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Exercise-based cardiac rehabilitation for people with ventricular assist devices:

Associate Professor Andrew Maiorana

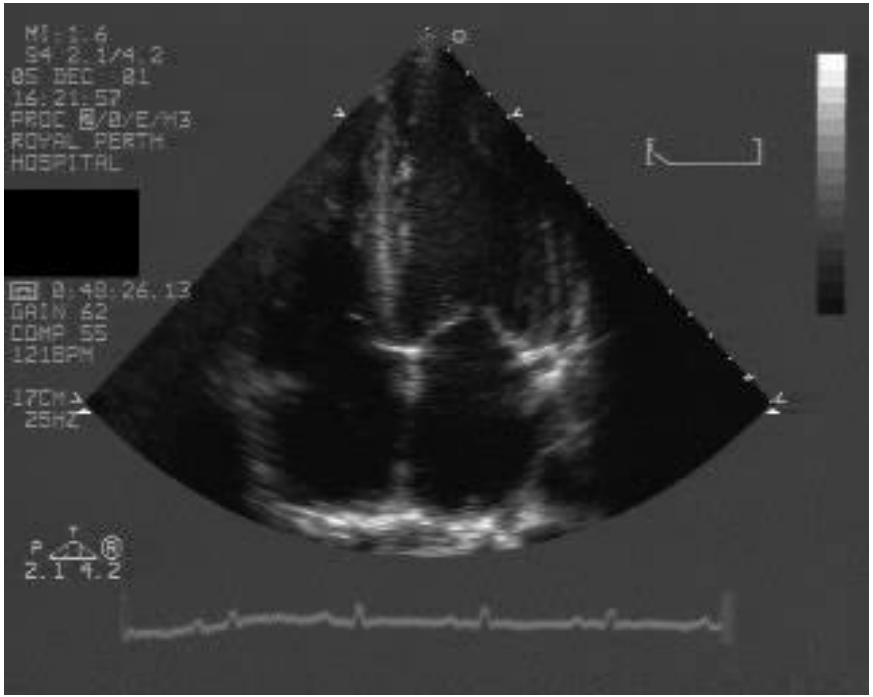
School of Physiotherapy and Exercise Science, Curtin University;

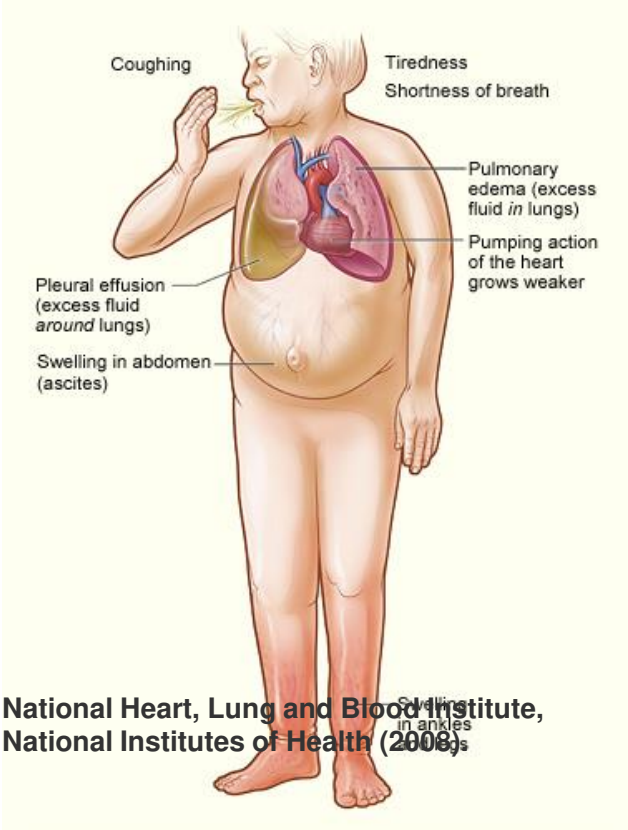
Advanced Heart Failure and Cardiac Transplant Service & Allied Health Department

