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Clinical Investigation

The prognostic value of the relationship between right atrial and pulmonary capillary wedge pressure in diverse cardiovascular conditions

Douglas Marshall Brinkley Jr., MD [a,*], Kalon K.L. Ho, MD, MSc [b], Mark H. Drazner, MD, MSc [c], Robb D. Kociol, MD [b]

[a] Cardiovascular Division, Department of Medicine, Vanderbilt University Medical Center, Nashville, TN, United States
[b] Cardiovascular Division, Department of Medicine, Beth Israel Deaconess Medical Center, Boston, MA, United States
[c] Cardiovascular Division, Department of Medicine, University of Texas Southwestern, Dallas, TX, United States

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ABSTRACT

Background: Physical examination of jugular venous pressure is used to estimate right atrial (RA) pressure and infer left-sided filling pressure to assist volume management. Previous studies in advanced heart failure patients showed about 75% concordance between RA and pulmonary capillary wedge (PCW) pressures. We sought to determine the relationship between mean RA and mean PCW pressure and assess the clinical significance in a broad population of patients undergoing invasive right heart catheterization (RHC).

Methods: We examined 4135 RHC cases at a single academic medical center from February 2007 to December 2014, analyzing baseline variables, hemodynamic data, and in-hospital mortality.

Results: The overall Pearson correlation for mean RA and PCW pressures was 0.68 with 70% concordance between dichotomized pressures (RA ≥10 and PCW ≥22 mmHg). Results were similar in subgroups with heart failure ($r = 0.67$, 72%), STEMI/NSTEMI ($r = 0.60$, 69%), unstable angina ($r = 0.78$, 69%), stable/no angina ($r = 0.72$, 67%), and valvular disease ($r = 0.61$, 72%; Chi-square $P = .15$). Mean RA pressure was independently associated with in-hospital mortality in multivariate analysis (OR 1.12 [95% CI 1.081-1.157] per 1 mmHg increase, $P < .001$). The RA/PCW ratio was not independently associated with in-hospital mortality. Mean RA pressure was also weakly associated with worse renal function (rho $= -0.16$, $P < .001$).

Conclusion: In patients undergoing right catheterization for diverse indications, the mean RA and PCW pressures correlated moderately well, but there was discordance in a sizable minority, in whom assessment of left-sided filling pressures using estimated jugular venous pressure may be misleading. Elevated right atrial pressure is a marker for in-hospital mortality.

The relationship between right and left ventricular filling pressures has been well characterized in patients with heart failure. Upon physical examination, elevated right atrial (RA) pressure as reflected by an elevated jugular venous pulsation (JVP) is the most sensitive and specific sign of an elevated left sided filling pressure.[1] RA and PCW pressure correlate moderately well in patients with both heart failure with reduced ejection fraction (HFrEF) and preserved ejection fraction (HFpEF), but pressures may be discordant in up to 30%.[2–4] While reducing filling pressures to relieve congestive symptoms is a primary goal during hospitalization for acute decompensated heart failure, hemodynamic data provides prognostic information.[5–8] The RA/PCW ratio appears relatively stable in heart failure patients undergoing hemodynamic-guided therapy, despite treatment with diuretics and vasoactive drugs.[7] The ratio is associated with death or heart failure hospitalization in patients with decompensated heart failure.[5,7] In addition, both RA pressure and elevated RA/PCW ratio are associated with impaired renal function.[7,9,10]

In contrast, the relationship between right- and left-sided filling pressures and its clinical importance is less well understood in patients without chronic heart failure. Shortly after Swan et al described use of the balloon-tipped pulmonary artery catheter in 1970,[11] Forrester et al reported no consistent relationship between RA and PCW pressure in small cohort of patients with acute myocardial infarction (MI).[12] Although hemodynamic data are often obtained for clinical management of patients with acute heart failure or cardiogenic shock, we sought to evaluate the relationship between hemodynamic variables, clinical outcomes, and inpatient mortality for patients with varied indications for invasive hemodynamic monitoring.[13] We hypothesized that the right–left relationship would vary by indication and could provide prognostic information, so we examined data in consecutive patients

* Reprint requests: D. Marshall Brinkley, Jr., MD, Vanderbilt University Medical Center, 1215 21st Ave. S., Nashville, TN 37232, United States
E-mail address: marshall.brinkley@vanderbilt.edu (D.M. Brinkley).

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Table I
Patient characteristics by indication for catheterization.

