

## Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

**eTable 1. Billing Procedure Codes Used to Identify PAP Sensor Implants**

	Billing Codes	Description
Inpatient Implants		
ICD-9-CM Proc. Code	38.26	Insertion of implantable pressure sensor without lead for intracardiac or great vessel hemodynamic monitoring
ICD-10-CM Proc. Code	02HQ30Z	Insertion of Pressure Sensor Monitoring Device into Right Pulmonary Artery, Percutaneous Approach
	02HR30Z	Insertion of Pressure Sensor Monitoring Device into Left Pulmonary Artery, Percutaneous Approach
Outpatient Implants		
CPT code	C9741	Right heart catheterization with implantation of wireless pressure sensor in the pulmonary artery, including any type of measurement, angiography, imaging supervision, interpretation, and report
	C2624	Implantable wireless pulmonary artery pressure sensor with delivery catheter, including all system components

**eTable 2. Diagnoses Codes Used to Identify Comorbidities**

<b>Comorbidities</b>	<b>ICD-9-CM</b>	<b>ICD-10</b>
Cardiac Arrhythmias	426.0, 426.13, 426.7, 426.9, 426.10, 426.12, 427.0–427.4, 427.6–427.9, 785.0, 996.01, 996.04, V45.0, V53.3	I44.1–I44.3, I45.6, I45.9, I47.x–I49.x, R00.0, R00.1, R00.8, T82.1, Z45.0, Z95.0
Diabetes	250.0–250.3, 250.4–250.9	E08.0, E08.1, E09.0, E09.1, E09.9, O24.0–O24.3, O24.8–O24.9, E10.0–E10.9, E11.0–E11.9, E12.0–E12.9, E13.0–E13.9, E14.0–E14.9, P70.2
Hypertension	401.x, 402.x–405.x	I10.x, I11.x–I13.x, I15.x, O10.x, O11.x, O16.x
Renal Failure	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585.x, 586.x, 588.0, V42.0, V45.1, V56.x	N18.x, N19.x, Z49.0x, Z49.3x, Z91.15, Z94.0, Z99.2
Chronic Pulmonary Disease	490–496, 500–505, 506.4	J40.x–J47.x, J60.x–J67.x, J68.4
Valvular Disease	093.2, 394.x–397.x, 424.x, 746.3–746.6, V42.2, V43.3	A52.0, I05.x–I08.x, I09.1, I09.8, I34.x–I39.x, Q23.0–Q23.3, Z95.2–Z95.4
Peripheral Vascular Disorder	093.0, 437.3, 440.x, 441.x, 443.1–443.9, 447.1, 557.1, 557.9, V43.4	I70.x, I71.x, I72.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.1, I79.8, K55.1, K55.8, K55.9, Z95.8
Pulmonary Circulation Disorders	415.0, 415.1, 416.x, 417.0, 417.8, 417.9	I26.x, I27.x, I28.9
Paralysis	334.1, 342.x, 343.x, 344.0–344.6, 344.9	G04.1, G80.0–G80.2, G81.x, G82.x, G83.0–G83.4, G83.5, G83.8, G83.9, I69.x, R532
Other neurological disorders	331.9, 332.0, 332.1, 333.4, 333.5, 333.92, 334.x–335.x, 336.2, 340.x, 341.x, 345.x, 348.1, 348.3, 780.3, 784.3	E75.x, G10.x–G13.x, G20.x–G21.x, G24.x, G25.4, G25.5, G25.81, G31.2, G31.8, G31.9, G32.x, G35.x–G37.x, G40.x, G47.x, G80.0, G89.0, G91.x, G93.1, G93.4, G93.8, G93.9, G94, R41.0, R41.82, R47.01, R56.x
Hypothyroidism	240.9, 243.x, 244.x, 246.1, 246.8	E00.x–E03.x, E89.0
Liver Disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 456.0–456.2, 570.x, 571.x, 572.2–572.8, 573.3, 573.4, 573.8, 573.9, V42.7	B18.x, I85.x, K70.x, K72.x–K74.x, K76.0, K76.2–K76.9, Z94.4
Peptic ulcer disease excluding bleeding	531.7, 531.9, 532.7, 532.9, 533.7, 533.9, 534.7, 534.9	K25.4–K25.7, K25.9, K26.4–K26.7, K26.9, K27.4–K27.7, K27.9, K28.4–K28.7, K28.9
Acquired immune deficiency syndrome	042.x–044.x	B20
Lymphoma	200.x–202.x, 203.0, 238.6	C81.x–C85.x, C86.x, C88.x, C90.x, C96.x, D47.Z9
Metastatic cancer	196.x–199.x	C77.x–C80.x, C7B.x
Solid tumor without metastasis	140.x–172.x, 174.x–195.x	C00.x–C26.x, C30.x–C34.x, C37.x–C41.x, C43.x, C45.x–C58.x, C60.x–C76.x, C7A.x, D03.x, E31.x
Rheumatoid arthritis/collagen vascular diseases	446.x, 701.0, 710.0–710.4, 710.8, 710.9, 711.2, 714.x, 719.3, 720.x, 725.x, 728.5, 728.89, 729.30	L94.0, L94.1, L94.3, M05.x, M06.x, M08.x, M12.0, M32.x–M35.x, M45.x,