Fiona Stanley Hospital

Background: Heart Failure

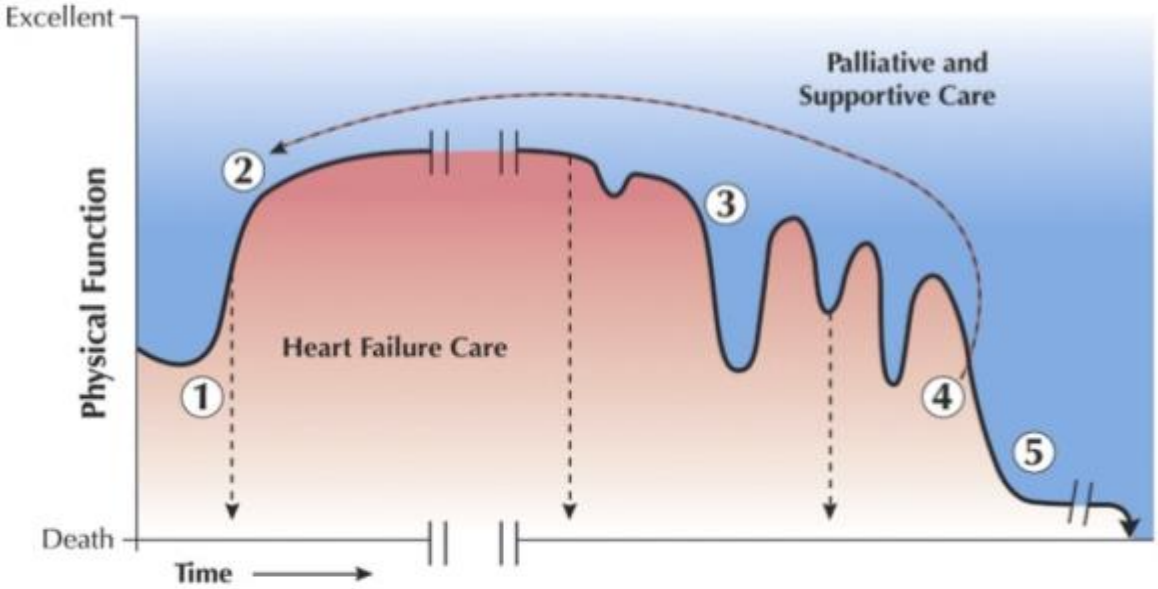
- Chronic Heart Failure (CHF): inability of the heart to generate sufficient cardiac output to meet the metabolic demands of the body.





National Heart, Lung and Blood Institute, National Institutes of Health (2008).

Natural history of heart failure



Sudden Death Event

Transplant or Left Ventricular Assist Device

Goodlin SJ J Am Coll Cardiol 2009;54:386-96.

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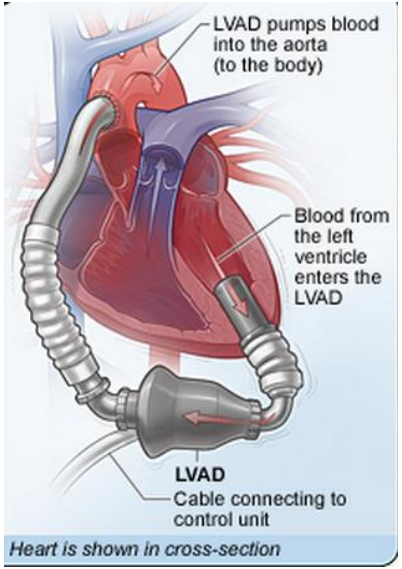
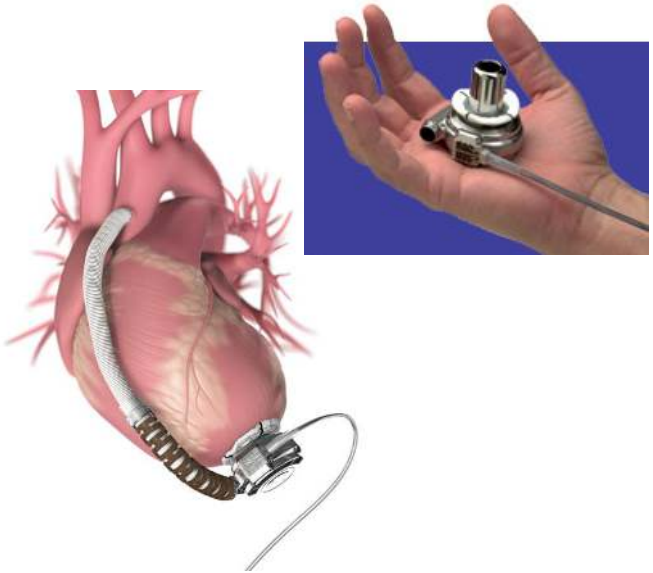
What is a Left Ventricular Assist Device (VAD) ?

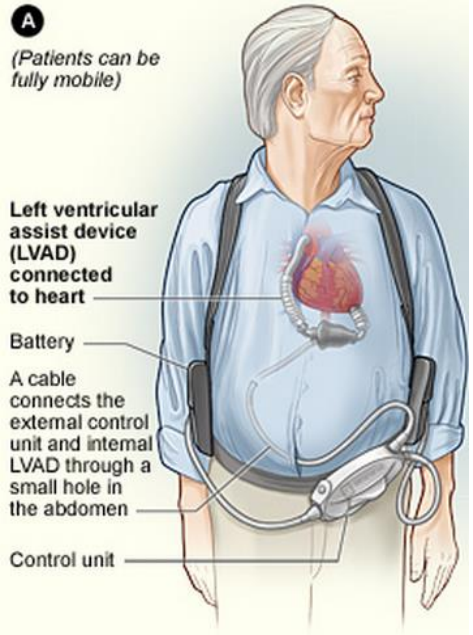
Electromechanical pump implanted into the LV to augment cardiac output (CO).



