

Figure 1: An axial cMRI image at the level of PA bifurcation, where measurements of the diameter of the main PA (in blue) and the diameter of the aorta (Ao, in red) were obtained to calculate PA/Ao ratio. Abbreviations: Ao, aorta; cMRI, cardiac magnetic resonance imaging; PA, pulmonary artery.

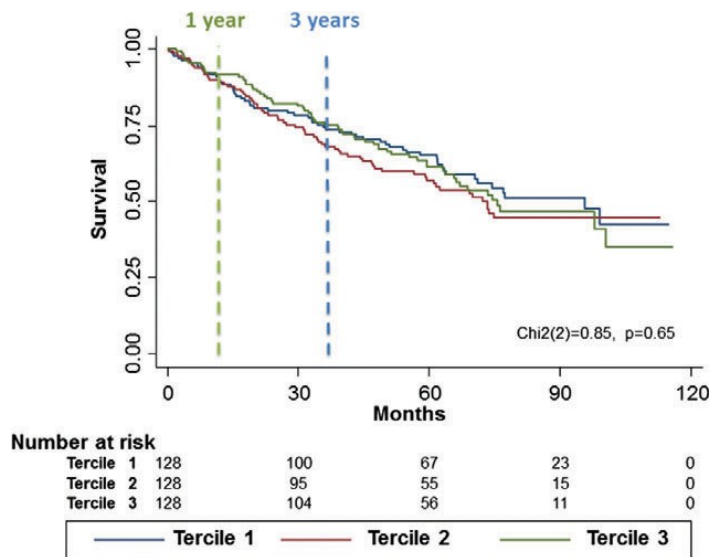


Figure 2: Kaplan–Meier curve for the primary outcome of death from all causes and HF hospitalizations. There was no difference in the primary outcome for patients among the 3 PA/Ao tertiles.

Abbreviations: Ao, aorta; HF, heart failure; PA, pulmonary artery

TABLE 1: Characteristics of patients by diagnosis and for patients with HF by tertiles of PA/Ao ratio

