior to consent.
3. HFH within 12 months prior to consent and/or elevated NT-proBNP (or BNP) within 30 days prior to consent defined as:
    a. Subjects with LVEF ≤40%: NT-proBNP ≥1000 pg/ml (or BNP ≥250 pg/ml).
    b. Subjects with LVEF >40%: NT-proBNP ≥700 pg/ml (or BNP ≥175 pg/mL).
    c. Thresholds for NT-proBNP and BNP (for both LVEF ≤ 40% and LVEF >40%) will be corrected for BMI using a 4% reduction per BMI unit over 25 kg/m².[1]
4. ≥18 years of age
5. Chest circumference of <65 inches, if BMI is >35 kg/m²
6. Written informed consent obtained from subject

1. Thresholds for NT-proBNP and BNP (for both LVEF ≤ 40% and LVEF >40%) were corrected for BMI using a 4% reduction per BMI unit over 25 kg/m² per the Frankenstein equation.

7. Willing and able to upload PA pressure information and comply with the follow-up requirements

Patients were not permitted to enroll in the GUIDE-HF Trial (Randomized Arm) if they met any of the following exclusion criteria:

1. Intolerance to all neuro-hormonal antagonists (i.e., intolerance to angiotensin converting enzyme-inhibitors (ACE-I), angiotensin receptor blockers (ARB), angiotensin-neprilysin inhibitors (ARNi), and beta-blockers)
2. ACC/AHA Stage D refractory HF (including having received or currently receiving pharmacologic circulatory support with inotropes)
3. Received or are likely to receive an advanced therapy (e.g., mechanical circulatory support or cardiac transplant) in the next 12 months
4. NYHA Class IV HF patients with:
    a. Continuous or chronic use of scheduled intermittent inotropic therapy for HF and an INTERMACS level of ≤4, OR
    b. Persistence of fluid overload with maximum (or dose equivalent) diuretic intervention
5. Glomerular Filtration Rate (eGFR) <25 ml/min and non-responsive to diuretic therapy, or receiving chronic dialysis
6. Inability to tolerate or receive dual antiplatelet therapy or anticoagulation therapy for one month post-implantation
7. Significant congenital heart disease that has not been repaired and would prevent implantation of the CardioMEMS™ PA Sensor
8. Implanted with mechanical right heart valve(s)
9. Unrepaired severe valvular disease
10. Pregnant or planning to become pregnant in the next 12 months
11. An active, ongoing infection, defined as being febrile, an elevated white blood cell count, on intravenous antibiotics, and/or positive cultures (blood, sputum or urine).
12. History of current or recurrent (≥ 2 episodes) pulmonary emboli and/or deep vein thromboses
13. Major cardiovascular event (e.g., unstable angina, myocardial infarction, percutaneous coronary intervention, open heart surgery, or stroke, etc.) within 90 days prior to consent
14. Implanted with Cardiac Resynchronization Therapy (CRT)-Pacemaker (CRT-P) or CRT-Defibrillator (CRT-D) for less than 90 days prior to consent
15. Enrollment into another trial with an active treatment arm
16. Anticipated life expectancy of <12 months
17. Any condition that, in the opinion of the Investigator, would not allow for utilization of the CardioMEMS HF System to manage the subject using information gained from hemodynamic measurements to adjust medications, including the presence of unexpectedly severe pulmonary hypertension (e.g., trans-pulmonary gradient >15) at implant RHC, a history of non-compliance, or any condition that would preclude CardioMEMS PA Sensor implantation.

Follow-up Schedule

All randomized patients were scheduled to return for follow-up examinations at 6 and 12 months. Adverse events and complications were recorded at all visits.

The key time points are shown in Table 6 summarizing schedule of treatments and evaluations.

Table 6. Schedule of Treatments and Evaluations

Visit Trial Activity	Baseline (up to – 60 days)	Implant (time zero)	Prior to Discharge	Phone Contact[1] (Randomized Arm Only)	6 months (+/-14 days)	12 months (+/-30 days)
Informed Consent Process	X					
Assessment of Inclusion/ Exclusion Criteria	X					
Demographic Information	X					
Cardiovascular History	X					
BMI (and Chest Circumference if BMI >35kg/m^2)	X					
Limited Echo for EF (if no EF documented)	(X)					
EQ-5D-5L and KCCQ-12 Administration	X				X	X
Creatinine and Calculation of eGFR	X				X	X
NT-proBNP (or BNP)	X				X	X
Medication Review and Documentation	X		X		X	X
HF Exam (Including NYHA Assessment)	X				X	X
6MHW Test	X				X	X
CardioMEMS™ HF System Information		X				
Catheterization Laboratory PA Pressure Measurements		X				
Randomization (Randomized Arm Only[2])			X			
Subject Teaching / Compliance Assessment			X	X	X	X
Subject Contact Worksheet				X		
Medication Update Documentation		(X)	(X)	(X)	(X)	(X)
Reportable AEs	(X)	(X)	(X)	(X)	(X)	(X)
Protocol Deviation	(X)	(X)	(X)	(X)	(X)	(X)
Non-AE Device Issues		(X)	(X)	(X)	(X)	(X)
Death	(X)	(X)	(X)	(X)	(X)	(X)

(X) If applicable/as it occurs

1. All sites will be required to be in contact with each subject in the Randomized Arm (including subjects in the Treatment and Control Groups) at least once every two weeks during the first three months from the date of implantation and then at least once per month from three months to the 12 month follow-up visit.
2. Randomization should be completed as soon as possible but within 24 hours of implant, and prior to discharge.

Clinical Endpoints

With regards to effectiveness, the primary endpoint is a composite of the following:

- Hospitalization (≥ 24 hours) with the primary reason for admission being acute decompensated HF and intravenous administration of diuretic therapy
- An unscheduled or unplanned admission to the emergency department, hospital outpatient observation visit,

or hospital inpatient visit and intravenous administration of diuretic therapy

- All-cause mortality

With regards to safety, the secondary safety endpoint is freedom from Device or System Related Complications (DSRCs) at 12 months post-implantation.

DSRC was defined as an adverse event that was related to or possibly related to the system (wireless pressure sensor or external electronics) and had at least one of the following characteristics:

- Treated with invasive means (other than intramuscular medication or an RHC used for diagnostic purposes)
- Resulted in the death of the subject
- Resulted in the explant of the device

With regard to success/failure criteria, study success was defined as demonstrating superiority for the primary endpoint hypotheses below at a significance level of 2.5%:

H0: Hazard ratio (HR) for the Composite Endpoint at 12 months (Treatment to Control) ≥ 1

H1: HR for the Composite Endpoint at 12 months (Treatment to Control) <1

or

H0: $e^{\beta 1} \geq 1$

H1: $e^{\beta 1} < 1$

where e is the exponential function and β1 is the regression coefficient obtained from the covariate representing randomized group (Treatment or Control) in the Andersen-Gill model. Thus, the hazard ratio is the exponentiation of the regression coefficient for randomized group. This is equivalent to testing the regression coefficient against zero.

All randomized subjects were included in the analysis population.

Accountability of PMA Cohort

A total of 1022 patients were consented for trial enrollment and underwent a right heart catheterization and attempted implantation of a CardioMEMS™ device. Of these, 22 did not receive an implant, primarily due to anatomical/physiological conditions identified during the right heart catheterization. The observed PA sensor implant success rate was 97.8%. The remaining 1000 subjects who received a successful implant were randomized 1:1 to either the Treatment group (N = 497) or the Control group (N = 503). At the time of database lock, 854 (85.4%) randomized subjects completed the 12-month follow-up visit. Figure 4 summarizes the subject disposition in the PMA study.

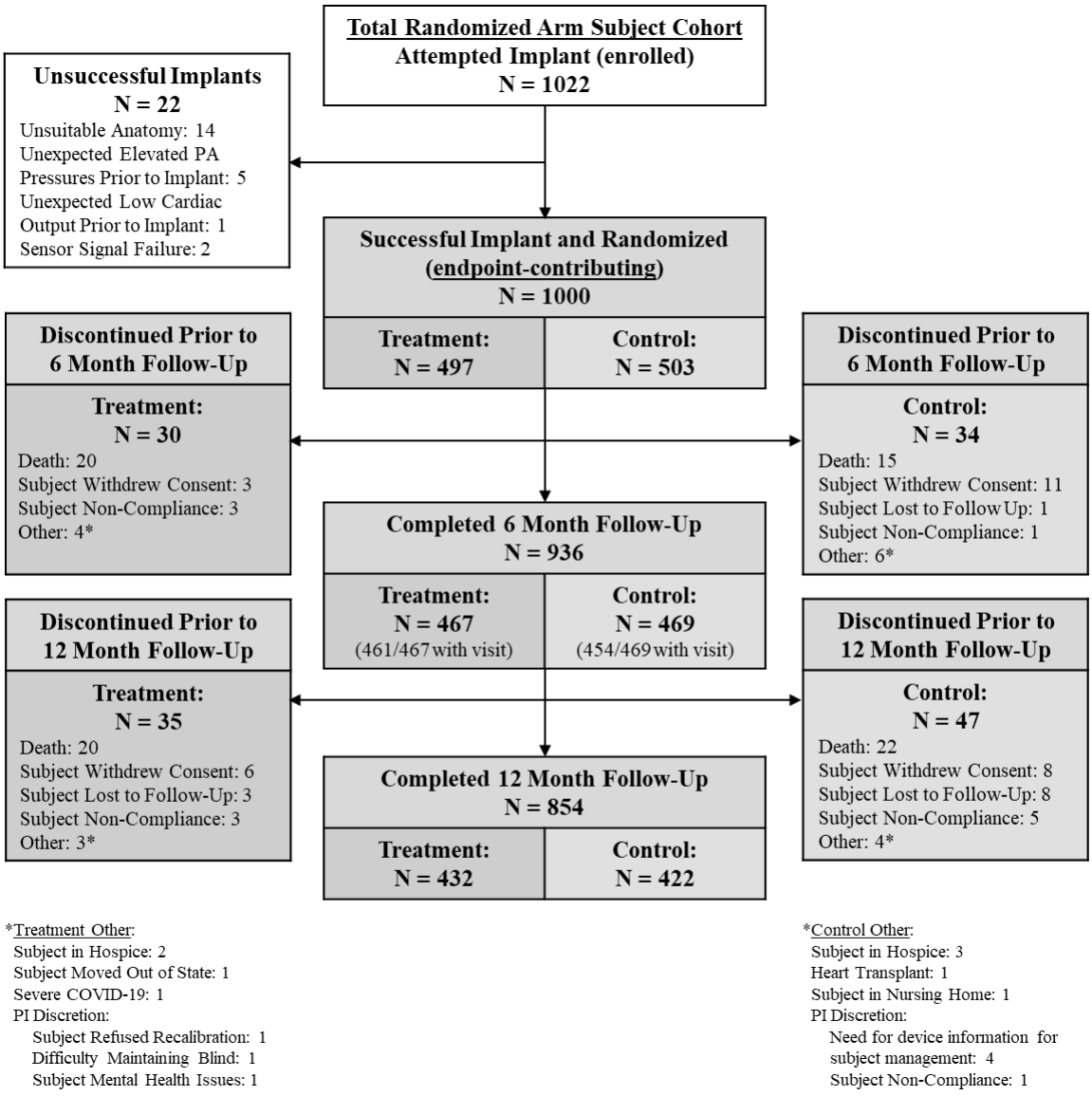


Figure 4. Subject Disposition

The protocol specified the following analysis populations:

Endpoint Analysis Population: All randomized subjects (N = 1000)

Safety Population: All enrolled subjects (N = 1022)

Study Population Demographics and Baseline Parameters

The demographics of the study population are typical for a heart failure study that enrolls NYHA Class II-IV patients in the US. The mean age was 69.2 ± 11 years and 37.5% were female. NYHA II, III, and IV patients account for 29.6%, 65.0%, and 5.4% of the randomized subjects. Table 7 presents the demographics and patient characteristics by randomized group. The Treatment and Control groups were balanced in all relevant demographics and baseline characteristics.

Table 7. Subject Demographics and Characteristics (Endpoint Analysis Population)

	Treatment (N=497)	Control (N=503)	p-value[1]
Age – year	69.2 ± 11.1 (497)	69.2 ± 11.0 (503)	0.8996
Female Sex	37.6% (187/497)	37.4% (188/503)	0.9480
Race			
White	81.1% (403/497)	80.5% (405/503)	0.8725
Black	17.5% (87/497)	18.5% (93/503)	0.7420
Asian	0.0% (0/497)	0.2% (1/503)	1.0000
American Indian or Alaskan Native	0.4% (2/497)	0.4% (2/503)	1.0000
Pacific Islanders	0.0% (0/497)	0.0% (0/503)	
Other	1.2% (6/497)	0.6% (3/503)	0.3389
Ethnicity			
Hispanic	3.2% (16/497)	3.4% (17/503)	1.0000
Non-Hispanic	96.0% (477/497)	96.0% (483/503)	1.0000
Unknown	0.8% (4/497)	0.6% (3/503)	0.7241
Body mass index – kg/m^2	32.9 ± 8.3 (497)	33.8 ± 8.4 (503)	0.0571
NYHA Class			
II	29.4% (146/497)	29.8% (150/503)	0.8900
III	64.8% (322/497)	65.2% (328/503)	0.8947
IV	5.8% (29/497)	5.0% (25/503)	0.5778
Medical History			
Ischemic etiology	41.6% (207/497)	37.8% (190/503)	0.2198
Previous myocardial infarction	29.0% (144/497)	31.4% (158/503)	0.4093
Previous percutaneous coronary intervention	33.2% (165/497)	31.4% (158/503)	0.5885
Previous coronary artery bypass grafting	27.2% (135/497)	27.0% (136/503)	1.0000
Diabetes	48.9% (243/497)	51.9% (261/503)	0.3759
Cerebrovascular accident	13.3% (66/497)	12.9% (65/503)	0.9254
Atrial flutter or fibrillation	60.4% (300/497)	57.9% (291/503)	0.4404
Vital Signs and Hemodynamic Analyses			
Heart rate – bpm	73.8 ± 12.5 (497)	74.2 ± 12.3 (503)	0.7438
Systolic blood pressure – mmHg	121.6 ± 19.1 (497)	120.8 ± 18.1 (503)	0.6134
Diastolic blood pressure – mmHg	69.2 ± 10.8 (497)	69.0 ± 10.8 (503)	0.7996
Left ventricular ejection fraction – %	39.4 ± 17.3 (497)	40.7 ± 16.9 (503)	0.1870
Left ventricular ejection fraction >40%	45.1% (224/497)	48.7% (245/503)	0.2546
Pulmonary artery systolic pressure –mmHg	44.9 ± 13.9 (497)	45.2 ± 14.6 (503)	0.9194
Pulmonary artery diastolic pressure –mmHg	18.9 ± 8.0 (497)	18.8 ± 7.7 (503)	0.8203
Pulmonary artery mean pressure –mmHg	29.2 ± 9.5 (497)	29.4 ± 10.0 (503)	0.9631
Pulmonary capillary wedge pressure –mmHg	17.3 ± 8.0 (495)	17.6 ± 7.9 (503)	0.6171
Cardiac output – L/min	4.83 ± 2.62 (497)	4.70 ± 1.46 (503)	0.8459
Cardiac index – L/min/m^2	2.27 ± 1.11 (497)	2.19 ± 0.63 (503)	0.4609

Table 7. Subject Demographics and Characteristics (Endpoint Analysis Population)

	Treatment (N=497)	Control (N=503)	p-value[1]
Ambulatory Hemodynamics during First Week			
Pulmonary artery systolic pressure –mmHg	46.3 ± 14.4 (497)	46.2 ± 13.3 (499)	0.7640
Pulmonary artery diastolic pressure –mmHg	22.4 ± 7.8 (497)	22.7 ± 7.4 (499)	0.4141
Pulmonary artery mean pressure –mmHg	31.8 ± 10.2 (497)	31.9 ± 9.6 (499)	0.6693
Heart rate – bpm	78.8 ± 11.7 (497)	79.4 ± 11.9 (499)	0.7893
Laboratory Analyses			
Serum creatinine level – µmol/L	128.5 ± 44.5 (495)	133.5 ± 48.5 (495)	0.1548
Estimated glomerular filtration rate – ml/min/1.73m^2	54.3 ± 21.3 (495)	52.8 ± 20.8 (494)	0.2469
B-type natriuretic peptide level – pg/m	520.7 ± 689.2 (261)	552.4 ± 954.0 (256)	0.8499
N-terminal pro-B-type natriuretic peptide level – pg/mL	2460 ± 3707 (219)	2183 ± 2803 (225)	0.5287
Treatment History			
Previous cardiac resynchronization therapy	28.6% (142/497)	32.4% (163/503)	0.1926
Previous implantation of defibrillator	42.9% (213/497)	40.8% (205/503)	0.5217
Guideline-Directed Medical Therapy			
ACE-Inhibitor or ARB or ARNi	64.2% (319/497)	63.6% (320/503)	0.8953
ARNi	29.2% (145/497)	27.6% (139/503)	0.6236
Beta Blocker	89.3% (444/497)	87.9% (442/503)	0.4873
Mineralocorticoid Receptor Antagonist	47.7% (237/497)	42.9% (216/503)	0.1440
Diuretic	95.4% (474/497)	95.0% (478/503)	0.8827
Hydralazine	16.3% (81/497)	15.9% (80/503)	0.9315
Nitrate	19.9% (99/497)	20.5% (103/503)	0.8749
SGLT2 Inhibitor	1.3% (2/152)	1.4% (2/140)	1.0000
Enrollment Type			
Heart failure hospitalization in year prior only	34.2% (170/497)	38.0% (191/502)	0.2114
Elevated natriuretic peptide level in 30 day prior only	46.3% (230/497)	42.2% (212/502)	0.2032
Heart failure hospitalization in year prior and elevated natriuretic peptide level in 30 day prior	19.5% (97/497)	19.7% (99/502)	0.9367
KCCQ-12 at Baseline – Overall Summary Score	54.9 ± 24.3 (494)	54.9 ± 23.8 (497)	0.8876
6MHW at Baseline – m	235.2 ± 120.2 (474)	229.6 ± 123.0 (482)	0.4459

Continuous Variables: Mean ± SD (n); Categorical Variables: Percent (n/N)

1. Continuous variables compared using Wilcoxon Rank Sum test, and categorical variables compared using Fisher's exact test.

Safety and Effectiveness Results

Effectiveness Results

Primary Endpoint

The primary endpoint analysis was based on all randomized subjects. At 12 months, there were 253 primary endpoint events in the Treatment group compared with 289 events in the Control group. The difference between the groups represented a non-significant 12% relative risk reduction in the primary endpoint events (0.563 vs. 0.640 events per patient-year; HR 0.88, 95% CI 0.74-1.05, p=0.1624). Since the 97.5% upper confidence bound of the hazard ratio was not less than 1, the primary endpoint was not met.

The table below presents the primary endpoint analysis and the components. There were 185 heart failure hospitalizations in the treatment group and 225 in the control group (0.410 vs. 0.497 events per patient; HR 0.83, 95% CI 0.68-1.01). The rates of urgent heart failure ED/outpatient visits or mortality were similar between the two groups.

The timing of the pivotal study overlapped with the COVID-19 pandemic. The effects of the pandemic on the study outcomes are further assessed in the sensitivity analysis section below.

Table 8. Primary Endpoint Analysis and Components

Endpoint[1]	**Treatment (N=497) Events (Rate**[2]**)**	**Control (N=503) Events (Rate**[2]**)**	**Hazard Ratio (95% CI) p-value**[3]
HF Hospitalization + ED/ OP + Death (Primary Endpoint)	253 (0.563)	289 (0.640)	0.88 (0.74, 1.05), p=0.1624
HF Hospitalization + ED/OP (Secondary Endpoint)	213 (0.474)	252 (0.557)	0.85 (0.70, 1.03), p=0.0958
HF Hospitalization	185 (0.410)	225 (0.497)	0.83 (0.68, 1.01)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	28 (0.065)	27 (0.063)	1.04 (0.61, 1.77)
Death	40 (0.094)	37 (0.086)	1.09 (0.70, 1.70)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date.
2. Event Rate is an annualized rate estimated from the Andersen-Gill model.
3. Hazard Ratio, 95% Confidence Interval, and p-value estimated from the Andersen-Gill model with robust sandwich variance estimates.