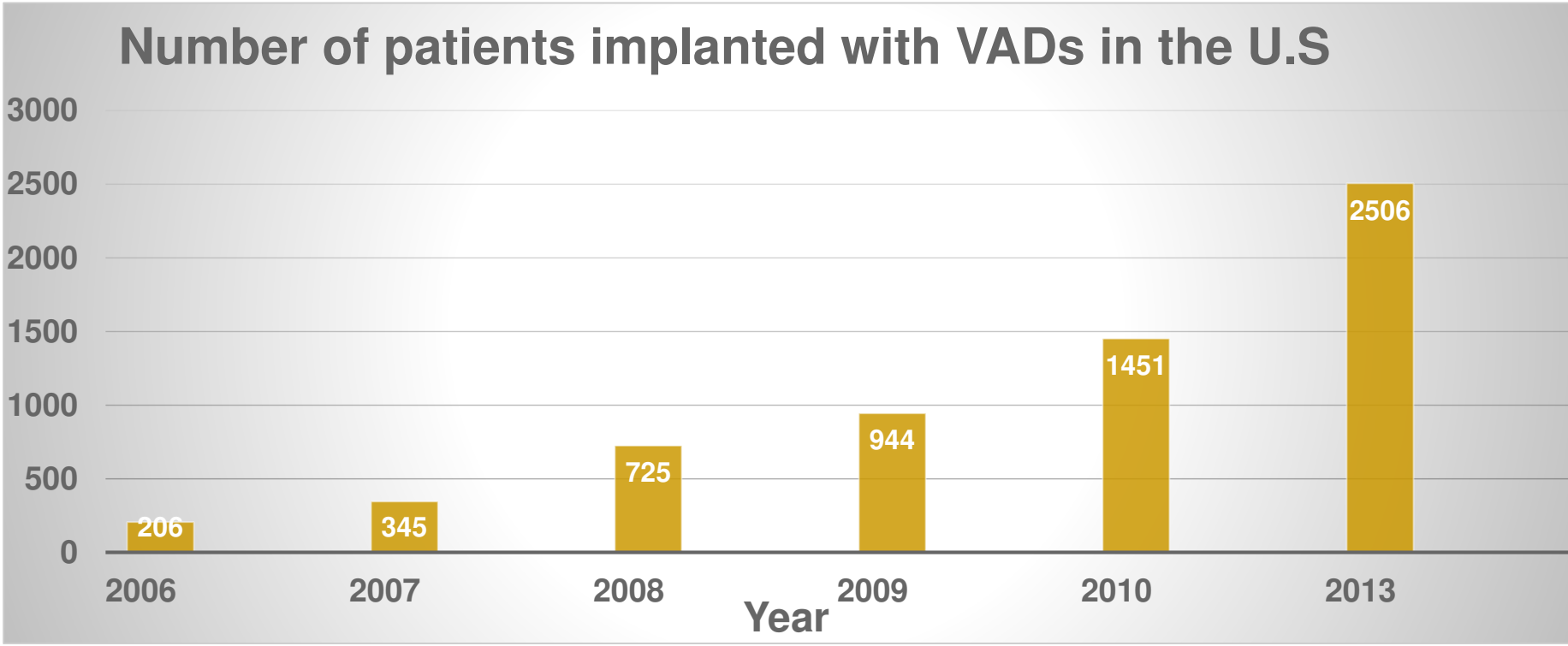
a. Heartmate II/III



b. Heartware HVAD



LVAD implantation rates are increasing



Birks et al., 2011

Background

- LVADs are implanted as:
  - Bridge to transplant (or eligibility)
  - Bridge to recovery
  - Destination therapy
- LVAD implantation is associated with improved:
  - Survival
  - Quality of life (QoL)
  - Exercise tolerance

Maybaum et al., 2007; Rogers et al., 2010

Effects of LVAD implantation on aerobic capacity

	Pre-VAD (n = 46)	6 mths Post-VAD (n =30)	12 mths Post-VAD (n = 13)
Peak VO_2, mL/kg/min	9.9±2.1	14.3±5.1	14.6±4.6
Percentage of predicted peak VO_2	32.3±7.4	41.4±12.7	42.0±15.0
VO_2 at AT mL/kg/min	8.2±1.1	9.9±2.6	10.3±2.2

- Factors limiting aerobic capacity in LVADs
  - right ventricular dysfunction
  - inability to increase cardiac output (CO) during exercise
  - peripheral maladaptations associated with HF(skeletal myopathy, endothelial dysfunction)

McDiarmid et al Congest Heart Fail 2013 ;19 : 11-15.

Structured rehabilitation

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Current exercise training trial

- RCT of moderate intensity continuous exercise vs. high intensity interval training (HIIT).
- MICT - continuous aerobic exercise at 50 to 60% VO_2 reserve for 28 minutes
- HIIT - 4 sets of 4 minutes of aerobic exercise at 80 to 90% of VO_2 reserve, interspersed with 3 minutes of active recovery at 50 to 60% of VO_2 reserve
- Primary outcome measure: VO_2peak

