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Early Physical Rehabilitation after Continuous Flow Left Ventricular Assist Device Implantation: Suggested Protocol and a Pilot Study

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Abstract

Background: Left Ventricular Assist Device (LVAD) implantation is an optional therapy for patients with end stage heart failure. Physical rehabilitation after an LVAD implantation is beneficial for the patient's recovery. A detailed protocol for and our experience with a very early post LVAD implantation individualized physical rehabilitation is presented.

Method: Twelve patients who underwent LVAD implantations between April 2010 and April 2011 were included in the study. As soon as the patients were able to walk by themselves (7-10 days post-op), they started aerobic exercise on a treadmill and on the Nustep: combining hand and leg aerobic exercise. Exercise was started at low intensity and for short intervals. The target was to increase intensity and duration. Progress was based on Both Subjective (Borg Scale) and objective (6 Minutes Walk Test: 6MWT) parameters.

Results: Walking time and speed on the treadmill was increased from two 2-4 minutes intervals to one continuous 10 minutes exercise. The time and intensity on the Nustep increased from two intervals of 1-3 minutes to one continuous 16 minutes exercise and from 10-20 watts to 30 watts, respectively. An improvement was seen in the 6MWT from baseline to hospital discharge: 131 ± 91 meters to 262 ± 84 meters respectively ($p<0.01$) and from discharge to the first LVAD clinic visit: 251 ± 80 meters to 307 ± 88 m meters respectively ($p<0.01$). All patients reported improvement in carrying the 2-2.5 Kg of battery weight (from difficult to tolerable).

Discussion: A very early stage rehabilitation program after LVAD implantation is feasible and may improve the functional capacity and the ability to carry the LVAD batteries of the LVAD supported patient. Larger studies are needed to determine the optimal time to start rehabilitation program post LVAD implantation.

Keywords: Physical rehabilitation; Exercise; LVAD Implantation

Introduction

Heart Failure (HF) is a common disease associated with major disabilities, reduced quality of life, increased morbidity and high mortality rate [1-4]. The prevalence and economic burden associated with HF has been constantly growing over the last years. Despite improvement in the implementation of the guidelines for the management of HF, ensuring that most patients receive evidence-based therapies, HF remains a progressive disease with dismal prognosis [5-8].

With the advances in the mechanical circulatory support technologies, a growing group of patients with end stage HF that did not have any other therapeutic option, can now benefit from implantation of a Left Ventricular Assist Device (LVAD). Indications for LVAD implantation include: bridge to heart transplantation, bridge to transplant ability, bridge to recovery and recently also as destination (permanent) therapy [9-11].

It is well established that with the support of an LVAD, there is general improvement in the functional capacity, quality of life and survival of patients with advanced HF.

In contrast to first generations of assist devices, the low complication rate associated with the 2nd (axial flow) and 3rd (centrifugal flow) generations of assist devices as well as their improved durability and reliability enables prompt discharge home of almost all LVAD supported patients [12-16].

Due to the severe disability caused by advanced HF, most of the patients undergoing LVAD implantation are de-conditioned pre operatively, with further worsening during the immediate post-operative period.

Cardiac rehabilitation improves functional capacity of patients with heart diseases in general and in HF patients in particular [17,18].

It has been recently shown that physical rehabilitation for patients after LVAD implantation with the indication of destination (permanent) therapy, improves their functional capacity and surgical outcomes [19,20].

Early exercise rehabilitation after LVAD implantation with aerobic exercise starting with short intervals has been suggested to reduce post-operative complications and shorten the hospitalization period [19,21].

Early mobilization of patients after LVAD implantation was found to be safe and beneficial for achieving smooth return to "normal" and independent life. Mobilization started as early as 48 hours post LVAD implantation at the ICU has been described and appears to be safe [8,22,23].

Specific features distinguish rehabilitation of LVAD recipients from rehabilitation of patients recovering from any other cardiac disease or heart surgery. Due to the continuous flow, blood pressure, heart rate and oxygen saturation are immeasurable by the standard sphygmomanometer and pulse oxymeter in the LVAD supported patient, thus making their target heart rate irrelevant as well [24,25].

Although precautions should be taken when considering weight carrying in patients that have recently undergone open chest operations (post mid-sternotomy), the need to carry the battery's weight by the LVAD recipients overpasses those limitations and forces the treating physiologists to tailor a special training program for those patients [26]. Another important issue that the LVAD supported patient must consider during rehabilitation is the dependence of the cardiac output supplied by the LVAD function on optimal blood volume.

The purpose of our study was to assess the feasibility and safety of very early post LVAD implantation exercise training protocol and the results of a pilot study implementing the suggested protocol.