		M46.0, M46.1, M46.5, M46.8, M46.9, M48.8x, M49.x
Coagulopathy	286.x, 287.1, 287.3–287.5	D65–D68.x, D69.1, D69.3–D69.6, O99.1x
Obesity	278.0	E66.x, O99.2x, R939, Z68.3x-Z68.5x
Weight Loss	260.x–263.x, 783.2, 799.4	E40.x–E46.x, R63.4, R63.6
Fluid and Electrolyte disorders	253.6, 276.x	E86.x, E87.x
Blood Loss	280.0	D50.0, O90.81, O99.0x
Deficiency Anemia or Chronic blood loss anemia	280.1–280.9, 281.x	D50.1, D50.8, D50.9, D51.x–D53.x, D63.x, D64.9
Alcohol Abuse	265.2, 291.1–291.3, 291.5–291.9, 303.0, 303.9, 305.0, 357.5, 425.5, 535.3, 571.0–571.3, 980.x, V11.3	F10.x
Drug Abuse	292.x, 304.x, 305.2–305.9, V65.42	F11.x–F16.x, F18.x, F19.x, F55.x, O99.32x
Psychoses	F11.x–F16.x, F18.x, F19.x, F55.x, O99.32x	F20.x, F22.x–F25.x, F28.x, F29.x, F30.x, F31.x, F32.4, F32.5, F33.4x, F34.8x, F34.9, F39, F44.89, F84.3
Depression	296.2, 296.3, 296.5, 300.4, 309.x, 311	F32.x, F33.x, F34.1, F41.2, F43.21
Chronic Ischemic Heart Disease	414.xx	I25.xx

*Coding based on Moore BJ, White S, Washington R, Coenen N, Elixhauser A. Identifying increased risk of readmission and in-hospital mortality using hospital administrative data: The AHRQ Elixhauser Comorbidity index. Med Care. 2017 Jul; 55(7):698-705 and HCSRN: Health care systems research network [http://hcsrn.org/sas/standard\\_macros.sas](http://hcsrn.org/sas/standard_macros.sas)*

**eTable 3. Billing Codes Used to Identify HF Hospitalization**

ICD-9 CODE	ICD-9 CODE DESCRIPTION	ICD-10 CODE	ICD-10 CODE DESCRIPTION
402.01	Malignant hypertensive heart disease with heart failure	I110	Hypertensive heart disease with heart failure
402.11	Benign hypertensive heart disease with heart failure	I110	Hypertensive heart disease with heart failure
402.91	Unspecified hypertensive heart disease with heart failure	I110	Hypertensive heart disease with heart failure
404.01	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified	I130	Hypertensive heart and chronic kidney disease with heart failure and stage 1 through stage 4 chronic kidney disease, or unspecified chronic kidney disease
404.11	Hypertensive heart and chronic kidney disease, benign, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified	I130	Hypertensive heart and chronic kidney disease with heart failure and stage 1 through stage 4 chronic kidney disease, or unspecified chronic kidney disease
404.91	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and with chronic kidney disease stage I through stage IV, or unspecified	I130	Hypertensive heart and chronic kidney disease with heart failure and stage 1 through stage 4 chronic kidney disease, or unspecified chronic kidney disease
404.03	Hypertensive heart and chronic kidney disease, malignant, with heart failure and with chronic kidney disease stage V or end stage renal disease	I132	Hypertensive heart and chronic kidney disease with heart failure and with stage 5 chronic kidney disease, or end stage renal disease
404.13	Hypertensive heart and chronic kidney disease, benign, with heart failure and chronic kidney disease stage V or end stage renal disease	I132	Hypertensive heart and chronic kidney disease with heart failure and with stage 5 chronic kidney disease, or end stage renal disease
404.93	Hypertensive heart and chronic kidney disease, unspecified, with heart failure and chronic kidney disease stage V or end stage renal disease	I132	Hypertensive heart and chronic kidney disease with heart failure and with stage 5 chronic kidney disease, or end stage renal disease
428.0	Congestive heart failure, unspecified	I509	Heart failure, unspecified
428.9	Heart failure, unspecified	I509	Heart failure, unspecified
428.1	Left heart failure	I501	Left ventricular failure
428.20	Systolic heart failure, unspecified	I5020	Unspecified systolic (congestive) heart failure
428.21	Acute systolic heart failure	I5021	Acute systolic (congestive) heart failure
428.22	Chronic systolic heart failure	I5022	Chronic systolic (congestive) heart failure
428.23	Acute on chronic systolic heart failure	I5023	Acute on chronic systolic (congestive) heart failure