	No Definite Evidence of HF, n = 38	Evidence of HF, n = 384	P Value	PA/Ao Tertile 1, n = 128	PA/Ao Tertile 2, n = 128	PA/Ao Tertile 3, n = 128	P Value
<b>cmRI measurements</b>							
Max Ao diameter, mm	34.3 (31.4–36.9)	33.5 (30.8–36.3)	0.998	35.4 (33.1–38.4)	33.6 (31.2–35.7)	31.7 (28.9–34.0)	<0.001
Min Ao diameter, mm	33.9 (30.4–36.4)	32.5 (29.5–35.1)	0.891	34.5 (31.9–37.1)	32.7 (30.19–34.7)	30.0 (28.2–33.1)	<0.001
Max PA diameter, mm	28.8 (26.2–33.8)	29.4 (26.7–32.4)	0.934	26.3 (24.3–28.8)	29.5 (27.3–32.1)	32.5 (29.7–35.7)	<0.001
Min PA diameter, mm	25.1 (22.5–28.8)	25.9 (23.5–28.7)	0.585	23.8 (21.7–26.0)	25.9 (23.7–28.0)	28.8 (26.1–31.5)	0.024
PA/Ao ratio	0.90 (0.77–0.99)	0.87 (0.79–0.97)	0.975	0.76 (0.71–0.79)	0.88 (0.85–0.92)	1.00 (0.97–1.07)	NA
Max PA/BSA	14.5 (13.1–15.8)	15.3 (13.9–16.7)	0.090	14.1 (12.6–15.2)	15.3 (14.0–16.4)	16.6 (15.4–18.3)	<0.001
<b>Demographics</b>							
Age, y	62 (11)	69 (11)	0.009	71 (9)	68 (11)	63 (12)	<0.001
Male sex	27 (71)	312 (81)	0.131	109 (85)	101 (79)	102 (80)	0.377
BMI, kg/m <sup>2</sup>	32 (6)	28 (5)	0.002	28 (5)	29 (5)	29 (6)	0.142
BSA, m <sup>2</sup>	2.0 (0.2)	1.9 (0.2)	0.086	1.9 (0.2)	2.0 (0.2)	2.0 (0.2)	0.313
IHD	17 (44)	252 (65)	0.011	88 (69)	86 (67)	78 (61)	0.379
DM	9 (24)	104 (27)	0.652	26 (20)	38 (30)	40 (31)	0.104
HTN	23 (61)	196 (51)	0.264	70 (55)	68 (53)	58 (45)	0.275
COPD	4 (11)	27 (7)	0.431	11 (9)	8 (6)	8 (6)	0.699
<b>NYHA class</b>							
I	13 (34)	77 (20)	0.080	28 (22)	27 (21)	22 (17)	
II	12 (32)	180 (47)		72 (56)	53 (41)	55 (43)	0.019
III	13 (34)	140 (33)		28 (22)	48 (38)	51 (40)	
SBP, mm Hg	135 (22)	133 (25)	0.557	136 (25)	133 (24)	129 (26)	0.083
Heart rate, bpm	70 (14)	67 (14)	0.172	67 (12)	66 (15)	68 (16)	0.588
AF	1 (3)	86 (22)	0.004	28 (22)	33 (26)	25 (19)	0.480
Congestion ≥3	3 (8)	46 (12)	0.477	6 (5)	19 (15)	21 (16)	0.008
<b>JVP</b>							
Raised 1–4 cm	0 (0)	29 (7)	0.167	4 (3)	9 (7)	16 (13)	0.026
Up to the earlobe	0 (0)	5 (1)		0 (0)	3 (2)	2 (2)	
<b>Laboratory testing</b>							
Hb, g/dL	14.1 (1.6)	13.5 (1.7)	0.032	13.7 (1.7)	13.3 (1.8)	13.6 (1.8)	0.221
Cr, μmol/L	94 (82–103)	99 (82–122)	0.012	102 (88–124)	105 (78–111)	92 (78–111)	0.036
Urea, mmol/L	5.6 (4.5–6.8)	6.5 (5.1–8.6)	0.023	7.0 (5.0–8.9)	6.5 (5.2–8.2)	6.2 (4.8–8.5)	0.387
Albumin, g/L	39 (3)	38 (3)	0.067	38 (3)	38 (3)	38 (4)	0.355
Bilirubin, μmol/L	14 (7)	16 (6)	0.315	16 (7)	15 (7)	16 (6)	0.371
NT-proBNP, ng/L	97 (49–154)	1010 (448–2262)	<0.001	875 (411–2326)	942 (449–2079)	1137 (463–2262)	0.959
<b>Medications</b>							
β-Blocker	19 (50)	306 (80)	<0.001	100 (78)	104 (81)	102 (80)	0.824
ACEI/ARB	28 (74)	336 (88)	0.018	113 (88)	110 (86)	113 (88)	0.807
Aldosterone antagonist	10 (26)	139 (36)	0.224	45 (35)	48 (38)	46 (36)	0.924
Loop diuretic	16 (42)	263 (69)	0.001	81 (63)	90 (70)	92 (72)	0.289

TABLE 1 (Continued)

