Clinical Investigation

Pulmonary Artery Pulsatility Index Is Associated With Right Ventricular Failure After Left Ventricular Assist Device Surgery

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ABSTRACT

Background: Right ventricular failure (RVF) is a major cause of morbidity and mortality after CF-LVAD implantation. We explored the association of pulmonary artery compliance (PAC), pulmonary artery elastance (PAE), and pulmonary artery pulsatility index (PAPi) in addition to established parameters as preoperative determinants of postoperative RVF after CF-LVAD surgery.

Methods and Results: We retrospectively reviewed 132 consecutive CF-LVAD implantations at Tufts Medical Center from 2008 to 2013. Clinical, hemodynamic, and echocardiographic data were studied. RVF was defined as the unplanned need for a right ventricular assist device or inotrope dependence for ≥14 days. Univariate analysis was performed. RVF occurred in 32 of 132 patients (24%). PAC and PAE were not changed, whereas the PAPi was lower among patients with versus without postoperative RVF (1.32 ± 0.46 vs 2.77 ± 1.16; $P < .001$). RA pressure, RA to pulmonary capillary wedge pressure ratio (RA:PCWP), and RV stroke work index (RVSWI) were also associated with RVF. Using receiver operating characteristic curve–derived cut-points, PAPi < 1.85 provided 94% sensitivity and 81% specificity (C-statistic = 0.942) for identifying RVF and exceeded the predictive value of RA:PCWP, RVSWI, or RA pressure alone.

Conclusions: PAPi is a simple hemodynamic variable that may help to identify patients at high risk of developing RVF after LVAD implantation. (*J Cardiac Fail 2016;22:110–116*)

Key Words: Right ventricular failure, left ventricular assist device, hemodynamics.

Right ventricular failure (RVF) after continuous-flow left ventricular assist device (CF-LVAD) surgery remains a major cause of morbidity and mortality, with a reported incidence of ~20% in clinical trials.[1,2] Postoperative RVF, defined as prolonged inotrope dependence of at least 14 days or the need for a right ventricular assist device (RVAD), has been associated with bleeding, end-organ dysfunction, extended intensive care unit stays, and reduced survival to transplantation.[3–7] Delayed RVAD support has been associated with increased in-hospital mortality of up to 50% in isolated LVAD recipients in contrast to initial biventricular assist device (BiVAD) implantation.[8,9] Determining which patients who are at highest risk of developing RVF after CF-LVAD surgery remains a challenging clinical problem and, if possible, may improve clinical outcomes by allowing for earlier treatment aimed at RV protection.

After CF-LVAD surgery, several factors predispose to RVF, including increased RV preload, increased RV diameter due to shift of the interventricular septum away from the RV free wall, and an increased demand for RV output to match CF-LVAD flow. This combination of anatomic and hemodynamic alterations is compounded by pulmonary venous hypertension and subclinical RVF in patients with chronic left heart failure. Previously identified hemodynamic variables that correlate with RVF include elevated right atrial (RA) pressure, elevated RA to pulmonary capillary wedge pressure ratio (RA:PCWP), and reduced RV stroke work index (RVSWI). More recently, correlates of RV afterload, including pulmonary artery compliance (PAC) and pulmonary artery elastance (PAE), have been explored in patients with pulmonary hypertension due to left heart disease.[10,11] We recently defined the pulmonary artery pulsatility index (PAPi) as a measure of RVF in acute myocardial infarction.[12]

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No studies have examined whether indices such as PAC, PAE, and PAPi correlate with RVF after CF-LVAD surgery. In the present study, we explored the central hypothesis that these novel hemodynamic metrics may identify patients at high risk of developing RVF after CF-LVAD implantation.

Methods

Patients

The medical records of 132 consecutive patients undergoing CF-LVAD implantation at Tufts Medical Center from March 2008 to September 2013 were retrospectively reviewed. The study was approved by the Institutional Review Board. Demographic, clinical, laboratory, hemodynamic, and echocardiographic data were evaluated for their association with the development of RVF. Hemodynamic data were obtained from pulmonary artery (PA) catheter tracings interpreted by individuals blinded to the study protocol before LVAD surgery (within 24 hours), after surgery (within 6 hours), and 24 h after surgery. RVF was defined as inotrope dependence for ≥14 days or right-side circulatory support with a percutaneous or surgical RVAD.