428.30	Diastolic heart failure, unspecified	I5030	Unspecified diastolic (congestive) heart failure
428.31	Acute diastolic heart failure	I5031	Acute diastolic (congestive) heart failure
428.32	Chronic diastolic heart failure	I5032	Chronic diastolic (congestive) heart failure
428.33	Acute on chronic diastolic heart failure	I5033	Acute on chronic diastolic (congestive) heart failure
428.40	Combined systolic and diastolic heart failure, unspecified	I5040	Unspecified combined systolic (congestive) and diastolic (congestive) heart failure
428.41	Acute combined systolic and diastolic heart failure	I5041	Acute combined systolic (congestive) and diastolic (congestive) heart failure
428.42	Chronic combined systolic and diastolic heart failure	I5042	Chronic combined systolic (congestive) and diastolic (congestive) heart failure
428.43	Acute on chronic combined systolic and diastolic heart failure	I5043	Acute on chronic combined systolic (congestive) and diastolic (congestive) heart failure

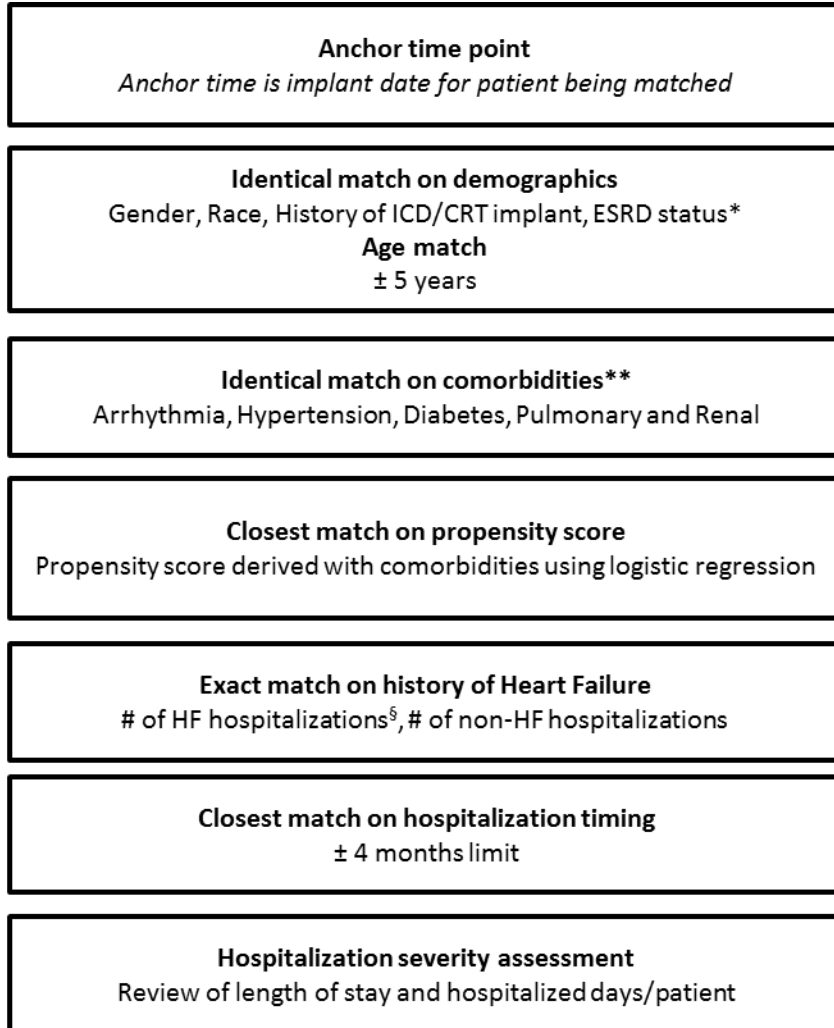
**eTable 4. Baseline Patient Characteristics: All Elixhauser Comorbidities that were not used for Matching criteria**