	No Definite Evidence of HF, n = 38	Evidence of HF, n = 384	P Value	PA/Ao Tertile 1, n = 128	PA/Ao Tertile 2, n = 128	PA/Ao Tertile 3, n = 128	P Value
<b>cMRI measurements</b>							
LVEDV, mL	135 (113-156)	207 (163-254)	<0.001	200 (158-242)	210 (162-265)	211 (172-257)	0.111
LVEF, %	60 (7)	40 (13)	<0.001	39 (31-48)	40 (31-46)	37 (29-48)	0.451
LV mass, g	115 (97-139)	145 (122-177)	<0.001	148 (124-181)	145 (123-179)	145 (120-174)	0.731
Max LA volume (4ch), mL	69 (53-90)	106 (77-138)	<0.001	96 (67-127)	107 (79-140)	114 (79-148)	0.036
LAEF (4ch), %	54 (48-58)	40 (24-52)	<0.001	42 (27-53)	41 (27-52)	37 (20-52)	0.371
RVEDV, mL	154 (122-170)	146 (119-176)	0.518	135 (111-161)	147 (116-178)	156 (126-193)	0.005
RVEF, %	56 (49-58)	52 (44-60)	0.495	54 (45-60)	54 (47-60)	51 (40-60)	0.084
RV mass, g	46 (40-57)	51 (42-63)	0.341	49 (40-59)	51 (43-64)	54 (45-69)	0.017
Mitral regurgitation							0.769
Mild	8 (21)	149 (39)	0.030	48 (38)	46 (36)	55 (43)	
Moderate/severe	0 (0)	13 (3)		4 (3)	4 (3)	5 (4)	
Tricuspid regurgitation							0.384
Mild	8 (21)	100 (26)	0.700	28 (22)	32 (25)	40 (32)	
Moderate/severe	0 (0)	2 (1)		0 (0)	1 (1)	1 (1)	

Abbreviations: 4ch, 4-chamber view; ACEI, angiotensin-converting enzyme inhibitor; AF, atrial fibrillation; Ao, aorta; ARB, angiotensin II receptor blocker; BMI, body mass index; BSA, body surface area; cMRI, cardiac magnetic resonance imaging; COPD, chronic obstructive pulmonary disease; Cr, creatinine; DM, diabetes mellitus; Hb, hemoglobin; HF, heart failure; HTN, hypertension; IHD, ischemic heart disease; IQR, interquartile range; JVP, jugular venous pressure; LA, left atrium; LAEF, left atrial ejection fraction; LV, left ventricle; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; Max, maximum; Min, minimum; NA, not available/not applicable; NT-proBNP, N-terminal pro B-type natriuretic peptide; NYHA, New York Heart Association; PA, pulmonary artery; PA/Ao, pulmonary artery/aorta diameter ratio; RV, right ventricle; RVEDV, right ventricular end-diastolic volume; RVEF, right ventricular ejection fraction; SBP, systolic blood pressure; SD, standard deviation. Data are presented as mean and SD if the variable is normally distributed and median and intertertile range if not. The statistical difference between variables is given for the comparison between patients with and without HF, and between tertiles of PA/Ao only in patients with HF. For RV size and function, only 11 measurements were available for patients considered not to have HF and 313 for those considered to have HF.

Table 2: Variables associated with PA/Ao ratio in patients with HF (N = 384)

Variables	Univariable Analysis <sup>a</sup>		Multivariable Analysis Overall <sup>b</sup>		Multivariable Analysis LVEF ≤40% <sup>c</sup>		Multivariable Analysis LVEF >40% <sup>c</sup>	
	Correlation Coefficient	P Value	Unstandardized Coefficients (95% CI)	T Stat; P Value	Unstandardized Coefficients, 95% CI	T Stat; P Value	Unstandardized Coefficients (95% CI)	T Stat; P Value
Age, y	-0.311	<0.001	-0.004 (-0.005 to -0.003)	-5.855; <0.001	-0.005 (-0.007 to -0.003)	-4.776; <0.001	-0.003 (-0.005 to -0.002)	-3.723; <0.001
			-0.005 (-0.006 to -0.003)	-5.994; <0.001	-0.005 (-0.007 to -0.003)	-4.615; <0.001	-0.004 (-0.006 to -0.001)	-3.165; 0.002
SBP, mm Hg	-0.108	0.035						
Heart rate, bpm	0.046	0.37						
BMI, kg/m <sup>2</sup>	0.042	0.41						
BSA, m <sup>2</sup>	0.032	0.53						
Cr, μm ol/L	-0.095	0.06					0.000 (-0.001 to 0.000)	-1.976; 0.05
							—	—
Urea, mmol/L	-0.012	0.81						
Hb, g/dL	-0.034	0.50						
Albumin, g/L	-0.019	0.71						
Bilirubin, μmol/L	0.008	0.87						
Log(NT-proBNP)	0.028	0.058						
LVEDV, mL	0.108	0.034					—	—
							-0.001 (-0.001 to 0.000)	-2.467; 0.015
LVEF, %	-0.047	0.36						
LV mass, g	-0.046	0.37						
LA max (4ch), mL	0.124	0.016	0.000 (0.000 to 0.001)	2.623; 0.009				
			—	—				
LAEF (4ch), %	-0.097	0.060						
RVEDV, mL	0.244	<0.001	—	—			—	—
			0.001 (0.000 to 0.001)	2.484; 0.014			0.001 (0.000 to 0.002)	3.216; 0.002
RVEF, %	-0.148	0.009						
RV mass, g	0.133	0.019						

