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Relationship between Exercise Parameters and Noninvasive Indices of Right Ventricular Function in Patients with Biventricular Circulation and Systemic Right Ventricle

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Abstract

Objectives—In patients with systemic right ventricles (RV) in a biventricular circulation, exercise capacity and RV function often deteriorate over time and echocardiographic assessment of systemic RV function is difficult. The purpose of this study was to examine the relationship between exercise capacity and RV function and to determine which noninvasive imaging parameters correlate most closely with exercise capacity.

Design—Patients with a systemic RV (D-loop transposition of the great arteries (TGA) after atrial switch procedure or physiologically “corrected” TGA) who underwent cardiopulmonary exercise testing (CPX) and noninvasive imaging (cardiac magnetic resonance [CMR] and echocardiography [echo]) within 1 year of CPX were identified. Regression analysis was used to evaluate the relationship between exercise variables and noninvasive indices of ventricular function.

Results—We identified 92 patients with 149 encounters (mean age 31.0 y, 61% male, 70% D-loop TGA) meeting inclusion criteria. Statistically significant correlations between % predicted peak oxygen uptake (%pVO₂) and RV ejection fraction (EF) ($r=0.29$, $p=0.0007$), indexed RV end-systolic volume ($r=-0.25$, $p=0.002$), and Tei index ($r=-0.22$, $p=0.03$) were found. In patients without additional hemodynamically significant lesions, the correlations between %pVO₂ and RV EF ($r=0.37$, $p=0.0007$) and the Tei index ($r=-0.28$, $p=0.03$) strengthened and a correlation

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emerged between %pVO₂ and dP/dt_{ic} ($r=0.31$, $p=0.007$). On multivariable analysis, Tei index was the only statistically significant correlate of %pVO₂ ($p=0.04$).

Conclusions—In patients with systemic RVs in a biventricular circulation, CMR-derived RVEF and echo-derived Tei index correlate with %pVO₂. On multivariable analysis, the Tei index was the strongest predictor of peak %pVO₂ response.

Keywords

transposition of the great arteries; systemic RV; Tei index; exercise capacity

1-Introduction

A growing number of patients with transposition of the great arteries (TGA) and a systemic right ventricle (RV) are reaching adulthood. These patients often have poor exercise tolerance (1–3) and abnormal ventricular function (4–6). Understanding the relationship between these two phenomena may help clinicians prognosticate and devise rational clinical management strategies for this unique and physiologically complex population. This task is complicated, however, by the complex anatomy of the RV and by the limited echocardiographic windows that are typically encountered in these patients. As a result, standard echocardiographic approaches to the assessment of ventricular function, which rely on geometric assumptions, are invalid, impractical, and/or unreliable in patients with systemic RVs (5). Consequently, cardiac magnetic resonance imaging (CMR) is increasingly being utilized to assess the RV function of these patients (7). However, there are several limitations to CMR including expense, lack of portability, limited availability, artifacts from implants containing stainless steel, and relative contraindication in patients with a pacemaker or implantable defibrillator (8). For these reasons, an echocardiographic index of ventricular function that is both reliable and clinically/physiologically valid would be of particular value in this patient population. We therefore undertook this study to assess the relationship between quantitative assessments of exercise capacity, CMR derived estimates of RV ejection fraction (EF), and echocardiographic indices of ventricular function that are not confounded by the RV's irregular anatomy and geometry.

2-Methods

2.1 Patient Sample

We performed a retrospective chart review to identify patients with biventricular circulation and a systemic RV, either surgically corrected (atrial switch procedure) D-loop TGA (D-TGA) or physiologically “corrected” TGA (cc-TGA). In these patients, we obtained non-invasive imaging parameters (echocardiography and CMR) of systemic RV function and correlated these with exercise performance. We first identified patients who underwent both cardiopulmonary exercise (CPX) testing and CMR between 2002–2013. A majority of these patients also had echocardiograms during this time period and were used in the analysis. Patients were included in the analyses if CMR ± echocardiography occurred within one year of CPX. Several patients had multiple qualifying CPX and imaging studies during the study period which were included in the analysis using statistical adjustments for serial measurements (see *Statistical Analysis*-2.5). Studies were excluded if they had significant

intracardiac shunting, interval transcatheter or surgical procedures between imaging and exercising testing, additional complex heart disease (e.g., heterotaxy or severe Ebstein anomaly), or non-cardiac conditions that might affect exercise capacity, such as pregnancy. Furthermore, all studies were separated into two subgroups to allow for analyses in those with and without other conditions (such as valvular dysfunction) that might adversely affect peak oxygen uptake (VO_2) independent of ventricular function. The subgroups were named “simple” or “complex, respectively. The majority of studies categorized as “complex” had severe tricuspid regurgitation, tricuspid valve replacement, main or branch pulmonary artery stenosis, or presence of a left ventricular-to-pulmonary artery conduit.