<b>Comorbidities — no. (%)</b>	<b>Treatment Cohort</b>	<b>Control Cohort</b>	<b>p-value</b>
Valvular Disease	471 (43.3)	475 (43.7)	0.90 NS
Peripheral Vascular Disorder	308 (28.3)	279 (25.7)	0.18 NS
Pulmonary Circulation Disorders	318 (29.3)	330 (30.4)	0.61 NS
Paralysis	n < 11	n < 11	0.60 NS
Other neurological disorders	101 (9.3)	79 (7.3)	0.10 NS
Hypothyroidism	277 (25.5)	285 (16.2)	0.72 NS
Liver Disease	71 (6.5)	94 (8.6)	0.08 NS
Peptic ulcer disease excluding bleeding	24 (2.2)	27 (2.5)	0.78 NS
Acquired immune deficiency syndrome	n < 11	n < 11	0.45 NS
Lymphoma	19 (1.7)	19 (1.7)	1.00 NS
Metastatic cancer	15 (1.4)	10 (0.9)	0.42 NS
Solid tumor without metastasis	90 (8.3)	66 (6.1)	0.06 NS
Rheumatoid arthritis/Collagen vascular diseases	60 (5.5)	61 (5.6)	1.00 NS
Coagulopathy	125 (11.5)	116 (10.7)	0.59 NS
Obesity	339 (31.2)	325 (29.9)	0.55 NS
Weight Loss	73 (6.7)	79 (7.3)	0.67 NS
Fluid and Electrolyte disorders	507 (46.6)	541 (49.8)	0.16 NS
Blood Loss	26 (2.4)	22 (2.0)	0.66 NS
Deficiency Anemia or Chronic blood loss anemia	157 (14.4)	149 (13.7)	0.67 NS
Alcohol Abuse	40 (3.7)	52 (4.8)	0.24 NS
Drug Abuse	31 (2.9)	37 (3.4)	0.54 NS
Psychoses	20 (1.8)	30 (2.8)	0.20 NS
Depression	218 (20.1)	220 (20.2)	0.96 NS

