

## Case Report

## Inspiratory Muscle Training in a Patient with Left Ventricular Assist Device

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The use of mechanical assist devices as a 'bridge' to cardiac transplantation, as a "bridge" to recovery, or as a destination therapy in end-stage heart failure, is increasing. Studies of different modes of rehabilitation in this population are lacking. We report the benefits of inspiratory muscle training on the exercise capacity and quality of life in the recipient of a left ventricular assist device.

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**H**ear transplantation (HTx) is the ultimate treatment option for end-stage heart failure. However, because of the shortage of donor hearts this therapy can be offered to only a very small number of patients. Therefore, mechanical circulatory support of the failing heart, such as the left ventricular assist device (LVAD), has been suggested as a "bridge" or as an alternative therapy to HTx (the REMATCH Investigators, 2004).<sup>1</sup> The increasing use of LVADs offers severely impaired patients an opportunity for exercise rehabilitation before HTx; therefore, additional emphasis must be placed on patient rehabilitation. Jaski et al (the EVADE trial, 1997)<sup>2</sup> reported that supine and upright exercise testing shows increases in cardiac output and oxygen consumption, confirming that the LVAD provides adequate outflow during stress. The decrease in exercise capacity in LVAD recipients is related, apart from prolonged bed rest, to skeletal muscle alterations, such as a shift from type I oxidative slow-twitch to type II fast-twitch glycolytic fibres, decreased mitochondrial volume and oxidative enzyme activity due to pre-existing chronic heart failure (CHF).<sup>3</sup> Respiratory muscle strength and endurance also tend to be reduced in CHF patients, possi-

bly as a result of muscle underperfusion, histological abnormalities and early diaphragmatic fatigue.<sup>4</sup> Recent evidence suggests that inspiratory muscle training (IMT) improves exercise capacity and reduces dyspnoea in this population.<sup>5,6</sup> To our knowledge, however, there are no studies investigating the potential benefits of IMT in LVAD recipients. This report documents the resulting benefits of IMT in the first patient implanted with an LVAD in Greece.

### Case presentation

A 62-year-old man who had progressive and refractory heart failure secondary to ischaemic cardiomyopathy, despite maximal doses of inotropic infusions and intra-aortic balloon pump, was transferred from another hospital to our coronary care unit. Facing imminent death, he was supported with an LVAD (TCI Heartmate XVE) as a "bridge" to HTx. He mobilised at an early stage and participated in a progressively more intensive rehabilitation program supervised by a physical therapist, aimed at dynamic exercise, strength and endurance, which also included the use of a stationary bicycle. Four weeks post-implant, the patient performed a cardiopulmonary exercise test (CPET) on

the treadmill, using the Dargie protocol,<sup>7</sup> achieving a peak  $\text{VO}_2$  of 11.0 ml/kg/min. Eight weeks post-implant he achieved independent ambulation in the ward, able to go up and down the stairs. At this point, he was discharged from the hospital with advice for light upper and lower limb exercises and a daily walk of 30-40 minutes. His progress was monitored in the hospital at least once a week. Twelve weeks after LVAD implantation, CPET was repeated and the patient achieved a peak  $\text{VO}_2$  of 12.1 ml/kg/min. We decided to include this patient in an in-hospital IMT program for CHF patients in order to investigate the potential additive effects of IMT on his exercise capacity.<sup>6</sup> The patient was on oral anticoagulation, an ACE-inhibitor, a calcium antagonist and aspirin. He gave written informed consent for participating in this study, which was approved by our hospital's Ethics Committee.