2.2 Cardiopulmonary Exercise Testing

Patients underwent a progressive symptom-limited exercise tests using stationary upright cycle ergometers with a continuous graded workload (ramp protocol)(9). During the exercise tests, electrocardiographic monitoring and breath-by-breath expiratory gas analyses were performed according to standard institutional protocol (MedGraphics metabolic cart, St. Paul, MN). Cuff blood pressure measurements were acquired at 2-minute intervals. Pulse oximetry was continuously monitored to determine oxygen saturation. Patients were verbally encouraged to expend a maximal effort. Due to the variations in patient age, size, and gender, all indices of exercise function were expressed as a percentage of predicted values (10). To minimize the confounding effects of inadequate patient effort, we excluded data from studies in which patients did not achieve a respiratory exchange ratio at peak exercise 1.09(11,12).

2.3 Echocardiographic Protocol

Two-dimensional (2D) echocardiography was performed with utilization of multiple Doppler techniques (Philips Medical Systems, Andover, MA, USA). Retrospective off-line analyses of mean dP/dt during isovolumetric contraction (dP/dt_{ic}), the Tei index, and tricuspid annular plane systolic excursion (TAPSE) were undertaken on 3 consecutive heartbeats. The dP/dt_{ic} was calculated as the difference between the aortic diastolic pressure and an assumed ventricular end-diastolic pressure of 5 mm Hg divided by the isovolumetric contraction time. Aortic diastolic pressure was obtained using an automated blood pressure system. The isovolumetric contraction time was measured as the time interval between systemic atrioventricular (AV) valve closure and aortic valve opening. Measurements were made using Doppler echocardiography as previously described (13,14). The Tei index was calculated as the sum of the isovolumetric contraction time and isovolumetric relaxation time divided by the ejection time. Measurements were made using Doppler echocardiography and calculations carried out as described previously (15). TAPSE was measured using 2D echocardiography. The cursor was placed at the junction between the tricuspid valve annulus and the right ventricular lateral wall in the 4-chamber view, and the extent of systolic motion of the valvular ring towards the apex was measured as previously described (16). For each parameter, the mean of three measurements was used for the final calculations. To assess the reproducibility of the echocardiographic parameter, 19 studies were randomly selected and the relevant measurements were repeated by the same observer (blinded to the original measurement) and a blinded second observer.

2.4 CMR Protocol

Studies were performed using a commercially available 1.5-T scanner (Philips Healthcare, Best, the Netherlands). The details of the CMR technical parameters used in our laboratory were previously published (17). Briefly, steady-state free precession cine imaging of the ventricles was performed during breath-holding in ventricular 2-chamber, 4-chamber, and short-axis planes. The short-axis stack provided complete coverage from base to apex of both ventricles (12 to 14 equidistant slices, typical slice thickness 7–8 mm). Ventricular volumes were measured in the short-axis plane at end-systole (smallest volume) and end-diastole (largest volume) and the interventricular septum was included in the left ventricular mass. All ventricular volume measurements were indexed to body surface area (BSA).

2.5 Statistical Analysis

Continuous variables are presented as mean $\pm$ standard deviation (SD) and categorical variables as counts and percentages. The primary endpoint was percent predicted pVO_2 . The association of anatomic complexity and TGA anatomy with $\%pVO_2$ was assessed using generalized estimating equations (GEE) modeling, which accounts for clustering of repeated measurements on the same subject. The relationship between $\%pVO_2$ and potential predictors was assessed by calculating Pearson correlation coefficients. P-values for the correlation coefficients were calculated using GEE modeling. Univariable analyses to determine the association between a dichotomous outcome of pVO_2 ($\%pVO_2 < 60\%$ and $\%pVO_2 \geq 60\%$) and potential predictors were performed using GEE regression modeling; GEE regression modeling was also used in multivariable analysis where the outcome was a continuous measure $\%pVO_2$. Intra-rater reliability was assessed by calculating the intraclass correlation coefficient (ICC). Inter-rater reliability was summarized by providing the median and interquartile range; the Wilcoxon Signed Rank test was used to determine significance. Areas under the receiver-operator characteristic (ROC) curve were calculated to determine if the combination of strongest imaging variables enhanced our ability to predict exercise tolerance using a cutoff value of 60% peak predicted VO_2 representing the mean value reported in the literature (18). P-values < 0.05 were considered statistically significant. Intra-rater reliability was performed using SPSS v21.0 (SPSS: An IBM Company); all other analyses were performed using SAS v9.3 (SAS 9.3 Cary, NC, USA).

