Comparison of Resting and Dynamic Measures of Stroke Volume in Children with Syncope

Bradley J. Conant, MD, MATrg; Garick D. Hill, MD, MS; Adam W. Powell, MD, MS

Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, USA

Abstract

Neurocardiogenic syncope is a common concern in pediatric patients. Previous research has shown low left ventricular mass and stroke volume limitations on cardiac imaging as the primary etiology for symptoms. Minimal research has been performed on how measures of resting stroke volume relate to measures of dynamic cardiac performance and stroke volume in symptomatic patients with neurocardiogenic syncope. Additionally, there has been no research on how Innocor inert gas rebreathing relates to echocardiographic measures of stroke volume in pediatric patients with neurocardiogenic syncope. A retrospective chart review identified all patients <21 years old with a cardiopulmonary exercise test and echocardiogram performed on the same day from October 2017 to December 2023 for neurocardiogenic syncope (n=101, 15.2±2.3 years-old). Most patients also had body composition measured using bioimpedance analysis (BIA). Comparison between groups was performed with a student t-test, and correlations were performed using Pearson's correlation. P<0.05 was considered significant. Data presented as mean ± SD. There were 22 patients (36% male; age 15.6±2.4) who had either syncope or a vasodepressor response to exercise compared to 79 patients (29% male; age 15.0±2.3) without symptoms. Height, weight, BMI, and body composition were not significantly different between groups. Patients with a positive syncope evaluation had lower Z-scores for left ventricular (LV) end-diastolic volume (-1.2±1.3 v. -0.4±1.3, p=0.01) and LV end-systolic volume (-1.0±1.4 v. -1.1±1.1, p=0.001) and lower percent predicted peak oxygen pulse (O_2pulse) (95.5±14.0% v. 104.6±18.5%, p=0.04) compared to those without symptoms during testing. Resting stroke volume measured by echocardiography was correlated with Innocor measurements of resting (r=0.53, p<0.0007) and peak (r=0.32, p=0.009) stroke volume, peak O_2pulse (r=0.61, p<0.0001), total body water (r=0.67, p<0.0001), and skeletal muscle mass (r=0.67, p<0.0001). Youth with symptoms following exercise testing have lower LV volumes and lower peak O_2pulse during cardiopulmonary exercise testing compared to those without symptoms. Resting stroke volume on echocardiogram is associated with Innocor derived stroke volume, peak O_2pulse, total body water, and skeletal muscle mass.

Objectives

- Evaluate the correlation between stroke volume as measured by echocardiography and Innocor inert gas rebreathing.
- Evaluate relationships between resting and dynamic measures of cardiac performance.
- Compare resting and dynamic cardiac function in children with and without exertional syncope.

Methods

- Single site retrospective chart review of patients presenting with syncope and having cardiopulmonary exercise testing and echocardiography performed.
- Exclusion criteria: CPET and echo performed on different days, incomplete or unavailable echo data, congenital heart disease, treadmill CPET protocol, incomplete CPET data, submaximal CPET
- Body composition data obtained using bioelectrical impedance analysis (BIA) (InBody370; InBody, Cerritos, CA, USA).
- Inert gas rebreathing data collected using Innocor (Innocor CO; Cosmed, Rome, Italy).
- Positive syncope evaluation defined by vital sign changes and/or loss of postural tone
- Pearson's correlation coefficient used to evaluate correlations between echo, Innocor, BIA, and CPET variables.
- Student T-tests used to compare factors between patients with positive and negative syncope evaluations.
- P < 0.05 considered statistically significant.