Characteristic	Total n = 4135	Heart failure n = 969	Acute MI n = 468	Unstable angina n = 725	Stable-none n = 888	Valvular n = 1085
Demographic						
Age, y	69 ± 13	67 ± 13	69 ± 13	68 ± 12	68 ± 12	71 ± 13
Male, %	2418 (58)	583 (60)	287 (61)	414 (57)	553 (62)	581 (54)
White, %	3459 (85)	748 (79)	369 (82)	615 (85)	768 (87)	959 (90)
Diabetes, %	1394 (34)	383 (40)	159 (34)	288 (40)	303 (34)	261 (24)
Hypertension, %	3229 (78)	742 (77)	353 (75)	620 (86)	713 (80)	801 (74)
Lung disease, %	711 (17)	214 (22)	63 (13)	125 (17)	133 (15)	176 (16)
History of PCI, %	822 (20)	160 (17)	98 (21)	253 (35)	190 (21)	121 (11)
History of CABG, %	560 (14)	117 (12)	63 (13)	147 (20)	125 (14)	108 (10)
History of HF, %	1375 (33)	599 (62)	88 (18)	127 (18)	146 (16)	415 (38)
BMI, kg/m^2	29 ± 7	29 ± 7	28 ± 5	31 ± 7	30 ± 7	28 ± 6
GFR, ml/min/1.73m^2	65 ± 29	59 ± 28	64 ± 39	67 ± 15	68 ± 28	68 ± 27
LVEF, %†	48 ± 16	38 ± 17	40 ± 15	51 ± 14	53 ± 12	56 ± 11
Presentation						
STEMI, %	278 (7)	6 (1)	266 (57)	3 (0)	3 (0)	0 (0)
PCI performed, %	903 (22)	109 (11)	307 (66)	254 (35)	209 (24)	24 (2)
Shock, %	113 (3)	113 (12)	0 (0)	0 (0)	8 (0)	0 (0)
NYHA class, %‡						
1	380 (13)	69 (7)	23 (7)	61 (15)	120 (27)	107 (14)
2	809 (29)	196 (22)	20 (6)	133 (33)	191 (44)	269 (35)
3	922 (33)	349 (39)	44 (14)	131 (32)	108 (25)	290 (37)
4	721 (25)	284 (32)	221 (72)	84 (21)	19 (4)	113 (15)
Hemodynamic						
Heart rate, bpm	71 ± 17	74 ± 19	82 ± 21	67 ± 15	66 ± 15	69 ± 16
CI, L/min per square meter	2.6 ± 0.7	2.4 ± 0.7*	2.6 ± 0.8	2.7 ± 0.6	2.7 ± 0.6	2.6 ± 0.6
RA, mm Hg	11 ± 5	12 ± 6*	13 ± 6*	10 ± 5	10 ± 4	9 ± 5
PCW, mm Hg	18 ± 8	21 ± 9*	21 ± 9*	16 ± 7	16 ± 7	18 ± 8*
RA/PCW ratio	0.62 ± 0.33	0.62 ± 0.41*	0.64 ± 0.38	0.65 ± 0.22	0.65 ± 0.23	0.55 ± 0.35*
Mortality, %	115 (2.8)	33 (3.4)	56 (12.0)	3 (0.4)	13 (1.5)	10 (0.9)
LOS, days	1 [0-6]	4 [0-8]	4 [3-9]	1 [0-3]	1 [0-1]	1 [0-7]

Values represent mean ± standard deviation or median [interquartile range] for continuous variables and number (%) for categorical. BMI, body mass index; CABG, coronary artery bypass graft; CI, cardiac index; GFR, estimated glomerular filtration rate; HF, heart failure; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association functional class; PCI, percutaneous coronary intervention; PCW, pulmonary capillary wedge pressure; RA, right atrial pressure; STEMI, ST-segment elevation myocardial infarction; *$P < .05$ versus other subgroups for hemodynamic data; †69% missing; ‡32% missing.

meeting inclusion criteria undergoing right heart catheterization at a single academic center.

Methods

Population

This study was approved by the institutional review board of Beth Israel Deaconess Medical Center. The authors are solely responsible for the design and conduct of this study, analyses, writing, and its final contents. No extramural funding was used to support this work. The hospital cardiac catheterization laboratory database was queried for all adult patients who underwent right heart catheterization from January 2003 to December 2014 (n = 6010). We included only the first right heart catheterization for each unique patient (n = 5323) and extracted the initial measured mean right atrial and pulmonary capillary wedge pressures captured using Maclab version 6.9.6. Cases with missing hemodynamic data were excluded. Oxygen consumption was usually assumed and cardiac output calculated by the Fick method. Variables were defined using the National Cardiovascular Data Registry (NCDR) Cath-PCI data dictionaries for versions 2.0–4.4. Cases were classified according to indications for cardiac catheterization including heart failure (HF), ST-segment elevation myocardial infarction (STEMI) or non-ST-segment elevation myocardial infarction (NSTEMI), unstable angina, stable or no angina, and valvular disease (n = 4135). Catheterization for pulmonary hypertension and other indications were excluded. Serum creatinine from the catheterization date was extracted from the medical record. If no value was available on the same day, the closest value within the prior 30 days was used. Estimated glomerular filtration rate (GFR) was calculated using the simplified modified diet in renal disease (MDRD) equation.[14] Imputation was not performed.

Statistical analysis

STATA version 14 (STATA Corp, College Station, TX) was used for all analyses. Values are presented as mean (±standard deviation), number (%), or median [interquartile range] unless otherwise specified. Categorical data were compared using Fisher's exact test, and continuous data were compared using a t-test or Wilcoxon test. Select continuous data were compared among subgroups using ANOVA with the Bonferroni correction for pairwise testing. The relationships between continuous RA pressure, PCW pressure, and GFR quartile were assessed using Pearson's or Spearman's correlation. Mean RA and PCW pressures were dichotomized as RA <10 mmHg or RA ≥10 mmHg and PCW <22 mmHg or PCW ≥22 mmHg for comparison to prior studies.[2-4,15] Agreement between these was assessed by the kappa statistic. Logistic regression was performed to determine factors associated with in-hospital mortality. RA/PCW ratio was log-transformed for regression. Variables with univariate $P < .10$ were entered by stepwise forward-selection and retained if $P < .05$. Models were examined for residual distribution, multicollinearity, and Hosmer-Lemeshow goodness-of-fit. Subgroup analyses were performed both based on key variables and excluding patients with lower RA and PCW pressures.[7]

Results

Data were extracted from the first right heart catheterization from January 2003 through December 2014 for the aforementioned common indications in 4135 unique patients. Patients were predominantly male (58%) and white (85%) with a mean age of 69 years. History of diabetes mellitus (34%), hypertension (78%), heart failure (33%), either percutaneous coronary intervention or bypass (34%), and chronic kidney