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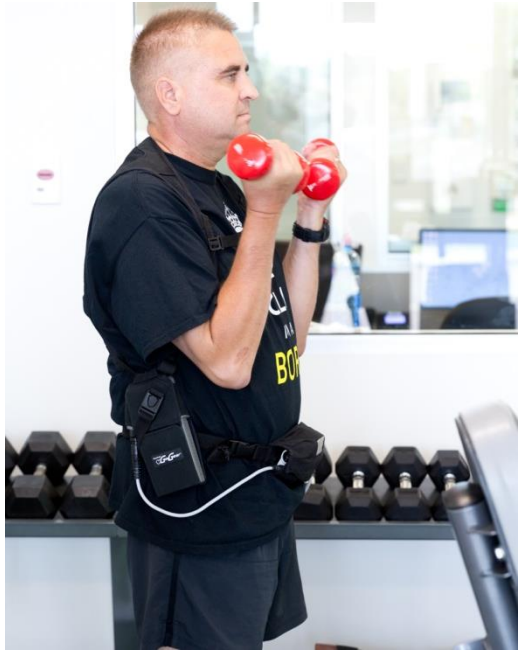
Progressive resistance training



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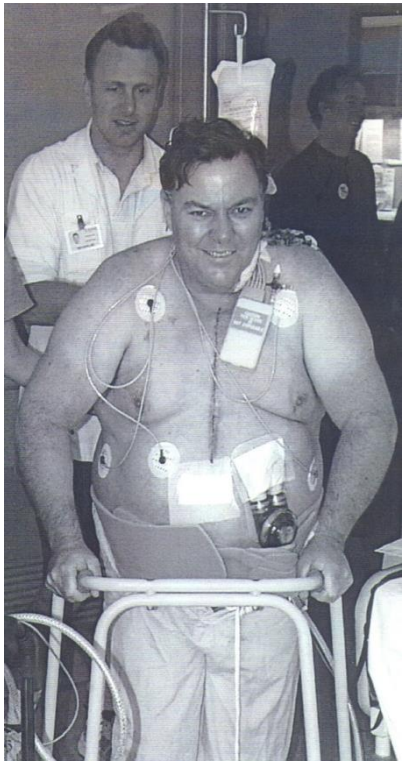
Buffing up for transplant



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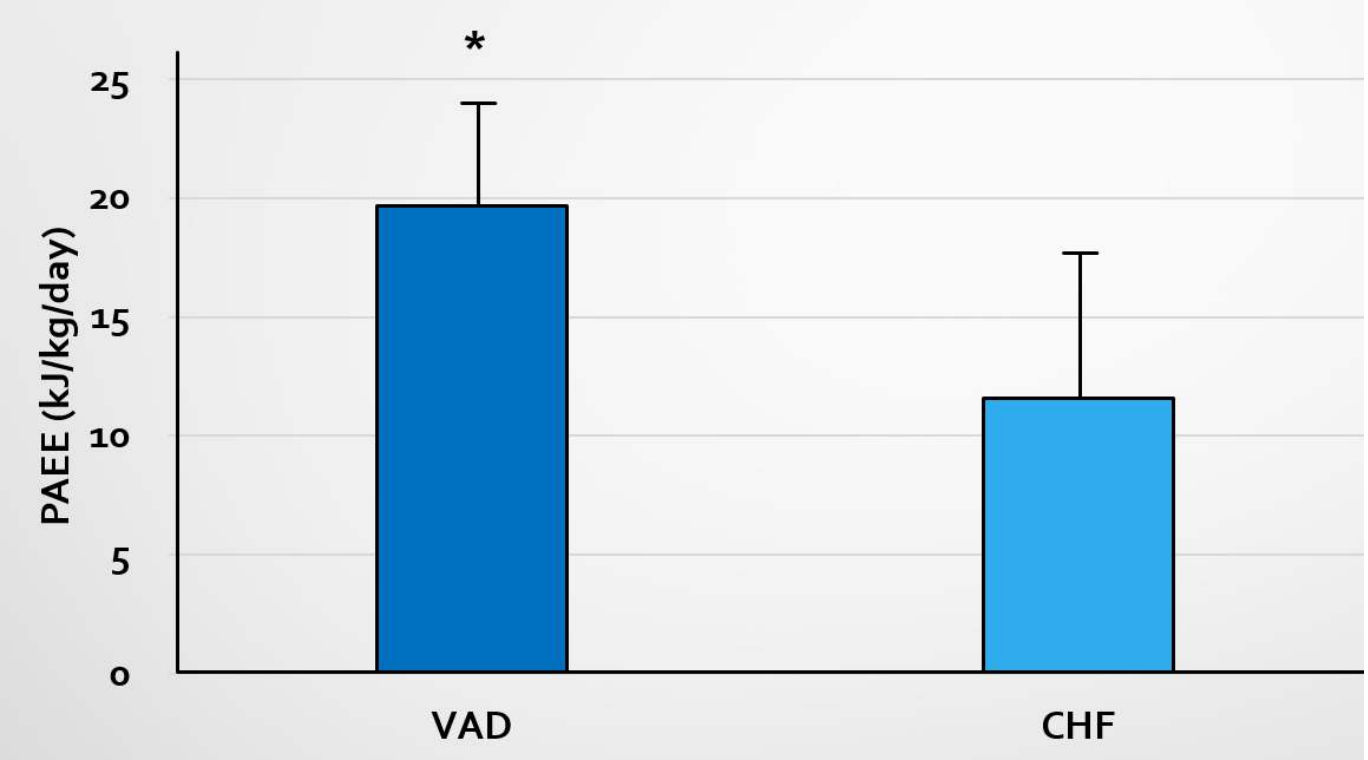
Physical activity energy expenditure