Hemodynamic Calculations

RVSWI was calculated as (mean PA pressure − mean RA pressure) × stroke volume index, where the stroke volume index was calculated as the cardiac index divided by the heart rate. PAC was calculated as stroke volume/(PA systolic pressure − PA diastolic pressure). PAE was calculated as PA systolic pressure/stroke volume. PAPi was defined as (PA systolic pressure − PA diastolic pressure)/RA pressure. The RVF risk score was calculated as the sum of points assigned for vasopressor requirement (4 points), aspartate aminotransferase ≥80 IU/L (2 points), bilirubin ≥2 mg/dL (2.5 points), and creatinine ≥2.3 mg/dL (3 points) as previously described.[13]

Statistics

Univariate analysis was performed to identify baseline determinates of RVF. Continuous variables were compared with the use of an unpaired Student *t* test, and categoric variables were compared with the use of Fisher exact test. Receiver operating characteristic curves and the areas under the curves (AUCs) were calculated for univariate hemodynamic predictors of RVF. The AUC for the PAPi was compared with the other AUCs with the use of a previously described method.[14] $P < .05$ was accepted as significant for all statistical tests. Statistical analysis was performed with the use of Sigma Plot version 12.5 (Systat Software, San Jose, California).

Results

After CF-LVAD implantation, patients without RVF were supported on inotropes for 6.4 ± 3.4 days compared with 26.1 ± 17.8 days for patients with RVF. Survival to 180 days censored for transplantation was lower among patients who developed RVF (89% vs 65%; $P = .004$). The PAPi was higher among patients who survived to 180 days compared with those who did not (2.65 ± 1.44 vs 1.97 ± 0.85; $P = .03$), whereas PAC (2.46 ± 1.22 vs 2.33 ± 1.07; $P = .68$) and PAE (1.07 ± 0.45 vs 1.18 ± 0.57; $P = .36$) were not significantly different.

Table 1. Preoperative Clinical Characteristics

Characteristic	No RVF (n = 100)	RVF (n = 32)	*P* Value
Age (y)	56.4 ± 12.7	56.5 ± 10.5	.98
Sex (male)	81 (80%)	20 (65%)	.469
Destination therapy	30 (30%)	8 (26%)	.179
IABP use	53 (52%)	18 (58%)	.682
Medical history			
Nonischemic CM	57 (57%)	26 (81%)*	.045
Hyperlipidemia	46 (46%)	9 (29%)	.145
Hypertension	38 (38%)	11 (35%)	.831
Diabetes mellitus	38 (38%)	10 (32%)	.672
Smoking (quit >6 mo)	48 (48%)	12 (39%)	.417
Smoking (active)	10 (10%)	0	.116
Coronary artery disease	47 (47%)	10 (32%)	.214
Previous myocardial infarction (>6 wk)	39 (39%)	9 (29%)	.518
Recent myocardial infarction (<6 wk)	4 (4%)	0	.571
Previous CABG surgery	20 (20%)	3 (10%)	.28
Cerebrovascular disease	7 (7%)	1 (3%)	.68
Peripheral vascular disease	7 (7%)	0	.198
Atrial fibrillation/flutter	41 (41%)	19 (61%)	.063
Cardiac resynchronization therapy	37 (37%)	17 (55%)	.095
Chronic kidney disease (any stage)	33 (33%)	10 (32%)	1
Chronic kidney disease (stage IV/V)	3 (3%)	0	1
Medications			
Aspirin	77 ((76%)	15 (48%)*	<.01
Clopidogrel	16 (16%)	5 (16%)	.915
Coumadin	52 (52%)	14 (45%)	.541
Beta-blocker	68 (67%)	15 (48%)	.085
Angiotensin-converting enzyme inhibitor	48 (48%)	17 (55%)	.383
Angiotensin receptor blocker	12 (12%)	2 (6%)	.421
Aldosterone antagonist	63 (62%)	18 (58%)	.816
Digoxin	44 (44%)	14 (45%)	.766
Statin	51 (51%)	14 (45%)	.715
Inotropes†	53 (53%)	18 (58%)	.471

Data are presented as mean ± SD or n (%). RVF, right ventricular failure; IABP, intra-aortic balloon pump; CM, cardiomyopathy; CABG, coronary artery bypass grafting.

*$P < .05$.

†Inotropes defined as dobutamine, milrinone, or dopamine.

Baseline characteristics of the study population are provided in Table 1. RVF as defined by prolonged inotrope dependence of ≥14 days occurred in 30 patients and as defined by need for RVAD in 2 patients. Of the 2 patients requiring RVAD implantation, 1 received a percutaneous RVAD (Tandem Heart; Cardiac Assist, Pittsburgh, Pennsylvania) on postoperative day 4, and 1 received a surgical RVAD (Heartware, Framingham, Massachusetts) on postoperative day 8. Among the 30 patients who required prolonged inotropes, 3 were discharged on inotropes. The overall incidence of postoperative RVF among LVAD recipients was 24% (32/132 patients). 20% of Heartmate II (HMII) recipients (19/95) and 35% of Heartware (HW) recipients (13/37) developed RVF ($P = .075$ for interaction by device type). The groups were similarly