Methods

Patients: Eighteen consecutive patients with end stage HF refractory to medical therapy were supported with a LVAD at our center between August 2010 and November 2011 using the continuous flow devices Thoratec Heart Mate II (n=14) and the Heart Ware (n=4) by the median-sternotomy approach. Five patients (four implanted with Heart Mate II and one with Heart Ware) suffered from post-operative complications, mainly worsening right ventricular failure with prolonged hospitalization. Those patients were considered to be too sick for participating in the early rehabilitation program by the managing physician and the physiotherapist and were therefore excluded from the study. Another patient (Heart Ware) who was unable to walk on the treadmill due to pre LVAD implantation orthopedic disability was also excluded from the study. This patient was trained on a sitting bicycle. The remaining 12 patients formed the study group.

Prior to the LVAD implantation, all patients were in severe de-compensated HF, hospitalized in the cardiac intensive care unit for inotropic support (INTERMACS 2-3).

Exercise Test: All patients performed the 6 minutes' walk (6 MWT) test 3 times; the first just before the beginning of the first training session (at that time some patients used a cart to carry the batteries and controller), the second was performed prior to hospital discharge and the third during the first post discharge visit at the LVAD clinic, approximately 2 weeks from hospital discharge. The simple to perform, Six minute walk test during the first training session, helped determine the initial treadmill speed (it reflected the patient's normal walking speed). During the last two follow up 6 MWTs, all patients carried the batteries on a bag hanging from their shoulder.

Protocol design

Post-operative physical therapy: During the first stage of the physical re-habilitation program patients had to be: hemodynamic stable, weaned from the respirator and the inotropic support and in good mental state. This was usually achieved between the first 24 hours to the 6th post-operative day. At that phase, the LVAD supported patients were treated by a physiotherapist same as all the other post cardiothoracic surgery patients. The aims of the first phase were to regain the ability to perform the activities of daily living (ADL) like rising from a recumbent position to sitting and from sitting to standing and walking. As early as possible, patients were encouraged to engage in the physiotherapist training protocol starting with light balance, improving the range of motion and strength of the upper limb, neck and thorax. All ADL and in particular training in changing positions and walking were performed while the patient was carrying the LVAD bag on his back or shoulder. In this way, patients practiced the state of new balance (the body mass center shifted to the chosen side of the 2-2.5 kg bag). The duration of first phase, before the initiation of the exercise cardiac rehabilitation, was 1- 6 days (Figure 1).

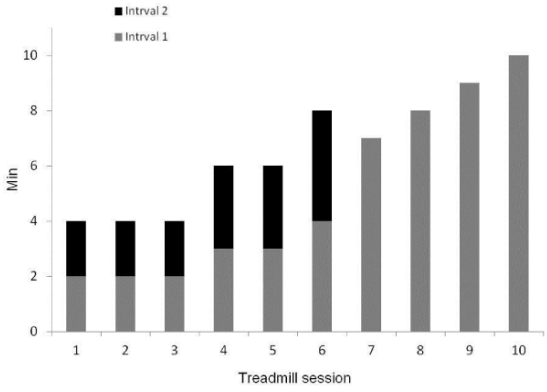

Figure 1: Schematic description of the treadmill protocol. The first and second interval corresponds to the total amount of time in a treadmill session per minute. The gap between interval 1 and 2 is the resting time determined by the patient's subjective feelings (8 in the Borg scale).

Aerobic exercise training protocol

Post-operative weeks: After gaining ADL independence, the post-LVAD implantation hospitalization based exercise training protocol began. Exercise was performed 4 times per week for the remaining of the hospital stay which was determined by the medical condition of the patient. The principles of the training were gradual advancing from interval training to continuous training, from training of the lower limbs first to both upper and lower limbs and from with no to with carrying the batteries. At first, for short exercise-long rest intervals without the batteries and controller load and gradually progressing according to every patient's abilities, to longer exercise, shorter resting intervals until a continuous exercise with the batteries load was achieved. The patient who was not able to walk on the treadmill due to his orthopedic disabilities was trained on the bicycle following the same training principles.

Devices used:

- Nustep cross-trainer: NuStep TRS 4000 recumbent, Ann Harbor MI, USA. Sit down cross trainer that combines hands and legs aerobic exercise.
- Treadmill: Johnson T8000 pro, Johnson Health Tech. CO. Taichung Hsien, Taiwan.

During all the training sessions patients were monitored mainly by the Borg scale (see below). When measurable, patients were also monitored by the blood oxygen saturation (using a fingertip pulse oxymeter).

