New Approaches in the Management of Congestive Heart Failure: Implications for Cardiac Rehabilitation

I. Left Ventricular Assist Devices

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**Introduction**

Congestive heart failure (CHF) impacts society both on an individual level with personal suffering and on a general level through rising economic cost due to increasing incidence and prevalence of CHF. Prognosis is poor with only one-half of patients alive at 5 years and 20% at ten years after diagnosis. (1,2)

**Left Ventricular Assist Devices**

During the pre-cyclosporin days, cardiac transplantation success was dependent upon donor match and was not available as definitive therapy for CHF. This stimulated interest in development of left ventricular assist devices (LVADs) and several devices have now been approved for clinical use. In our centre, the program for use of these devices began in 1990 with the pneumatically driven extra corporeal Thoratec VAD (Thoratec Laboratories Corp., Pleasanton CA). The implanted electrical Novacor left ventricular assist system (LVAS) (World Heart Corp., Ottawa, ON) was introduced in 1998.

Both devices have an inflow cannula which is inserted into the left ventricular apex. The outflow cannula of the device is then inserted into the aorta. When using the Thoratec, the cannulae cross below the costal margins with the pump lying outside the body over the left abdomen. (See Figure 1) The Novacor pump is implanted in a pre-peritoneal pocket posterior to the left rectus abdominus muscle. (See Figure 2) Unidirectional pulsatile blood flow is assured by the use of Bjork-Shirley inlet and outlet valves in the Thoratec VAD and porcine inline valves in the Novacor.

**Figure 1: Thoratec™ Left Ventricular Assist Device**, reprinted with permission of Thoratec Laboratories Corp.
Through the negative and positive pressures produced by the pneumatic battery powered control unit the Thoretec VAD generates a stroke volume (SV) of 65 ml and provides an output of up to 7 L/m. There are 3 operating modes; volume or fill mode, R wave synchronous mode allowing pump diastole to occur during left ventricle (LV) systole, and asynchronous mode. The fill to empty mode offers a physiological responsiveness and provides optimal device output.

The Novacor provides a maximum SV of 70 ml and an output of up to 10-12 L/min. As with the Thoratec, there is a fill to empty mode, a synchronized mode and a third mode called fixed rate where rate and volume are predetermined.

**Criteria for Device Insertion and Type**

The choice of device to be used is influenced by body size. Patients with a body surface area of less than 1.3 m$^2$ are more comfortable with the Thoratec system. Patients young as 7 years of age have been fitted with this device. (3) As well, extra dissection is needed for an intracorporeal device, which may be undesirable in severe CHF/cardiogenic shock situations. The larger output offered by the Novacor favours longer implantation and larger body type.

The predominant feature of a patient presenting for LVAD implantation is decompensating heart failure, which is refractory to medical management, including inotropes. Laboratory results will show rapidly progressing end-organ dysfunction secondary to poor perfusion. There will be a reduced exercise capacity with dyspnea and orthopnea, largely attributed to pulmonary edema. Patients on the transplant list are monitored for deterioration in level of function and cardiac output. The indications for LVAD insertion are listed in Table 1.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Level indicating VAD candidate</th>
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<tbody>
<tr>
<td>Cardiac Index</td>
<td>&lt; 2 L/min/m$^2$</td>
</tr>
<tr>
<td>PCWP and CVP</td>
<td>&gt;18-20 mm Hg</td>
</tr>
<tr>
<td>SVR</td>
<td>&gt;2100 dynes-sec/cm$^2$</td>
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<tr>
<td>MAP</td>
<td>&lt; 60 mm Hg</td>
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</table>
Early Rehabilitation of LVAD Patients

Post operative rehabilitation starts once the patient has stable haemodynamic parameters and has minimal bleeding. Weaning from the ventilator takes place within 24-48 hours. Continued inotropic support for the right ventricle may be needed for up to two weeks. Care is taken to promote wound healing and prevent the most common long-term complication, which is infection. Anti-coagulation will be adjusted to prevent the occurrence of thromboembolic events. Cardiac arrhythmias when severe and persistent may disrupt rehabilitation as cardiac output will drop. Patients who have an automatic implantable cardiac defibrillator (AICD) should have the defibrillator activated.

While in the critical care unit, the goals of rehabilitation will be centered on preventing the harmful consequences of prolonged bed rest. Patients can be separated into two categories: Those who have been awaiting transplantation and have LVAD insertion as part of CHF management to prevent severe end organ damage, and those who have had an acute devastating cardiac event and require LVAD surgery as a life saving measure. This paper will address the rehabilitation programme of the former group. This group has been following an exercise regime within their tolerance pre-operatively and is well prepared to resume activity post-operatively.

Respiratory care is aimed at maximizing inspiratory capacity, gas exchange and pulmonary secretion clearance. Mobilization begins with sitting over the edge of the bed within four hours of extubation. To minimize muscle atrophy, antigravity exercises at 4-5 repetitions, assisted or active, are performed along with deep breathing. By the following day, transfers to a chair have begun and exercise progresses in variety and in repetitions. Emphasis is placed on maintaining an erect posture as early abdominal discomfort may produce forward spinal flexion.

