ELSEVIER

The Journal of Heart and Lung Transplantation
http://www.jhltonline.org

STATE OF ART

Echocardiographic parameters associated with right ventricular failure after left ventricular assist device: A review

Jonathan Neyer, MD, Reza Arsanjani, MD, Jaime Moriguchi, MD, Robert Siegel, MD, and Jon Kobashigawa, MD

From the Cedars-Sinai Heart Institute, Los Angeles, California.

KEYWORDS:
left ventricular assist device;
patient evaluation;
survival;
right ventricular failure;
echocardiography

Left ventricular assist devices improve functional class and survival in selected patients with advanced heart failure, but right ventricular failure after surgery remains common and challenging to predict. Pre-operative echocardiography provides important information in the evaluation of patients before device implant. This review summarizes the data on this complex topic.
J Heart Lung Transplant ■■■■;■:■■■–■■■

Patients with advanced heart failure meeting criteria for left ventricular (LV) assist devices (LVADs) have improved functional class, quality of life, and survival compared with patients managed with medical therapy alone.[1–3] Despite the benefits associated with LVAD use, post-procedural LVAD complications and mortality are high. One of the most common and challenging complications of LVAD placement is the development of right ventricular (RV) failure, which occurs in 5% to 44% of patients,[4,5] with most recent continuous-flow series ranging between 10% and 30%.[6] The reason for RV dysfunction is thought to be related to the increase in right-sided pre-load and the shift of the intraventricular septum from LV unloading, which alters the contraction and relaxation of the RV.[7] RV failure after LVAD results in prolonged hospitalizations and is associated with a significant morbidity and mortality.[4,8,9] A better understanding of which patients are at risk for post-operative RV failure is needed to improve patient selection and improve outcomes.

A number of investigators have tried to correlate quantitative and qualitative features of pre-surgery echocardiograms with the development of RV failure after LVAD surgery (Table 1). The data are inconsistent; few variables reliably predict post-LVAD RV failure or other adverse outcomes across data sets. These inconsistencies may be due to a lack of a universal definition of RV failure, limited sample sizes, and differences in the patients selected for LVAD placement among heart failure centers. A wide variety of variables, including anatomic parameters, assessments of RV size and systolic function, LV characteristics, echocardiographically derived physiologic variables, and assessments of valvular function have been correlated with post-LVAD outcomes (Table 2). This review summarizes the published data detailing the echocardiographic assessment of the heart before LVAD placement and directions for future research.

Risk scores

RV risk scores (Table 1) have been used to predict post-operative RV failure from a combination of pre-operative clinical, laboratory, hemodynamic, and echocardiographic

Reprint requests: Jaime Moriguchi, MD, Cedars-Sinai Heart Institute, California Heart Center, 8526 Wilshire Blvd, 3rd Flr, Beverly Hills, CA, 90211. Telephone: 310-248-8300. Fax: 310-248-8333.
E-mail address: jaime.moriguchi@cshs.org

1053-2498/$ - see front matter
http://dx.doi.org/10.1016/j.healun.2015.12.018

Table 1 Clinical Tools for Assessing Risk for Right Ventricular Failure or Mortality After LVAD Since 2008

First author	Publication date	No.	Devices implanted	Components of score[a]	Definition of RV failure	Major findings
Fitzpatrick[5]	2008	167	Pulsatile 98% Continuous 2%	1. Cardiac index 2. RV stroke work index 3. **Severe RV dysfunction** 4. Preoperative creatinine 5. Previous cardiac surgery	Need for biventricular support	Sensitivity of 83% and specificity of 80% to predict successful LVAD support using a cutoff of 50 points.
Matthews[8]	2008	197	Pulsatile 86% Continuous 14%	1. Vasopressor requirement 2. Aspartate aminotransferase 3. Bilirubin 4. Creatinine	Need for post-operative intravenous inotrope support for >14 days, inhaled nitric oxide for >48 h, right-sided circulatory support, or hospital discharge on an inotrope	Area under the ROC curve for the risk score was 0.73 ± 0.04
Potapov[10]	2008	54	Pulsatile 31% Continuous 69%	1. **Tricuspid incompetence** 2. **RV end-diastolic diameter >35 mm** 3. **RV ejection fraction <30%** 4. **Right atrial dimension <50 mm** 5. **Short-/long-axis ratio >0.6**	Within 48 hours: RVAD implant or 2 of the following: 1. Mean arterial pressure <55 mmHg 2. CVP >16 mmHg 3. Mixed venous saturation < 55% 4. Cardiac index <2 liters/min/m^2 5. Inotropic support >20 units	OR for RV failure after LVAD implantation for Grade III or IV tricuspid regurgitation was 4.7 ($p = 0.012$)
Puwanant[11]	2008	33	Pulsatile 45% Continuous 55%	1. **Tricuspid annular plane motion**	Need for inotropic support or pulmonary vasodilators for >14 days post-operatively	A cutoff of 7.5 mm yields a sensitivity of 48%, specificity of 91%, and area under the ROC curve of 0.81
Drakos[4]	2011	175	Pulsatile 86% Continuous 14%	1. Preoperative need for IABP 2. Increased PVR 3. Destination Therapy 4. Inotrope dependency 5. Obesity 6. ACE inhibitor and/or angiotensin II receptor blocker use 7. β-blocker use	Need for inhaled nitric oxide for >48 hours, IV inotropes >14 days and/or RV device insertion	Area under the ROC curve to predict RV failure was 0.743 ± 0.037
Kormos[9]	2011	484	Continuous 100%	1. CVP 2. Need for preoperative vent 3. BUN >39 mg/dl	Need for RVAD, continuous inotropic support for at least 14 days or late inotropic support starting 14 days after implantation	The following were associated with RV failure after multivariate analysis: 1. CVP/pulmonary capillary wedge pressure ratio >0.63 (OR, 2.3; 95% CI, 1.2–4.3) 2. Need for preoperative vent (OR, 5.5; 95% CI, 2.3–13.2) 3. BUN >39 mg/dl (OR, 2.1; 95% CI, 1.1–4.1)