VAD: 19.7 ± 6 kJ/kg/d, vs.
CHF: 11.6 ± 7 kJ/kg/d; p=0.01

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Physical activity duration at different intensities

Physical activity intensity (METs)	VAD group (min/day)	CHF group (min/day)	p-value
Sedentary (< 1.5)	1275 ± 99	1339 ± 75	0.048*
Light (1.5 - 3)	133 ± 43	89 ± 32	0.101
Moderate (3 - 6)	31 ± 22	12 ± 17	0.012*

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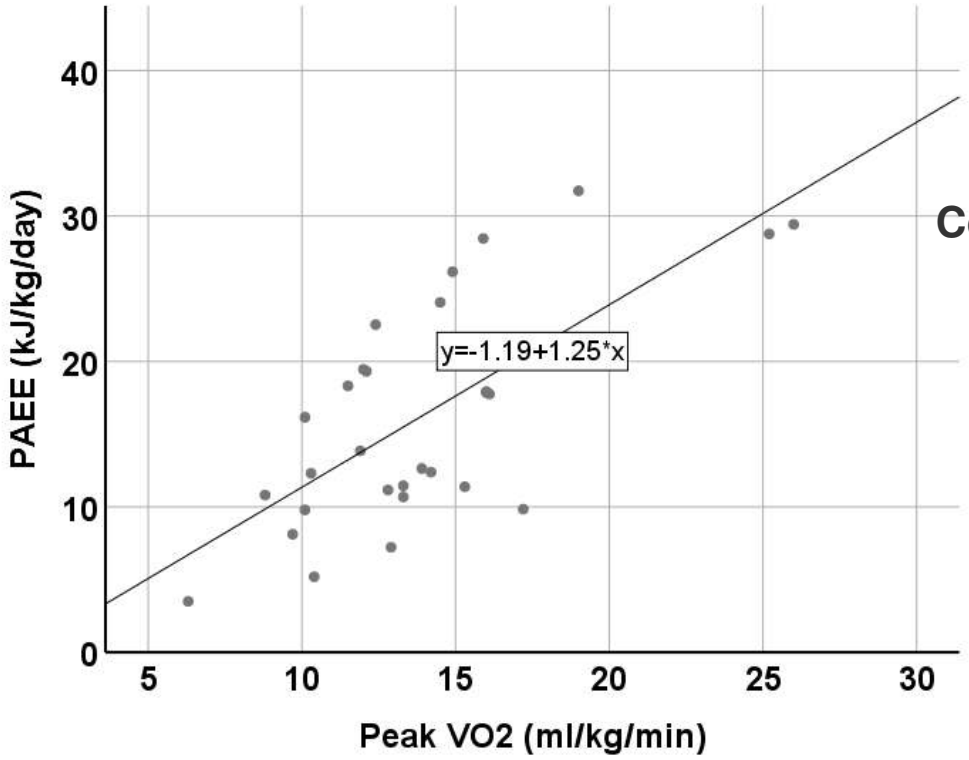
Relationship between physical activity energy expenditure and peak VO_2 in VAD and CHF patients.



Correlation coefficient: r_s= 0.523, p=0.01

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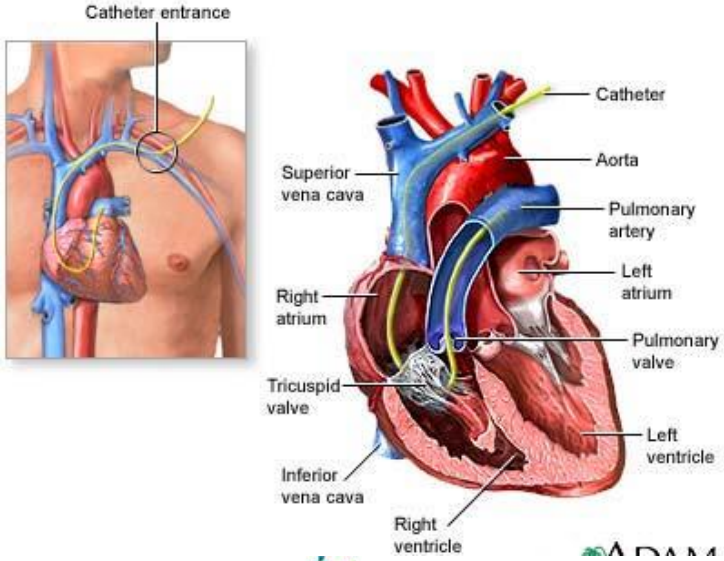
Restoring quality of life

Evaluating myocardial recovery

- Exercise right heart catheter study pre-LVAD explantation.



