# The Impact of Systemic and Pulmonary Afterload on the Pressure-Volume Relationship in Heart Failure using Direct Blood Volume Measurement

**James R. Davis[1], Veraprapas Kittipibul[1], Vinay Vasanthu[1], Marc Silver[2], Dmitry Yaranov[3], Marat Fudim[1]**

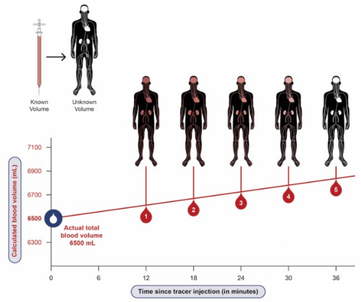
[1]Duke University, Durham, NC; [2]Banner University, Phoenix, AZ;
[3]Baptist Memorial Hospital, Memphis, TN

## BACKGROUND

- The dissociation between pressure measurements and actual volume measurements is a great challenge in assessing congestion in heart failure
- The impact of systemic and pulmonary afterload on the pressure-volume relationship is not well defined

## METHODS

- Heart failure patients enrolled at 2 hospitals underwent blood volume analysis (BVA) using indication dilution technique and same-day right heart catheterization.




- Total blood volume was reported as percent deviation from ideal values. The value between -8% to 8% is considered normal.
- Linear regression was used to predict TBV using right atrial pressure (RAP) or pulmonary capillary wedge pressure (PCWP) (**model 1**).
- Systemic vascular resistance (SVR) and pulmonary vascular resistance (PVR) were subsequently included (**Model 2**) followed by multivariate adjustments (adjusted for age, sex, LVEF: **model 3**).

## RESULTS

- A total of 94 patients were enrolled (**Table 1**).
- RAP is correlated TBV, but only weakly (**Model 1**, $R^2$=0.14, p=<0.01)(**Table 2**). With the addition of SVR and PVR, it remains weakly correlated (**Model 2**, $R^2$=0.15, p=0.03). SVR is inversely correlated with TBV ($R^2$=0.13, p=0.06). After multivariate adjustment (**Model 3**), RAP is no longer predictive of TBV but SVR remains inversely correlated with TBV ($R^2$=0.24, p=0.02). PVR does not alter the relationship between RAP and TBV.
- PCWP is correlated with TBV, but only weakly (**Model 1**, $R^2$=0.05, p=0.03). With the addition of SVR and PVR, the correlation between PCWP and TBV does not remain, but SVR is inversely correlated with TBV (**Model 2**, $R^2$=0.13, p=0.01). After multivariate adjustment (**Model 3**), SVR remains inversely correlated with TBV ($R^2$=0.23, p=<0.01). PVR does not alter the relationship between PCWP and TBV.
- The relationship between RAP/PCWP and TBV by SVR/PVR tertiles is shown in **Figure 1**.

**SVR,** *but not PVR,*
is **inversely correlated**
with **direct measures of blood volume**
independent of filling pressures

**For more information, please email *james.davis2@duke.edu* or reach out on Twitter/X *@james_r_davis1.***

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## Table 1: Patient Characteristics

| Variables | Full Cohort (n=94) |
|---|---|
| **Demographics** | |
| Age (years) | 59.2 +/- 14.2 |
| Female | 34 (36%) |
| African American race | 34 (36%) |
| BMI (kg/m2) | 32.7 +/- 7.7 |
| **Heart Failure History** | |
| Heart failure with preserved ejection fraction | 37 (39%) |
| Left ventricular ejection fraction (LVEF) | 38.1 +/- 17.9 |
| **Co-morbidities** | |
| Hypertension | 60 (64%) |
| Diabetes | 30 (32%) |
| Chronic kidney disease | 30 (32%) |
| Atrial fibrillation | 36 (38%) |
| **Hemodynamics** | |
| Mean right atrial pressure (mmHg) | 11.0 +/- 5.6 |
| Mean pulmonary artery pressure (mmHg) | 29.9 +/- 10.9 |
| Pulmonacy capillary wedge pressure (mmHg) | 19.5 +/- 7.9 |
| Cardiac index (L/min/m2) | 2.4 +/- 0.8 |
| **Blood Volume Analysis** | |
| Total blood volume (TBV) (mL/70kg) | 5867.4 +/- 1809.5 |
| TBV % deviation | 6.5 +/- 20.3 |
| Red blood cell volume (RBC) (mL/70kg) | 2109.7 +/- 776.1 |
| RBCV % deviation | (-)2.7 +/- 22.5 |
| Plasma volume (PV) (mL/70kg) | 3757.7 +/- 1147.4 |
| PV % deviation | 12.4 +/- 23.9 |

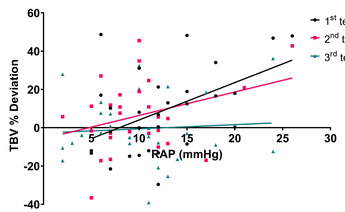
## Table 2: Predictive Models

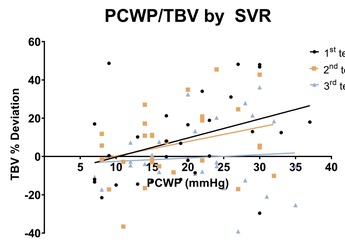
| Regression model | | TBV % deviation | | |
|---|---|---|---|---|
| | | Coefficient | p-values | $R^2$ |
| RAP | Model 1 - RAP | 1.34 | <0.01 | 0.14 |
| | Model 2 - RAP | 0.87 | 0.03 | 0.15 |
| | - SVR | -0.69 | 0.06 | |
| | - PVR | 2.51 | 0.13 | |
| | Model 3 - RAP | 0.69 | 0.098 | 0.24 |
| | - SVR | -0.88 | 0.02 | |
| | - PVR | 2.50 | 0.13 | |
| PCWP | Model 1 - PCWP | 0.59 | 0.03 | 0.05 |
| | Model 2 - PCWP | 0.49 | 0.07 | 0.13 |
| | - SVR | -0.90 | 0.01 | |
| | - PVR | 2.69 | 0.11 | |
| | Model 3 - PCWP | 0.31 | 0.25 | 0.23 |
| | - SVR | -1.03 | <0.01 | |
| | - PVR | 2.84 | 0.09 | |

**Model 1:** only pressure parameters (RAP or PCWP)
**Model 2:** pressure and afterload parameters (SVR and PVR)
**Model 3:** pressure and afterload parameters adjusted by age, sex, LVEF

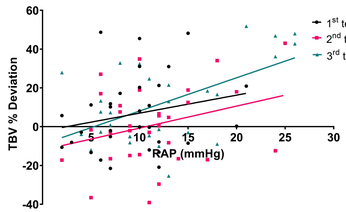
## FIGURE 1: Relationship between TBV and RAP/PCWP

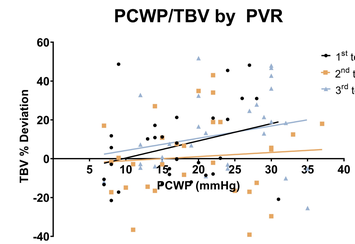
### SVR




### PVR




## CONCLUSIONS

- SVR is inversely correlated with direct measures of volume status independent of filling pressures. In contrast, PVR does not significantly alter pressure-volume relationship.
- After accounting for afterload, the pressure-volume discordance persists.
- Further studies of the roles of the venous system on the pressure-volume relationship are needed.

## DISCLOSURE INFORMATION

Presenting author (JRD) has no conflicts of interest to disclose.

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