3-Results

3.1 Patient Characteristics

We identified 112 patients based on diagnosis and timing of imaging and exercise testing. Of those, 20 were excluded for the following reasons: 13 for intracardiac shunting (residual ventricular septal defect or baffle leak), 3 for interval transcatheter or surgical procedures between imaging and exercising testing, and 4 for additional complex heart disease (e.g. heterotaxy or severe Ebstein anomaly). Thus, 92 patients with 149 encounters were included in this analysis; 70% ($n=64$) had surgically palliated D- TGA and 30% of patients ($n=28$) had cc-TGA. Of the 149 encounters, 101 (68%) occurred in patients from the “simple” category; the remainder were considered “complex”. Demographics from each patient’s most recent encounter are summarized in Table 1: 61% were male, the average age was 31.0

years, and the mean %pVO₂ was 69.4 ±16.1% of predicted. The mean peak heart rate was 88±12.7 % of predicted.

Of these 149 total encounters, 94 had echocardiographic studies adequate for inclusion representing 69 patients. In this group 70% of patients had D-TGA and 30% were considered “complex”. The dP/dt_{ic} and Tei index were calculated in 62 encounters. TAPSE was calculated in 78 encounters. The mean CMR and echocardiographic parameters of RV function fell within the low-normal range, as summarized in Table 2. When comparing patients with suitable echocardiographic images for inclusion versus those without, there were no significant differences between the groups for gender, diagnosis, anatomic complexity, and age or % pVO₂.

3.2 Correlation between imaging variables and exercise capacity

When evaluating the CMR variables, weak but statistically significant correlations were found between %pVO₂ and both the RV ejection fraction (RVEF) and indexed RV end systolic volume (RVESVi) (Table 3). The strongest correlation was found between RVEF and %pVO₂ (r= 0.29, p =0.0007). RVESVi had a slightly weaker correlation (r= -0.25, p = 0.002). Notably, indexed RV mass, indexed RV end diastolic volume (RVEDVi), CMR derived stroke volume and RV mass:volume ratio did not significantly correlate with %pVO₂.

In the overall cohort, the Tei index was the only echocardiographic variable that correlated with %pVO₂ (r = -0.22, p = 0.03; Table 3). The dP/dt_{ic} and TAPSE were not found to correlate with exercise capacity. There was no significant correlation with exercise capacity in fractional area change in the total cohort or subgroups. In addition, gender, age, and anatomy (D-TGA vs. cc-TGA) were not significantly associated with %pVO₂. An additional analysis was performed by using a cutoff value of %pVO₂ < 60% predicted to represent significant exercise limitation (18,19). Individually, RVEF emerged as the only CMR or echocardiography variable that differed significantly in patients with %pVO₂ ≥ 60% versus < 60% (p = 0.02; Table 4). ROC curve analysis revealed that combining echo and CMR data offered little advantage to either modality alone (Figs1). Using the ROC curves, an RVEF of >55% had a specificity of 90% but sensitivity of 30% for predicting peak VO₂ ≥ 60%. The majority of patients with peak VO₂ ≥ 60% had a Tei index <0.47 with a specificity of 80% and sensitivity of 48% (Figs 2). No correlation was found between peak VO₂ in ml/mg/kg/min with any imaging variable.

3.3 Subgroup Analyses

Analyses were also undertaken in the subgroup of patients in the “simple” category (N = 64; 77% with D-TGA). Within this subgroup, the correlation coefficients for RVEF (r = 0.37, p=0.0007), RVESVi (r = -0.31, p < 0.0001), and the Tei index (r = -0.28, p = 0.03) with %pVO₂ strengthened when compared to the overall cohort. Additionally, dP/dt_{ic} and RVEDVi emerged as being correlated with exercise capacity, with correlation coefficients of 0.31 (p = 0.007) and - 0.21 (p = 0.01), respectively. Results from these subgroup analyses are summarized in Table 3. Within the simple subgroup, the presence of D-TGA was

associated with a lower %pVO₂ when compared to those with cc-TGA (70.2 ±15.8 v 80.9 ±13.0, p = 0.004).