COVID-19 Impact Sensitivity Analysis

COVID-19 Sensitivity Analysis for Interaction

The COVID-19 pandemic occurred while the pivotal study was still ongoing. Across North America, hospitals saw notable reduction in heart failure hospital admissions during COVID-19 lockdowns. Using the national emergency declaration date (March 13, 2020) in the United States as the onset date, a total of 71.7% of follow-up had been completed prior to COVID-19. The median follow-up prior to COVID-19 was 8.4 months.

The applicant added a COVID-19 impact sensitivity analysis (dated July 7, 2020) to the statistical analysis plan prior to data unblinding. The sensitivity analysis would descriptively compare the primary endpoint event rates observed during subject follow-up occurring prior to the start of the COVID-19 pandemic to rates observed during subject follow-up occurring after the start of the pandemic to evaluate impact of COVID-19, as shown in Figure 5.

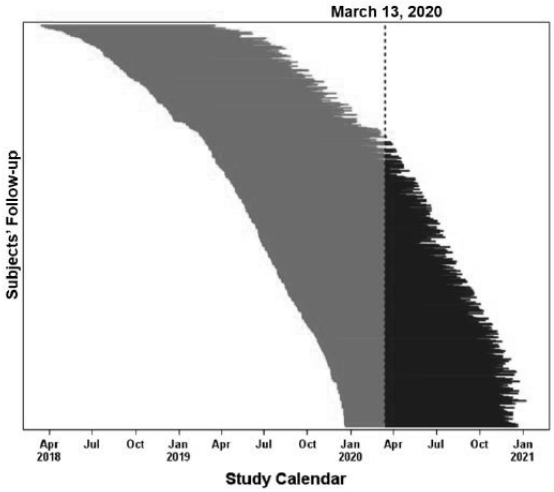


Figure 5. COVID-19 Impact Sensitivity Analysis

The sensitivity analysis demonstrated a qualitative interaction with a significant p-value of p=0.1129 (<p=0.15, pre-specified interaction p-value threshold), suggesting an impact of COVID-19 on the treatment effect observed in the Randomization Arm of the GUIDE-HF trial (Table 9). The hazard ratio for the primary endpoint events reversed from 0.81 prior to COVID-19 to 1.11 during COVID-19.

Table 9. Primary Endpoint – COVID-19 Impact Sensitivity Analysis

Endpoint[1]	Treatment (N=497) Events	Control (N=503) Events	Forest Plot	Hazard Ratio (95% CI)[2]
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)				**Interaction p-value[3]** p=0.1129
Prior to COVID-19[4]	177	224		0.81 (0.66, 1.00)
During COVID-19[4]	76	65	0.5 0.75 1 1.25 1.5 1.75	1.11 (0.80, 1.55)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date.
2. Contrast Hazard Ratio and 95% Confidence Interval estimated from the Andersen-Gill model with robust sandwich estimates.
3.Interaction p-value is a joint test on the interaction term of treatment group by COVID analysis time period.
4.Primary Endpoint events are analyzed through March 13, 2020 for Prior to COVID-19 and analyzed after March 13, 2020 for During COVID-19.

Since the COVID-19 sensitivity analysis suggested an effect of COVID-19 on the primary endpoint, the pre-pandemic data were further explored.

Pre-COVID-19 Analysis

Pre-pandemic Primary Endpoint Events

- Prior to COVID-19, there were a total of 177 primary endpoint events in the Treatment group compared with 224 events in the Control group (0.595 events vs. 0.730 events per patient, respectively). An HR of 0.81 (95% CI 0.66-1.00) for the primary endpoint, largely driven by a 27% reduction in risk for HFH, was observed.

The results of the analysis including data prior to COVID-19 only are shown in the table below:

Table 10. Primary Endpoint and Components – Including Data Prior to COVID-19 Only

Endpoint[1]	**Treatment (N=497) Events (Rate[2])**	**Control (N=503) Events (Rate[2])**	**Hazard Ratio (95% CI)[3]**
HF Hospitalization + ED/OP + Death (Primary Endpoint)	177 (0.595)	224 (0.730)	0.81 (0.66, 1.00)
HF Hospitalization + ED/OP (Secondary Endpoint)	147 (0.502)	199 (0.660)	0.76 (0.61, 0.95)
HF Hospitalization	124 (0.426)	176 (0.587)	0.73 (0.57, 0.92)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	23 (0.077)	23 (0.076)	1.02 (0.57, 1.82)
Death	30 (0.103)	25 (0.083)	1.24 (0.73, 2.10)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date. Primary Endpoint events are analyzed through March 13, 2020.
2. Event Rate is an annualized rate estimated from the Andersen-Gill model.
3. Hazard Ratio and 95% Confidence Interval estimated from the Andersen-Gill model with robust sandwich variance estimates.

Quality of Life Assessment and Functional Assessment (6MHW)

Health status changes over time were assessed by EuroQol 5-Dimension, 5-Level (EQ-5D-5L) Questionnaire and Kansas City Cardiomyopathy Questionnaire (KCCQ-12) at baseline, 6, and 12 months. While both Treatment and Control groups gained improvement at 6 months, there were no significant differences between the groups (Table 11).

The functional assessment of 6MHW distance did not show a significant improvement either within or between groups over the follow-up period.

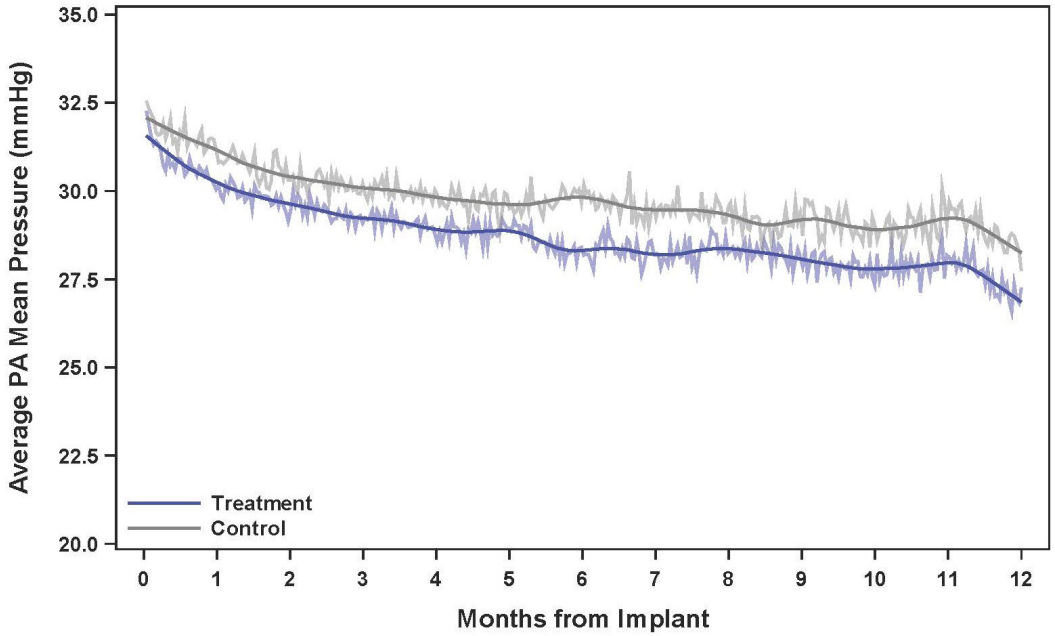
Table 11. KCCQ-12, EQ-5D-5L, and 6MHW

	6 Month Paired Change from Baseline			**12 Month Paired Change from Baseline**		
Component/ Analysis	**Treatment** Mean ± SD (n)	**Control** Mean ± SD (n)	Between Group p-value	**Treatment** Mean ± SD (n)	**Control** Mean ± SD (n)	Between Group p-value
KCCQ-12 Overall	7.44 ± 20.68 (449)	6.14 ± 24.72 (440)	0.3545[1]	5.20 ± 21.35 (421)	4.12 ± 22.50 (408)	0.4783[1]
Summary Score EQ-5D-5L Visual	3.09 ± 19.40 (449)	3.20 ± 21.69 (441)	0.9363[1]	0.94 ± 20,17 (421)	2.90 ± 20.71 (409)	0.1658[1]
Analogue Scale 6MHW Test Distance	0.01 ± 87.78 (332)	2.29 ± 93.69 (342)	0.7439[1]	-12.83 ± 100.08 (288)	-6.46 ± 106.57 (291)	0.4586[1]

1. Student-test comparing Treatment vs. Control change from baseline at 6 months and 12 months

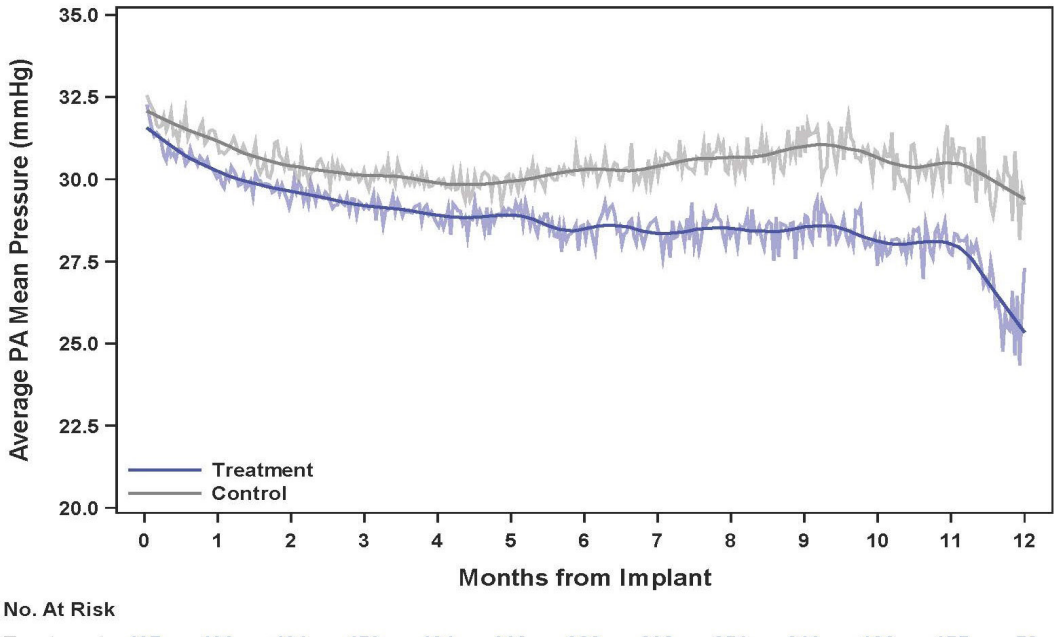
PA Pressures

A reduction in PA mean pressure over time was observed in the Treatment group compared to Control (-2.4 ± 5.2 mmHg vs. -1.7 ± 5.0 mmHg; Figure 6). A greater reduction in Treatment group PA mean pressure was also observed when limited to data prior to COVID-19 (-2.1 ± 4.8 mmHg vs. -1.4 ± 4.8 mmHg; Figure 7).



No. At Risk													
Treatment	497	496	491	486	480	473	468	465	456	447	441	422	193
Control	503	500	494	488	482	476	468	463	459	456	442	434	180

Figure 6. Average PA Mean Pressure Over Time



No. At Risk													
Treatment	497	496	491	459	404	360	328	290	251	216	182	155	58
Control	503	500	494	459	405	365	335	303	272	237	200	172	59

Figure 7. Average PA Mean Pressure Over Time – Data Prior to COVID-19 Only

Safety Results

Freedom from Device or System Related Complications (DSRC)

A total of 8 DSRC events occurred in 8 subjects in the safety population. The observed rate of freedom from Device or System Related Complications was 99.2% (1014/1022). None of the 8 DSRCs resulted in death or explant of the device, and most were vascular injury events due to vascular access or device implant. Table 12 presents a summary of DSRCs.

Table 12. Summary of DSRCs as Adjudicated by the CEC (Safety Population)

Cohort System Organ Class Preferred Term	Number of DSRCs	Proportion of Subjects with DSRCs	Treated with Invasive Means	DSRC Criteria Met	
				Resulted in Death	Resulted in Device Explant
Safety Population (N=1022)					
General Disorders and Administration Site Conditions	**5**	**0.49% (5/1022)**	**5**	**0**	**0**
Catheter Site Hematoma	1	0.10% (1/1022)	1	0	0
Catheter Site Hemorrhage	2	0.20% (2/1022)	2	0	0
Device Dislocation	1	0.10% (1/1022)	1	0	0
Device Malfunction	1	0.10% (1/1022)	1	0	0
Injury, Poisoning and Procedural Complications	**3**	**0.29% (3/1022)**	**3**	**0**	**0**
Arterial Injury	2	0.20% (2/1022)	2	0	0
Vascular Pseudoaneurysm	1	0.10% (1/1022)	1	0	0
Total	**8**	**0.78% (8/1022)**	**8**	**0**	**0**

Hospitalizations

Table 13 summarizes the all-cause hospitalizations reported during the 12-month follow-up for all randomized subjects. Treatment group experienced a lower all-cause hospitalizations rate comparing to the Control group (468 vs. 492) though similar proportion of subjects in each group had at least one hospitalization during the study.

Table 13. Summary of Hospitalizations as Adjudicated by the CEC (Endpoint Analysis Population)

	Treatment (N=497)		Control (N=503)	
Adjudicated Cause	**Count [Rate[1]]**	**Percent of Subjects with Event**	**Count [Rate[1]]**	**Percent of Subjects with Event**
Worsening heart failure	**233 [50.3]**	**27.4% (136/497)**	**269 [57.7]**	**30.4% (153/503)**
HF Hospitalization	185 [39.9]	24.1% (120/497)	225 [48.2]	27.6% (139/503)
Urgent HF Visit	28 [6.04]	4.4% (22/497)	27 [5.79]	5.0% (25/503)
Not a Protocol Defined HF Admission	20 [4.32]	3.4% (17/497)	17 [3.65]	3.0% (15/503)
Other cardiovascular	**200 [43.2]**	**27.4% (136/497)**	**186 [39.9]**	**25.0% (126/503)**
CABG	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Myocardial Infarction or Other Forms of Ischemic Heart Disease	26 [5.61]	4.0% (20/497)	46 [9.86]	7.6% (38/503)
Product Issue[2]	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Thrombosis or Thromboembolism	12 [2.59]	2.0% (10/497)	6 [1.29]	1.2% (6/503)
Valve Surgery	5 [1.08]	0.8% (4/497)	6 [1.29]	1.2% (6/503)
Ventricular or Atrial Arrhythmia	57 [12.3]	9.1% (45/497)	55 [11.8]	8.5% (43/503)
Other	99 [21.4]	14.7% (73/497)	72 [15.4]	11.9% (60/503)
Non-cardiovascular	**35 [7.55]**	**6.8% (34/497)**	**37 [7.93]**	**6.4% (32/503)**
Total	**468 [101.0]**	**47.1% (234/497)**	**492 [105.5]**	**46.5% (234/503)**

1. Rate is number of events per 100 subject years.
2. Hospitalization due to events related to the device.

Mortality

A total of 77 subjects died in the study. There were 40 (0.094) all-cause deaths in the Treatment group and 37 (0.086) all-cause deaths in the Control group. Table 14 presents the causes of deaths between the two groups per CEC adjudication.

Table 14. Summary of Deaths as Adjudicated by the CEC (Endpoint Analysis Population)

Adjudicated Cause	Treatment (N=497)	Control (N=503)
Cardiovascular	**6.0% (30/497)**	**4.8% (24/503)**
Cardiovascular procedure	0.2% (1/497)	0.0% (0/503)
Heart failure	3.4% (17/497)	3.0% (15/503)
Sudden cardiac death	2.2% (11/497)	1.8% (9/503)
Other	0.2% (1/497)	0.0% (0/503)
Non-cardiovascular	**1.6% (8/497)**	**2.6% (13/503)**
Gastrointestinal	0.0% (0/497)	0.2% (1/503)
Hemorrhage	0.0% (0/497)	0.2% (1/503)
Infection	0.6% (3/497)	0.6% (3/503)
Inflammatory, Immune (including autoimmune)	0.0% (0/497)	0.2% (1/503)
Neurological	0.2% (1/497)	0.2% (1/503)
Pulmonary	0.2% (1/497)	0.4% (2/503)
Renal	0.4% (2/497)	0.4% (2/503)
Other non-cardiovascular	0.2% (1/497)	0.4% (2/503)
Undetermined cause of death	**0.4% (2/497)**	**0.0% (0/503)**
Total	**8.0% (40/497)**	**7.4% (37/503)**

There were no device-related deaths.

Two subjects died within 30 days after the procedure. A patient with ischemic cardiomyopathy, atrial fibrillation and a history of valvular heart disease status post TAVR developed abdominal pain post-operatively. The patient was found to have ischemic bowel and died on post-operative day two. The death was adjudicated as procedure-related but not device-related. Another patient died of sudden cardiac arrest on day 29 after the procedure. CEC adjudicated the death as not device- or procedure-related.

Adverse Events

Table 15 presents a summary of adverse events as reported by investigators. There were no unanticipated adverse device effects. Tables 16 and 17 present the serious and non-serious adverse device effects reported in the pivotal study.

Table 15. Summary of Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
Adverse Event Class	**Events [Rate[1]]**	**Percent of Subjects with Event**	**Events [Rate[1]]**	**Percent of Subjects with Event**
SAE	729 [157.3]	56.7% (282/497)	799 [171.3]	53.3% (268/503)
ADE	16 [3.45]	3.0% (15/497)	20 [4.29]	4.0% (20/503)
SADE	9 [1.94]	1.8% (9/497)	15 [3.22]	2.4% (12/503)
UADE	0 [0.00]	0.0% (0/497)	0 [0.00]	0.0% (0/503)

1. Rate is number of events per 100 subject years.

Table 16. Summary of Serious Adverse Device Effects (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate[1]]**	**Percent of Subjects with Event**	**Events [Rate[1]]**	**Percent of Subjects with Event**
Overall Follow-Up				

Table 16. Summary of Serious Adverse Device Effects (As Reported by Investigator)

System Organ Class Preferred Term	Treatment (N=497)		Control (N=503)	
	Events [Rate[1]]	Percent of Subjects with Event	Events [Rate[1]]	Percent of Subjects with Event
Cardiac Disorders	**2 [0.43]**	**0.4% (2/497)**	**0 [0.00]**	**0.0% (0/503)**
Arrhythmia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Cardiac Failure Congestive	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
General Disorders and Administration Site Conditions[2]	**4 [0.86]**	**0.8% (4/497)**	**4 [0.86]**	**0.8% (4/503)**
Catheter Site Hematoma	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Catheter Site Hemorrhage	4 [0.86]	0.8% (4/497)	1 [0.21]	0.2% (1/503)
Device Deployment Issue[3]	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Device Dislocation[4]	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Injury, Poisoning and Procedural Complications	**1 [0.22]**	**0.2% (1/497)**	**2 [0.43]**	**0.4% (2/503)**
Arterial Injury	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Vascular Pseudoaneurysm	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Respiratory, Thoracic and Mediastinal Disorders	**0 [0.00]**	**0.0% (0/497)**	**6 [1.29]**	**1.0% (5/503)**
Hemoptysis	0 [0.00]	0.0% (0/497)	4 [0.86]	0.6% (3/503)
Pulmonary Embolism	0 [0.00]	0.0% (0/497)	2 [0.43]	0.4% (2/503)
Vascular Disorders	**2 [0.43]**	**0.4% (2/497)**	**3 [0.64]**	**0.6% (3/503)**
Embolism	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Hematoma	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Thrombosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Total	**9 [1.94]**	**1.8% (9/497)**	**15 [3.22]**	**2.4% (12/503)**

1. Rate is number of events per 100 subject years.
2. Administration Site Conditions refers to events associated with site at which the device is administered
3. Device did not completely detach from delivery catheter upon initial deployment, but was ultimately deployed and confirmed to be working successfully.
4. Partial dislodgement of a left ventricular pacemaker lead during the CardioMEMS™ device implantation procedure, requiring subsequent lead revision. All SADEs occurred in NYHA Class II/III subjects prior to COVID-19.