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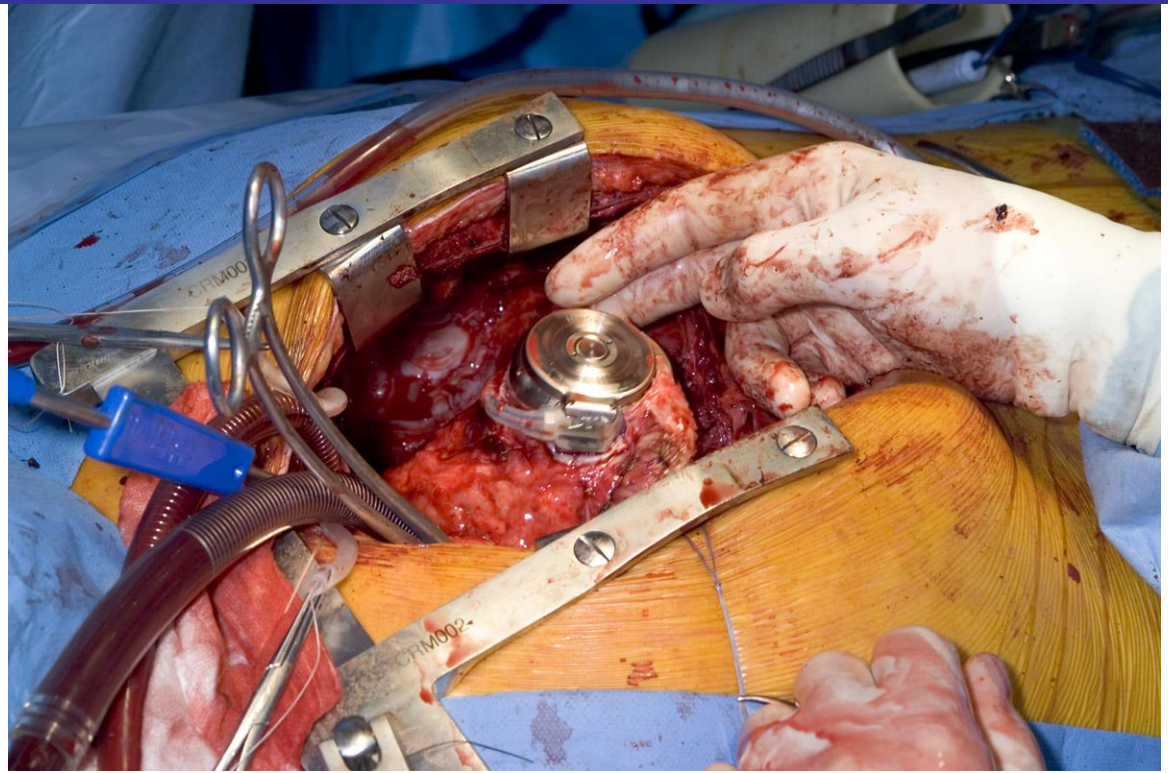
Results

Metabolic and cardiovascular responses during peak CPET at 2400rpm and 1800rpm

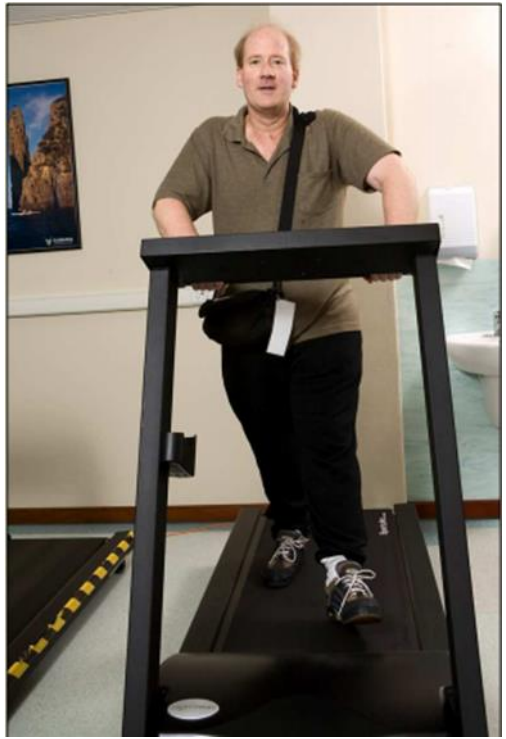
Parameter	2400 rpm	1800 rpm
Peak $\dot{V}O_2$ (ml/kg/min)	23.2 (59% predicted)	22.8 (58% predicted)
$\dot{V}_E/\dot{V}CO_2$ slope	22.3	24
Duration (min)	16:00	16:40
HR max. (bpm)	144	148
BP max (mmHg)	145/85	145/80
Rating of exertion	very hard	very hard

Wood, Maiorana, et al. J Heart Lung Transplant 2008; 27:695-7.

LVAD Explantation



Patient assessments



Review at 3/12

- NYHA class I
- No hospital readmissions
- Return to work
- Preserved LV function
- Excellent exercise tolerance
- Completed City to Surf !!

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Acknowledgements:

- Advanced Heart Failure and Cardiac Transplant Service, FSH.
- Cardiovascular Rehabilitation team, FSH.
- The patients!