3.4 Multivariable Analyses

Multivariable analyses were conducted using variables that were clinically meaningful as well as those with the strongest correlations with %pVO₂ in GEE modeling. These included age, type of anatomy (D-TGA vs. cc-TGA), anatomic complexity (simple or complex), RVEF, Tei index, and dP/dt_{ic}. Of these, only the complexity of disease (p=0.003) and Tei index (p=0.04) remained significantly correlated with %pVO₂, as summarized in Table 5.

Inter- and Intra-observer Variability—The inter- and intra-observer agreement was assessed for the Tei index and dP/dt_{ic}. The median difference in raters for the Tei index was 0.014 units (Interquartile range (−0.03, 0.08), p-value=0.62). The median difference in raters for dP/dt_{ic} was 0.0 units (Interquartile range (−56.8, 129.1), p-value=0.47). For intra-rater reliability, the intraclass correlation coefficient (ICC) for the Tei index was 0.67 (95% CI 0.29, 0.87) and the ICC for dP/dt_{ic} was 0.56 (95% CI 0.12, 0.82).

4- Discussion

Patients with D-looped TGA who have undergone an atrial switch procedure and those with physiologically corrected TGA live with a RV that provides systemic output. This systemic RV exhibits unique myocardial mechanics, with predominant circumferential free wall shortening, and a lack of normal torsion (20,21). The mechanisms that contribute to systemic (right) ventricular dysfunction and exercise intolerance in this unique set of patients are poorly understood. This study attempts to better understand the relationship between these two important measures.

Weak, but statistically significant, correlations existed between imaging parameters and exercise function (%pVO₂) in patients with systemic RVs. For the entire study group, the CMR-derived RVEF and the echocardiographically-determined Tei index were the parameters that correlated best with exercise function. Notably the TAPSE, fractional area change and dP/dt were not correlated with exercise capacity in the overall cohort. We noted, however, that the correlation between exercise function and the non-invasive indices of ventricular function was enhanced when patients with complex anatomy/physiology (e.g., patients with valvular dysfunction that might adversely affect peak VO₂, independent of ventricular function) were excluded from the analyses. In this subgroup, the strength of the correlations resembled those encountered in patients with tetralogy of Fallot and was superior to that observed among patients with Fontan physiology (22,23). The lack of correlation with peak VO₂ (when expressed as ml/kg/min) suggests that weight-normalized values of VO₂ should be interpreted in the context of the patient's age and gender.

The lack of a strong correlation between the imaging parameters and exercise function in this population probably reflects the fact that many factors besides ventricular systolic function (e.g., chronotropic response, pulmonary function, vascular function, skeletal muscle function, oxygen extraction, etc.) may influence a patient's exercise performance. The fact that the Tei index emerged as the strongest correlate of exercise function supports this

concept as it is the only parameter studied that incorporates evaluation of function during both systole and diastole. Furthermore, it must be noted that the imaging parameters of ventricular function were acquired with the patients at rest, and do not necessarily reflect the patients' cardiac function during exercise.

Past studies of patients with systemic RVs in a biventricular circulation have yielded conflicting results regarding the relationship between exercise function and non-invasive indices of ventricular function. Giardini et al reported an excellent correlation between CMR-derived RVEF and peak oxygen uptake (24). Norozi et al found a strong correlation between the Tei index and peak VO_2 in 32 TGA patients following the Mustard procedure (25). In contrast, Grewal et al found that the RVEF of cc-TGA patients with well-preserved exercise function did not differ from those with moderate-severely reduced exercise function (19). Similarly, neither Hornung et al nor Winter et al found a significant relationship between exercise performance and RVEF in patients with D-TGA and cc-TGA (4,26). Budts et al found no correlation between peak VO_2 and either TAPSE or qualitative estimates of RV function in patients who had undergone atrial switch procedures for D-TGA (27).

Our study is unique in that it compares the clinical validity of CMR and echocardiographic indices of RV function in the same group of patients with TGA and systemic RVs. This approach yielded some clinically relevant insights. On univariable analysis, the correlation between %p VO_2 and the CMR-derived RVEF was somewhat stronger than that observed between %p VO_2 and any of the echocardiographic indices of ventricular function. However, when the analyses were limited to patients with simple anatomy/physiology, the correlation of echo parameters with exercise function improved to have coefficients similar to CMR. Furthermore, on multivariable analysis, the Tei index was the only variable that correlated with % predicted p VO_2 .