Table 17. Summary of Adverse Device Effects (As Reported by Investigator)

System Organ Class Preferred Term	Treatment (N=497)		Control (N=503)	
	Events [Rate[1]]	Percent of Subjects with Event	Events [Rate[1]]	Percent of Subjects with Event
Cardiac Disorders	**0 [0.00]**	**0.0% (0/497)**	**2 [0.43]**	**0.4% (2/503)**
Arrhythmia	0 [0.00]	0.0% (0/497)	2 [0.43]	0.4% (2/503)
General Disorders and Administration Site Conditions	**9 [1.94]**	**1.8% (9/497)**	**18 [3.86]**	**3.6% (18/503)**
Catheter Site Hematoma	2 [0.43]	0.4% (2/497)	3 [0.64]	0.6% (3/503)
Catheter Site Hemorrhage	4 [0.86]	0.8% (4/497)	6 [1.29]	1.2% (6/503)
Device Deployment Issue	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)

Table 17. Summary of Adverse Device Effects (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate[1]]**	**Percent of Subjects with Event**	**Events [Rate[1]]**	**Percent of Subjects with Event**
Device Dislocation	0 [0.00]	0.0% (0/497)	3 [0.64]	0.6% (3/503)
Device Information Output Issue	2 [0.43]	0.4% (2/497)	2 [0.43]	0.4% (2/503)
Device Malfunction	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Pyrexia	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Vessel Puncture Site Pain	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Injury, Poisoning and Procedural Complications	**2 [0.43]**	**0.4% (2/497)**	**0 [0.00]**	**0.0% (0/503)**
Arterial Injury	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Laceration	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Nervous System Disorders	**1 [0.22]**	**0.2% (1/497)**	**0 [0.00]**	**0.0% (0/503)**
Presyncope	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Respiratory, Thoracic and Mediastinal Disorders	**3 [0.65]**	**0.6% (3/497)**	**0 [0.00]**	**0.0% (0/503)**
Hemoptysis	3 [0.65]	0.6% (3/497)	0 [0.00]	0.0% (0/503)
Vascular Disorders	**1 [0.22]**	**0.2% (1/497)**	**0 [0.00]**	**0.0% (0/503)**
Hypotension	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Total	**16 [3.45]**	**3.0% (15/497)**	**20 [4.29]**	**4.0% (20/503)**

Note: All ADEs occurred in NYHA Class II/III subjects prior to COVID-19.

1. Rate is number of events per 100 subject years.

Note: Rate is number of events per 100 subject years

Serious Adverse Events

A serious adverse event (SAE) was defined as an adverse event not related to the use of the device but meeting seriousness criteria (requiring hospitalization or invasive intervention or resulting in a life-threatening illness or injury). A summary of non-device-related investigator-reported SAEs is provided in the table below.

Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
Blood and Lymphatic System Disorders	**11 [2.37]**	**1.6% (8/497)**	**8 [1.72]**	**1.4% (7/503)**
Anemia	9 [1.94]	1.2% (6/497)	8 [1.72]	1.4% (7/503)
Thrombocytopenia	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Cardiac Disorders	**302 [65.2]**	**32.6% (162/497)**	**389 [83.4]**	**38.8% (195/503)**
Acute Myocardial Infarction	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Angina Pectoris	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Angina Unstable	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Aortic Valve Disease	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Arrhythmia	53 [11.4]	9.5% (47/497)	54 [11.6]	9.1% (46/503)
Atrioventricular Block Complete	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cardiac Aneurysm	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cardiac Arrest	3 [0.65]	0.6% (3/497)	4 [0.86]	0.8% (4/503)
Cardiac Failure Congestive	216 [46.6]	26.2% (130/497)	276 [59.2]	30.8% (155/503)
Cardiac Perforation	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cardiac Valve Disease	1 [0.22]	0.2% (1/497)	4 [0.86]	0.6% (3/503)
Cardiogenic Shock	8 [1.73]	1.6% (8/497)	6 [1.29]	1.0% (5/503)
Cardiomyopathy	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Coronary Artery Disease	1 [0.22]	0.2% (1/497)	9 [1.93]	1.6% (8/503)
Intracardiac Thrombus	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Ischemic Cardiomyopathy	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Mitral Valve Disease	1 [0.22]	0.2% (1/497)	3 [0.64]	0.4% (2/503)
Mitral Valve Incompetence	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Myocardial Infarction	11 [2.37]	2.0% (10/497)	16 [3.43]	3.2% (16/503)
Pericardial Effusion	1 [0.22]	0.2% (1/497)	3 [0.64]	0.6% (3/503)
Pericarditis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Prinzmetal Angina	0 [0.00]	0.0% (0/497)	2 [0.43]	0.4% (2/503)
Restrictive Cardiomyopathy	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Tachycardia	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Ear and Labyrinth Disorders	**2 [0.43]**	**0.4% (2/497)**	**0 [0.00]**	**0.0% (0/503)**
Vertigo	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Vertigo Positional	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Endocrine Disorders	**2 [0.43]**	**0.4% (2/497)**	**0 [0.00]**	**0.0% (0/503)**
Hypothyroidism	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Inappropriate Antidiuretic Hormone Secretion	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Gastrointestinal Disorders	**29 [6.26]**	**4.8% (24/497)**	**33 [7.08]**	**5.0% (25/503)**
Abdominal Pain	0 [0.00]	0.0% (0/497)	2 [0.43]	0.4% (2/503)
Colitis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Colitis Ischemic	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Colonic Stenosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Constipation	2 [0.43]	0.4% (2/497)	1 [0.21]	0.2% (1/503)
Diarrhea	2 [0.43]	0.4% (2/497)	1 [0.21]	0.2% (1/503)

Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
Duodenal Ulcer	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Dysphagia	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Gastritis	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Gastrointestinal Hemorrhage	10 [2.16]	1.8% (9/497)	20 [4.29]	3.2% (16/503)
Gastrointestinal Necrosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Gastroesophageal Reflux Disease	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hemorrhoidal Hemorrhage	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Ileus	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Impaired Gastric Emptying	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Intestinal Ischemia	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Nausea	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Pancreatic Mass	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Pancreatitis	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Pancreatitis Acute	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Proctitis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Small Intestinal Obstruction	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Spigelian Hernia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Vomiting	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
General Disorders and Administration Site Conditions[1]	**49 [10.6]**	**8.2% (41/497)**	**34 [7.29]**	**6.2% (31/503)**
Accidental Death[2]	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Asthenia	4 [0.86]	0.8% (4/497)	3 [0.64]	0.6% (3/503)
Catheter Site Hematoma	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Chest Pain	32 [6.90]	5.4% (27/497)	25 [5.36]	4.6% (23/503)
Death[3]	3 [0.65]	0.6% (3/497)	0 [0.00]	0.0% (0/503)
Device Dislocation[4]	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Device Electrical Impedance Issue[5]	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Device Malfunction[6]	0 [0.00]	0.0% (0/497)	3 [0.64]	0.6% (3/503)
Fatigue	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Generalized Edema	2 [0.43]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hypothermia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Implant Site Hemorrhage	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Multi-Organ Failure	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Polyp	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Sudden Cardiac Death[7]	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hepatobiliary Disorders	**4 [0.86]**	**0.8% (4/497)**	**4 [0.86]**	**0.8% (4/503)**
Cholangitis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cholelithiasis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hepatic Cirrhosis	2 [0.43]	0.4% (2/497)	2 [0.43]	0.4% (2/503)
Hepatic Function Abnormal	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Ischemic Hepatitis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Immune System Disorders	**0 [0.00]**	**0.0% (0/497)**	**2 [0.43]**	**0.4% (2/503)**

1. Administration Site Conditions refers to events associated with site at which the device is administered.
2. Traumatic death in an accident.
3. Unknown event leading to death.
4. Hip prosthesis dislocation, unrelated to study device.
5. Broken pacemaker lead, unrelated to study device.
6. Cardiac pacemaker or ICD malfunction, unrelated to study device.
7. Sudden cardiac death due to ischemic heart disease.

Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
Drug Hypersensitivity	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Heart Transplant Rejection	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Infections and Infestations	**99 [21.4]**	**15.3% (76/497)**	**113 [24.2]**	**16.9% (85/503)**
Abscess	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Anal Abscess	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Bronchitis	2 [0.43]	0.4% (2/497)	7 [1.50]	1.4% (7/503)
Cellulitis	6 [1.29]	1.0% (5/497)	8 [1.72]	1.4% (7/503)
Central Nervous System Abscess	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Clostridial Infection	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Coronavirus Infection	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Cystitis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Endocarditis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Gastroenteritis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Gastroenteritis Viral	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Gastrointestinal Infection	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Herpes Zoster	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Infection	29 [6.26]	5.4% (27/497)	39 [8.36]	6.8% (34/503)
Influenza	3 [0.65]	0.6% (3/497)	1 [0.21]	0.2% (1/503)
Intervertebral Discitis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Mycotic Aneurysm	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Pneumonia	27 [5.83]	4.8% (24/497)	32 [6.86]	5.8% (29/503)
Sepsis	18 [3.88]	3.4% (17/497)	10 [2.14]	2.0% (10/503)
Septic Shock	0 [0.00]	0.0% (0/497)	4 [0.86]	0.8% (4/503)
Upper Respiratory Tract Infection	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Urinary Tract Infection	3 [0.65]	0.6% (3/497)	4 [0.86]	0.8% (4/503)
Wound Infection	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Injury, Poisoning and Procedural Complications	**15 [3.24]**	**2.8% (14/497)**	**16 [3.43]**	**3.0% (15/503)**
Cervical Vertebral Fracture	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Fall	4 [0.86]	0.8% (4/497)	6 [1.29]	1.0% (5/503)
Femur Fracture	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hip Fracture	2 [0.43]	0.4% (2/497)	3 [0.64]	0.6% (3/503)
Iliotibial Band Syndrome	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Joint Injury	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Laceration	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Multiple Fractures	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Pelvic Fracture	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Road Traffic Accident[1]	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Spinal Compression Fracture	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Spinal Fracture	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Subdural Hematoma	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Vascular Pseudoaneurysm	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Investigations	**21 [4.53]**	**3.8% (19/497)**	**21 [4.50]**	**3.0% (15/503)**
Anticoagulation Drug Level Below Therapeutic	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Blood Creatinine Increased	18 [3.88]	3.4% (17/497)	17 [3.65]	2.6% (13/503)
International Normalized Ratio Decreased	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)

1. Multiple injuries and surgical procedures resulting from a motor vehicle accident.

Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
International Normalized Ratio Increased	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Left Ventricular End-Diastolic Pressure Increased	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Transaminases Increased	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Troponin Increased	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Metabolism and Nutrition Disorders	**25 [5.39]**	**4.8% (24/497)**	**24 [5.15]**	**4.0% (20/503)**
Dehydration	8 [1.73]	1.6% (8/497)	2 [0.43]	0.4% (2/503)
Diabetes Mellitus	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Diabetic Ketoacidosis	0 [0.00]	0.0% (0/497)	2 [0.43]	0.4% (2/503)
Fluid Overload	2 [0.43]	0.4% (2/497)	2 [0.43]	0.2% (1/503)
Gout	2 [0.43]	0.4% (2/497)	2 [0.43]	0.4% (2/503)
Hyperglycemia	5 [1.08]	1.0% (5/497)	5 [1.07]	0.8% (4/503)
Hyperkalemia	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Hypoglycemia	2 [0.43]	0.4% (2/497)	4 [0.86]	0.8% (4/503)
Hypokalemia	1 [0.22]	0.2% (1/497)	3 [0.64]	0.6% (3/503)
Hypovolemia	1 [0.22]	0.2% (1/497)	3 [0.64]	0.6% (3/503)
Lactic Acidosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Type 2 Diabetes Mellitus	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Musculoskeletal and Connective Tissue Disorders	**14 [3.02]**	**2.4% (12/497)**	**4 [0.86]**	**0.8% (4/503)**
Arthralgia	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Back Pain	5 [1.08]	0.6% (3/497)	0 [0.00]	0.0% (0/503)
Compartment Syndrome	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Fibromyalgia	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Muscular Weakness	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Myopathy	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Osteoarthritis	2 [0.43]	0.4% (2/497)	1 [0.21]	0.2% (1/503)
Rhabdomyolysis	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Rheumatoid Arthritis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Spinal Osteoarthritis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Neoplasms Benign, Malignant and Unspecified (Incl Cysts and Polyps)	**2 [0.43]**	**0.4% (2/497)**	**2 [0.43]**	**0.4% (2/503)**
Colon Cancer	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Lung Neoplasm	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Esophageal Adenocarcinoma	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Squamous Cell Carcinoma	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Nervous System Disorders	**42 [9.06]**	**7.4% (37/497)**	**28 [6.00]**	**4.8% (24/503)**
Carotid Artery Stenosis	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Cerebrovascular Accident	12 [2.59]	2.2% (11/497)	6 [1.29]	1.2% (6/503)
Cerebrovascular Disorder	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cervicogenic Headache	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
CNS Ventriculitis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Complicated Migraine	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Convulsion	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Dizziness	4 [0.86]	0.8% (4/497)	4 [0.86]	0.8% (4/503)
Encephalopathy	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Hemorrhage Intracranial	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Headache	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)

Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
Hepatic Encephalopathy	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Hypoesthesia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Metabolic Encephalopathy	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Myoclonus	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Partial Seizures	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Presyncope	3 [0.65]	0.6% (3/497)	0 [0.00]	0.0% (0/503)
Sciatica	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Subarachnoid Hemorrhage	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Syncope	12 [2.59]	2.4% (12/497)	8 [1.72]	1.6% (8/503)
Transient Ischemic Attack	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Vertebral Artery Stenosis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Psychiatric Disorders	**3 [0.65]**	**0.6% (3/497)**	**6 [1.29]**	**1.0% (5/503)**
Depression	0 [0.00]	0.0% (0/497)	3 [0.64]	0.4% (2/503)
Mental Disorder	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Mental Status Changes	2 [0.43]	0.4% (2/497)	3 [0.64]	0.6% (3/503)
Renal and Urinary Disorders	**29 [6.26]**	**4.8% (24/497)**	**41 [8.79]**	**7.6% (38/503)**
Hematuria	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Nephrolithiasis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Obstructive Uropathy	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Renal Failure	3 [0.65]	0.6% (3/497)	1 [0.21]	0.2% (1/503)
Renal Failure Acute	21 [4.53]	3.6% (18/497)	29 [6.22]	5.6% (28/503)
Renal Failure Chronic	2 [0.43]	0.4% (2/497)	6 [1.29]	1.0% (5/503)
Urinary Retention	3 [0.65]	0.6% (3/497)	2 [0.43]	0.4% (2/503)
Reproductive System and Breast Disorders	**1 [0.22]**	**0.2% (1/497)**	**1 [0.21]**	**0.2% (1/503)**
Benign Prostatic Hyperplasia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Vaginal Hemorrhage	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Respiratory, Thoracic and Mediastinal Disorders	**42 [9.06]**	**6.8% (34/497)**	**52 [11.2]**	**7.6% (38/503)**
Acute Respiratory Failure	3 [0.65]	0.6% (3/497)	8 [1.72]	1.6% (8/503)
Asthma	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Chronic Obstructive Pulmonary Disease	13 [2.80]	1.8% (9/497)	24 [5.15]	2.8% (14/503)
Chronic Respiratory Disease	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Cough	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Dyspnea	7 [1.51]	1.4% (7/497)	8 [1.72]	1.6% (8/503)
Epistaxis	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Hemoptysis	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Hypoxia	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Pleural Effusion	5 [1.08]	0.8% (4/497)	4 [0.86]	0.8% (4/503)
Pneumothorax	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Pulmonary Alveolar Hemorrhage	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Pulmonary Embolism	1 [0.22]	0.2% (1/497)	1 [0.21]	0.2% (1/503)
Pulmonary Hypertension	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Respiratory Failure	4 [0.86]	0.8% (4/497)	3 [0.64]	0.6% (3/503)
Sleep Apnea Syndrome	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)

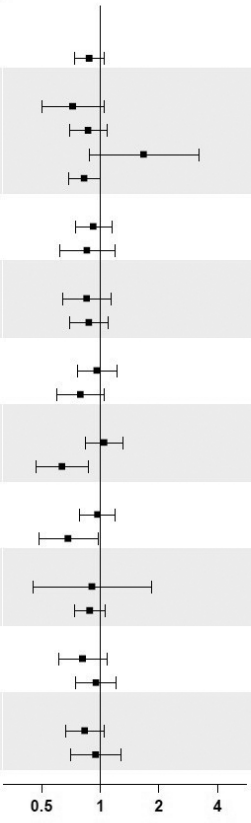
Table 18. Summary of Serious Adverse Events (As Reported by Investigator)

	Treatment (N=497)		Control (N=503)	
System Organ Class Preferred Term	**Events [Rate]**	**Percent of Subjects with Event**	**Events [Rate]**	**Percent of Subjects with Event**
Skin and Subcutaneous Tissue Disorders	**2 [0.43]**	**0.4% (2/497)**	**0 [0.00]**	**0.0% (0/503)**
Angioedema	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hyperhidrosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Surgical and Medical Procedures	**0 [0.00]**	**0.0% (0/497)**	**1 [0.21]**	**0.2% (1/503)**
Cardiac Pacemaker Replacement	0 [0.00]	0.0% (0/497)	1 [0.21]	0.2% (1/503)
Vascular Disorders	**35 [7.55]**	**5.0% (25/497)**	**20 [4.29]**	**3.6% (18/503)**
Aortic Aneurysm	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Bleeding Varicose Vein	2 [0.43]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Embolism	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Extremity Necrosis	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hematoma	2 [0.43]	0.4% (2/497)	0 [0.00]	0.0% (0/503)
Hypertension	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Hypertensive Crisis	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Hypotension	14 [3.02]	2.6% (13/497)	11 [2.36]	2.2% (11/503)
Lymphoedema	2 [0.43]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Orthostatic Hypotension	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Peripheral Arterial Occlusive Disease	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Peripheral Vascular Disorder	1 [0.22]	0.2% (1/497)	2 [0.43]	0.4% (2/503)
Shock	1 [0.22]	0.2% (1/497)	0 [0.00]	0.0% (0/503)
Thrombosis	5 [1.08]	0.8% (4/497)	3 [0.64]	0.4% (2/503)
Total	**729 [157.3]**	**56.7% (282/497)**	**799 [171.3]**	**53.3% (268/503)**

Subgroup Analyses

The primary endpoint was evaluated in subgroups of NYHA Class, qualifying category, ejection fraction, age, sex, race, ethnicity, ischemic cardiomyopathy, and prior cardiac device implant. Figures 8 and 9 show the forest plots for all follow-up and pre-COVID-19, respectively. Women notably derived more benefit than men with 36% reduction in primary endpoint events. African American subjects also gained a larger treatment effect, though minorities (African American and Hispanic subjects) in both the Treatment group and the Control group experienced high rates of primary endpoint events.