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Results

Haemodynamic and echo. responses at rest and during submaximal exercise* at 2400rpm and 1800rpm

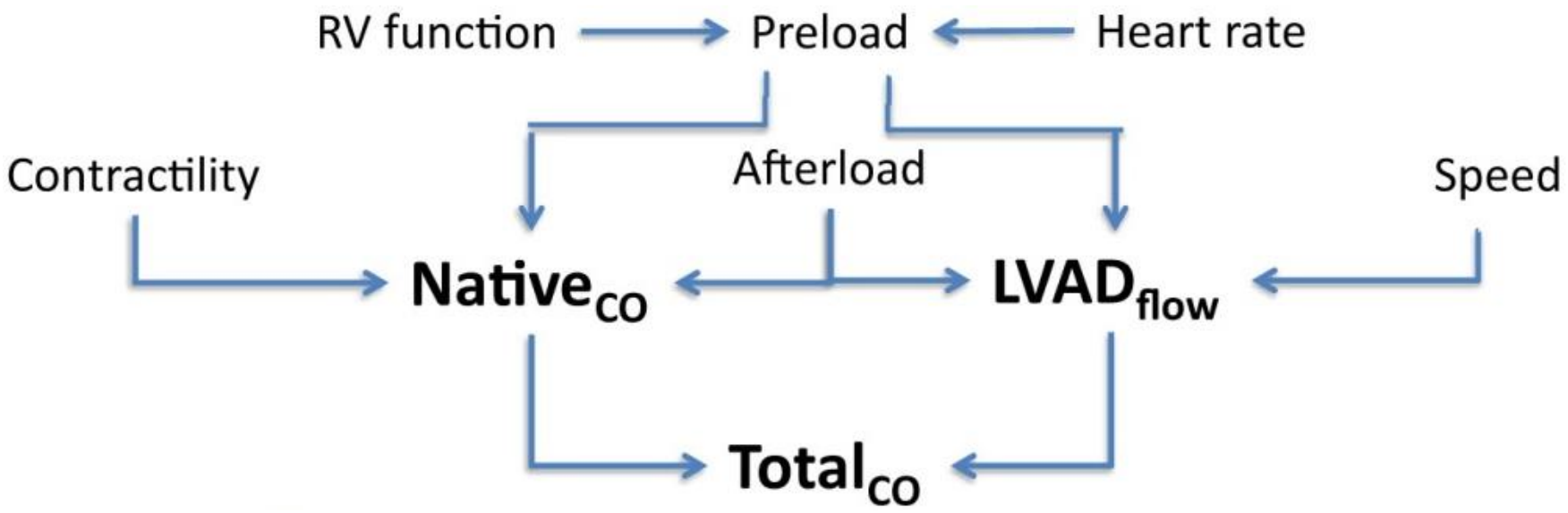
Parameter	Rest 2400rpm	Rest 1800rpm	Exercise* 1800rpm
CI (L/min/m^2)	4.4	4.0	4.9
HR (bpm)	83	88	132
LVEDD (cm)	4.8	5.0	4.7
LVESD (cm)	3.5	3.6	3.5

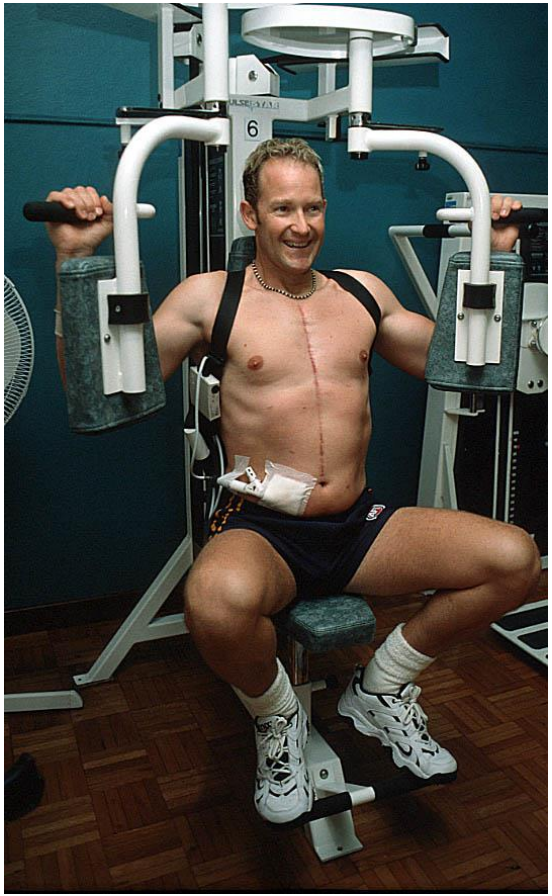
* Submaximal exercise = 60% peak $\dot{V}O_2$

No signs/symptoms of cardiac compromise at rest or during exercise with pump speed at 1800rpm.

Wood, Maiorana, et al. J Heart Lung Transplant 2008; 27:695-7.