*NS—nonsignificant*

*p-values for all comorbidities from Chi-square test*

## eFigure 1. Algorithm for Matched Patient Identification



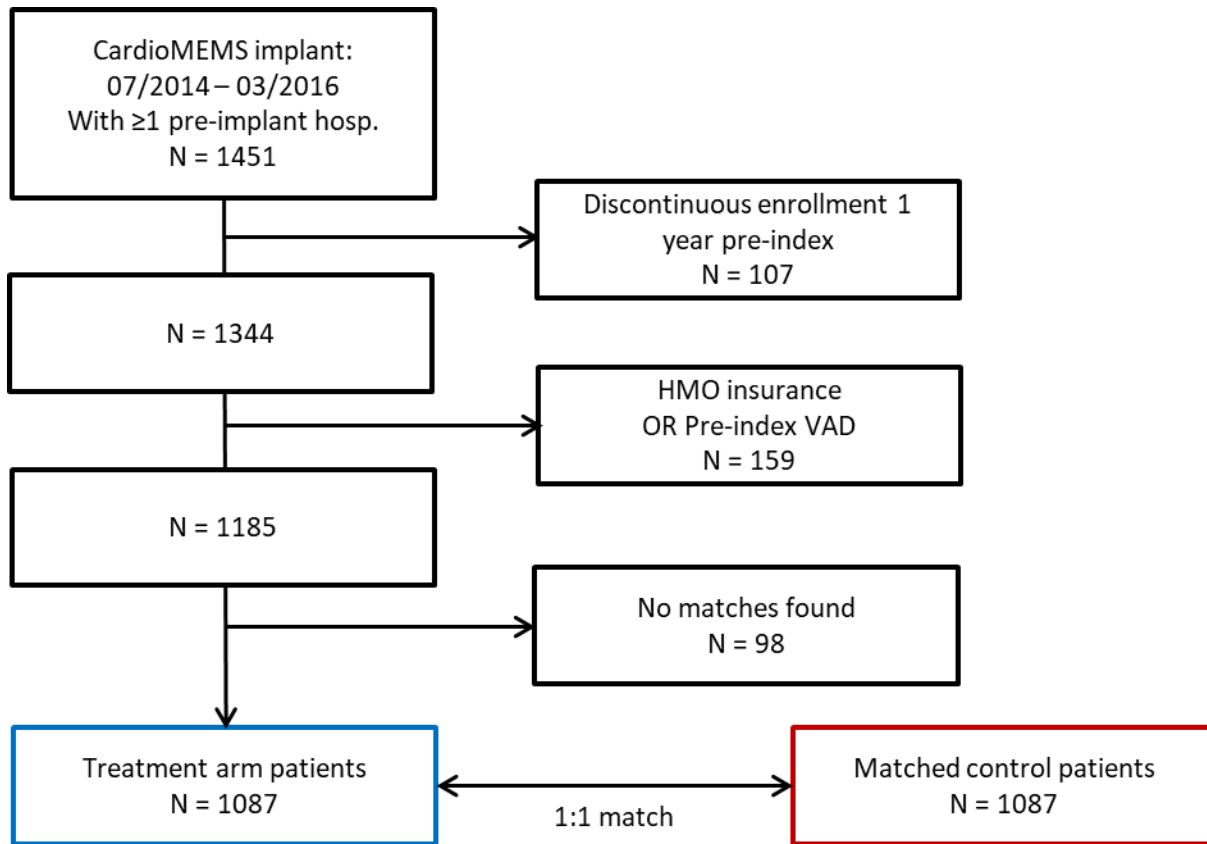
\*ESRD = End stage Renal Disease status from Medicare Status Code

\*\* Comorbidities based on AHRQ Elixhauser Comorbidities. Details in Supplementary Table 2

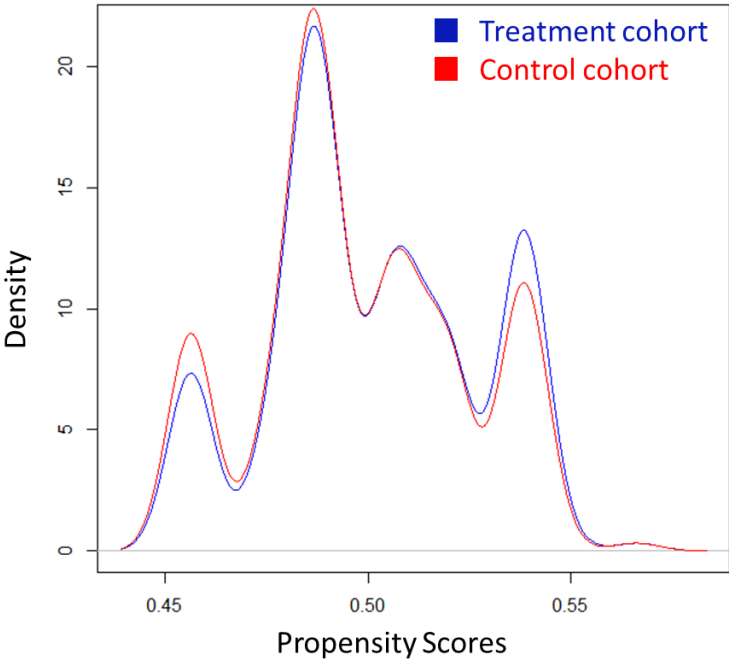
<sup>§</sup> HF hospitalizations identified using diagnoses codes detailed in Supplementary Table 3