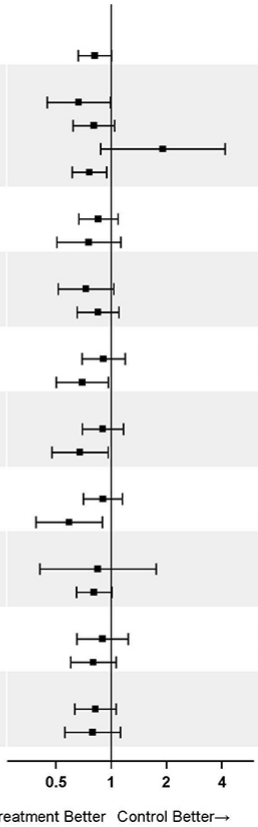
Subgroup	N	Treatment Events (Rate)	Control Events (Rate)	HR (95% CI)	Subgroup p-value	Interaction p-value
Overall	1000	253 (0.563)	289 (0.640)	0.88 (0.74, 1.05)	0.16	
NYHA Class						
NYHA Class II	296	53 (0.401)	75 (0.554)	0.72 (0.50, 1.05)	0.086	0.095
NYHA Class III*	650	171 (0.589)	198 (0.677)	0.87 (0.70, 1.08)	0.21	
NYHA Class IV	54	29 (1.527)	16 (0.910)	1.68 (0.88, 3.20)	0.12	
NYHA Class II and III	946	224 (0.525)	273 (0.633)	0.83 (0.69, 1.00)	0.050	0.046†
Qualification						
HFH in year prior	557	181 (0.757)	212 (0.820)	0.92 (0.74, 1.14)	0.47	0.71
Elevated BNP/NT pro-BNP only	442	72 (0.350)	77 (0.409)	0.86 (0.62, 1.19)	0.36	
Ejection Fraction						
HFpEF (EF>40%)*	469	90 (0.442)	114 (0.518)	0.85 (0.64, 1.14)	0.28	0.90
HFrEF (EF≤40%)*	531	163 (0.677)	175 (0.773)	0.88 (0.70, 1.10)	0.26	
Age						
Below Median (<71 Years)*	492	156 (0.730)	173 (0.758)	0.96 (0.76, 1.22)	0.75	0.30
Median and Above (≥71 Years)*	508	97 (0.420)	116 (0.529)	0.79 (0.60, 1.05)	0.11	
Sex						
Men*	625	178 (0.656)	171 (0.625)	1.05 (0.84, 1.31)	0.67	0.010
Women*	375	75 (0.434)	118 (0.681)	0.64 (0.47, 0.87)	0.004	
Race						
Caucasian*	807	189 (0.516)	194 (0.531)	0.97 (0.79, 1.20)	0.78	0.095
African American*	179	60 (0.811)	94 (1.184)	0.68 (0.48, 0.97)	0.035	
Ethnicity						
Hispanic*	33	18 (1.257)	21 (1.383)	0.91 (0.45, 1.83)	0.79	0.95
Non-Hispanic*	960	232 (0.544)	264 (0.615)	0.88 (0.73, 1.07)	0.20	
Ischemic Cardiomyopathy						
Ischemic*	397	99 (0.545)	112 (0.670)	0.81 (0.61, 1.08)	0.16	0.40
Non-Ischemic*	560	142 (0.578)	160 (0.607)	0.95 (0.75, 1.21)	0.69	
Device Implant						
With CRT-D/CRT-P/ICD*	562	162 (0.633)	188 (0.759)	0.83 (0.67, 1.04)	0.11	0.48
Without CRT-D/CRT-P/ICD *	438	91 (0.482)	101 (0.508)	0.95 (0.71, 1.28)	0.73	



*Pre-specified subgroup
†Interaction p-value testing Randomization Group by NYHA Class II and III vs. Class IV

Figure 8. Subgroup Analyses – All Follow-up

Subgroup	N	Treatment Events (Rate)	Control Events (Rate)	HR (95% CI)	Interaction p-value
Overall	1000	177 (0.595)	224 (0.730)	0.81 (0.66, 1.00)	
NYHA Class					
NYHA Class II	296	43 (0.393)	70 (0.591)	0.67 (0.45, 0.99)	0.074
NYHA Class III	650	114 (0.552)	141 (0.686)	0.80 (0.62, 1.04)	
NYHA Class IV	54	20 (3.123)	13 (1.632)	1.91 (0.88, 4.18)	
NYHA Class II and III	946	157 (0.497)	211 (0.653)	0.76 (0.61, 0.95)	0.035*
Qualification					
HFH in year prior	557	133 (0.771)	166 (0.905)	0.85 (0.67, 1.09)	0.58
Elevated BNP/NT pro-BNP only	442	44 (0.358)	58 (0.474)	0.76 (0.51, 1.13)	
Ejection Fraction					
HFpEF (EF>40%)	469	57 (0.401)	85 (0.551)	0.73 (0.51, 1.03)	0.50
HFrEF (EF≤40%)	531	120 (0.738)	139 (0.870)	0.85 (0.65, 1.10)	
Age					
Below Median (<71 Years)	492	112 (0.746)	130 (0.820)	0.91 (0.69, 1.19)	0.22
Median and Above (≥71 Years)	508	65 (0.442)	94 (0.635)	0.70 (0.50, 0.97)	
Sex					
Men	625	121 (0.687)	139 (0.763)	0.90 (0.70, 1.17)	0.21
Women	375	56 (0.462)	85 (0.683)	0.68 (0.48, 0.96)	
Race					
White	807	135 (0.607)	154 (0.673)	0.90 (0.71, 1.15)	0.091
Black	179	38 (0.721)	70 (1.221)	0.59 (0.39, 0.89)	
Ethnicity					
Hispanic	33	17 (1.575)	19 (1.860)	0.85 (0.41, 1.76)	0.84
Non-Hispanic	960	157 (0.586)	202 (0.726)	0.81 (0.65, 1.01)	
Ischemic Cardiomyopathy					
Ischemic	397	83 (0.682)	87 (0.760)	0.90 (0.65, 1.24)	0.61
Non-Ischemic	560	91 (0.526)	125 (0.658)	0.80 (0.60, 1.06)	
Device Implant					
With CRT-D/CRT-P/ICD	562	117 (0.776)	144 (0.945)	0.82 (0.63, 1.06)	0.92
Without CRT-D/CRT-P/ICD	438	60 (0.424)	80 (0.535)	0.79 (0.56, 1.12)	



*Interaction p-value testing Randomization Group by NYHA Class II and III vs. Class IV

Figure 9. Subgroup Analyses – Prior to COVID-19

Within the subgroup analyses, an interaction was observed for NYHA class, with the subgroup of NYHA Class IV patients (N = 54) demonstrating a different treatment effect than NYHA Class II and/or III patients. NYHA Class II/III patients overall demonstrated a 24% reduction in primary endpoint events prior to COVID-19 (HR 0.76, 95% CI 0.61-0.95) while NYHA Class IV patients did worse with hemodynamic-guided HF therapy during the same period (HR 1.91, CI 0.88-4.18). The NYHA Class sensitivity analysis demonstrated an interaction p-value of p=0.035, and separate analysis for each NYHA Class is provided below.

NYHA Class II

The baseline demographics and key characteristics for the NYHA Class II patients in the Treatment group and the Control group were balanced and listed in the table below.

Table 19. Demographics and Baseline Assessments – NYHA Class II Subjects

	Treatment (N=146)	**Control (N=150)**
Age – yr	69.8 ± 10.9 (146)	69.8 ± 10.5 (150)
Female Sex	33.6% (49/146)	34.0% (51/150)
Race		
White	84.2% (123/146)	82.0% (123/150)
Black	15.1% (22/146)	17.3% (26/150)
Other	0.7% (1/146)	0.7% (1/150)
Ethnicity		
Hispanic	2.7% (4/146)	4.0% (6/150)
Non-Hispanic	95.2% (139/146)	96.0% (144/150)
Unknown	2.1% (3/146)	0.0% (0/150)
Body mass index – kg/m^2	30.7 ± 7.3 (146)	32.5 ± 7.4 (150)
Medical History		
Ischemic etiology	43.2% (63/146)	45.3% (68/150)
Diabetes	49.3% (72/146)	44.7% (67/150)
Atrial flutter or fibrillation	56.8% (83/146)	58.0% (87/150)
Vital Signs and Hemodynamic Analyses		
Left ventricular ejection fraction – %	39.2 ± 17.2 (146)	39.8 ± 16.1 (150)
Left ventricular ejection fraction >40%	42.5% (62/146)	44.0% (66/150)
Pulmonary capillary wedge pressure – mmHg	16.9 ± 8.2 (145)	17.7 ± 8.4 (150)
Cardiac output – L/min	4.61 ± 1.30 (146)	4.51 ± 1.10 (150)
Cardiac index – L/min/m^2	2.27 ± 0.61 (146)	2.14 ± 0.48 (150)
Laboratory Analyses		
Serum creatinine level – µmol/L	123.1 ± 40.7 (146)	128.3 ± 44.7 (144)
Estimated glomerular filtration rate – ml/min/1.73m^2	56.7 ± 21.5 (146)	54.6 ± 19.2 (143)
B-type natriuretic peptide level – pg/mL	472.8 ± 480.3 (61)	525.4 ± 727.7 (69)
N-terminal pro-B-type natriuretic peptide level – pg/mL	2526 ± 3842 (76)	1537 ± 985 (72)
Treatment History		
Previous cardiac resynchronization therapy	26.7% (39/146)	35.3% (53/150)
Previous implantation of defibrillator	49.3% (72/146)	40.0% (60/150)
Guideline-Directed Medical Therapy		
ACE-Inhibitor or ARB or ARNi	69.2% (101/146)	70.0% (105/150)
ARNi	32.9% (48/146)	30.0% (45/150)
Beta Blocker	89.7% (131/146)	91.3% (137/150)
Mineralocorticoid Receptor Antagonist	43.2% (63/146)	33.3% (50/150)
Diuretic	90.4% (132/146)	93.3% (140/150)
Hydralazine	11.6% (17/146)	20.0% (30/150)
Nitrate	17.8% (26/146)	16.7% (25/150)
SGLT2 Inhibitor	2.2% (1/46)	0.0% (0/41)
Enrollment Type		
Heart failure hospitalization in year prior only	32.2% (47/146)	32.7% (49/150)
Elevated natriuretic peptide level in 30 day prior only	50.7% (74/146)	49.3% (74/150)
Heart failure hospitalization in year prior and elevated natriuretic peptide level in 30 day prior	17.1% (25/146)	18.0% (27/150)

Table 19. Demographics and Baseline Assessments – NYHA Class II Subjects

	Treatment (N=146)	Control (N=150)
Patient Reported Outcomes		
KCCQ-12 at Baseline – Overall Summary Score	69.7 ± 20.7 (145)	66.4 ± 20.5 (147)
6MHW as Baseline – m	285.5 ± 111.3 (142)	264.8 ± 120.3 (146)

Continuous Variables: Mean ± SD (n); Categorical Variables: Percent (n/N)

The primary endpoint event rates and components for NYHA Class II subjects for the full follow-up and prior to COVID-19 are presented in the table below. Before the pandemic, there were 43 primary endpoint events in the Treatment group compared with 70 events in the Control group, representing a 33% reduction in the 12-month rate of primary endpoint events (0.393 events per patient in the Treatment group vs. 0.591 events per patient in the Control group, HR 0.67)

Table 20. Primary Endpoint and Components – NYHA Class II Subjects

Endpoint[1]	Treatment (N=146) Events (Rate[2])	Control (N=150) Events (Rate[2])	Hazard Ratio (95% CI)[3]
Full Follow-Up			
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**53 (0.401)**	**75 (0.554)**	**0.72 (0.50, 1.05)**
Heart Failure Hospitalization + ED/OP	42 (0.317)	67 (0.493)	0.64 (0.43, 0.96)
Heart Failure Hospitalization	39 (0.298)	56 (0.417)	0.71 (0.47, 1.09)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	3 (0.025)	11 (0.089)	0.28 (0.08, 0.99)
Death	11 (0.086)	8 (0.061)	1.39 (0.56, 3.46)
Prior to COVID-19			COVID-19 Interaction p-value[4], p=0.1579
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**43 (0.393)**	**70 (0.591)**	**0.67 (0.45, 0.99)**
Heart Failure Hospitalization + ED/OP	33 (0.307)	62 (0.531)	0.58 (0.37, 0.89)
Heart Failure Hospitalization	30 (0.276)	51 (0.433)	0.64 (0.40, 1.01)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	3 (0.038)	11 (0.128)	0.30 (0.08, 1.06)
Death	10 (0.099)	8 (0.074)	1.34 (0.53, 3.39)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date.
2. Event Rate is an annualized rate estimated from the Andersen-Gill model.
3. Hazard Ratio and 95% Confidence Interval estimated from the Andersen-Gill model with robust sandwich variance estimates.
4. Interaction p-value is a joint test on the interaction term of treatment group by COVID analysis time period.

NYHA Class III

Table 21 presents the baseline demographics and key characteristics for the NYHA Class III patients in the Treatment group and the Control group.

Table 21. Demographics and Baseline Assessments – NYHA Class III Subjects

	Treatment (N=322)	Control (N=328)
Age – yr	68.8 ± 11.3 (322)	69.0 ± 11.2 (328)
Female Sex	39.8% (128/322)	38.7% (127/328)
Race		
White	80.7% (260/322)	79.6% (261/328)
Black	17.7% (57/322)	19.5% (64/328)
Other	1.8% (6/322)	1.2% (4/328)
Ethnicity		
Hispanic	3.7% (12/322)	2.7% (9/328)
Non-Hispanic	96.0% (309/322)	96.6% (317/328)
Unknown	0.3% (1/322)	0.6% (2/328)
Body mass index – kg/m^2	33.9 ± 8.4 (322)	34.2 ± 8.5 (328)

Table 21. Demographics and Baseline Assessments – NYHA Class III Subjects

	Treatment (N=322)	Control (N=328)
Medical History		
Ischemic etiology	40.7% (131/322)	35.1% (115/328)
Diabetes	48.1% (155/322)	56.1% (184/328)
Atrial flutter or fibrillation	61.8% (199/322)	57.9% (190/328)
Vital Signs and Hemodynamic Analyses		
Left ventricular ejection fraction – %	39.9 ± 17.2 (322)	41.0 ± 17.3 (328)
Left ventricular ejection fraction >40%	47.2% (152/322)	50.6% (166/328)
Pulmonary capillary wedge pressure – mmHg	17.2 ± 7.9 (321)	17.4 ± 7.6 (328)
Cardiac output – L/min	4.96 ± 3.11 (322)	4.76 ± 1.59 (328)
Cardiac index – L/min/m^2	2.29 ± 1.30 (322)	2.20 ± 0.67 (328)
Laboratory Analyses		
Serum creatinine level – µmol/L	129.1 ± 44.2 (320)	134.5 ± 49.3 (326)
Estimated glomerular filtration rate – ml/min/1.73m^2	53.7 ± 21.0 (320)	52.5 ± 21.6 (326)
B-type natriuretic peptide level – pg/mL	550.8 ± 763.1 (181)	573.9 ± 1054.3 (176)
N-terminal pro-B-type natriuretic peptide level – pg/mL	2258 ± 3316 (133)	2431 ± 3235 (140)
Treatment History		
Previous cardiac resynchronization therapy	28.3% (91/322)	30.5% (100/328)
Previous implantation of defibrillator	40.4% (130/322)	41.5% (136/328)
Guideline-Directed Medical Therapy		
ACE-Inhibitor or ARB or ARNi	62.1% (200/322)	61.9% (203/328)
ARNi	27.3% (88/322)	26.5% (87/328)
Beta Blocker	89.8% (289/322)	87.2% (286/328)
Mineralocorticoid Receptor Antagonist	49.7% (160/322)	46.3% (152/328)
Diuretic	97.2% (313/322)	95.7% (314/328)
Hydralazine	17.4% (56/322)	14.0% (46/328)
Nitrate	20.8% (67/322)	22.6% (74/328)
SGLT2 Inhibitor	1.0% (1/98)	2.2% (2/92)
Enrollment Type		
Heart failure hospitalization in year prior only	35.7% (115/322)	40.1% (131/327)
Elevated natriuretic peptide level in 30 day prior only	44.4% (143/322)	40.4% (132/327)
Heart failure hospitalization in year prior and elevated natriuretic peptide level in 30 day prior	19.9% (64/322)	19.6% (64/327)
Patient Reported Outcomes		
KCCQ-12 at Baseline – Overall Summary Score	49.7 ± 23.1 (320)	50.7 ± 23.3 (325)
6MHW as Baseline – m	218.9 ± 116.1 (306)	218.1 ± 121.4 (312)

Note: Continuous Variables: Mean ± SD (n); Categorical Variables: Percent (n/N)

Table 22 presents the primary endpoint event rates and components for NYHA Class III subjects for the full follow-up and prior to COVID-19. Before the pandemic, there were 114 primary endpoint events in the Treatment group compared with 141 events in the Control group. The difference represents a 20% reduction in the 12-month rate of primary endpoint events (0.552 events per patient in the Treatment group vs. 0.686 events per patient in the Control group, HR 0.80).

Table 22. Primary Endpoint and Components – NYHA Class III Subjects

Endpoint[1]	Treatment (N=322) Events (Rate[2])	Control (N=328) Events (Rate[2])	Hazard Ratio (95% CI)[3]
Full Follow-Up			
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**171 (0.589)**	**198 (0.677)**	**0.87 (0.70, 1.08)**
Heart Failure Hospitalization + ED/OP	147 (0.502)	171 (0.580)	0.86 (0.69, 1.09)
Heart Failure Hospitalization	127 (0.431)	156 (0.526)	0.82 (0.64, 1.04)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	20 (0.073)	15 (0.054)	1.34 (0.68, 2.62)
Death	24 (0.089)	27 (0.100)	0.90 (0.52, 1.55)

Prior to COVID-19			COVID-19 Interaction p-value[4], p=0.2840
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**114 (0.552)**	**141 (0.686)**	**0.80 (0.62, 1.04)**
Heart Failure Hospitalization + ED/OP	96 (0.460)	126 (0.606)	0.76 (0.58, 1.00)
Heart Failure Hospitalization	81 (0.389)	115 (0.555)	0.70 (0.52, 0.94)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	15 (0.077)	11 (0.057)	1.36 (0.62, 2.97)
Death	18 (0.108)	15 (0.091)	1.19 (0.60, 2.36)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date.
2. Event Rate is an annualized rate estimated from the Andersen-Gill model.
3. Hazard Ratio and 95% Confidence Interval estimated from the Andersen-Gill model with robust sandwich variance estimates.
4. Interaction p-value is a joint test on the interaction term of treatment group by COVID analysis time period.

NYHA Class IV

Table 23 presents the baseline demographics and key characteristics for the NYHA Class IV patients (N = 54).

Table 23. Demographics and Baseline Assessments – NYHA Class IV Subjects		
	Treatment (N=29)	**Control (N=25)**
Age – yr	70.3 ± 8.8 (29)	67.3 ± 12.2 (25)
Female Sex	34.5% (10/29)	40.0% (10/25)
Race		
White	69.0% (20/29)	84.0% (21/25)
Black	27.6% (8/29)	12.0% (3/25)
Other	3.4% (1/29)	4.0% (1/25)
Ethnicity		
Hispanic	0.0% (0/29)	8.0% (2/25)
Non-Hispanic	100.0% (29/29)	88.0% (22/25)
Unknown	0.0% (0/29)	4.0% (1/25)
Body mass index – kg/m2	33.4 ± 10.0 (29)	37.0 ± 11.2 (25)
Medical History		
Ischemic etiology	44.8% (13/29)	28.0% (7/25)
Diabetes	55.2% (16/29)	40.0% (10/25)
Atrial flutter or fibrillation	62.1% (18/29)	56.0% (14/25)
Vital Signs and Hemodynamic Analyses		
Left ventricular ejection fraction – %	34.1 ± 17.8 (29)	42.2 ± 16.7 (25)
Left ventricular ejection fraction >40%	34.5% (10/29)	52.0% (13/25)
Pulmonary capillary wedge pressure – mmHg	19.6 ± 9.1 (29)	18.5 ± 8.5 (25)
Cardiac output – L/min	4.40 ± 1.16 (29)	4.98 ± 1.61 (25)
Cardiac index – L/min/m2	2.08 ± 0.53 (29)	2.23 ± 0.74 (25)
Laboratory Analyses		
Serum creatinine level – µmol/L	148.9 ± 58.7 (29)	149.9 ± 56.2 (25)
Estimated glomerular filtration rate – ml/min/1.73m2	49.3 ± 23.0 (29)	45.3 ± 17.2 (25)
B-type natriuretic peptide level – pg/mL	386.8 ± 482.7 (19)	378.9 ± 329.9 (11)
N-terminal pro-B-type natriuretic peptide level – pg/mL	4653 ± 6525 (10)	3092 ± 3946 (13)
Treatment History		
Previous cardiac resynchronization therapy	41.4% (12/29)	40.0% (10/25)
Previous implantation of defibrillator	37.9% (11/29)	36.0% (9/25)
Guideline-Directed Medical Therapy		
ACE-Inhibitor or ARB or ARNi	62.1% (18/29)	48.0% (12/25)
ARNi	31.0% (9/29)	28.0% (7/25)
Beta Blocker	82.8% (24/29)	76.0% (19/25)
Mineralocorticoid Receptor Antagonist	48.3% (14/29)	56.0% (14/25)

Table 23. Demographics and Baseline Assessments – NYHA Class IV Subjects		
	Treatment (N=29)	**Control (N=25)**
Diuretic	100.0% (29/29)	96.0% (24/25)
Hydralazine	27.6% (8/29)	16.0% (4/25)
Nitrate	20.7% (6/29)	16.0% (4/25)
SGLT2 Inhibitor	0.0% (0/8)	0.0% (0/7)
Enrollment Type		
Heart failure hospitalization in year prior only	27.6% (8/29)	44.0% (11/25)
Elevated natriuretic peptide level in 30 day prior only	44.8% (13/29)	24.0% (6/25)
Heart failure hospitalization in year prior and elevated natriuretic peptide level in 30 day prior	27.6% (8/29)	32.0% (8/25)
Patient Reported Outcomes		
KCCQ-12 at Baseline – Overall Summary Score	39.0 ± 20.2 (29)	40.5 ± 22.5 (25)
6MHW as Baseline – m	153.2 ± 119.3 (26)	164.4 ± 108.2 (24)
Continuous Variables: Mean ± SD (n); Categorical Variables: Percent (n/N)		

Table 24 presents the primary endpoint event rates and components for NYHA Class IV subjects for the full follow-up and prior to COVID-19. Before the pandemic, there were 20 primary endpoint events in the Treatment group compared with 13 events in the Control group. The hazard ratio was 1.91 with a wide confidence interval.