Pre- and post IMT, apart from the CPET test, sub-maximal exercise capacity was assessed using the 6-min walk test and dyspnoea by the Borg scale (6-20), at the end of both the walk and treadmill testing. Pulmonary function was evaluated by standard spirometry and the quality of life by three different questionnaires, the Specific Activity Questionnaire (SAQ), the Minnesota Living with Heart Failure (LHFE) and the Left Ventricular Dysfunction-36 (LVD-36).<sup>8</sup>

Inspiratory muscle strength was assessed by measuring maximum static inspiratory pressure (P<sub>I</sub>max) at residual volume (RV), expressed in cmH<sub>2</sub>O. Inspiratory muscle endurance was assessed by asking the subject to maintain P<sub>I</sub>max over time, from RV to total lung capacity (TLC), and was termed as sustained maximal inspiratory pressure (SPI<sub>I</sub>max), expressed in cmH<sub>2</sub>O/s/10<sup>3</sup>. Measurements were made using an electronic pressure manometer with a 2 mm leak to avoid glottis closure, interfaced with a computer running purpose-designed software (TRAINAIR<sup>®</sup>, Project Electronics Ltd, Kent, UK). A computer template was then created at 60% of SPI<sub>I</sub>max, measured at each training session, and the patient progressed through the exercise by reducing the rest time interval between each respiratory effort.<sup>6</sup> The patient was exercised to respiratory fatigue 3 times weekly for 10 weeks, while visual feedback was used through the software to enhance the training response (Figure 1). The arterial blood pressure (BP) was measured by a cuff sphygmomanometer and the heart rate (HR) by a three-lead ECG monitor (SC 9000, Siemens) during training.

His HR increased (from 84 to 92 bpm) during training (at respiratory fatigue) but the mean arterial BP did not (89.5 vs. 87.8 mmHg). Post-IMT, inspiratory muscle

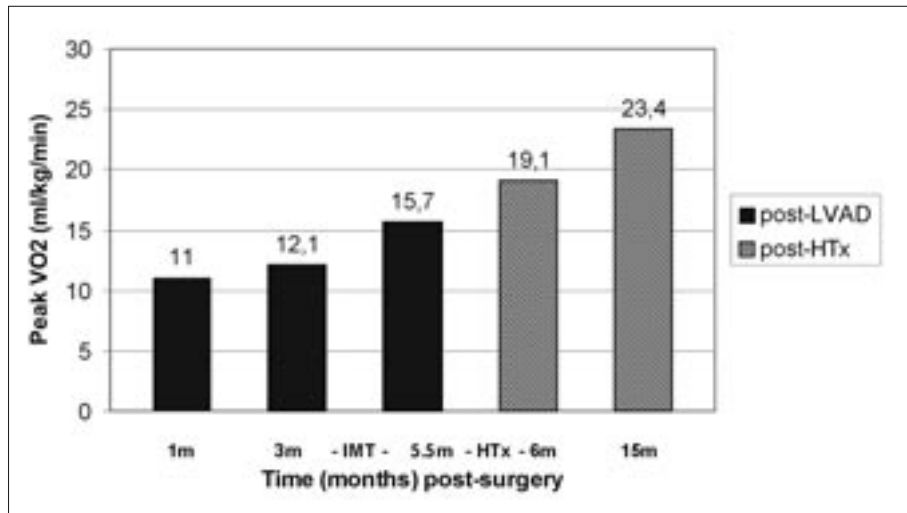


**Figure 1.** Patient performing inspiratory muscle exercises.

strength (P<sub>I</sub>max, 83.07 vs. 59.5 cmH<sub>2</sub>O), endurance (SPI<sub>I</sub>max, 282 vs. 163 cmH<sub>2</sub>O/s/10<sup>3</sup>), and dynamic lung volumes (FVC, 76.07 vs. 63.28% and FEV<sub>1</sub>, 68.91 vs. 62.21%) were all improved. An increase in both exercise capacity assessed by peak  $\text{VO}_2$  (15.7 vs. 12.1 ml/kg/min), and oxygen consumption at the anaerobic threshold (AT) (9.8 vs. 9 ml/kg/min) was observed after IMT, while the ventilatory equivalent for carbon dioxide (VE/VCO<sub>2</sub>, 34 vs. 36) tended to be reduced. Walking distance (463 vs. 414 m) increased and dyspnoea rating remained the same after both the walk test (7 vs. 7) and ergospirometry (11 vs. 11). Quality of life score was improved in all 3 questionnaires: SAQ (6 vs. 5 mets), LHFE (14 vs. 21), and LVD-36 (22 vs. 31%). Nine months post-implantation the patient was successfully transplanted. Six months post-transplantation his peak  $\text{VO}_2$  was 19.1 ml/kg/min, while 15 months after the transplant peak  $\text{VO}_2$  further increased to 23.4 ml/kg/min (Figure 2). He continues to do well, enjoying a normal life in a provincial town in Greece.

