Commentary: Flow is Fundamental

Berhane Worku MD¹,², Charles Mack¹,³, Ivancarmine Gambardella¹,²

1: Weill Cornell Medical College Department of Cardiothoracic Surgery
2: New York Presbyterian Brooklyn Methodist Hospital Department of Cardiothoracic Surgery
3: New York Presbyterian Queens Hospital Department of Cardiothoracic Surgery

Word Count: 486
Disclosures: none

Correspondence
Berhane Worku
New York Presbyterian Brooklyn Methodist Hospital
Department of Cardiothoracic Surgery
506 6th Street
Brooklyn, NY 11215
Central Message: The passive cardiac index is the amount of right heart flow that is driven by venous pressure (calculated as RAP/mPAP x CI), and is a strong predictor of RVF and mortality after LVAD implantation.

Central Picture Legend: Current RVF risk prediction models versus passive cardiac index

Figure 1 Legend: Current RVF risk prediction models versus passive cardiac index

Numerous risk prediction models for right ventricular failure (RVF) after left ventricular assist device (LVAD) implantation exist, incorporating clinical, laboratory, and echocardiographic parameters as well as hemodynamic parameters of RV function based on pressure measurements, with limited widespread utility\textsuperscript{1-6}. Preoperative assessment indicating a high risk of RVF frequently contraindicates LVAD implantation\textsuperscript{1-12}.

In the current report Tang et al. describe their institutional experience in 383 patients undergoing LVAD implantation. They devise a new parameter, the passive cardiac index (pasCI), which assesses the amount of right heart flow that is driven by central venous pressure (calculated as RAP/mPAP x CI), as opposed to active cardiac index which is the amount of right heart flow that is driven by right ventricular contractility (mPAP-RAP/mPAP x CI). Patients with increased pasCI had more renal and hepatic dysfunction, RVF, need for RVAD, and mortality. They further demonstrate that while pulmonary artery pulsatility index (PAPI), a pressure derived parameter, correlated with RVF rates and need for RVAD, it did not correlate with mortality, hence the prognostic superiority of pasCI, a flow derived parameter\textsuperscript{13}.
This is certainly a very exciting, novel way to think about how RV dysfunction relates to poor clinical outcomes in general and after LVAD implantation. The idea for pasCI came from Fontan circulation physiology in which passive venous pressure generated by LV forward flow and LV diastolic “suction force” drives the entire right heart flow as there is no active right ventricular contraction, and therefore the pasCI equals the entire CI. The Fontan patient tolerates this by maintaining low pulmonary vascular resistance, but the typical LVAD candidate, in whom pulmonary vascular resistance is typically elevated, may not. As the authors eloquently explain, in the LVAD candidate, venous pressure may be chronically elevated to help augment cardiac output (elevated pasCI), but this compensation comes at the cost of congestion related end-organ dysfunction. Renal congestion, for example, leads to a viscous cycle of volume retention and further venous pressure elevation.

The utility of the pasCI in predicting outcomes after LVAD implantation is in its association not just with RVF and RVAD requirement as with other pressure measurements (PAPI), but with actual survival. This is likely due to its derivation from flow measurements, and association with end organ damage. Its clinical applicability will be dependent on validation in separate LVAD patient populations. Perhaps incorporation of such a flow derived hemodynamic variable into models similar to those listed above may offer improved prognostic utility compared to pressure derived variables. Similar to strategies used to forecast market movements, these risk models offer a technical analysis of the problem by looking at the variables that statistically trend most strongly with RVF to predict its occurrence. Yang et. al. offer a more fundamental analysis of RVF, suggesting that it is venous pressure driven flow
rather than pressure itself that is the intrinsic problem. They are to be congratulated for offering such insight to such an intractable problem.
1. Matthews JC, Koelling TM, Pagani FD, Aaronson KD. The right ventricular score: A preoperative tool for assessing the risk of right ventricular failure after in left ventricular assist device candidates. J Am Coll Cardiol 2008;51:2163-2172


Current right ventricular failure risk prediction models

- Demographic and clinical variables
  - Age
  - Obesity
  - Medications
- Laboratory parameters of end-organ function
  - Blood urea nitrogen/creatinine
  - Liver function tests
  - Wrist blood salt count
  - Hemoglobin
- Ventilator dependence
- Vasopressor/Inotrope/Mechanical Support requirements
- Echocardiographic parameters
  - Right ventricular dysfunction
  - Tricuspid regurgitation
- Hemodynamic pressure-derived parameters
  - Right atrial pressure
  - Right atrial pressure/wedge pressure
  - Transpulmonary gradient
  - Pulmonary vascular resistance

Passive cardiac index (pasCI) and active cardiac index (actCI)

\[
\text{pasCI} + \text{actCI} = \text{ Entire CI}
\]

\[
\left(\frac{\text{RAP}}{\text{mPAP}} \times \text{CI}\right) + \left(\frac{\text{mPAP-RAP}}{\text{mPAP}} \times \text{CI}\right) = \text{ Entire CI}
\]

Passive cardiac index is a flow-based parameter associated with:

- Right ventricular failure
- RVAD need
- Mortality
Current right ventricular failure risk prediction models

- Demographic and clinical variables
  - Age
  - Glucosy
  - Medications
- Laboratory parameters of end-organ function
  - Blood urea nitrogen/creatinine
  - Liver function tests
  - Urine blood salicount
  - Hemoglobin
- Ventilator dependence
- Vasopressor/Inotropic/Mechanical Support requirements
- Echocardiographic parameters
  - Right ventricular dysfunction
  - Tricuspid regurgitation
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Passive cardiac index (pasCI) and active cardiac index (actCI)

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pasCI + actCI = Entire CI
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\left( \frac{RAP}{mPAP} \times CI \right) + \left( \frac{mPAP-RAP}{mPAP} \times CI \right) = Entire CI
\]

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