**eFigure 2. Patient Cohort Identification**

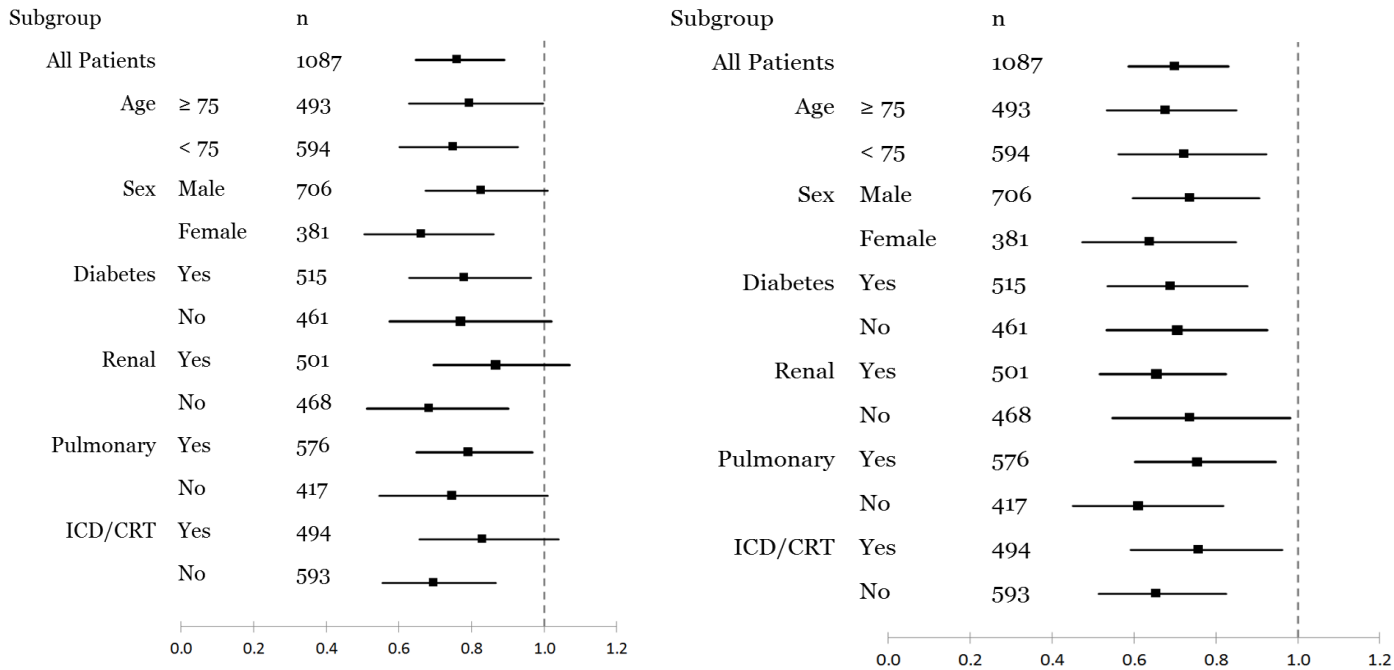


**eFigure 3. Propensity score Match comparison**



*Propensity score based on history of Arrhythmia, Hypertension, Diabetes, Pulmonary and Renal*

**eFigure 4. Clinical outcomes (Heart Failure Hospitalizations and Mortality) in Subgroups of Interest in the 12-months after PA pressure sensor implant**

