Ako et al. Journal of Cardiovascular Magnetic Resonance 2015, 17(Suppl 1):Q2
http://www.jcmr-online.com/content/17/S1/Q2

Journal of Cardiovascular Magnetic Resonance

WALKING POSTER PRESENTATION Open Access

MR augmented cardiopulmonary exercise testing - a novel method of assessing cardiovascular function

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From 18th Annual SCMR Scientific Sessions
Nice, France. 4-7 February 2015

Background

Reduced exercise capacity is a common feature of many cardiovascular diseases. Quantitative assessment of exercise capacity is usually achieved by measuring peak oxygen consumption (VO_2). However, measuring peak VO_2 alone neglects the different components of reduced exercise capacity: namely reduced cardiac output (CO) and oxygen extraction (ΔcO_2). A better approach would be to simultaneously measure VO_2 and CO and then calculate ΔcO_2. This could be achieved using MR augmented cardio-pulmonary exercise testing (MR-CPET)

The aims of this study were to demonstrate: 1) MR-CPET is feasible and well tolerated, 2) peak VO_2 in the MR scanner correlates with conventional peak VO_2, and 3) variation in peak VO_2 is related to both peak CO and peak oxygen extraction (ΔcO_2) as calculated by the Fick equation.

Methods

17 healthy volunteers (21-55 years) underwent MR-CPET. Exercise was performed on MR-compatible ergometer (Lode, Groningen, The Netherlands) and VO_2 was assessed using a commercial respiratory gas analyzer (Ultima, MedGraphics, St. Paul, USA) with a modified sampling tube that was MR compatible. Aortic flow was continuously measured using a previously validated UNFOLD-SENSE spiral PCMR sequence. Images were reconstructed using a graphical processing units card and analyzed using an in-house plug-ins for OsiriX software. Conventional CPET was also performed within 2 weeks of MR-CPET.

For both test, participants were asked to rate i) concern ii) comfort and iii) perceived helplessness.

Results

15 out of 17 volunteers completed exercise; exclusions were due to claustrophobia (n=1) and inability to master exercise technique (n=1). Reported concern and discomfort was higher with MR-CPET, although still within acceptable limits.

Peak VO_2, peak VCO_2 and VE showed strong correlation between conventional CPET and MR-CPET: VO_2 peak ($r=0.94$, $p<0.001$); VCO_2 ($r=0.87$, $p<0.001$); VE ($r=0.88$, $p<0.001$). Resting and peak values VO_2, CO, HR, SV and ΔcO_2 are shown in table 1. Multiple linear regression analysis demonstrated that both peak CO and ΔcO_2 were independent predictors of peak VO_2 measured during MR-CPET (beta=0.73 and 0.38 respectively, $p<0.0001$) and conventional CPET (beta=0.78, 0.28 respectively, $p<0.0001$). Representative VO_2, CO and ΔcO_2 are shown in figure 1.

Conclusions

MR-CPET is feasible, well tolerated and demonstrates physiology not apparent with conventional CPET. In

Table 1 Resting and peak values during MR-CPET

	Resting	Peak	
Variable	Mean (SD)	Mean (SD)	p
Heart Rate (bpm)	73.70 (27.18)	132.08 (15.40)	<0.0001
Stroke Volume (ml/beat)	106.63 (30.91)	110.36 (27.76)	0.42
Cardiac Output (l/min)	7.59 (4.67)	14.36 (1.73)	<0.0001
VO2 (l/min)	0.25 (0.77)	1.56 (0.07)	<0.0001
ΔO2content	0.03 (0.02)	0.11 (0.01)	<0.0001

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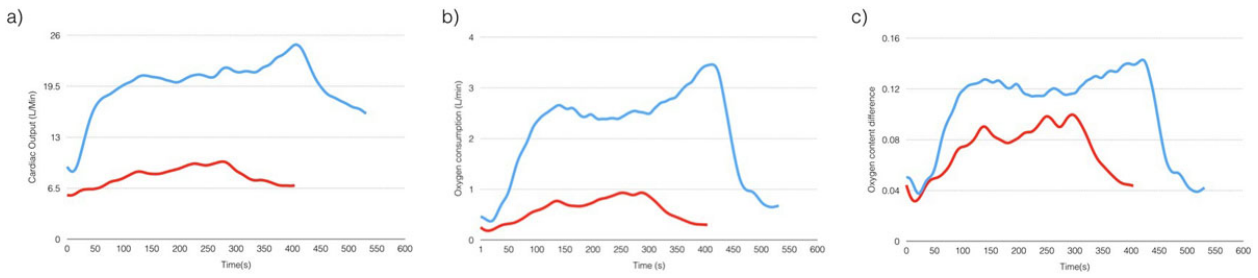

Figure 1

this study, we have shown that MR-CPET allows assessment of the differing contributions of CO and ΔcO_2 to variation in peak VO_2. We believe that will be useful in understanding to origin of reduced exercise capacity in cardiac disease.

Funding

British Heart Foundation, Great Ormond Street Children's Charity.

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Published: 3 February 2015

doi:10.1186/1532-429X-17-S1-Q2
Cite this article as: Ako *et al.*: MR augmented cardiopulmonary exercise testing - a novel method of assessing cardiovascular function. *Journal of Cardiovascular Magnetic Resonance* 2015 **17**(Suppl 1):Q2.