Table 24. Primary Endpoint and Components – NYHA Class IV Subjects

Endpoint[1]	**Treatment (N=29) Events (Rate[2])**	**Control (N=25) Events (Rate[2])**	**Hazard Ratio (95% CI)[3]**
Full Follow-Up			
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**29 (1.527)**	**16 (0.910)**	**1.68 (0.88, 3.20)**
Heart Failure Hospitalization + ED/OP	24 (1.337)	14 (0.840)	1.59 (0.80, 3.18)
Heart Failure Hospitalization	19 (1.130)	13 (0.826)	1.37 (0.66, 2.84)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	5 (0.535)	1 (0.121)	4.43 (0.52, 38.0)
Death	5 (0.279)	2 (0.123)	2.26 (0.44, 11.6)
Prior to COVID-19			COVID-19 Interaction p-value[4], p=0.9455
Heart Failure Hospitalization + ED/OP + Death (Primary Endpoint)	**20 (3.123)**	**13 (1.632)**	**1.91 (0.88, 4.18)**
Heart Failure Hospitalization + ED/OP	18 (3.110)	11 (1.516)	2.05 (0.88, 4.77)
Heart Failure Hospitalization	13 (2.597)	10 (1.493)	1.74 (0.68, 4.43)
HF Emergency Department/Hospital Outpatient Visit (ED/OP)	5 (0.576)	1 (0.128)	4.51 (0.52, 38.9)
Death	2 (0.268)	2 (0.223)	1.20 (0.18, 8.15)

1. Endpoints include CEC adjudicated Heart Failure (HF) Hospitalizations or HF Emergency Department/Hospital Outpatient Visits (ED/OP) with an admission date after the date of implant hospitalization discharge through 395 days after the date of implant. All Cause Deaths are included from implant date to 395 days after implant date.
2. Event Rate is an annualized rate estimated from the Andersen-Gill model.
3. Hazard Ratio and 95% Confidence Interval estimated from the Andersen-Gill model with robust sandwich variance estimates.
4. Interaction p-value is a joint test on the interaction term of treatment group by COVID analysis time period.

Summary/Key Takeaways

Despite the limitations of COVID-19 occurring during the follow-up of the study, the results of the GUIDE-HF Randomized Arm support the continued safety and effectiveness of the CardioMEMS™ HF System within an expanded population, as shown by reduced HF hospitalizations. The treatment benefit observed in NYHA Class II subjects and those with elevated NT-proBNP/BNP but without a recent hospitalization for HF suggests that intervention in NYHA Class II heart failure, even prior to the occurrence of HF events, can provide benefit.

Pivotal Data from the CHAMPION Trial

The CHAMPION (CardioMEMS HF Sensor Allows Monitoring of Pressures to Improve Outcomes in NYHA Functional Class III Heart Failure Patients) clinical trial was a prospective, multi-center, single-blind, randomized, clinical trial in 550 patients across 64 centers in the United States.

Purpose

The goal of the CHAMPION clinical trial was to determine if physicians could reduce HF hospitalizations by managing patient PA pressures using the CardioMEMS™ HF System.

Methods

Study Design

550 patients with NYHA Class III HF and a prior HF hospitalization within 12 months were randomized to standard of care plus the CardioMEMS HF System (Treatment group; 270 patients) or to standard of care only (Control group; 280 patients). All patients were implanted with the PA Sensor and took daily readings from home.

Patients were enrolled regardless of their baseline ejection fraction so that patients with both reduced and preserved systolic function were included. Physicians had access to pulmonary artery pressure information for patients in the Treatment group but not for patients in the Control group.

Following the completion of Randomized Access, patients transitioned to a period of Open Access, during which PA pressures were provided to physicians for patients in both the Treatment and the Control groups. Specifically, physicians continued to have access to the Treatment group's PA pressures in an unchanged manner, whereas access to the Control group's PA pressure was provided for the first time.

Follow-Up Schedule

After right heart catheterization (RHC) and sensor implantation, all patients had follow-up study visits at 1 month, 3 months, 6 months, and every 6 months thereafter until study termination.

Study Endpoints

The primary and secondary endpoints were evaluated after 6 months of patient follow-up. The primary safety endpoints were 1) Freedom from device/system-related complications (DSRC), and 2) Freedom from pressure sensor failures. The primary efficacy endpoint was the rate of HF hospitalizations. All hospitalizations were adjudicated by an independent Clinical Events Committee (CEC) who were blinded to treatment assignment. Secondary endpoints were tested in a hierarchical fashion and included changes in PA pressures, proportion of subjects hospitalized for HF, days alive outside of the hospital for HF, and quality of life.

Because blinded follow-up continued until the last patient completed 6 months of follow-up, the average patient follow-up was much longer (17.6 months) and pre-specified supplementary analyses were conducted on the full duration of follow-up data (Randomized Access).

Patient Demographics and Disposition

575 patients were consented for trial enrollment and underwent right heart catheterization. Of these 575 patients, 25 (4.3%) underwent a right heart catheterization but did not receive an implant primarily because of anatomical/physiological conditions identified during the RHC. Of the 550 randomized patients, 270 were assigned to the Treatment group and 280 to the Control group. The two groups were similar with respect to baseline characteristics (See table below.)

Table 25. Patient Demographics

	Randomized Group		
	Treatment (N=270)	**Control (N=280)**	**p-value[1]**
Age (years)	61.3 ± 12.98 (270)	61.8 ± 12.73 (280)	0.5927
Male	194/270 (71.9%)	205/280 (73.2%)	0.7745
Race (White)	196/270 (72.6%)	205/280 (73.2%)	0.9236
Systolic BP (mmHg)	121.2 ± 22.52 (270)	123.2 ± 21.01 (280)	0.1286
Heart Rate (bpm)	72.4 ± 12.91 (269)	73.0 ± 12.14 (280)	0.4873
BMI	30.5 ± 6.50 (270)	30.9 ± 7.35 (280)	0.6228
BUN (mg/dL)	29.6 ± 17.99 (248)	28.1 ± 16.17 (267)	0.6325
Creatinine (mg/dL)	1.4 ± 0.47 (270)	1.4 ± 0.42 (280)	0.5560
GFR (mL/min/1.73m²)	60.4 ± 22.50 (270)	61.8 ± 23.20 (280)	0.5638
Ejection Fraction (EF>=40%)	62/270 (23.0%)	57/279 (20.4%)	0.5343
Cardiac Output (L/min)	4.5 ± 1.41 (270)	4.6 ± 1.54 (278)	0.5499
Cardiac Index (L/min/m²)	2.1 ± 0.59 (270)	2.2 ± 0.64 (278)	0.4405
PVR	2.9 ± 2.02 (270)	2.7 ± 1.82 (278)	0.4609
PA Wedge Pressure (mmHg)	17.5 ± 7.97 (270)	19.0 ± 8.12 (280)	0.0276
PA Mean Pressure (mmHg)	28.9 ± 9.92 (270)	29.9 ± 10.05 (280)	0.3021
CRT-D/ICD Implant	179/270 (66.3%)	197/280 (70.4%)	0.3145
Ischemic Cardiomyopathy	158/270 (58.5%)	174/280 (62.1%)	0.4327
Hypertension	207/270 (76.7%)	220/280 (78.6%)	0.6100
Hyperlipidemia	204/270 (75.6%)	218/280 (77.9%)	0.5458
Coronary Artery Disease	182/270 (67.4%)	202/280 (72.1%)	0.2290
History of MI	134/270 (49.6%)	137/280 (48.9%)	0.9320
Diabetes Mellitus	130/270 (48.1%)	139/280 (49.6%)	0.7337
AFIB	120/270 (44.4%)	135/280 (48.2%)	0.3932
COPD	76/270 (28.1%)	83/280 (29.6%)	0.7078
ACE/ARB use	205/270 (75.9%)	222/280 (79.3%)	0.3584
Beta Blocker use	243/270 (90.0%)	256/280 (91.4%)	0.6595

1. Wilcoxon Rank-Sum Test for continuous measures and Fisher's exact test for categorical measures.

The mean follow-up during Randomized Access was 17.6 months for a total duration of approximately 800 patient years. During the course of Randomized Access, 93 patients in the Treatment group and 110 patients in the Control group exited the study with the primary reason being death.

A total of 347 patients (177 in the Treatment group and 170 in the Control group) completed Randomized Access and entered Open Access. The mean follow-up during Open Access was 13 months for a total duration of approximately 400 patient years. During the course of Open Access, 58 patients in the Treatment group and 43 patients in the Control group exited the study with the primary reason being death.

Primary and Secondary Endpoint Results

Primary Safety Endpoints

The CHAMPION clinical trial met the two primary safety endpoints: (1) Freedom from device/system related complications (DSRC) and (2) Freedom from sensor failure. The protocol pre-specified objective performance criteria (OPC) were that at least 80% of patients were to be free from DSRC and at least 90% were to be free from pressure sensor failure. Of the 575 patients in the safety population, 567 (98.6%) were free from DSRC at 6 months (lower confidence limit 97.3%, $p<0.0001$). This lower limit of 97.3% is greater than the pre-specified OPC of 80% (See first and second tables below.) There were no sensor explants or repeat implants and all sensors were operational at 6 months for a freedom from sensor failure of 100% (lower confidence limit 99.3%, $p<0.0001$). This lower limit of 99.3% is greater than the pre-specified OPC of 90% (See third table below.)

Table 26. Primary Safety Endpoint – Freedom from Device/System Related Complications

Device/System Related Complications[1] (n=575)		Lower 95.2% Confidence Limit[2]	Objective Performance Criterion (OPC)	p-value[3]
Yes	**No**			
8 (1.4%)1	567 (98.6%)	97.3%	80%	p<0.0001

1. DSRCs (8 total) by group: Consented but not randomized (2), Treatment (3), Control (3)
2. Exact 95.2% Clopper-Pearson lower confidence limit
3. p-value from exact test of binomial proportions compared to 80% for all patients

Table 27. Primary Safety Endpoint – Description of Device/System Related Complications

Description	Number of Subjects with Device or System related complication (%) (N = 575)
Hemoptysis	1 (0.2%)
Sensor did not deploy	1 (0.2%)
Transient Ischemic Attack (TIA)	1 (0.2%)
Atypical chest pain	1 (0.2%)
Sepsis → death	1 (0.2%)
Atrial arrhythmia → death	1 (0.2%)
Arterial embolism (upper extremity)	1 (0.2%)
Pulmonary artery (in-situ) thrombus	1 (0.2%)
Total Subjects Experiencing aDSRC	**8 (1.4%[1], 95.2% LCB 97.3%)**

Table 28. Primary Safety Endpoint – Freedom from Pressure Sensor Failures

Pressure Sensor Failures (n=550)[1]		Lower 95.2% Confidence Limit[2]	Objective Performance Criterion (OPC)	p-value[3]
Yes	**No**			
0 (0.0%)	550 (100%)[1]	99.3%	90%	p<0.0001

1. Pressure sensor failure counts by group: Treatment (0), Control (0)
2. Exact 95.2% Clopper-Pearson lower confidence limit
3. p-value from exact test of binomial proportions compared to 90% for all patients

Primary Efficacy Endpoint

The primary efficacy endpoint of the CHAMPION clinical trial was the rate of HF hospitalizations during the first 6 months of Randomized Access. There were 84 HF hospitalizations in the Treatment group compared with 120 HF hospitalizations in the Control group. This difference between the groups represented a 28% reduction in the 6-month rate of HF hospitalization in the Treatment group (0.32 hospitalizations per patient in the Treatment group vs. 0.44 hospitalizations per patient in the Control group, HR 0.72, 95% CI 0.60-0.85, p = 0.0002) (See table below.)

Table 29. Primary Efficacy Endpoint – HF Hospitalization Rates During First Six months of Randomized Access

	Number of HF Hospitalizations	6 Month HF Hospitalization Rate	Hazard Ratio(95% CI) [p-value][1]
Treatment Group (n=270)	84	0.32	0.72 (0.60-0.85) p=0.0002
Control Group (n=280)	120	0.44	

1. p-value and hazard ratio from negative binomial regression model

Secondary Endpoints

The four secondary efficacy endpoints were analyzed hierarchically at six months (See table below.) At baseline, both Treatment and Control patients had similar PA mean pressures. When compared with patients in the Control group, the patients in the Treatment group had greater reduction in mean PA pressure (p=0.0077); were less likely to be hospitalized for heart failure (p=0.0292); spent more days alive outside of the hospital for heart failure (p=0.0280); and reported a better quality of life (Minnesota Living with Heart Failure Questionnaire) (p=0.0236).

Table 30. Secondary Efficacy Endpoints at Six Months

	Treatment	Control	p-value
Change from baseline in mean pulmonary artery pressure, area under the curve (mean mmHg – days)	-155.7 (n=265)	0.32	0.0077[1]
Proportion of patients hospitalized for heart failure(%)	55 (20.4%) (n=270)	80 (28.6%)	0.0292[2]
Days alive outside the hospital for heart failure (mean)	174.4 (n=270)	172.1 (n=280)	0.0280[3]
Minnesota Living with Heart Failure Questionnaire (mean [median])	45.2 [45.0] (n=229)	50.6 [52.0] (n=236)	0.0236[4]

1. p-value from analysis of covariance with baseline pressure as the covariate
2. p-value from Fisher's exact test
3. p-value from Wilcoxon rank sum test after controlling for subject duration in study (i.e., days alive outside the hospital / subject duration x 180)
4. p-value from two-group t-test

Medical Management

Physicians responded to Treatment patients' elevated PA pressures by making medication changes to lower PA pressures in an attempt to reduce the risk for HF hospitalization. Physicians documented all medication changes for all patients and indicated whether the change was made in response to PA pressures or standard of care information. During the six-month follow-up period, physicians made 1113 HF medication changes in the Treatment group and 1061 HF medication changes in the Control group in response to standard of care information. In the Treatment group only, physicians made 1404 HF medication changes in response to PA pressures, primarily through diuretics and vasodilators. This incremental HF management in response to PA pressures using the CardioMEMS™ HF System led to a significant reduction in HF hospitalizations.

Results from the Entire Randomized Access Period

HF Hospitalizations

During the entire Randomized Access period, the rate of HF hospitalizations was 33% lower in the Treatment group than in the Control group (0.46 vs. 0.68 annualized HF hospitalization rates, HR 0.67, 95%CI 0.55-0.80) (see table below). The magnitude of the effect during the entire Randomized Access period was slightly larger than that seen during the 6-month primary endpoint period (33% vs. 28%), indicating durability of the treatment effect. The number needed to treat (NNT) per year to prevent one HF hospitalization was 4. For every 100 patients treated, 23 HF hospitalizations would be prevented per year.

Table 31. HF Hospitalization Rates During Randomized Access

	Number of HF Hospitalizations	Annualized HF Hospitalization Rate	Hazard Ratio[1] (95% CI)	NNT Per Year to Prevent One HF Hospitalization
Treatment Group (n=270)	182	0.46	0.67 (0.55-0.80)	4
Control Group (n=280)	279	0.68		

1. Hazard ratio from Andersen-Gill model.

Mortality

The proportion of patients who died in the Treatment group (18.5%) was smaller than in the Control Group (22.9%) with a relative risk reduction of 20% (HR 0.80, 95% CI 0.55 – 1.15).

Freedom from Death or First HF Hospitalization

The proportion of patients who died or had at least one HF hospitalization in the Treatment group (44.8%) was smaller than in the Control Group (51.8%) with a relative risk reduction of 23% (HR 0.77, 95%, CI 0.60 – 0.98).

All Cause Hospitalizations

All-cause hospitalizations were reduced in the Treatment group (554 in the Treatment group vs. 672 in the Control group, HR 0.84, 95% CI 0.75 – 0.95). The NNT per year to prevent one all-cause hospitalization was 4. For every 100 patients treated, 26 all-cause hospitalizations would be prevented per year.

Death or All Cause Hospitalizations

Death or all-cause hospitalizations were reduced in the Treatment group (604 in the Treatment group vs. 736 in the Control group, HR 0.84, 95% CI 0.76 – 0.94). The NNT per year to prevent one death or all-cause hospitalization was 4. For every 100 patients treated, 29 deaths or all-cause hospitalizations would be prevented per year.

Results from the Open Access Period (Longitudinal Analysis)

In the Open Access period, physicians were given access to PA pressures in the Control group for the first time while access to PA pressures for the Treatment group continued. In the Control group (n=170), new physician access to PA pressures 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*). In the Treatment group (n=177), continued physician access to PA pressures resulted in the maintenance of low HF hospitalization rates (0.45 vs. 0.48, HR 0.93, 95% CI 0.70-1.22, p=0.5838*).

To account for potential longitudinal confounders, the change in HF hospitalization rates in the Control group as result of new access to PA pressures was compared to the change in HF hospitalization rates in the Treatment group. The change in HF hospitalization rates in the Control group was significantly greater than in the Treatment group (HR 0.56, 95% CI 0.38-0.83, p=0.0040*), indicating that the significant 48% reduction in HF hospitalization rates observed in the Control group was the result of physician access to PA pressure and not longitudinal effects.

(*P-values should be interpreted with caution because the analyses including Part 2 data were not specified before the onset of the study and there are various sources of confounding effects which cannot be separated from the treatment effect.)

Treatment Effects in Women

The CHAMPION study was not powered to show statistical significance for gender, thus a complete determination of the effect of the device in women cannot be made. At the request of the U.S. Food and Drug Administration (FDA), a post-hoc gender analysis was conducted for the CHAMPION study, and the initial finding of a treatment-by-gender interaction for the effect of the CardioMEMS device on the HF hospitalization rate was related to (1) fewer women being in the study and the short duration of follow-up leading to a small number of events in women; and (2) the low HF hospitalization rate in Control women due to an early excess of deaths in women in the Control group, which acted as a competing risk to censor the occurrence of hospitalizations for heart failure.

A further analysis of the treatment-by – gender interaction was performed over the full period of Randomized Access and by incorporating death in the Cox Proportional Hazards. When these limitations and confounding issues were evaluated over the full period, there was neither a qualitative nor quantitative treatment-by-gender interaction and the treatment effect remained positive, independent of gender. However, the analyses conducted do not alleviate the possibility of a diminished treatment effect in women. Given the small number of women enrolled and small number of events observed in women, the true treatment effect in this group remains uncertain. In order to further complement and evaluate the results obtained during the CHAMPION study, the effect of the device in women was studied as part of the post approval study (please refer to results in Long Term Data section.)

