Cardiac Output Measurement using the CO2-rebreathing Technique during Maximal Exercise Test in Children with Fontan Circulation.

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Introduction
Exercise performance is decreased in children with univentricular heart(UVH) after Fontan completion. The mechanism of exercise intolerance after Fontan is complex. Only few studies investigate the mechanism of decreased exercise, no studies highlight the pump function at maximal exercise. Cardiac output(CO) and stroke volume(SV) can be measured using the CO2-rebreathing(CO2-R) technique during exercise test(CPET).

Methods
Patients with univentricular heart in NYHA class I who were referred for CPET between 2010-2012 underwent CO measurement at rest (COrest) and within 10 seconds after peak exercise (COmax). Data were compared with children who performed a normal exercise test. Stroke volume at rest and at maximal exercise was calculated. SVdiff and COdiff was defined as SVmax and COmax minus SVrest and COrest. Data were expressed as mean±standard deviation.

Results
19 children with UVH (11,7±3,3 yrs, 38,9±9,9 kg) were compared with 38 controls (11,24 yr ±2,2, 39,6 kg±10kg). HR max (157,2±29,4 vs 190±11,4 bpm), VO2 max (32,1±7,8 vs 44,5±9,7 ml/min), test duration (9,9±3,6 vs 13,2±4,8 min) and load (76,6±35,7 vs 105±41,8 Watt) were statistically different. Respiratory exchange ratio reached 1 in both groups. 12 patients successfully underwent CO measurement. The reason for CO-R failure was technical (4) or non-cooperation (3). COrest (3,6±1,0 vs 5,82±2,4 l/min), COmax (8,8±2,7 vs 13,1±5,1 l/min)(P<0,001) and stroke volume(SV) at rest (43,7±/13,7 vs 62,8±/29,2 ml/beat) and max (71,9±18,6 vs 96,5±28,7 ml/beat)(P<0,05) were different. SVdiff (28,2±14,9 ml/beat vs 34,0±14,1) and COdiff (4,3±2,3 l/min vs 5,0 l/min) were not significantly different.

Conclusion
Children with UVH have lower maximal exercise performance due to a combination of chronotropic incompetence and decreased stroke volume, leading to lower cardiac output. Stroke volume and cardiac output are decreased at rest (resp 30% and 40% lower) and during maximal exercise (resp 25% and 33% lower) compared to the control group. Although there also is a tendency towards less increase in SVdiff and CODiff, the difference of CORest and SVrest and the chronotropic incompetence are more important to declare decreased C0max and SVmax. These findings demonstrate that even at rest patients with Fontan circulation have an important restricted pump function, worsening more at maximal exercise.