Right Ventricular Performance During Exercise in Patients With Heart Failure

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Purpose

The purpose of this study is to characterize resting and exertional right ventricular (RV) function during exercise among patients with heart failure with reduced ejection fraction (HFrEF).

Patient Characteristics

Table 1: Cohort Characteristics

Characteristic	HFrEF N=6
Age, yrs	60±9
Male sex, N (%)	5 (83)
Height, cm	178±7
Weight, kg	93±21
Body mass index, kg/m^2	29±6
Ischemic heart failure, N (%)	2 (33)
Left ventricular ejection fraction, %	25±10
Past Medical History	
Hypertension, N (%)	1 (17)
Sleep apnea, N (%)	3 (50)
Atrial fibrillation, N (%)	3 (50)
Diabetes Mellitus, N (%)	3 (50)
Chronic kidney disease, N (%)	3 (50)
Creatinine, mg/dL	1.4±0.4
Medications	
Beta-blockers, N (%)	4 (67)
ACE-I/ARB/ARNI, N (%)	5 (83)
Hydralazine, N (%)	1 (17)
Isosorbide, N (%)	1 (17)
Mineralocorticoid, N (%)	4 (67)
Diuretic, N (%)	3 (50)
Digoxin, N (%)	2 (33)
Supine hemodynamics	
Right atrial pressure, mmHg	6±4
Mean PA pressure, mmHg	25±13
PCWP, mmHg	13±9
PA Saturation, (%)	65±7
Arterial Saturation, (%)	95±1
Fick cardiac output, L/min	5.6±1.7

ACE-I: angiotensin converting enzyme inhibitor; ARB: Angiotensin receptor blocker; ARNI: angiotensin-receptor Neprilysin inhibitor; PA: pulmonary arterial; PCWP: pulmonary capillary wedge pressure

Materials and Methods

- Six patients (five males, 60±9 yrs) completed invasive cardiopulmonary exercise testing (CPET) on upright cycle ergometry with conductance catheters for real-time RV pressure-volume (PV) analysis, as well as radial arterial catheterization for blood pressure monitoring.
- Data were collected at rest, two submaximal levels of exercise (Steady-States 1, 2) below ventilatory threshold, and peak effort.
- Breath-by-breath gas-exchange parameters were determined by indirect calorimetry.
- Cardiac output (Q_c) was determined by direct Fick.