First phase: At the first session, patients performed interval training on the cross-trainer: starting with two repetitions of 2 minutes each, using only the lower limbs at 10 watts of work load without carrying the batteries with resting period as necessary. During the following training sessions, the exercising time and work load were prolonged to 5 minutes and 40 watts (exercising time and work intensity assessment according to Borg scale of 12-14). By the last training session of the first phase, the upper limbs were incorporated and the patients began practicing getting up and standing on the treadmill. The target of the first phase: five minutes of continuous training on the cross trainer using 4 limbs,

Second phase: Exercising on the treadmill. The LVAD supported patient was considered physically ready to start practicing on the treadmill when he reached 5 minutes of continuous training on the cross trainer using his 4 limbs. The treadmill training session consisted of interval training starting with two repetitions of two minutes walking on the treadmill at a speed of 1-2 km/h, no inclination, with a resting period between them. The speed of the treadmill was set with the intention to avoid reaching a score higher than 13 on the Borg scale at the end of the 2 minutes training. During the first treadmill training sessions, the batteries and controller were hung on the treadmill's handle and the exercising period on the cross trainer was gradually raised to 15-20 minutes.

During the following treadmill walking sessions, the exercising time was prolonged to two sessions of 6 minutes walking with a modifiable resting period in between.

Throughout the walking sessions, the patients were given the opportunity to rest and recover between the exercising intervals.

Upon improvement in the walking ability, the batteries were gradually placed in a bag hanging on the patient's shoulder for increasing periods of time starting for only one minute gradually increasing the carrying period to all the training sessions like they would do in their daily life activities once discharged from the hospital. The target of the second phase: walking on the treadmill continuously for 6 minutes carrying the batteries.

Third phase: the target of the second phase was to enable the patients to walk continuously for 6 minutes. Upon reaching this goal, the treadmill's speed was raised gradually and the walking time was increased to 8 minutes. During the following training sessions, the training period was gradually increased to 10 minutes of continuously walking on the treadmill (Figure 1). During the whole training process, the duration of the exercise and the speed of the treadmill were determined by the patient's subjective state (Borg scale), slowing the treadmill's speed and/or shortening the training duration or delaying the progress to the next phase, with the intention to stay below the stress intensity of 14 on the Borg scale. The duration of the recovery time between the two exercising intervals was determined by the patient's state: the second interval was started when the patient reached Borg scale score of 8. The resting period was gradually shortened until completely abolished so the patient would walk continuously with no need for a resting period between the training intervals.

Statistical analysis: Data are presented as the mean ± SD. Statistical analysis was performed with two-tailed paired and unpaired Student t tests, as appropriate. For the sequential analysis of the three exercise tests in the same patients, repeated measures analysis of variance (ANOVA) was used. If relevant, 95% confidence intervals (CIs) of differences were calculated. A p value of 0.05 was considered statistically significant. All analyses were performed using SPSS version 8.0 for Windows.

Results

Study group

Twelve consecutive patients (three females mean age 57.3 ± 7 years) who successfully overcame the first week of the, post-operative physical therapy (see above) were included in the study.

The etiology of HF was ischemic cardiomyopathy in 8 patients and non-ischemic in four. Eight patients were treated with the intention to be eventually transplanted (bridge to transplantation) and four patients were intended to be permanently supported by the LVAD (destination therapy). The pre-LVAD implantation hemodynamic parameters were: mean left ventricular ejection fraction of 25.5% ± 4.4%, cardiac output 3.5 ± 0.7 liter/min, mean pulmonary pressure 39 ± 17mm Hg, mean right atrial pressure of 11 ± 6 mm Hg and pulmonary vascular resistance of 4 ± 2.7 wood units.

The results of the 6MWT: A significant improvement was observed between the first 6MWT performed just before the beginning of the first training (on the 7-10 post-operative day) session and the second study performed after the in-hospital training program, before hospital discharge (3-4 weeks post operation): 131 ± 91 meters vs. 262 ± 84 meters respectively ($p<0.01$). Similar improvement though less pronounced was seen between the second 6MWT performed before hospital discharge and the third study performed at the first post hospital discharge visit to the LVAD clinic (6-8 weeks post operation): 251 ± 80 meters vs. 307 ± 88 m meters respectively ($p<0.01$) (Figures 2 and 3).

Although all patients improved their 6MWT from baseline to the second test at the end of the in-hospital training sessions and from the second test to the third, most of the improvement occurred between the first and the second 6MWT: during or as a result of the in-hospital exercise program (Figure 2).

On average, it took 2.5 ± 1.5 (range 1-5 sessions) training sessions (3-7 days from the beginning of the training protocol) to achieve the target of the first phase: five minutes of continuous training on the cross trainer using 4 limbs.

The target of the second phase: walking on the treadmill continuously for 6 minutes carrying the batteries was achieved after 5 ± 1.5 training sessions (range: 3-8 sessions).