The figures below depict the Freedom from HF Hospitalization and Freedom from Death for Men and Women over the Full Randomized Period (Part 1). Figure 10 below depicts the composite endpoint of Freedom from HF Hospitalization or Death for Men and Women over the Full Randomized Period (Part 1). They illustrate the apparent difference in treatment effect by gender. As seen in the first figure below, for HF hospitalizations alone, treatment and control women have similar outcomes. However, as seen in second figure below, control women had an increased early mortality creating a competing risk for HF hospitalizations i.e., fewer control women were alive to have HF hospitalizations. The third figure below examines Freedom from HF Hospitalization or Death and indicates a non-significant trend favoring women in the treatment group.

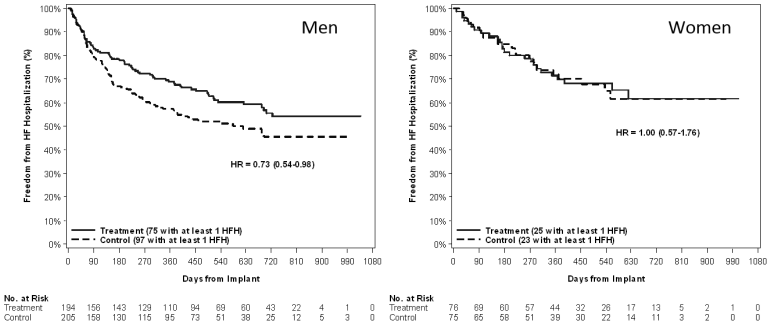


Figure 10. Freedom from HF Hospitalization over the Full Randomized Period (Part 1).

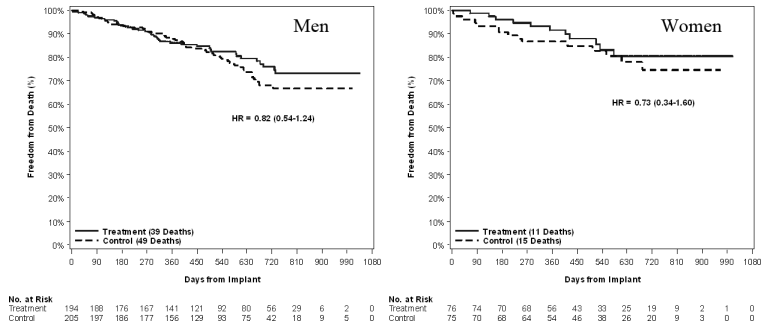


Figure 11. Freedom from Death over the Full Randomized Period (Part 1).

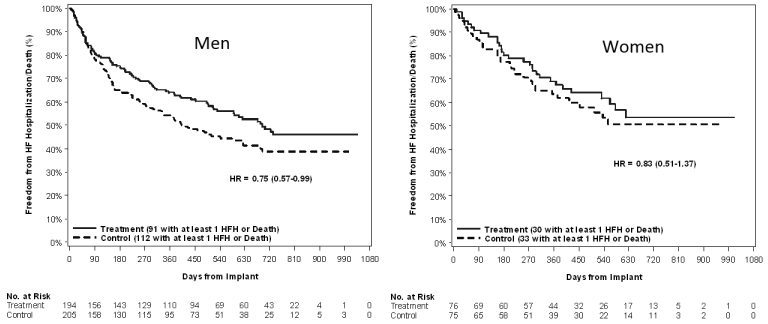


Figure 12. Freedom from HF Hospitalization or Death over the Full Randomized Period (Part 1).

Also performed were an Anderson-Gill Model with Frailty, Anderson Gill Model with Robust Sandwich Estimates (RSE) and Negative Binomial Regression using an endpoint of time to HF hospitalization or death in Part 1 and Part 1 + Part 2. As seen in the two tables below, all the competing risk analyses taking death into account as a competing risk show that there was no evidence of a treatment-by-gender interaction if a p-value of 0.05 is used. However, when analyses for interaction by gender are conducted, a p-value of 0.15 is typically used because the analysis is typically not powered appropriately. When considering a p-value of 0.15, there was some evidence of treatment-by-gender interaction in the competing risk analyses under the following models:

- AG Model with Frailty for Part 1
- NB Regression for Part 1
- AG Model with Robust Sandwich Estimate for Part 1 + Part 2
- GEE NB Regression for Part 1 + Part 2

Table 32. Results of treatment by gender interaction using different statistical models

Models	Estimate	SE	p-value
Part 1			
Cox Model: Endpoint of first HFR hospitalization or Death	-0.113	0.289	0.6968
Cox Model: Endpoint of first HFR hospitalization	-0.330	0.327	0.3131
AG Model with Frailty: Endpoint of HFR hospitalization or Death	-0.373	0.239	0.1211
AG Model with Frailty: Endpoint of HFR hospitalization	-0.531	0.262	0.0459
AG Model with RSE: Endpoint of HFR hospitalization or Death	-0.433	0.316	0.1712
AG Model with RSE: Endpoint of HFR hospitalization	-0.577	0.360	0.1094
NB Regression: Endpoint of HFR hospitalization or Death	-0.412	0.242	0.0896
NB Regression: Endpoint of HFR hospitalization	-0.573	0.191	0.0027

Table 32. Results of treatment by gender interaction using different statistical models

Models	Estimate	SE	p-value
Part 1 + Part 2			
Cox Model: Endpoint of first HFR hospitalization or Death	-0.204	0.249	0.4121*
Cox Model: Endpoint of first HFR hospitalization	-0.427	0.284	0.1331*
AG Model with Frailty: Endpoint of HFR hospitalization or Death	-0.376	0.274	0.1697*
AG Model with Frailty: Endpoint of HFR hospitalization	-0.588	0.271	0.0301*
AG Model with RSE: Endpoint of HFR hospitalization or Death	-0.477	0.274	0.0816*
AG Model with RSE: Endpoint of HFR hospitalization	-0.642	0.313	0.0399*
GEE NB Regression: Endpoint of HFR hospitalization or Death	-0.488	0.283	0.0841*
GEE NB Regression: Endpoint of HFR hospitalization	-0.761	0.319	0.0172*

Table 33. The Treatment vs. Control effects by Gender over Part 1 and over Part 1+ Part 2 under different models

Males	Hazard Ratio	p-value
Part 1 (Treatment vs. Control)		
AG Model with Frailty: Endpoint of HFR hospitalization or Death	0.67	0.0007
AG Model with Frailty: Endpoint of HFR hospitalization	0.64	0.0004
Part 1 + Part 2 (Former Control vs. Control)		
AG Model with Frailty: Endpoint of HFR hospitalization or Death	0.70	0.0176*
AG Model with Frailty: Endpoint of HFR hospitalization	0.53	<0.0001*
Females		
Part 1 (Treatment vs. Control)		
AG Model with Frailty: Endpoint of HFR hospitalization or Death	0.99	0.9440
AG Model with Frailty: Endpoint of HFR hospitalization	1.07	0.7584
Part 1 + Part 2 (Former Control vs. Control)		
AG Model with Frailty: Endpoint of HFR hospitalization or Death	0.80	0.4512*
AG Model with Frailty: Endpoint of HFR hospitalization	0.61	0.1482*

(*p-values should be interpreted with caution because the analyses including Part 2 data were not specified before the onset of the study and there are various sources of confounding effects which cannot be separated from the treatment effect.)

Non-Serious Adverse Device Events

There were 17 non-serious adverse device events that occurred over Part 1. There were no additional non-serious adverse device events over Part 2 of the clinical trial. These events were rare and are well known adverse events that occur during right heart catheterization procedures (See table below.)

Table 34. Non-serious Adverse Device Events Over Part 1 and Part 2

	Part 1						Part 2	
	TREATMENT (270)		CONTROL (280)		ALL PATIENTS (550)			
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
All Patients with an Event	5 (1.9%)	6	7 (2.5%)	11	12 (2.2%)	17	0 (0%)	0
General disorders and administration site conditions	1 (0.4%)	1 (16.7%)	4 (1.4%)	6 (54.5%)	5 (0.9%)	7 (41.2%)	0 (0%)	0 (0%)
Catheter site bleeding	0	0	1	1	1	1	0	0
Catheter site ecchymosis	0	0	1	1	1	1	0	0
Catheter site hematoma	0	0	1	1	1	1	0	0
Chest discomfort	0	0	1	1	1	1	0	0
Chest pain	0	0	1	1	1	1	0	0
Non-cardiac chest pain	1	1	0	0	1	1	0	0
Vessel puncture site pain	0	0	1	1	1	1	0	0

Table 34. Non-serious Adverse Device Events Over Part 1 and Part 2

	Part 1						Part 2	
	TREATMENT (270)		CONTROL (280)		ALL PATIENTS (550)			
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Investigations	2 (0.7%)	2 (33.3%)	1 (0.4%)	1 (9.1%)	3 (0.5%)	3 (17.6%)	0 (0%)	0 (0%)
Cardiac monitoring abnormal	1	1	0	0	1	1	0	0
Heart rate irregular	0	0	1	1	1	1	0	0
Serum creatinine increased	1	1	0	0	1	1	0	0
Respiratory, thoracic and mediastinal disorders	2 (0.7%)	2 (33.3%)	1 (0.4%)	1 (9.1%)	3 (0.5%)	3 (17.6%)	0 (0%)	0 (0%)
Hemoptysis	1	1	1	1	2	2	0	0
Dyspnea	1	1	0	0	1	1	0	0
Cardiac disorders	1 (0.4%)	1 (16.7%)	1 (0.4%)	1 (9.1%)	2 (0.4%)	2 (11.8%)	0 (0%)	0 (0%)
Congestive heart failure	1	1	0	0	1	1	0	0
Ventricular tachycardia	0	0	1	1	1	1	0	0
Nervous system disorders hematoma	0 (0.0%)	0 (0.0%)	1 (0.4%)	1 (9.1%)	1 (0.2%)	1 (5.9%)	0 (0%)	0 (0%)
Dizziness	0	0	1	1	1	1	0	0
Vascular disorders	0 (0.0%)	0 (0.0%)	1 (0.4%)	1 (9.1%)	1 (0.2%)	1 (5.9%)	0 (0%)	0 (0%)
Vessel perforation	0	0	1	1	1	1	0	0

Non-Serious Adverse Events Not Related to the Device

Table 35. Non-Serious Adverse Events Not Related to the Device Over Part 1 and Part 2

	Part 1						Part 2	
	TREATMENT (270)		CONTROL (280)		ALL PATIENTS (550)		ALL PATIENTS (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
All Patients with an Event	216 (80.0%)	1229	223 (79.6%)	1135	439 (79.8%)	2364	219 (63.1%)	787
Blood and lymphatic system disorders	27 (10.0%)	37	22 (7.9%)	28	49 (8.9%)	65	13 (3.7%)	16
Cardiac disorders	81 (30.0%)	140	69 (24.6%)	117	150 (27.3%)	257	49 (14.1%)	71
Congenital, familial and genetic disorders	0 (0.0%)	0	0 (0.0%)	0	0 (0.0%)	0	3 (0.9%)	3
Ear and labyrinth disorders	6 (2.2%)	6	2 (0.7%)	2	8 (1.5%)	8	2 (0.6%)	2
Endocrine disorders	4 (1.5%)	4	9 (3.2%)	10	13 (2.4%)	14	7 (2.0%)	7
Eye disorders	12 (4.4%)	12	14 (5.0%)	16	26 (4.7%)	28	7 (2.0%)	8
Gastrointestinal disorders	64 (23.7%)	104	60 (21.4%)	96	124 (22.5%)	200	48 (13.8%)	70
General disorders and administration site conditions	64 (23.7%)	102	45 (16.1%)	80	109 (19.8%)	182	50 (14.4%)	62
Hepatobiliary disorders	1 (0.4%)	1	7 (2.5%)	10	8 (1.5%)	11	3 (0.9%)	3
Immune system disorders	4 (1.5%)	4	4 (1.4%)	4	8 (1.5%)	8	4 (1.2%)	4

Table 35. Non-Serious Adverse Events Not Related to the Device Over Part 1 and Part 2

	Part 1						Part 2	
	TREATMENT (270)		CONTROL (280)		ALL PATIENTS (550)		ALL PATIENTS (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Infections and infestations	76 (28.1%)	129	91 (32.5%)	150	167 (30.4%)	279	65 (18.7%)	99
Injury, poisoning and proceduralcomplications	32 (11.9%)	44	32 (11.4%)	37	64 (11.6%)	81	32 (9.2%)	43
Investigations	32 (11.9%)	51	26 (9.3%)	40	58 (10.5%)	91	22 (6.3%)	25
Metabolism and nutrition disorders	66 (24.4%)	116	52 (18.6%)	88	118 (21.5%)	204	37 (10.7%)	53
Musculoskeletal and connectivetissue disorders	49 (18.1%)	75	58 (20.7%)	73	107 (19.5%)	148	56 (16.1%)	70
Neoplasms benign, malignant and unspecified (incl. cysts and polyps)	6 (2.2%)	8	9 (3.2%)	9	15 (2.7%)	17	6 (1.7%)	7
Nervous system disorders	61 (22.6%)	86	50 (17.9%)	67	111 (20.2%)	153	47 (13.5%)	56
Psychiatric disorders	34 (12.6%)	46	29 (10.4%)	36	63 (11.5%)	82	25 (7.2%)	31
Renal and urinary disorders	33 (12.2%)	55	35 (12.5%)	45	68 (12.4%)	100	21 (6.1%)	21
Reproductive system and breastdisorders	7 (2.6%)	8	16 (5.7%)	16	23 (4.2%)	24	11 (3.2%)	13
Respiratory, thoracic and mediastinal disorders	68 (25.2%)	97	70 (25.0%)	117	138 (25.1%)	214	47 (13.5%)	66
Skin and subcutaneous tissuedisorders	23 (8.5%)	26	24 (8.6%)	28	47 (8.5%)	54	9 (2.6%)	9
Surgical and medical procedures	17 (6.3%)	21	16 (5.7%)	20	33 (6.0%)	41	16 (4.6%)	19
Vascular disorders	41 (15.2%)	57	39 (13.9%)	46	80 (14.5%)	103	27 (7.8%)	29

Serious Adverse Events Over Part 1 and Part 2

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
All Patients with an Event	**198 (73.3%)**	**797**	**217 (77.5%)**	**956**	**415 (75.5%)**	**1753**	**201 (57.9%)**	**647**
Cardiac disorders	**138 (51.1%)**	**333**	**151 (53.9%)**	**443**	**289 (52.5%)**	**776**	**119 (34.3%)**	**238**
Congestive heart failure	99	204	121	274	220	478	80	140
Heart failure	10	15	13	22	23	37	10	12
Ventricular tachycardia	10	14	12	16	22	30	8	9
Myocardial infarction	7	7	14	14	21	21	9	9
Cardiac pain	13	19	7	22	20	41	0	0
Atrial fibrillation	3	5	10	11	13	16	4	4
Cardiomyopathy	5	6	8	11	13	17	6	7
Cardiopulmonary arrest	3	3	7	7	10	10	3	3
Unstable angina	4	4	5	5	9	9	4	6
Coronary artery disease	5	5	3	3	8	8	4	4

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Ventricular arrhythmia	3	3	5	7	8	10	0	0
Ventricular fibrillation	5	6	2	2	7	8	2	2
Anginal discomfort	1	1	5	8	6	9	2	4
Cardiac arrest	2	2	4	4	6	6	6	6
Ischemic cardiomyopathy	3	4	3	3	6	7	6	7
Atrial flutter	2	2	3	3	5	5	3	3
Cardiogenic shock	2	2	3	3	5	5	3	3
Acute decompensated HF	2	2	1	1	3	3	0	0
ADHF	2	2	0	0	2	2	0	0
Acute coronary syndrome	1	2	1	1	2	3	1	1
Arrhythmia	1	1	1	1	2	2	1	1
Atrial arrhythmia	1	1	1	1	2	2	0	0
Cardiac failure	0	0	2	2	2	2	0	0
Heart disease, unspecified	1	1	1	1	2	2	1	1
Non-ischemic cardiomyopathy	1	1	1	1	2	2	0	0
Sick sinus syndrome	1	1	1	1	2	2	0	0
Angina unstable	0	0	1	1	1	1	0	0
Arrhythmia ventricular	1	1	0	0	1	1	0	0
Arrhythmia ventricular (NOS)	1	1	0	0	1	1	0	0
Atrial tachycardia	0	0	1	1	1	1	0	0
Bradycardia	0	0	1	1	1	1	2	2
Bradycardia-tachycardia syndrome	0	0	1	1	1	1	0	0
Cardiac arrhythmia	1	1	0	0	1	1	1	1
Cardiomegaly	0	0	1	1	1	1	0	0
Cardiorenal syndrome	1	1	0	0	1	1	1	2
Chronic heart failure	1	1	0	0	1	1	0	0
Congestive cardiac failure aggravated	0	0	1	1	1	1	0	0
Coronary artery disease progression	1	1	0	0	1	1	0	0
Coronary atherosclerosis	1	1	0	0	1	1	0	0
Coronary spasm	0	0	1	1	1	1	0	0
Decompensated heart failure	1	1	0	0	1	1	0	0
End stage cardiac failure	0	0	1	1	1	1	0	0
Heart failure, congestive	0	0	1	1	1	1	0	0
Heart valve incompetence	1	1	0	0	1	1	0	0
Intermediate coronary syndrome	0	0	1	1	1	1	0	0
Junctional tachycardia	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Left ventricular dysfunction	1	1	0	0	1	1	0	0
Mitral valve incompetence	1	1	0	0	1	1	1	1
Multi-valvular regurgitation	0	0	1	1	1	1	0	0
Non ST segment elevation myocardial infarction	1	1	0	0	1	1	0	0
Non-sustained ventricular tachycardia	1	1	0	0	1	1	0	0
Pacemaker mediated tachycardia	1	1	0	0	1	1	0	0
Paroxysmal supraventricular tachycardia	1	1	0	0	1	1	0	0
Pericardial disease	1	1	0	0	1	1	0	0
Pericardial effusion	1	1	0	0	1	1	0	0
Pericarditis	0	0	1	1	1	1	1	1
Premature ventricular contractions	0	0	1	1	1	1	0	0
Supraventricular tachycardia	0	0	1	1	1	1	0	0
Sustained ventricular tachycardia	1	1	0	0	1	1	0	0
Tachycardia	0	0	1	1	1	1	0	0
Tricuspid insufficiency	0	0	1	1	1	1	0	0
Ventricular ectopic beats	1	1	0	0	1	1	0	0
Ventricular rhythm	0	0	1	1	1	1	0	0
Wide complex tachycardia	0	0	1	1	1	1	0	0
Wide complex ventricular tachycardia	1	1	0	0	1	1	0	0
Asystole	0	0	0	0	0	0	2	2
Congestive cardiomyopathy	0	0	0	0	0	0	1	1
End stage heart disease	0	0	0	0	0	0	1	1
Hemopericardium	0	0	0	0	0	0	1	1
Palpitation	0	0	0	0	0	0	1	1
Paroxysmal atrial fibrillation	0	0	0	0	0	0	1	1
Polymorphic ventricular tachycardia	0	0	0	0	0	0	1	1
Tachycardia supraventricular	0	0	0	0	0	0	1	1
Infections and infestations	**45 (16.7%)**	**62**	**61 (21.8%)**	**90**	**106 (19.3%)**	**152**	**52 (15.0%)**	**76**
Pneumonia	11	11	15	16	26	27	17	19
Urinary tract infection	5	7	5	6	10	13	5	5
Bronchitis	3	3	5	6	8	9	3	3