As one might expect, patients with complex anatomy/physiology tended to have lower exercise tolerance compared to patients with simple D-TGA or cc-TGA. However, on multivariable analysis there was no difference in the exercise capacity of D-TGA patients and the cc-TGA patients. Though their anatomy and cardiac outcomes may differ, our results suggest that systemic RV function contributes to low exercise capacity in these patients, highlighting the continued need to better define reliable and clinically meaningful imaging parameters of RV function.

4.1 How should systemic ventricular function in patients with systemic RV's in a biventricular circulation be assessed?

Based on our data, poor exercise function is a result of multiple factors which includes decreased systemic RV function. While some non-invasive imaging techniques (TAPSE, FAC) failed to show correlation with exercise capacity, the Tei index was the one echocardiographic measure that showed correlation near that of CMR derived RVEF in our cohort of patients. As well, the dP/dt_{ic} may be of additional benefit in those without anatomic/hemodynamic complexity. Thus we suggest a revision of the standard echocardiographic protocol of the systemic RV in TGA patients to include these variables as they may add to the clinical assessment.

4.2 Limitations

The relatively small study numbers and the retrospective nature of this study limited our ability to adjust for multiple confounders. The study was also limited by its reliance upon data acquired for clinical use, rather than in the context of a clinical trial. Prior studies have shown strain analyses to be useful to predict exercise capacity as well as cardiac events in patients with systemic RV's (19,21,28). While these data are thought provoking and important, during the period of our study strain analyses were not standardly integrated into the clinical echocardiographic studies of our echocardiography laboratory. We therefore could not include these analyses in our study. Additionally, we were unable to evaluate the correlation of dyssynchrony with exercise tolerance.

5- Conclusions

Correlations are seen between %pVO₂ and echocardiographic or CMR indices of ventricular function. Correlations between noninvasive imaging and exercise capacity are stronger in patients without complex disease. The Tei index emerged as the echocardiographic measure that correlated best with exercise function in addition to CMR derived RVEF. In patients without additional anatomic/physiologic lesions, the dP/dt_{ic} may have additional value in assessing ventricular function. The clinical value of these echocardiographic indices approaches that of CMR-based estimates of RVEF in comparison to exercise capacity and should be included in the standard echocardiographic assessment of TGA patients with systemic right ventricles.

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Figure 1.

Both the Tei index and CMR derived right ventricular ejection fraction have moderate ability to discriminate patients with severely limited exercise capacity but there is little additional benefit when these modalities are used together.

Tei- Tei index, RVEF- Right ventricular ejection fraction

Figure 2.

Patients without severe exercise limitation had a lower Tei index; the best sensitivity/specificity for correlation with peak VO₂ < 60% predicted was found at a Tei index value of 0.47 or lower.

VO₂- oxygen uptake

Table 1

Patient Characteristics (n = 92)

Characteristic	Value
Female	36 (39%)
Male	56 (61%)
d-TGA	64 (70%)
cc-TGA	28 (30%)
Anatomy	
Complex	28 (30%)
Simple	64 (70%)
Age (years)	31.0 (10.2)
BMI	26.1 (5.5)
Moderate to severe TR	8 (9%)
% Pred pVO₂	69.4 (16.1)
< 60%	27 (29%)
60%	65 (71%)
Peak HR	160 (22.8)
% Pred Peak HR	89 (12.7)

Data are expressed as mean $\pm$ SD or number (percentage)

BMI: body mass index

TR: tricuspid regurgitation

pVO₂: peak oxygen uptake

HR: heart rate

Table 2

CMR and echocardiographic indices of RV function in patients with complex and simple anatomy