Abbreviations: Ao, aorta; BMI, body mass index; BSA, body surface area; CI, confidence interval; Cr, creatinine; Hb, hemoglobin; HF, heart failure; LA, left atrium; LAEF, left atrial ejection fraction; LV, left ventricle; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; Max, maximum; NT-proBNP, N-terminal pro B-type natriuretic peptide; PA, pulmonary artery; PA/Ao, pulmonary artery/aorta diameter ratio; RV,

right ventricle; RVEDM, right ventricular end-diastolic mass; RVEDV, right ventricular end-diastolic volume; RVEF, right ventricular ejection fraction; SBP, systolic blood pressure. Results were obtained from univariable and multivariable linear regression models. Variables included in multivariable models: age, LVEDV, LA max 4ch, SBP, Cr, log NT-proBNP (+ RVEDV, RVEDM, RVEF).

<sup>a</sup>The first column on the left (univariable analysis) represents the correlation between PA/Ao diameter ratio and the variables studied.

<sup>b</sup>The column for the multivariable analysis (center) shows the coefficients for slope of the linear relation between all the variables independently associated with PA/Ao for the overall population of patients with HF excluding (top;  $R^2 = 0.13$ , adjusted  $R^2 = 0.11$ ) or including (bottom;  $R^2 = 0.18$ , adjusted  $R^2 = 0.15$ ) measures of RV function (available for 313 patients only).

<sup>c</sup>On the right, the 2 different models were repeated for patients with LVEF  $\leq 40\%$  (RV excluded:  $R^2 = 0.16$ , adjusted  $R^2 = 0.13$ ; RV included:  $R^2 = 0.17$ , adjusted  $R^2 = 0.13$ ) and with LVEF  $> 40\%$  (RV excluded:  $R^2 = 0.13$ , adjusted  $R^2 = 0.10$ ; RV included:  $R^2 = 0.25$ , adjusted  $R^2 = 0.19$ ).

Table 3: Univariable and multivariable Cox regression models for a combined endpoint of all-cause mortality and admissions for HF in patients with HF (n = 384 patients with HF who had 181 events during a median FU of 1759 days [IQR, 998–2269 days])