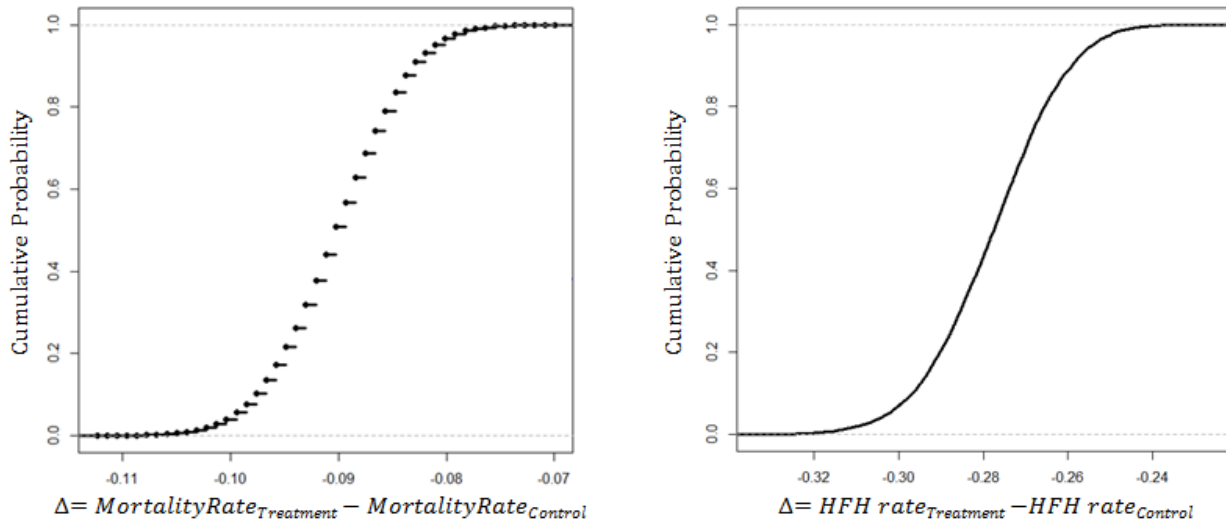


**S4a. Hazard ratio for HFH (Treatment vs. Control)**

**S4b. Hazard ratio for Mortality (Treatment vs. Control)**

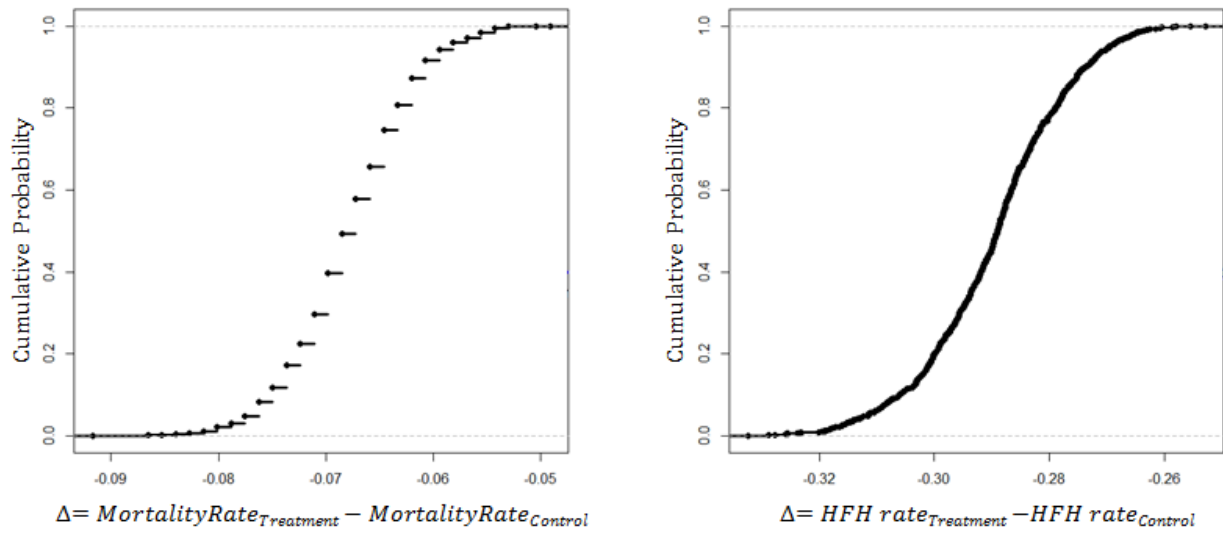
*Hazard ratio derived from Andersen-Gill extension to the cox proportional hazards model*

eFigure 5. Distribution of outcomes amongst all matches



Comparative Effectiveness of PAP Sensor-Based Management: Bootstrap Model				
Primary Endpoints	Treatment Cohort (n = 1087)	Control Cohort [IQR] (n= 41,347)	Relative Risk [IQR]	p-value
HF Hospitalization — HFH/yr	0.65	0.93 [0.90 0.95]	0.70 [0.68 0.72]	p < 0.01
Mortality — Death/yr	0.22	0.31 [0.30 0.32]	0.71 [0.69 0.73]	p < 0.01

eFigure 6. Distribution of outcomes in patients treated at CMEM implanting sites



Comparative Effectiveness of PAP Sensor-Based Management: Bootstrap Model				
Primary Endpoints	Treatment Cohort (n = 774)	Control Cohort [IQR] (n = 8,973)	Relative Risk [IQR]	p-value
HF Hospitalization — HFH/yr	0.52	0.81 [0.80 0.84]	0.64 [0.63 0.66]	p < 0.01
Mortality — Death/yr	0.22	0.28 [0.27 0.29]	0.76 [0.74 0.79]	p < 0.01