	Overall	Anatomic Complexity			TGA Anatomy		
		Complex	Simple	P-value	D-loop TGA	cc-TGA	P-value
<u>CMR</u>							
RV ESVi (ml/m ²)	64.1 (25.7)	65.4 (21.1)	63.4 (27.7)	0.75	66.0 (28.1)	59.0 (17.1)	0.17
RV EDVi (ml/m ²)	122.2 (33.5)	128.7 (35.5)	119.1 (32.3)	0.27	122.7 (36.5)	121.0 (24.4)	0.80
RV Mass (g/m ²)	45.8 (16.0)	46.9 (15.8)	45.3 (16.1)	0.69	47.6 (17.4)	41.3 (10.5)	0.03
RV EF %	0.49 (0.09)	0.50 (0.09)	0.48 (0.10)	0.43	0.48 (0.09)	0.52 (0.09)	0.04
<u>Echocardiography</u>							
Tei Index	0.52 (0.19)	0.53 (0.18)	0.52 (0.20)	0.79	0.52 (0.21)	0.53 (0.16)	0.74
dP/dt _{ic}	881.5 (283.7)	826.8 (266.2)	907.5 (291.2)	0.26	818.1 (209.0)	1005.2 (365.9)	0.03
TAPSE	10.4 (3.5)	11.0 (4.3)	10.1 (3.1)	0.32	9.8 (3.2)	11.6 (4.0)	0.05

Data are expressed as mean ± SD or number (percentage).

RV ESVi: Right ventricular end systolic volume, indexed

RV EDVi: Right ventricular end diastolic volume, indexed

RV EF: Right ventricular ejection fraction

TAPSE: tricuspid annular plane systolic excursion.

Table 3

Pearson correlation coefficients for clinical/imaging parameters with %pVO₂ in the overall cohort and in subgroup of patients with “simple” anatomy

Parameter	Overall Cohort		Simple Anatomy	
	Correlation Coefficient (r)	P-Value	Correlation Coefficient (r)	P-value
<u>CMR</u>				
RV ESVi (ml/m ²)	−0.25	0.002	−0.31	<0.0001
RV EDVi (ml/m ²)	−0.13	0.18	−0.21	0.01
RV Mass (g/m ²)	−0.05	0.71	−0.06	0.65
RV EF %	0.29	0.0007	0.37	0.0007
RV Stroke volume	0.05	0.69	−0.03	0.69
<u>Echocardiography</u>				
Tei Index	−0.22	0.03	−0.28	0.03
dP/dt _{ic}	0.17	0.12	0.31	0.007
TAPSE	0.16	0.25	0.17	0.35

pVO₂: peak oxygen uptake

RV ESVi: Right ventricular end systolic volume, indexed

RV EDVi: Right ventricular end diastolic volume, indexed

RV EF: Right ventricular ejection fraction

TAPSE: tricuspid annular plane systolic excursion

Table 4

Variables among patients with and without reduced exercise capacity

Characteristic	Normal/Mild Reduction (pVO ₂ ≥ 60%)	Moderate/Severe Reduction (pVO ₂ < 60%)	p-value
Clinical			
Female	48 (44%)	14 (35%)	0.45
Age (years)	29.6 (9.6)	32.6 (8.7)	0.10
BMI	26.2 (5.3)	24.8 (4.5)	0.21
D-Loop anatomy	78 (72%)	30 (75%)	0.73
Complex disease	28 (26%)	20 (50%)	0.03
CMR			
RV ESVi (ml/m²)	60.2 (20.9)	74.5 (33.8)	0.08
RV EDVi (ml/m²)	118.3 (27.4)	132.3 (44.7)	0.14
RV Mass (g/m²)	44.9 (15.6)	48.2 (17.0)	0.44
RV EF %	0.50 (0.09)	0.46 (0.09)	0.02
Echocardiography			
Tei Index	0.49 (0.18)	0.59 (0.20)	0.10
dP/dt_{ic}	917.5 (311.1)	805.8 (201.8)	0.11
TAPSE	10.6 (3.5)	9.9 (3.6)	0.40

BMI: body mass index

pVO₂: peak oxygen uptake

RV ESVi: Right ventricular end systolic volume, indexed

RV EDVi: Right ventricular end diastolic volume, indexed

RV EF: Right ventricular ejection fraction

TAPSE: tricuspid annular plane systolic excursion.

Data are expressed as mean with percentage or standard deviation.

Table 5Multivariable Model of predictors for %pVO₂

Characteristic	Estimate	95% Confidence Interval	p value
Age (years)	0.10	(−0.49, 0.69)	0.73
D-Looped anatomy	−7.77	(−18.84, 3.29)	0.17
Complex disease	−13.77	(−22.99, −4.56)	0.003
RV EF %	18.69	(−35.07, 72.46)	0.50
Tei index	−21.04	(−40.62, −1.47)	0.04
dP/dt _{ic}	0.0003	(−0.01, 0.01)	0.96

RV EF: Right ventricular ejection fraction

%pVO₂: % predicted peak oxygen uptake