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Cellulitis	1	1	6	7	7	8	1	1
Sepsis	3	4	4	4	7	8	7	9
Acute bronchitis	1	1	4	4	5	5	2	2
Bacteremia	1	1	3	5	4	6	2	2
Upper respiratory infection	2	2	2	2	4	4	1	1
Influenza	3	3	0	0	3	3	0	0
Cellulitis of leg	0	0	2	2	2	2	0	0
Cellulitis of legs	0	0	2	2	2	2	0	0
Central line infection	0	0	2	2	2	2	2	2
Endocarditis	0	0	2	2	2	2	0	0
Foot infection	2	3	0	0	2	3	0	0
Gastroenteritis	2	3	0	0	2	3	3	3
Incision site infection	1	3	1	4	2	7	1	1
Infection	0	0	2	2	2	2	1	1
Osteomyelitis	1	1	1	1	2	2	1	1
Pyelonephritis	1	1	1	1	2	2	0	0
Respiratory infection	1	1	1	1	2	2	0	0
Viral gastroenteritis	1	1	1	1	2	2	0	0
Abscess	1	1	0	0	1	1	0	0
Acute diverticulitis	1	1	0	0	1	1	0	0
Acute pyelonephritis	0	0	1	1	1	1	0	0
Bacterial endocarditis	0	0	1	1	1	1	0	0
Bacterial infection	1	1	0	0	1	1	0	0
C.difficile colitis	1	1	0	0	1	1	0	0
Catheter site infection	0	0	1	1	1	1	0	0
Cellulitis of arm	0	0	1	1	1	1	0	0
Cellulitis of hand	1	1	0	0	1	1	0	0
Clostridium difficile infection	1	1	0	0	1	1	0	0
Community acquired pneumonia	0	0	1	1	1	1	1	1
Diverticulitis	1	1	0	0	1	1	2	2
Gastritis viral	0	0	1	1	1	1	0	0
Gastroenteritis adenovirus	1	1	0	0	1	1	0	0
Groin abscess	1	1	0	0	1	1	0	0
HIV-related dementia	0	0	1	1	1	1	0	0
Infection MRSA	0	0	1	1	1	1	0	0
Infection NOS	0	0	1	1	1	1	1	1
Klebsiella bacteremia	1	1	0	0	1	1	0	0
Maxillary sinusitis	1	1	0	0	1	1	0	0
Methicillin-resistant staphylococcal aureus sepsis	0	0	1	1	1	1	0	0
Obstructive pneumonia	1	1	0	0	1	1	0	0
Otitis media	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Pneumonia MRSA	1	1	0	0	1	1	0	0
Prostatitis Escherichia coli	0	0	1	1	1	1	0	0
Purulent bronchitis	0	0	1	1	1	1	0	0
Salmonella infection, unspecified	0	0	1	1	1	1	0	0
Sepsis MRSA	0	0	1	1	1	1	1	2
Septic shock	0	0	1	1	1	1	3	3
Septicemia	0	0	1	1	1	1	0	0
Septicemia staphylococcal	0	0	1	1	1	1	0	0
Serratia infection	0	0	1	1	1	1	0	0
Sinusitis	0	0	1	1	1	1	1	1
Staphylococcal infection	1	1	0	0	1	1	0	0
Urosepsis	1	1	0	0	1	1	0	0
Viral infection	1	1	0	0	1	1	1	1
Viremia	0	0	1	1	1	1	0	0
Wound infection	0	0	1	1	1	1	0	0
Arthritis infective	0	0	0	0	0	0	1	1
Bronchopneumonia	0	0	0	0	0	0	1	1
Clostridium difficile colitis	0	0	0	0	0	0	3	3
Cytomegalovirus viremia	0	0	0	0	0	0	1	1
Febrile cold (excluding flu like illness)	0	0	0	0	0	0	1	1
Febrile infection	0	0	0	0	0	0	1	1
GI infection	0	0	0	0	0	0	1	1
Infection pseudomonas aeruginosa	0	0	0	0	0	0	1	1
MRSA colonization	0	0	0	0	0	0	1	1
MRSA wound infection	0	0	0	0	0	0	1	1
Pneumonia aspergillus	0	0	0	0	0	0	1	1
Septic joint	0	0	0	0	0	0	1	1
Suppurative peritonitis, other	0	0	0	0	0	0	1	1
Respiratory, thoracic and mediastinal disorders	**44 (16.3%)**	**58**	**52 (18.6%)**	**85**	**96 (17.5%)**	**143**	**32 (9.2%)**	**40**
Dyspnea	16	23	19	24	35	47	10	10
Respiratory failure	6	6	11	11	17	17	2	2
COPD exacerbation	4	4	11	20	15	24	5	5
Pleural effusion	3	3	3	4	6	7	3	3
Shortness of breath	4	4	2	3	6	7	0	0
Aspiration pneumonia	2	2	1	1	3	3	1	1
Epistaxis	0	0	3	3	3	3	2	2
Pulmonary hypertension	2	3	1	1	3	4	2	2
Respiratory distress	3	3	0	0	3	3	0	0
COPD	1	1	1	1	2	2	0	0
Dyspnea exertional	1	1	1	1	2	2	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Hypoxemia	0	0	2	2	2	2	0	0
Pneumonitis	0	0	2	2	2	2	0	0
Pulmonary edema	0	0	2	2	2	2	1	1
Pulmonary infiltration	0	0	2	2	2	2	1	1
Pulmonary thromboembolism	2	2	0	0	2	2	0	0
Acute respiratory failure	0	0	1	1	1	1	0	0
Apnea	1	1	0	0	1	1	0	0
Asthma	1	1	0	0	1	1	0	0
Asthma aggravated	0	0	1	1	1	1	0	0
Bronchitis asthmatic	0	0	1	1	1	1	0	0
Difficulty breathing	0	0	1	1	1	1	0	0
Dyspnea exacerbated	1	1	0	0	1	1	0	0
Exacerbation of asthma	0	0	1	1	1	1	0	0
Hemoptysis	0	0	1	1	1	1	1	3
Hypoxia	0	0	1	1	1	1	3	3
Productive cough	0	0	1	1	1	1	0	0
Pulmonary mass	1	1	0	0	1	1	0	0
Respiratory arrest	1	2	0	0	1	2	0	0
Chronic obstructive pulmonary disease	0	0	0	0	0	0	3	3
Cough	0	0	0	0	0	0	1	1
Hypoventilation	0	0	0	0	0	0	1	1
Pulmonary embolus	0	0	0	0	0	0	1	1
Tachypnea	0	0	0	0	0	0	1	1
General disorders and administration site conditions	**35 (13.0%)**	**43**	**30 (10.7%)**	**40**	**65 (11.8%)**	**83**	**36 (10.4%)**	**46**
Chest pain	16	20	10	11	26	31	17	26
Weakness	3	5	7	7	10	12	0	0
Chest pain (non-cardiac)	2	2	4	7	6	9	0	0
Fever	1	1	3	3	4	4	2	2
General malaise	3	3	0	0	3	3	1	1
Death	1	1	1	1	2	2	7	7
Pain	2	2	0	0	2	2	0	0
Sudden cardiac death	1	1	1	1	2	2	1	1
Anasarca	0	0	1	1	1	1	0	0
Central line complication	1	2	0	0	1	2	0	0
Chest discomfort	0	0	1	1	1	1	0	0
Chest pain aggravated	0	0	1	1	1	1	0	0
Chronic fatigue	0	0	1	1	1	1	0	0
Edema of lower extremities	1	2	0	0	1	2	2	2
Fatigue	1	1	0	0	1	1	0	0
Fatigue extreme	1	1	0	0	1	1	0	0
Febrile reaction	0	0	1	1	1	1	0	0
Fever of unknown origin	0	0	1	1	1	1	1	1

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Infusion site bleeding	0	0	1	1	1	1	0	0
Multi-organ failure	0	0	1	1	1	1	0	0
Non-cardiac chest pain	0	0	1	1	1	1	1	1
Substernal chest pain	0	0	1	1	1	1	0	0
Sudden death	1	1	0	0	1	1	0	0
Swelling	1	1	0	0	1	1	0	0
Edema	0	0	0	0	0	0	1	1
Malaise	0	0	0	0	0	0	1	1
Organ failure	0	0	0	0	0	0	1	1
Thrombus in catheter	0	0	0	0	0	0	1	1
Ulcer	0	0	0	0	0	0	1	1
Vascular disorders	**33 (12.2%)**	**42**	**27 (9.6%)**	**28**	**60 (10.9%)**	**70**	**15 (4.3%)**	**15**
Hypotension	15	20	13	14	28	34	6	6
Hematoma	2	2	2	2	4	4	0	0
Orthostatic hypotension	2	2	2	2	4	4	0	0
Deep vein thrombosis leg	3	4	0	0	3	4	0	0
Low output state	3	3	0	0	3	3	0	0
Peripheral arterial disease	2	2	1	1	3	3	0	0
Claudication	2	2	0	0	2	2	1	1
DVT of legs	2	2	0	0	2	2	0	0
Aortic stenosis	0	0	1	1	1	1	0	0
Arterial thrombosis (limbs)	1	1	0	0	1	1	0	0
DVT	0	0	1	1	1	1	1	1
Deep vein thrombosis	0	0	1	1	1	1	0	0
Extremity necrosis	0	0	1	1	1	1	0	0
Hemorrhage, unspecified	1	1	0	0	1	1	0	0
Hemorrhagic shock	1	1	0	0	1	1	0	0
Hypertension	0	0	1	1	1	1	1	1
Hypovolemic shock	1	1	0	0	1	1	2	2
Labile blood pressure	0	0	1	1	1	1	0	0
Peripheral vascular disease	0	0	1	1	1	1	0	0
Shock hemorrhagic	0	0	1	1	1	1	0	0
Subclavian artery thrombosis	1	1	0	0	1	1	0	0
Thromboembolic event	0	0	1	1	1	1	0	0
Bleeding	0	0	0	0	0	0	1	1
Cardiovascular collapse	0	0	0	0	0	0	1	1
Hypertensive emergency	0	0	0	0	0	0	1	1
Ischemia	0	0	0	0	0	0	1	1
Nervous system disorders	**29 (10.7%)**	**37**	**28 (10.0%)**	**38**	**57 (10.4%)**	**75**	**27 (7.8%)**	**32**
Syncope	12	15	7	8	19	23	9	13
CVA	2	2	4	4	6	6	2	2

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Stroke	3	3	2	2	5	5	3	3
Presyncope	0	0	3	3	3	3	2	2
Carotid artery stenosis	1	1	1	1	2	2	0	0
Dizziness	1	1	1	1	2	2	1	1
Embolic stroke	1	1	1	1	2	2	0	0
Subarachnoid hemorrhage	1	1	1	1	2	2	0	0
Anoxic encephalopathy	0	0	1	1	1	1	0	0
Ataxia	1	1	0	0	1	1	0	0
Cerebellar infarction	1	1	0	0	1	1	0	0
Cerebral degeneration	1	1	0	0	1	1	0	0
Cerebral infarct	0	0	1	1	1	1	0	0
Cerebrovascular accident	1	1	0	0	1	1	0	0
Disorder brain (chronic)	1	1	0	0	1	1	0	0
Embolic cerebral infarction	0	0	1	1	1	1	0	0
Encephalopathy	0	0	1	1	1	1	1	1
Headache	0	0	1	1	1	1	0	0
Hemorrhagic stroke	0	0	1	1	1	1	0	0
Hepatic encephalopathy	1	1	0	0	1	1	0	0
Hypertensive encephalopathy	0	0	1	1	1	1	0	0
Intracranial hemorrhage	1	1	0	0	1	1	0	0
Ischemic stroke	0	0	1	1	1	1	0	0
Loss of consciousness	1	2	0	0	1	2	1	1
Numbness	0	0	1	2	1	2	0	0
Ophthalmoplegic migraine	0	0	1	1	1	1	0	0
Paresthesia	0	0	1	1	1	1	0	0
Sciatica	1	1	0	0	1	1	0	0
Seizure	1	1	0	0	1	1	0	0
Slurred speech	0	0	1	1	1	1	0	0
Somnolence	1	1	0	0	1	1	0	0
Syncope convulsive	1	1	0	0	1	1	0	0
TIA	0	0	1	1	1	1	2	2
Unresponsive to stimuli	0	0	1	1	1	1	1	1
Vasovagal symptoms	0	0	1	1	1	1	0	0
Weakness left or right side	0	0	1	1	1	1	0	0
Brain injury	0	0	0	0	0	0	1	1
Restless leg syndrome	0	0	0	0	0	0	1	1
Todd’s paralysis	0	0	0	0	0	0	1	1
Transient ischemic attacks	0	0	0	0	0	0	2	2
Vocal cord paralysis	0	0	0	0	0	0	1	1

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Renal and urinary disorders	**33 (12.2%)**	**41**	**24 (8.6%)**	**34**	**57 (10.4%)**	**75**	**20 (5.8%)**	**22**
Acute on chronic renal failure	11	12	9	10	20	22	1	1
Acute renal failure	9	10	7	9	16	19	8	9
Renal insufficiency	9	11	3	4	12	15	5	5
Acute renal insufficiency	0	0	2	2	2	2	0	0
Azotemia	1	1	1	1	2	2	0	0
Chronic kidney disease	1	1	1	1	2	2	0	0
Renal failure	1	1	1	1	2	2	1	1
Acute tubular necrosis	0	0	1	1	1	1	0	0
Chronic renal failure worsened	0	0	1	1	1	1	0	0
End stage renal failure	0	0	1	1	1	1	0	0
Hematuria	1	1	0	0	1	1	0	0
Kidney failure	1	1	0	0	1	1	0	0
Lupus nephritis	0	0	1	1	1	1	0	0
Nephrolithiasis	1	1	0	0	1	1	0	0
Renal artery stenosis	1	1	0	0	1	1	0	0
Renal function abnormal	1	1	0	0	1	1	0	0
Uremia	0	0	1	1	1	1	0	0
Urinary retention	0	0	1	1	1	1	2	2
Chronic renal failure	0	0	0	0	0	0	1	1
Kidney disorder	0	0	0	0	0	0	1	1
Renal disease	0	0	0	0	0	0	1	1
Renal failure acute on chronic	0	0	0	0	0	0	1	1
Gastrointestinal disorders	**24 (8.9%)**	**35**	**31 (11.1%)**	**49**	**55 (10.0%)**	**84**	**36 (10.4%)**	**53**
GI bleed	6	7	7	7	13	14	9	10
Abdominal pain	3	3	5	6	8	9	2	2
Diarrhea	4	4	1	1	5	5	2	2
Nausea	4	4	1	1	5	5	0	0
Gastritis	3	3	1	1	4	4	1	1
Gastrointestinal bleed	0	0	4	6	4	6	6	8
Vomiting	2	2	2	4	4	6	1	1
Constipation	0	0	3	3	3	3	1	1
Pancreatitis	2	2	1	1	3	3	1	1
Ascites	2	2	0	0	2	2	0	0
Dysphagia	1	1	1	1	2	2	2	2
Emesis	2	2	0	0	2	2	0	0
Esophagitis	0	0	2	2	2	2	0	0
Gastroparesis	0	0	2	2	2	2	1	2
Abdominal bloating	1	1	0	0	1	1	0	0
Abdominal wall hematoma	0	0	1	1	1	1	0	0
Chronic epigastric pain	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Dental caries	0	0	1	1	1	1	0	0
Esophageal spasm	1	1	0	0	1	1	0	0
Esophagitis ulcerative	1	1	0	0	1	1	0	0
Gastric polyps	0	0	1	1	1	1	0	0
Gastritis erosive	0	0	1	1	1	1	0	0
Ileus	0	0	1	1	1	1	0	0
Incarcerated umbilical hernia	0	0	1	1	1	1	0	0
Ischemic colitis	0	0	1	1	1	1	1	2
Melena	1	1	0	0	1	1	0	0
Odynophagia	0	0	1	1	1	1	0	0
Rectal bleeding	0	0	1	3	1	3	1	1
Rectal fistula	0	0	1	1	1	1	0	0
Rectal prolapse	0	0	1	1	1	1	0	0
Ventral hernia	1	1	0	0	1	1	2	4
Decay dental	0	0	0	0	0	0	1	1
Duodenitis	0	0	0	0	0	0	1	1
Fecal impaction (causing obstruction)	0	0	0	0	0	0	1	1
Gastric ulcer	0	0	0	0	0	0	1	1
Gastric ulcer haemorrhage	0	0	0	0	0	0	1	1
Gastrointestinal bleed	0	0	0	0	0	0	1	1
Gastrointestinal bleeding	0	0	0	0	0	0	2	2
Hematemesis	0	0	0	0	0	0	1	2
Hematochezia	0	0	0	0	0	0	2	2
Mesenteric ischemia	0	0	0	0	0	0	1	1
Reflux esophagitis	0	0	0	0	0	0	1	1
Right upper quadrant pain	0	0	0	0	0	0	1	1
Small bowel obstruction	0	0	0	0	0	0	1	1
Metabolism and nutrition disorders	**26 (9.6%)**	**33**	**28 (10.0%)**	**38**	**54 (9.8%)**	**71**	**24 (6.9%)**	**30**
Dehydration	7	9	5	5	12	14	8	8
Hyperglycemia	3	4	5	6	8	10	1	1
Hypoglycemia	4	4	2	2	6	6	2	2
Failure to thrive	2	2	3	4	5	6	1	1
Hypokalemia	2	2	3	3	5	5	3	3
Hypovolemia	2	2	3	3	5	5	0	0
Electrolyte imbalance	2	2	2	2	4	4	0	0
Hypervolemia	2	2	2	2	4	4	0	0
Hyponatremia	1	1	3	3	4	4	4	4
Diabetes	2	2	1	1	3	3	0	0
Hyperkalemia	1	1	2	2	3	3	1	1
Diabetes mellitus loss of control	1	1	1	1	2	2	0	0
Anorexia	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Diabetes mellitus	1	1	0	0	1	1	0	0
Hypercalcemia	0	0	1	1	1	1	0	0
Ketoacidosis (diabetic)	0	0	1	1	1	1	0	0
Volume overload	0	0	1	1	1	1	0	0
Diabetes mellitus inadequate control	0	0	0	0	0	0	1	1
Diabetic ketoacidosis	0	0	0	0	0	0	1	1
Gout	0	0	0	0	0	0	1	1
Gout aggravated	0	0	0	0	0	0	2	2
Gout flare	0	0	0	0	0	0	2	3
Hyperosmolar state	0	0	0	0	0	0	1	1
Hypoglycemic attack	0	0	0	0	0	0	1	1
Surgical and medical procedures	**24 (8.9%)**	**28**	**29 (10.4%)**	**34**	**53 (9.6%)**	**62**	**14 (4.0%)**	**15**
Implantable cardioverter defibrillator insertion	4	4	2	2	6	6	0	0
Pacemaker battery replacement	1	1	5	5	6	6	3	3
Cardiac resynchronization therapy	2	2	2	2	4	4	0	0
Heart transplant	1	1	3	3	4	4	2	2
Cardiac catheterization	3	5	0	0	3	5	0	0
Implantable defibrillator replacement	0	0	3	3	3	3	0	0
Amputation	0	0	2	2	2	2	0	0
Cardiac ablation	1	1	1	1	2	2	0	0
Cardiac resynchronization therapy	0	0	2	2	2	2	0	0
Cardioversion	1	1	1	1	2	2	0	0
Cholecystectomy	0	0	2	2	2	2	0	0
Foot surgery	1	1	1	1	2	2	1	1
Inguinal hernia repair	1	1	1	1	2	2	0	0
Abdominal hernia repair	1	1	0	0	1	1	0	0
Brachytherapy	1	1	0	0	1	1	0	0
Cardiac pacemaker revision	1	1	0	0	1	1	0	0
Central line placement	0	0	1	1	1	1	0	0
Colostomy closure	1	1	0	0	1	1	0	0
Epicardial lead placement	1	1	0	0	1	1	1	1
Gallbladder operation	0	0	1	1	1	1	0	0
Gastric bypass	0	0	1	1	1	1	0	0
Implantable defibrillator insertion	1	1	0	0	1	1	1	1
Incisional drainage	1	1	0	0	1	1	0	0
Knee total replacement	0	0	1	1	1	1	0	0
Mitral valve replacement	0	0	1	1	1	1	0	0
Neuroma removal	1	1	0	0	1	1	0	0
Parotidectomy	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Polypectomy	1	1	0	0	1	1	0	0
Stent placement	1	1	0	0	1	1	0	0
Total hip replacement	1	1	0	0	1	1	0	0
Total knee replacement	0	0	1	2	1	2	0	0
Tricuspid valve repair	0	0	1	1	1	1	0	0
Arteriovenous graft	0	0	0	0	0	0	1	1
Catheterization cardiac	0	0	0	0	0	0	2	2
Hospitalization NOS	0	0	0	0	0	0	1	1
Knee surgery NOS	0	0	0	0	0	0	1	1
Left ventricular assist device insertion	0	0	0	0	0	0	1	1
Ventricular assist device insertion	0	0	0	0	0	0	1	1
Injury, poisoning and procedural complications	**18 (6.7%)**	**21**	**16 (5.7%)**	**19**	**34 (6.2%)**	**40**	**15 (4.3%)**	**16**
Lead dislodgement	2	2	2	2	4	4	0	0
Hip fracture	0	0	3	3	3	3	1	1
Bleeding postoperative	1	1	1	1	2	2	0	0
Device malfunction	0	0	2	2	2	2	0	0
Fall	2	2	0	0	2	2	2	2
Head injury	0	0	2	2	2	2	0	0
Lead conductor fracture	2	2	0	0	2	2	0	0
Subdural hematoma	2	2	0	0	2	2	2	2
Accidental overdose	1	1	0	0	1	1	0	0
Ankle fracture	1	1	0	0	1	1	0	0
Cardiac pacemaker malfunction	0	0	1	1	1	1	0	0
Compression fracture	0	0	1	1	1	1	0	0
Contusion	0	0	1	1	1	1	0	0
Device lead damage	0	0	1	1	1	1	0	0
Device lead issue	1	1	0	0	1	1	0	0
Digoxin toxicity	1	1	0	0	1	1	3	3
Femur fracture	0	0	1	1	1	1	0	0
Fracture rib	1	1	0	0	1	1	0	0
Fractured hip	1	1	0	0	1	1	0	0
Fractured nose	1	1	0	0	1	1	0	0
Fractured pelvis NOS	1	1	0	0	1	1	0	0
Hematoma traumatic	1	1	0	0	1	1	0	0
Humerus fracture	0	0	1	1	1	1	0	0
Medical device complication	0	0	1	1	1	1	0	0
Migration of implant	1	1	0	0	1	1	0	0
Motor vehicle accident	1	1	0	0	1	1	0	0
Pneumothorax traumatic	1	1	0	0	1	1	0	0
Skin avulsion injury	0	0	1	1	1	1	0	0
Subdural haemorrhage	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Chemical pneumonitis	0	0	0	0	0	0	1	1
Device complication	0	0	0	0	0	0	5	5
Overdose accidental	0	0	0	0	0	0	1	1
Sciatic nerve injury	0	0	0	0	0	0	1	1
Musculoskeletal and connective tissue disorders	**11 (4.1%)**	**14**	**13 (4.6%)**	**13**	**24 (4.4%)**	**27**	**16 (4.6%)**	**17**
Back pain	0	0	2	2	2	2	1	1
Chest wall pain	1	1	1	1	2	2	0	0
Degenerative joint disease	1	1	1	1	2	2	1	1
Arthritis	1	1	0	0	1	1	1	1
Arthritis single joint	0	0	1	1	1	1	0	0
Back pain aggravated	1	2	0	0	1	2	0	0
Charcot's joint	0	0	1	1	1	1	0	0
Groin pain	0	0	1	1	1	1	0	0
Hemarthrosis involving lower leg	1	1	0	0	1	1	0	0
Lumbar spinal stenosis	0	0	1	1	1	1	0	0
Lupus erythematosus	0	0	1	1	1	1	1	2
Muscle necrosis	1	1	0	0	1	1	0	0
Musculoskeletal chest pain	1	1	0	0	1	1	0	0
Neck pain	1	1	0	0	1	1	1	1
Olecranon bursitis	0	0	1	1	1	1	0	0
Osteoarthritis knee	0	0	1	1	1	1	0	0
Polymyositis	1	1	0	0	1	1	0	0
Pseudogout	0	0	1	1	1	1	0	0
Rheumatoid arthritis	1	1	0	0	1	1	0	0
Rotator cuff tear	1	1	0	0	1	1	1	1
Scleroderma	0	0	1	1	1	1	0	0
Shoulder blade pain	1	1	0	0	1	1	0	0
Spinal column stenosis	1	1	0	0	1	1	0	0
Cervical spondylosis	0	0	0	0	0	0	1	1
Foot pain	0	0	0	0	0	0	1	1
Joint instability	0	0	0	0	0	0	1	1
Knee pain	0	0	0	0	0	0	1	1
Low back pain	0	0	0	0	0	0	1	1
Osteoarthritis knees	0	0	0	0	0	0	1	1
Pain in joint involving lower leg	0	0	0	0	0	0	1	1
Shoulder pain	0	0	0	0	0	0	1	1
Spinal stenosis NOS	0	0	0	0	0	0	1	1
Spondylolisthesis	0	0	0	0	0	0	1	1
Blood and lymphatic system disorders	**13 (4.8%)**	**14**	**10 (3.6%)**	**13**	**23 (4.2%)**	**27**	**14 (4.0%)**	**20**
Anemia	11	12	8	10	19	22	11	12

