Limited preload reserve during exercise limits exercise capacity in healthy Fontan patients.

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Introduction: Factors controlling cardiac output in a Fontan circulation are still poorly understood. This study aimed at evaluating changes in exercise hemodynamics using a novel cardiac magnetic resonance (CMR) methodology during mild, moderate and strenuous exercise.

Methods: Ten Fontan patients (6 male, age 20±4 years, NYHA 1-2) underwent CMR at rest and during supine exercise on a programmable cycle ergometer. Systemic ventricular volumes were obtained at rest (heart rate 72±14 bpm) and during mild (100±10 bpm), moderate (122±15 bpm) and strenuous (144±15 bpm) exercise. Images were acquired using an ungated, free-breathing real-time CMR sequence (12-18 contiguous 8mm slices). Software was developed to allow for synchronization of short and long-axis images with compensation for respiratory phase translation. Endocardial borders were delineated using a bi-plane model. Simultaneously, radial and pulmonary artery pressures were measured

Results: Cardiac output (CO) increased continuously during exercise (6.8±1.6 vs 10.0±3.2 vs 11.8±3.2 vs 12.5±3.1 l/min; P<0.0001). The increase in CO depended on a 106±49% increase in heart rate as stroke volume (SV) did not change from rest to mild exercise and decreased during moderate and strenuous exercise (95±19 vs 100±21 vs 96±20 vs 87±16 ml; P<0.0001). End-diastolic volume (EDV) decreased during strenuous exercise (169±38 vs 174±39 vs 170±38 vs 162±36 ml; P=0.029), whereas end-systolic volume (ESV) did not change during exercise (74±31 vs 74±31 vs 73±32 vs 75±32 ml; P=0.944). Ejection fraction (EF) decreased during strenuous exercise (57±10 vs 58±10 vs 59±11 vs 55±11 %, P=0.029) Pulmonary artery pressures (9±3 vs 14±4 vs 17±4 vs 21±5 mmHg; P<0.0001) and mean systemic artery pressures (81±7 vs 92±7 vs 100±6 vs 106±4 mmHg; P<0.0001) increased during exercise. Arteriovenous oxygen difference increased from 5.5±1.2 to 9.6±1.9 ml/100ml (P=0.001).

Conclusions: A decrease in SV and EDV during exercise despite a blunted heart rate response indicates a limited ventricular preload reserve. The decreased preload reserve in a Fontan circuit is an important determinant limiting exercise capacity.