		Total Cohort (n = 101)	Negative Syncope Evaluation (n = 79)	Positive Syncope Evaluation (n = 22)	P-value
Demographics					
	Sex	Male = 31 Female = 70	Male = 23 Female = 56	Male = 8 Female = 14	0.5
	Age	15.2 ± 2.3	15.0 ± 2.3	15.6 ± 2.4	0.3
	Height (cm)	165.5 ± 10.6	164.8 ± 10.8	167.8 ± 9.9	0.3
	Weight (kg)	59.8 ± 13.6	58.8 ± 13.4	63.2 ± 13.9	0.2
	BMI (kg/m2)	21.6 ± 3.7	21.4 ± 3.7	22.2 ± 3.9	0.3
BIA (n = 96)					
	SMM (kg)	26.0 ± 6.1	25.6 ± 6.2	27.2 ± 5.7	0.3
	SMM (% predicted)	104.3 ± 13.1	104.3 ± 13.8	104.3 ± 10.7	0.9
	Body Fat (kg)	13.1 ± 7.1	12.7 ± 6.8	14.3 ± 7.8	0.4
	Body Fat (%)	21.1 ± 8.7	20.9 ± 8.7	21.8 ± 8.7	0.7
	Total Body Water (kg)	34.2 ± 7.4	33.7 ± 7.5	35.8 ± 6.9	0.2
Echocardiography (n = 101)					
	LV EDV (mL)	122.2 ± 29.9	123.6 ± 31.0	117.0 ± 25.8	0.4
	LV EDV (Z-score)	-0.54 ± 1.3	-0.36 ± 1.3	-1.2 ± 1.3	**0.01**
	LV ESV (mL)	48.2 ± 13.2	49.1 ± 13.6	45.1 ± 10.4	0.2
	LV ESV (Z-score)	-0.3 ± 1.2	-0.1 ± 1.1	-1.0 ± 1.4	**0.001**
	LV EF (% predicted)	60.6 ± 3.1	60.4 ± 3.2	61.5 ± 2.8	0.1
	LV EF (Z-score)	-0.6 ± 0.7	-0.7 ± 0.7	-0.4 ± 0.7	0.1
	Stroke Volume (mL)	73.9 ± 17.7	74.5 ± 18.2	71.9 ± 15.8	0.5
	LV Mass (g)	103.2 ± 29.4	102.1 ± 30.4	107.4 ± 25.5	0.5
	LV Mass Index (g/m2)	25.9 ± 6.2	25.9 ± 6.2	26.2 ± 6.0	0.8
Resting Innocor (n = 89)					
	Cardiac Output (L/min.)	5.1 ± 1.4	5.1 ± 1.4	5.1 ± 1.4	0.9
	Cardiac Index (L/m2/min.)	3.1 ± 0.7	3.1 ± 0.7	3.0 ± 0.7	0.1
	Stroke Volume (mL)	67.4 ± 19.9	67.3 ± 19.4	67.7 ± 20.2	0.9
Peak Innocor (n = 64)					
	Cardiac Output (L/min.)	10.7 ± 3.0	10.6 ± 3.0	11.3 ± 3.4	0.5
	Cardiac Index (L/m2/min.)	6.5 ± 1.5	6.5 ± 1.5	6.7 ± 1.9	0.7
	Stroke Volume (mL)	59.2 ± 17.2	58.7 ± 17.1	61.6 ± 18.5	0.6
CPET (n = 101)					
	Resting HR	65.1 ± 11.2	64.7 ± 11.4	66.5 ± 10.5	0.7
	Peak HR	182.5 ± 10.9	181.7 ± 10.8	185.6 ± 10.9	0.1
	RER	1.2 ± 0.1	1.2 ± 0.09	1.3 ± 0.1	**0.04**
	Peak VO2 (mL/min.)	2104 ± 612.0	2098.1 ± 637.2	2125.3 ± 524.3	0.9
	Peak VO2 (mL/kg/min.)	35.5 ± 6.6	35.5 ± 6.5	34.0 ± 6.9	0.4
	Peak VO2 (% predicted)	93.8 ± 16.8	95.1 ± 17.3	88.9 ± 14.4	0.1
	Peak O2 Pulse	11.5 ± 3.3	11.5 ± 3.3	11.6 ± 3.0	0.9
	Peak O2 Pulse (% predicted)	102.6 ± 18.0	104.6 ± 18.5	95.5 ± 14.0	**0.04**
	Peak SBP (mm Hg)	170.3 ± 18.3	170.5 ± 17.1	169.5 ± 22.5	0.8
	HR Recovery (1 min.)	36.3 ± 13.4	37.8 ± 13.2	31.0 ± 12.7	**0.03**

Table 1: Baseline demographics and results of bioelectrical impedance (InBody), echocardiography, inert gas rebreathing (Innocor), and cardiopulmonary exercise testing (CPET).

Variable	R	P-value
Resting Innocor SV	0.53	< 0.0001
Peak Innocor SV	0.32	0.009
Peak O2 Pulse	0.61	< 0.0001
Total Body Water	0.67	<0.0001
Total Body Fat	0.2	0.04
Total SMM	0.67	< 0.0001

Table 2: Relationship between resting stroke volume on echocardiogram and selected Innocor, CPET, and BIA variables

Variable	R	P-value
Total Body Water	0.46	0.0002
Total SMM	0.48	< 0.0001
Peak O2 Pulse	0.49	< 0.0001

Table 3: Relationship between peak stroke volume on Innocor and selected BIA and CPET variables

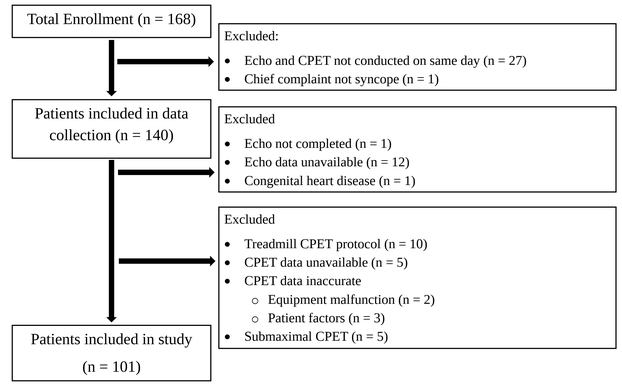

Figure 1: Application of exclusion criteria to identify patients eligible for study inclusion.

Results

- The average age of patients was 15.2 ± 2.3 years with a range of 9.6-20.8. Baseline characteristics were similar between groups.
- All patients had an echocardiogram and CPET study performed. 96 patients also had BIA performed. 89 patients had resting Innocor data and 64 had peak exercise Innocor data recorded.
- 22 patients met criteria for a positive syncope evaluation after CPET (loss of postural tone and/or hypotension/bradycardia without loss of tone)
- Echocardiographic measurement of stroke volume showed significant correlation with resting and peak stroke volumes via Innocor, peak O2 pulse during CPET, and BIA measurement of total body water, body fat, and skeletal muscle mass.
- Peak exercise stroke volume via Innocor showed significant correlation with peak O2 pulse and BIA measurement of total body water and skeletal muscle mass
- Patients with symptoms following CPET had lower LV EDV and ESV z-scores and had lower percent predicted peak O2 pulse than those with negative syncope evaluation.

Conclusions

- Children with symptoms after CPET have relatively lower left ventricular EDV and ESV compared to those without symptoms.
- Children with symptoms after CPET have lower peak O2 pulse than those without symptoms.
- Resting echo stroke volume is associated with Innocor stroke volume, peak exercise stroke volume, peak oxygen pulse, total body water, and skeletal muscle mass.

Acknowledgements

- The Heart Institute Research Core
- CCHMC Cardiopulmonary Exercise Lab