When muscle strength has a grade of 3/5 ambulation is initiated, often by the third or fourth day. The concept of rate of perceived exertion (RPE) is introduced as this measure is helpful in progressing exercise intensity. The 0-10 scale is used aiming for the 3-5 range. During exercise sessions, the following haemodynamic parameters are recorded pre and post exercise: native heart rate (HR), blood pressure (BP) as well as LVAD mode of operation, rate, output (OP), and stroke volume (SV). Oxygen saturation is recorded and dyspnea assessed using a scale 0-4, based on the number of breaths needed to count to 15. Exercise sessions will be deferred when, HR > 130 bpm, SBP < 80 mm Hg, LVAD rate < 50 bpm, LVAD OP <3.0 L/min, LVAD SV <30 ml, dyspnea level >2, and the presence of sustained VT/VF. (5)

Early education into device management begins at this time with both patient and family. Transfers to the cardiac surgery ward take place as early as one week and a more intensive rehabilitation begins with goals centered on preparing the patient for independence and discharge. A progressive exercise programme utilizing treadmill or cycle ergometer increases aerobic capacity. Weight training maximizes muscle strength in preparation for prednisone use post transplant, thus, minimizing steroid myopathy. Stretching is incorporated to gain flexibility and prevent injuries. Patients are encouraged
to take responsibility for these exercises by performing one session without therapist supervision.

Discharge from hospital is considered when the patient’s medical and haemodynamic status is stable and they are psychologically prepared for independence. Both the patient and a designated caregiver must demonstrate competency in management of medical issues and LVAD operation. The patient and their companion will have access to 24 hour emergency resources including biomechanical personnel. Attendance at an outpatient rehabilitation programme continues on a 2-3 times a week basis with the patient completing his home programme including treadmill or cycle ergometer on off days.

**Exercise Physiology of LVAD**

Echocardiographic studies have shown that the LVAD functions either in series or in parallel with LV contraction. In the fill mode, the aortic valve will open if the LV generates sufficient pressure and the system operates in parallel. At rest, measured CO will match the LVAD OP indicating a series function, whereas, during exercise CO exceeds device OP indicating parallel function. Pneumatic devices have a peak heart rate of 140 bpm and electrical devices 120 bpm, which will limit peak exercise capacity. Other limiting factors are the degree of RV failure and the peripheral vascular and skeletal changes of CHF which limit venous return. The use of angiotensin-converting enzyme (ACE) inhibitors is used to decrease after load.

Murali et al. compared the exercise tolerance of recent LVAD patients with NYHA III CHF patients and reported peak oxygen consumptions (Pk VO2) of 16.2±3.5 ml/kg/min and 14.8±4.1ml/kg/min respectively. Improvements in VO2 and exercise capacity occur with time indicating that non-cardiac factors are likely responding to training programmes. Jaski et al. studied LVAD subjects performing supine and upright treadmill exercises. A similar Pk VO2 of 14.1±2.9ml/kg/min with treadmill exercise was found. Treadmill Pk LVAD OP was 7.8±2.5L/min. Fick CO performed in supine was similar to LVAD OP at rest, however during exercise the VAD OP rose 1.6±1.1L/min compared to the Fick systemic OP which rose 2.8±1.9L/min indicating parallel function of the LV-LVAD system. The highest CO was 12.9L/min with the LVAD providing 9.4 L/min or 73% of the total CO.

Foray used the 6-minute walk test to compare submaximal exercise capacity between LVAD and CHF groups. The distance walked by the LVAD patients was approximately one and one half times greater than that of severe heart failure patients.

**Survival and Quality of Life Outcomes**

Moskowitz et al. measured quality of life (QoL) in LAD patients before, during implantation and after transplantation. The patients’ preferences were determined by an interview process using the standard gamble technique. LVAD patients scored considerably higher than medically managed CHF patients and indicated an acceptable QoL.
The recent REMATCH study group (17) evaluated the use of LVAD in end stage CHF patients (NYHA IV) not eligible for transplantation. One-year rates of survival were 52% for the LVAD group and 25% for the medical therapy group and at 2 years 23% and 8% respectively. At one year, the LVAD group had a NYHA II classification and scored significantly better in the physical function and emotional role sub scales of the 36 item Medical Outcomes Study Short-Form General Health Survey (SF-36). In addition, a Beck Depression Inventory rate of 8 was in the normal range.

The LVAD group experienced problems with infection, bleeding and device related problems at a rate of 2.35 X the medical-therapy group. The continual modification of devices is aimed at reducing these complications and further studies evaluating different devices are planned.

Conclusion
LVAD assist has demonstrated its usefulness as a bridge to cardiac transplantation. However, the number of donor hearts worldwide, remaining fixed at 3,000 per year, falls far short of demand. The physical functioning and QoL of patients on the transplant waiting list steadily deteriorates. The use of LVAD’s has shown amelioration of this decline and remains a viable option to medical therapy in CHF.

References