Central haemodynamics of LVADs





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Assumptions

- Revisit Fick Equation
- Reducing LVAD speed creates resistance to flow (confirmed on echo at 2000rpm)

  → blood flow from the LV will take the path of least resistance via the aorta
- Impaired skeletal muscle oxidative capacity is evident in HF

  (Drexler et al. Ann Rev. Med 1996;47:241)

  → LVAD patients unlikely to be able to compensate for reduced O_2 delivery by increasing O_2 utilisation

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Exercise training in LVAD recipients

- Supervised exercise, 3 x per week 6weeks.
- 30 minutes treadmill walking
- 60% HRR

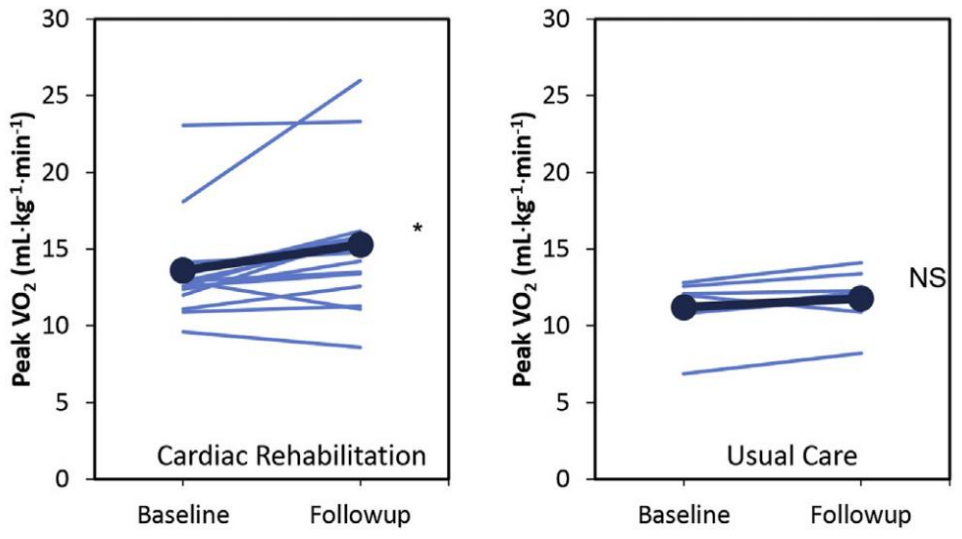

FIGURE 2 Peak VO_2 for Subjects in Both the CR and Usual Care Groups

Within-group improvement of 10%, but no significant differences between groups.

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Kerrigan et al., 2015.

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Background

- LVAD implantation is associated with improved:
  - Survival
  - Quality of life (QoL)
  - Exercise tolerance

  Maybaum et al., 2007; Rogers et al., 2010

- Despite these improvements, physical impairment persists with:
  - Exercise capacity <50% of predicted values
  - Lagging behind heart-transplanted patients

  Kugler et a;., 2011; Leibner et al., 2014; Dunlay et al., 2014

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Studies that assessed the effects of exercise training in VADs recipients

Author (Year)	Study Design	Sample Size	Exercise Program	Change in $\dot{V}O_2$ in Training Patients	Change in Match $\dot{V}O_2$ in Control Patients	*P* Between the 2 Groups
Laoutaris et al[37] (2011)	RCT	15 (10 TG vs 5 CG)	Walk, moderate-intensity aerobic exercise using a bike or treadmill, and high-intensity inspiratory muscle training	Peak $\dot{V}O_2$, mean ± SD ($mL \cdot kg^{-1} \cdot min^{-1}$) increased from 16.8 ± 3.7 to 19.3 ± 4.5 ($P = .008$)	Peak $\dot{V}O_2$, mean ± SD ($mL \cdot kg^{-1} \cdot min^{-1}$) increased from 14.9 ± 4 to 14.8 ± 4.2 ($P = .5$)	.1
Kugler et al[41] (2012)	Nonrandomized intervention study	70 (34 intervention vs 36 control)	Patients were equipped with bicycle ergometer and tailored, home-based, smartcard-guided training program	$\dot{V}O_{2max}$ (% pred) increased from 61 to 69 ($P = .05$)	$\dot{V}O_{2max}$ (% pred) increased from 59 to 62 ($P = .21$)	.05
Hayes et al[38] (2012)	Prospective, RCT	14 (7 TG vs 7 CG)	Cycling, treadmill, and upper and lower limb strengthening exercises	Peak $\dot{V}O_2$, mean ± SD ($mL \cdot kg^{-1} \cdot min^{-1}$) increased from 10.5 ± 2.3 to 14.8 ± 4.9	Peak $\dot{V}O_2$, mean ± SD ($mL \cdot kg^{-1} \cdot min^{-1}$) increased from 12.4 ± 1.7 to 15.3 ± 4.4	.43

Abbreviations: CG, control group; LVAD, left ventricular assist device; RCT, randomized controlled trial; $\dot{V}O_{2max}$, maximum oxygen uptake; TG, training group.

Alsara et al., 2014

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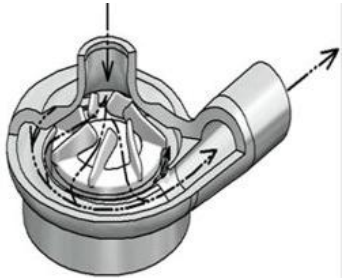
Types of LVADs

- Pulsatile flow
  - neumatically/electrically driven ‘ventricle’ that fill/empties mode.
  - CO during exercise increases as a function of preload and pump rate.
  - max. CO of >10 L/min

- Continuous flow
  - operate at a fix speed (HW – 2600rpm, HM II – 8600rpm)
  - flow influenced by pressure differential between inflow and outflow cannula.
  - CO of approximately 8.5L/min

a. Centrifugal



b. Axial

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