

## Reduced heart rate reserve in Fontan patients: chronotropic incompetence or chronotropic protection?

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**Background:** Patients with a Fontan circulation have limited exercise tolerance and impaired heart rate (HR) response to exercise. It remains to be determined whether this impaired chronotropic response reflects pathology of the sinoatrial node or is a consequence of altered cardiac hemodynamics. We aimed to evaluate the adequacy of heart rate and acceleration throughout exercise relative to metabolic demand and cardiac output.

**Methods:** 10 Fontan patients with normal sinus rhythm (all TCPC, age  $19.6 \pm 4.0$  years, age at TCPC  $7.2 \pm 4.6$  years; left ventricle in 8) and 20 healthy controls underwent supine bicycle exercise to near maximal exertion during cardiac magnetic resonance imaging with simultaneous invasive pressure recording via a pulmonary and radial artery catheter. Cardiac index (CI), stroke volume (SVi) and HR were assessed and exercise-induced increase ( $\Delta$ ) in CI, SVi and HR relative to the exercise level and increase in oxygen consumption ( $VO_2$ ) were calculated.

**Results:** Maximal exercise capacity and HR reserve was lower in Fontan patients compared to controls; HR and HR reserve when expressed in % of maximum was lower suggesting chronotropic incompetence (fig A). In contrast, at every exercise level, HR and increases in HR relative to workload and  $VO_2$  in absolute values were higher than in controls (fig B). The change in CI relative to the change in  $VO_2$  ( $\Delta CI/\Delta VO_2$ ) was similar between groups; Fontan patients had a higher increased  $\Delta HR/\Delta VO_2$  and reduced  $\Delta SVi/\Delta VO_2$ . The lower exercise capacity and HR reserve in Fontan patients was associated with failure of the systemic ventricle to maintain end-diastolic volume and SVi during exercise, suggesting insufficient preload reserve.

**Conclusions:** At every exercise intensity chronotropic responsiveness is preserved in Fontan patients, indicating normal sino-atrial function. However, exercise capacity and maximum HR are attenuated, likely as a consequence of reduced ventricular filling - Bainbridge reflex (1915). "Chronotropic incompetence" is therefore not a correct term to describe the diminished heart rate reserve in Fontan patients. Increases in HR at maximal exercise would most likely further reduce SVi because insufficient preload reserve, which might be harmful: the term "chronotropic protection" appears more appropriate !