## Discussion

The present study, performed during the recuperation phase of a bridge to HTx, indicates that IMT in an LVAD patient is safe, while it seems to improve exercise capacity and quality of life. In CHF patients, improvement in exercise capacity through respiratory muscle training has been related to a reduction in dyspnoea, possibly by altering proprioceptive receptor information situated in the respiratory muscles.<sup>5,6</sup> Diaphragmatic unloading may lead to a decrease in the work of breathing and metabolic distress, which in turn may help to redistribute blood flow away from



**Figure 2.** Improvement in aerobic capacity after support with a left ventricular assist device (LVAD), with inspiratory muscle training (IMT) and following heart transplantation (HTx).

the respiratory muscles to the limb muscles, as noted in healthy subjects during exercise.<sup>6,9</sup> A combination of different mechanisms may account for the IMT-induced increase in exercise capacity in our LVAD recipient.

First, increased exercise performance after IMT could be due to a higher consumption of oxygen by the respiratory muscles. There was a trend for an increase in  $\text{VO}_2$  at AT, thus a systemic aerobic effect on both respiratory and/or other muscles cannot be excluded. In addition,  $\text{VE}/\text{VCO}_2$  tended to decrease, indicating an improvement in the lactic acidosis threshold after IMT.

Second, unloading the diaphragm may have resulted in a decrease in peripheral sympathetic activity of reflex origin (modulation of diaphragmatic 'metaboreflex' response), enhanced limb muscle blood flow and/or oxidative capacity.<sup>9</sup> Unfortunately, no recordings of limb blood flow were taken during this exercise study.

Third, dynamic lung volumes were increased with IMT. However, an association between resting lung volumes and exercise capacity has yet to be confirmed in patients with CHF.<sup>10</sup>

In our patient, the LVAD was on 'fill-to-empty' setting, acting as a series pump. In this setting, the aortic valve remains largely closed and the native left ventricle is unloaded. IMT may have increased the venous return in our patient by increasing the negative intrathoracic pressure, and therefore right ventricular (RV) performance. Increasing the RV output, increases the LVAD rate and hence the output (i.e. if the rate of the LVAD increases from 70 bpm to 90 bpm, the LVAD output increases from 4.9 l/min to 6.3 l/min). We did not attempt to quantify a RV contribution to exercise capacity.

Post-training, our patient was able to exercise more at the same level of dyspnoea. Thus, a reduction in dyspnoea may be responsible for the improved exercise capacity in the LVAD recipient. Jong et al<sup>11</sup> report that maximal exercise performance is achieved 8-12 weeks after LVAD implantation, suggesting that period as the ideal time for a HTx. Although our patient started IMT 12 weeks post-implantation, it is still possible that the increase in exercise capacity observed with IMT could be partially due to a prolonged positive effect of the LVAD.

We have demonstrated an effective and safe way of improving exercise capacity and quality of life in a patient with an LVAD. Training the respiratory muscles was introduced for the first time as a potential method of rehabilitation in patients with LVAD. Although this is only a case report, our study addresses the need for prospective investigations of the effects of different modes of training on exercise performance in the unique setting of the LV-LVAD complex. As LVADs become more efficient, and complications from their long-term use diminish, chronic rehabilitation, including inspiratory muscle training, can be expected to become increasingly important.

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