Variables	Univariable Analysis			Multivariable Analysis		
	HR (95% CI)	$\chi^2$	P Value	HR (95% CI)	$\chi^2$	P Value
<b>Clinical data</b>						
Age, years	1.04 (1.03 to 1.06)	26.99	<0.001	1.02 (1.00 to 1.04)	5.89	0.015
Male sex	1.07 (0.89 to 1.29)	0.49	0.48			
NYHA class III vs I/II	1.58 (1.17 to 2.14)	9.04	0.003			
IHD (Y vs N)	1.28 (0.93 to 1.77)	2.28	0.13			
DM (Y vs N)	1.14 (0.82 to 1.58)	0.61	0.44			
COPD (Y vs N)	1.56 (0.95 to 2.58)	3.10	0.078			
AF (Y vs N)	1.06 (0.75 to 1.51)	0.11	0.74			
SBP, mm Hg	0.99 (0.99 to 1.00)	0.16	0.69			
Heart rate, bpm	1.00 (1.00 to 1.01)	0.63	0.43			
BMI, kg/m <sup>2</sup>	0.99 (0.96 to 1.02)	0.29	0.59			
BSA, m <sup>2</sup>	0.41 (0.22 to 0.77)	7.74	0.005			
Congestion ( $\geq 3$ vs $< 3$ )	1.55 (1.01 to 2.37)	4.05	0.044			
JVP ( $\geq 1$ vs 0)	1.09 (0.65 to 1.83)	0.11	0.74			
<b>Laboratory testing</b>						
Cr, $\mu\text{mol/L}$	1.01 (1.00 to 1.01)	21.50	<0.001			
Urea, mmol/L	1.09 (1.05 to 1.12)	24.94	<0.001			
Hb, g/dL	0.82 (0.76 to 0.90)	19.91	<0.001			
Albumin, g/L	0.92 (0.89 to 0.95)	19.54	<0.001			
Bilirubin, $\mu\text{mol/L}$	1.00 (0.98 to 1.01)	0.27	0.60			
Log(NT-proBNP)	2.44 (1.79 to 3.32)	32.24	<0.001	1.66 (1.50 to 2.41)	7.18	0.007
<b>cMRI measurements<sup>a</sup></b>						
LVEDV, mL	1.00 (0.99 to 1.01)	1.19	0.28			
LVEF, %	0.99 (0.98 to 1.00)	2.47	0.12			
LV mass, g	1.00 (0.99 to 1.01)	0.97	0.32			
LA max (4ch), mL	1.01 (1.00 to 1.01)	4.44	0.035			
LAEF (4ch), % <sup>b</sup>	0.98 (0.97 to 0.99)	19.39	<0.001			
RVEDV, mL	0.99 (0.99 to 1.00)	1.32	0.25			
RVEF, %	0.99 (0.97 to 1.00)	3.96	0.047			
RV mass, g	1.00 (1.00 to 1.01)	0.65	0.42			
Min Ao, mm	0.99 (0.97 to 1.03)	0.11	0.75			
Max Ao, mm	0.99 (0.95 to 1.02)	0.75	0.39			
Max PA, mm	0.99 (0.96 to 1.03)	0.12	0.73			
Min PA, mm	0.99 (0.98 to 1.01)	0.47	0.49			
PA/Ao ratio	1.20 (0.41 to 3.49)	0.12	0.73			
Max PA/BSA	1.05 (0.99 to 1.11)	2.32	0.13			

Abbreviations: 4ch, 4-chamber view; AF, atrial fibrillation; Ao, aorta; BMI, body mass index; BSA, body surface area; CI, confidence interval; cMRI, cardiac magnetic resonance imaging; COPD, chronic obstructive pulmonary disease; Cr, creatinine; DM, diabetes mellitus; FU, follow-up; Hb, hemoglobin; HF, heart failure; HR, hazard ratio; IHD, ischemic heart disease; IQR, interquartile range; JVP, jugular venous pressure; LA, left atrium; LAEF, left atrial ejection fraction; LV, left ventricle; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; Max, maximum; Min, minimum; N, no; NT-proBNP, N-terminal pro B-type natriuretic peptide; NYHA, New York Heart Association; PA, pulmonary artery; PA/Ao, pulmonary artery/aorta diameter ratio; RV, right ventricle; RVEDV, right ventricular end-

diastolic volume; RVEF, right ventricular ejection fraction; SBP, systolic blood pressure; Y, yes. Variables entered in multivariable models: age, NYHA class III vs I/II, COPD, BSA, congestion, Cr, Hb, albumin, Log(NT-proBNP), LA max.

<sup>a</sup>Measurements of RV size and function were not included in the multivariable analysis because these were available for only 313 patients (82%) with HF.

<sup>b</sup>LAEF only for patients in sinus rhythm with available data (n = 298).