Results

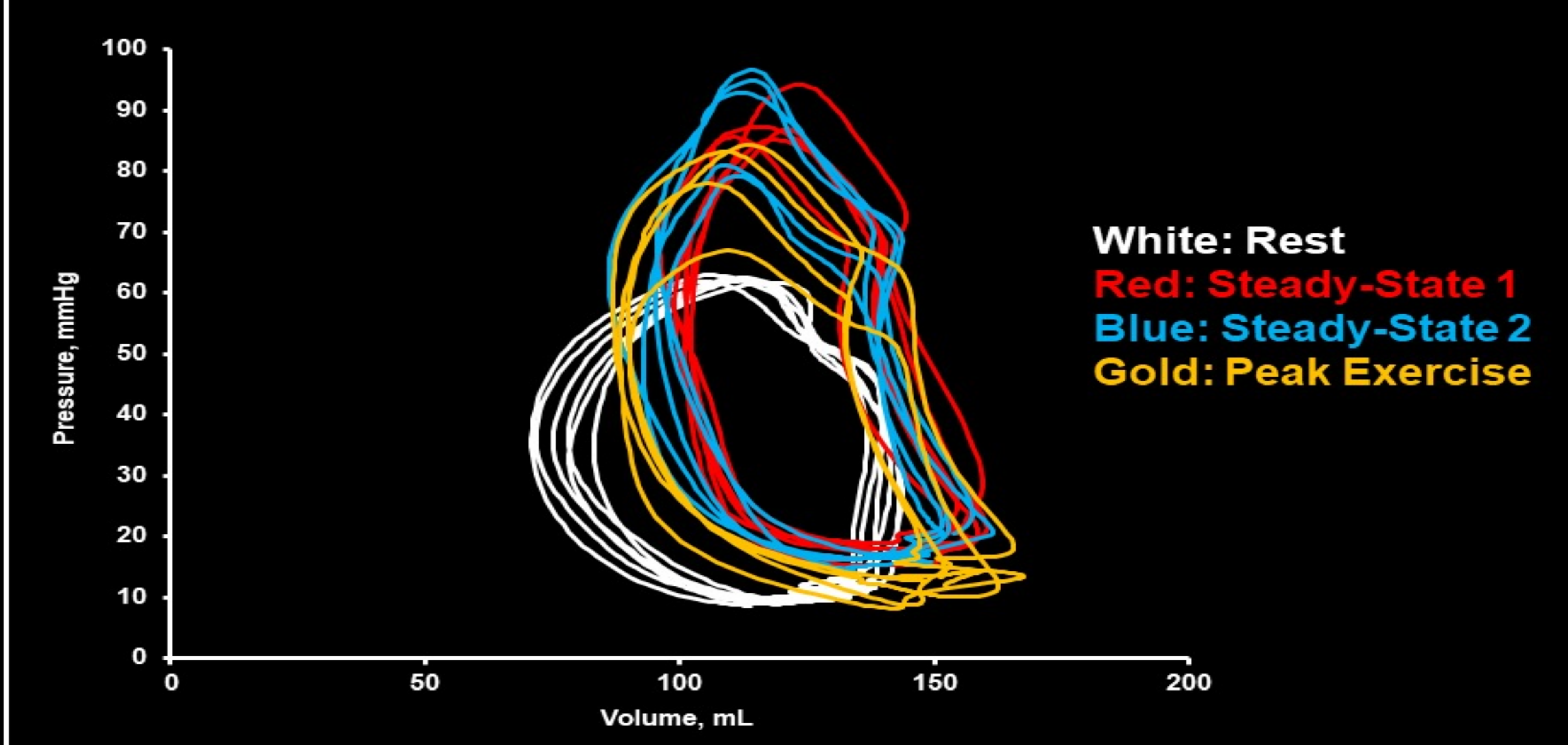
Table 2: Exercise Hemodynamics

Characteristic	**HFrEF N=6**	**P-value**
Oxygen uptake, ml/kg/min		
Rest	4.1±0.8	0.01
Steady-State 1	8.6±2.4	
Steady-State 2	10.4±2.1*	
Peak Exercise	11.8±5.0	
Respiratory Exchange Ratio		
Rest	0.96±0.15	0.33
Steady-State 1	0.86±0.08	
Steady-State 2	0.93±0.07	
Peak Exercise	0.95±0.08	
Mean arterial pressure, mmHg		
Rest	87±11	0.09
Steady-State 1	86±20	
Steady-State 2	93±8	
Peak Exercise	78±11	
Cardiac output, L/min		<0.01
Rest	4.5±1.2	
Steady-State 1	7.7±2.7*	
Steady-State 2	8.9±3.4	
Peak Exercise	8.8±1.9	
$dpdt_{max}$, mmHg/sec		<0.01
Rest	329±51	
Steady-State 1	464±104*	
Steady-State 2	538±108	
Peak Exercise	538±70	
$dpdt_{min}$, mmHg/sec		<0.01
Rest	-296±88	
Steady-State 1	-417±110*	
Steady-State 2	-430±109	
Peak Exercise	-463±70	
Stroke Work, mmHg*sec		0.02
Rest	1504±1105	
Steady-State 1	2371±588	
Steady-State 2	2417±535*	
Peak Exercise	2473±1305	

*P<0.05 compared to baseline

- VO2Max was severely reduced (11.8±5.0) and ventilatory efficiency was severely abnormal (46±15).
- Exercise Q_c increased from rest to Steady-State 1, but there were no increases thereafter at higher workloads or at peak effort.
- Exercise myocardial energetics (stroke work) were also blunted with a modest increase from rest to Steady-State 2.
- Diastolic reserve ($dpdt_{min}$) increased modestly from rest to Steady-State 1 only.
- **Table 2** displays exercise hemodynamics and gas-exchange parameters.
- An example figure of hemodynamics and RV PV loops during exercise is displayed in **Figure 1**.

Figure 1: Example right ventricular pressure-volume analysis during exercise from a 70yo man with history of ischemic cardiomyopathy.



Conclusion

HFrEF patients experience impairments in RV contractile and lusitropic reserve, and energy utilization during exercise. These findings demonstrate how exertional RV dysfunction contributes to impairments in functional capacity.