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Thrombocytopenia	1	1	1	1	2	2	1	1
Anemia microcytic	1	1	0	0	1	1	0	0
Leukocytosis	0	0	1	1	1	1	0	0
Neutropenia	0	0	1	1	1	1	0	0
Anemia aggravated	0	0	0	0	0	0	1	1
Hemolysis	0	0	0	0	0	0	1	5
Neutropenic fever	0	0	0	0	0	0	1	1
Investigations	**10 (3.7%)**	**10**	**5 (1.8%)**	**6**	**15 (2.7%)**	**16**	**3 (0.9%)**	**4**
Serum creatinine increased	2	2	1	2	3	4	0	0
Transplant evaluation	2	2	0	0	2	2	0	0
Anticoagulation drug level above therapeutic	1	1	0	0	1	1	0	0
Blood culture positive	1	1	0	0	1	1	0	0
Blood glucose fluctuation	0	0	1	1	1	1	0	0
INR	0	0	1	1	1	1	0	0
INR increased	1	1	0	0	1	1	0	0
International normalized ratio decreased	0	0	1	1	1	1	0	0
Mediastinoscopy	1	1	0	0	1	1	0	0
Pulmonary arterial pressure increased	1	1	0	0	1	1	1	1
QT interval prolonged	1	1	0	0	1	1	0	0
Ventricular filling pressure increased	0	0	1	1	1	1	0	0
Blood sugar abnormal	0	0	0	0	0	0	1	1
INR decreased	0	0	0	0	0	0	1	1
Urinary output diminished	0	0	0	0	0	0	1	1
Psychiatric disorders	**7 (2.6%)**	**7**	**7 (2.5%)**	**7**	**14 (2.5%)**	**14**	**6 (1.7%)**	**7**
Acute mental status changes	3	3	7	7	10	10	4	4
Agitation	1	1	0	0	1	1	0	0
Delirium toxic	1	1	0	0	1	1	0	0
Panic attack	1	1	0	0	1	1	0	0
Suicidal ideation	1	1	0	0	1	1	0	0
Mental status changes	0	0	0	0	0	0	2	2
Withdrawal syndrome	0	0	0	0	0	0	1	1
Hepatobiliary disorders	**6 (2.2%)**	**8**	**7 (2.5%)**	**8**	**13 (2.4%)**	**16**	**2 (0.6%)**	**3**
Acute cholecystitis	4	4	0	0	4	4	0	0
Cholecystitis	1	1	3	3	4	4	0	0
Cholelithiasis	2	2	0	0	2	2	2	2
Gallstones	0	0	1	1	1	1	1	1
Hepatic fibrosis	0	0	1	2	1	2	0	0
Injury to liver	1	1	0	0	1	1	0	0
Liver disorder	0	0	1	1	1	1	0	0

Table 36. Serious Adverse Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Portal hypertension	0	0	1	1	1	1	0	0
Neoplasms benign, malignant and unspecified (incl cysts and polyps)	**5 (1.9%)**	**7**	**4 (1.4%)**	**5**	**9 (1.6%)**	**12**	**5 (1.4%)**	**5**
Lung cancer	2	2	1	1	3	3	1	1
Large cell lung cancer	0	0	1	1	1	1	0	0
Lung nodule	0	0	1	1	1	1	0	0
Lymphocytic leukemia	0	0	1	1	1	1	0	0
Myelodysplastic syndrome	1	1	0	0	1	1	0	0
Ovarian cancer	1	1	0	0	1	1	0	0
Prostate cancer metastatic	0	0	1	1	1	1	0	0
Skin cancer	1	1	0	0	1	1	0	0
Small cell carcinoma of the lung	1	2	0	0	1	2	0	0
Adenoma	0	0	0	0	0	0	1	1
Breast cancer	0	0	0	0	0	0	1	1
Esophageal cancer	0	0	0	0	0	0	1	1
Lymphoma	0	0	0	0	0	0	1	1
Endocrine disorders	**2 (0.7%)**	**2**	**1 (0.4%)**	**1**	**3 (0.5%)**	**3**	**1 (0.3%)**	**1**
Adrenal insufficiency	1	1	0	0	1	1	0	0
Hypothyroidism	1	1	0	0	1	1	1	1
Myxedema	0	0	1	1	1	1	0	0
Immune system disorders	**2 (0.7%)**	**2**	**1 (0.4%)**	**1**	**3 0.5%)**	**3**	**0 (0.0%)**	**0**
Amyloidosis	1	1	0	0	1	1	0	0
Heart transplant rejection	0	0	1	1	1	1	0	0
Transplant rejection	1	1	0	0	1	1	0	0
Skin and subcutaneous tissue disorders	**0 (0.0%)**	**0**	**3 (1.1%)**	**3**	**3 (0.5%)**	**3**	**3 (0.9%)**	**4**
Diabetic ulcer	0	0	1	1	1	1	0	0
Foot ulcer	0	0	1	1	1	1	0	0
Venous stasis ulcer	0	0	1	1	1	1	0	0
Decubitus ulcer	0	0	0	0	0	0	1	1
Rash	0	0	0	0	0	0	1	2
Skin thinning of	0	0	0	0	0	0	1	1
Benign prostatic hypertrophy	0	0	1	1	1	1	0	0
Reproductive system and breast disorders	**0 (0.0%)**	**0**	**1 (0.4%)**	**1**	**1 (0.2%)**	**1**	**3 (0.9%)**	**3**
Enlarged prostate	0	0	0	0	0	0	1	1
Postmenopausal bleeding	0	0	0	0	0	0	1	1
Vaginal bleeding	0	0	0	0	0	0	1	1

Adverse Device Events

Table 37. Unanticipated or Serious Adverse Device Events Over Part 1 and Part 2

	Part 1						Part 2	
	Treatment (270)		Control (280)		All Patients (550)		All Patients (347)	
	Subjects	Events	Subjects	Events	Subjects	Events	Subjects	Events
Unanticipated Serious Adverse Device Events	0 (0.0%)	0	1 (0.4%)	1	1 (0.2%)	1	0 (0.0%)	0
Serious Adverse Device Events	2 (0.7%)	2	0 (0.0%)	0	2 (0.4%)	2	0 (0.0%)	0

Unanticipated Serious Adverse Device Events

There was one event during Part 1 reported as a USADE by the investigator but determined not to be serious or device system related by the CEC which reviewed the event on 27 Jun 2009. There were no additional USADEs over Part 2 of the clinical trial.

Serious Adverse Device Events

The two SADEs that occurred during Part 1 were hemoptysis during the implant procedure and an in-situ thrombosis during the right heart catheterization procedure. Both patients were treated and recovered without sequela. There were no additional SADEs over Part 2 of the clinical trial.

Long-Term Data from the CardioMEMS US Post – Approval Study

Summary of the Post-Approval Study Methods

Study Objective

The objective of the CardioMEMS US Post-Approval Study (PAS) was to confirm the safety and effectiveness of the CardioMEMS™ HF System in patients with New York Heart Association (NYHA) Class III heart failure (HF) (a minimum of 35% of the enrolled patients were to be women) who experienced a heart failure hospitalization (HFH) in the previous year.

Study Design

The PAS was a prospective, non-randomized, open-label, multi-center, post-approval study designed to characterize the use of the CardioMEMS HF System as a condition of premarket approval from the U.S. Food and Drug Administration (FDA).

Study Population

Subjects enrolled in the PAS were male and female patients of at least 18 years of age with NYHA Class III heart failure who were hospitalized for HF in the previous 12 months, who met all eligibility criteria, and provided written informed consent. A prerequisite of the study was that at least 35% of the enrolled patients were to be women.

Data Source

Part 11 compliant electronic case report forms (eCRFs) were utilized. Study site staff entered the information required by the protocol onto eCRFs using a validated system that conforms to FDA requirements for electronic data capture. Only authorized site personnel were permitted to enter the CRF data through the electronic data capture (EDC) system deployed by the Sponsor.

Key Study Endpoints

The primary safety endpoints were (1) freedom from device/system-related complications (DSRCs) at 2 years and (2) freedom from pressure sensor failure at 2 years. The primary effectiveness endpoint was the annualized HFH rate at 1 year compared to the annualized HFH rate for 1 year prior to implant.

Total Number of Enrolled Study Sites and Subjects, Follow-up Rate

A total of 1200 subjects were implanted (enrolled) with the CardioMEMS™ sensor at 104 investigational sites in the United States. An additional 14 subjects had attempted implants that were not successful and therefore were not enrolled in the study. These subjects were followed through 30 days per the study protocol before exiting and are included in appropriate analyses. All enrolled subjects were followed for 24 months or until they exited the study. The number of patients who completed 24 months of follow-up was 710 of the 1200 patients enrolled (59.2%).

Study Visits and Length of Follow-up

Following sensor implant, follow-up visits were scheduled at 1 month, 6 months, 12 months, 18 months, and 24 months. All subjects were followed until completion of their 24-month visit or withdrawal from the study. The average length of patient follow-up was 18.7 months.

Summary of the Post-Approval Study Results

Final Safety Findings

The pre-specified performance goals for each of the primary safety endpoints were that at least 80% of the patients were to be free from DSRC and at least 90% of patients were to be free of sensor failure at 24 months. The results (table below) show that freedom from DSRC at 24 months was 99.6% (1209/1214) with a lower confidence bound of 99.0% (0.990), exceeding the pre-specified performance goal of 80%. The results (table below) show that freedom from pressure sensor failure at 24 months was 99.9% with a lower confidence bound of 99.5%, exceeding the pre-specified performance goal of 90%. Both hypotheses had to be met in order to declare the study successful. Both primary safety endpoints were met.

Table 38. Primary Safety Endpoints

Safety Endpoint	Kaplan – Meier Estimate	Proportion	Lower Confidence Limit[3]	p-value[4]
Freedom from DSRC[1]	99.6%	99.6% (1209/1214)	99.0%	p<0.0001
Freedom from Pressure Sensor Failure[2]	99.9%	99.9% (1199/1200)	99.5%	p<0.0001

1. Denominator includes all subjects in the Safety Population.
2. Denominator includes all subjects in the Effectiveness Population.
3. Lower Exact 95% Clopper-Pearson confidence limit.
4. DSRC p-value tests the one-sided binomial proportion is greater than 80% with 95% confidence, and Pressure Sensor Failure p-value tests the one-sided binomial proportion is greater than 90% with 95% confidence.

Final Effectiveness Findings

The primary effectiveness endpoint for this study compares the annualized HFH rate (including recurrent events) at 12 months post-implant with the rate (including recurrent events) 12 months prior to implant. All follow-up through 12 months post – implant or until subject exited the study were included in the analysis. All subjects who were consented and successfully implanted with a pressure sensor–regardless of study completion status– were included in the analysis. The table below denotes the total number of HFHs for all patients in the year prior to implant (1600 HFHs) and for one year after CardioMEMS™ sensor implant (628 HFHs) for all successfully implanted subjects (n=1200). The HFH rate prior to sensor implant was 1.249 HFHs per patient year. After sensor implant, the rate of HFHs was reduced to 0.535 HFHs per patient year. This is a reduction of 57% in HFHs after treatment using the CardioMEMS sensor (p<0.0001).

Table 39. Annualized HFH Rate

	One Year Prior to Implant[1]	**One Year After Implant[2]**	**Ratio (95% CI), p-value[3]**
Number of HFHs	1600	628	0.43 (0.39, 0.47)
One Year HFH Rate[4]	1.249	0.535	P<0.0001

1. Includes all Clinical Events Committee (CEC) adjudicated HFHs with an admission date on the date of implant and through 390 days prior to date of implant.
2. Includes all CEC adjudicated HFHs with an admission date after the implant procedure discharge date through 390 days after the date of implant.
3. Hazard Ratio, 95% Confidence Interval, and p-value estimated from the Andersen-Gill model with robust sandwich estimates.
4. HFH Rate is an annualized rate estimated from the Andersen-Gill model.

As noted in the previous section, the CHAMPION trial was not powered to show statistical significance for gender. Because of this, the PAS had a requirement to enroll at least 35% women and a pre-specified effectiveness analysis of annualized HFH rate at one year compared the year prior to implant was evaluated in both women and men. The goal to enroll at least 35% women was met and approximately 38% of patients enrolled in the PAS were women. Note that the rate of HFH at one year in females (0.513) is comparable to that in males (0.553). This is important as it demonstrates that female subjects have a similar response to the use of CardioMEMS as male subjects.

Table 40. Primary Effectiveness by Sex

Sex	One Year Prior to Implant[1] Events (Rate[3])	One Year After Implant[2] Events (Rate[3])	Hazard Ratio (95% CI), p-value[4]	Interaction p-value
Male (N=748)	970 (1.214)	398 (0.553)	0.46 (0.40, 0.52), p<0.0001	0.1587
Female (N=452)	630 (1.319)	230 (0.513)	0.39 (0.33, 0.46), p<0.0001	

1. Includes all CEC adjudicated HFHs with an admission date on the date of implant and through 390 days prior to date of implant.
2. Includes all CEC adjudicated HFHs with an admission date after the implant procedure discharge date through 390 days after the date of implant.
3. HFH Rate is an annualized rate estimated from the Andersen-Gill model.
4. Hazard Ratio, 95% Confidence Interval, and p-value estimated from the Andersen-Gill model with robust sandwich estimates.

Study Strength and Weaknesses

The CardioMEMS US PAS is the first clinical study to produce long-term data on the CardioMEMS™ HF System. The PAS met both of its primary safety endpoints and demonstrated a large reduction (57%) in HFHs at one year. In comparison to the pivotal CHAMPION trial, where freedom from DSRC was 98.6% with a lower 95% confidence limit of 97.3%, the CardioMEMS US PAS freedom from DSRC of 99.6% with a lower confidence limit of 99.0% exceeded the pre-specified performance goal. In the CardioMEMS US PAS, one patient out of 1200 implanted patients (0.1%) had sensor failure, indicating a freedom from pressure sensor failure at 24 months of 99.9%, which is similar to the 100% freedom from sensor failure observed during the CHAMPION trial.

A limitation of the CardioMEMS US PAS single arm design is that there is not a direct comparator provided within the study population for outcomes. However, results from the CardioMEMS US PAS are supported by results from the CHAMPION trial and MEMS-HF study[1] (the first CardioMEMS study outside the US). In the CHAMPION pivotal trial, a 33% relative risk reduction in HFH was observed in treatment patients versus control over an 18-month average follow-up period.[2] Results similar to the CardioMEMS US PAS have been reported from the MEMS-HF study, where a 62% reduction in the HFH rate (HR:0.38, CI:0.31, 0.48; p<0.0001) was observed at 12 months. The CardioMEMS US PAS has demonstrated that the CardioMEMS HF System is safe (99.6% freedom from DSRCs and 99.9% freedom from sensor failure) and effective (57% reduction in HFH), thus demonstrating the long-term safety and efficacy of the CardioMEMS™ HF system.

FCC Statement

This device is approved for wireless transmission under FCC ID number R3PCS-A-000051. This device complies with Part 15 of the FCC Rules. Operation is subject to the following conditions:

- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.

Technical Support

For technical support, call 1 877 696 3754.

1. Angermann CE, Assmus, B, Anker, SD, et al. "Pulmonary artery pressure-guided therapy in ambulatory patients with symptomatic heart failure: the CardioMEMS European Monitoring Study for Heart Failure (MEMS-HF)". European Journal of Heart Failure. 2020. doi:10.1002/ejhf.1943
2. Abraham WT, Stevenson LW, Bourge RC, Lindenfeld JA, et al. "Sustained efficacy of pulmonary artery pressure to guide adjustment of chronic heart failure therapy : complete follow-up results from the CHAMPION randomized trial". Lancet. 2016;387:453-61

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