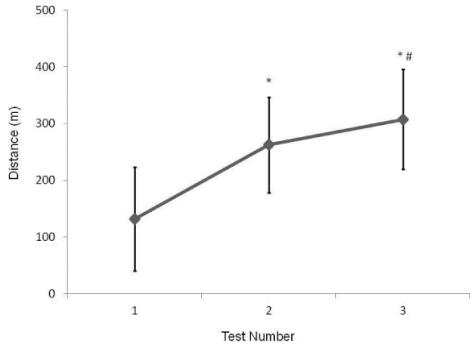

Figure 2: The average score of each 6 min walk test; 1 represents the start of the program, 2 before hospital discharge and 3, the first visit to the LVAD clinic (approximately 2 weeks post discharge) (*p<0.01, #p<0.01).

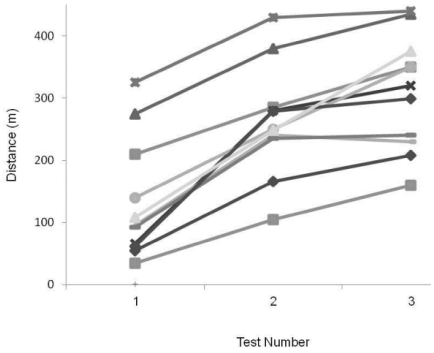

Figure 3: The individual score for the 12 patients' 6 minute walk test.

Discussion

In this study we propose a new physical rehabilitation protocol for LVAD supported patients and describe the results of implementing this protocol on a pilot of 12 patients undergoing LVAD implantation at our center.

Few studies have addressed cardiac rehabilitation of LVAD recipients and the optimal timing, duration and intensity of the training protocol for early rehabilitation in those patients has not yet been clearly described [20,21,26]. In general, exercise rehabilitation after LVAD implantation has been found to be beneficial in improving patients' recovery [19,20,26]. In the immediate post operative period, as in every patient undergoing cardiothoracic surgery, the aim of the rehabilitation is to facilitate patient's independence in ADL activities by means of physio-therapeutic intervention training the respiratory muscles and learning how to perform the daily life posture changes with emphasis on body balance. On achieving ADL independence, a process that takes approximately a week, the physical rehabilitation program was initiated. Difficulties in adjusting to the suggested level of work and intensity have been reported [27]. Those difficulties were related to the fact that in LVAD-supported patients, blood pressure is not always measurable and the significance of "target heart rate" in unclear [25]. Mean blood pressure is of major importance but in most of the LVAD supported patients can only be assessed using a vascular doppler probe. In those patients, the heart rate exerts its effects on total cardiac output by affecting the function of the right ventricle whereas its direct effect on the cardiac output supplied by the LVAD is small. LVAD related effective cardiac output is highly influenced by the systemic vascular resistance which declines during training increasing the effective cardiac output generated by the LVAD [25].

Moreover, the LVAD's batteries weight is an essential cofactor that needs to be addressed in the post operative training process and strongly contributes to the work intensity.

The need to carry the 2-2.5 kg batteries and controller also has to be addressed in the early rehabilitation period and poses a challenge to most patients. Furthermore, the relatively new surgical approach: the double tunnel technique for the LVAD driveline that suggests transferring the exit site of the driveline sub-cutaneously from the right to the left side of the abdomen: C-shaped technique, with the intention of lowering the driveline infection rate, shortens the length of the extracorporeal cable forcing the patients to carry the batteries and controller on one shoulder instead of on their back [28].

Another important issue that the LVAD supported patient must consider during rehabilitation that is unique to the process of rehabilitation of those patients, is the dependence of the cardiac output supplied by the LVAD function on optimal blood volume. Prior to the implantation of the LVAD, de-compensated HF patients are instructed to limit their water intake, but once supported by the LVAD, relative dehydration with reduced intravascular volume may result in exercise intolerance. In the LVAD supported patient, the combination of reduced blood volume (due to excessive diuresis, anemia or low fluid intake) and exercise induced decrease in the peripheral resistance may be one of the causes for the limited improvement in exercise capacity and the exertional weakness observed in those patients. We constructed a new training protocol for LVAD implanted patients considering the needs and peculiarities of this "new" group of cardiovascular patients.

The main objective of our exercise protocol was to improve the patients' exercise capacity following LVAD implantation. This was achieved by means of interval training gradually advancing towards continuous training. Milestones and exercise training goals were described.

Most of the patients (80%) were unable to perform the first 6MWT carrying the batteries and the controller. In the second and third 6MWT performed before hospital discharge and at the first follow up visit respectively, a gradual and consistent improvement in the walking distance was observed. The improvement was more pronounced between the first and second 6MWT than between the second and the third (Figure 2). Although partly related to the post operative rehabilitation process, the improvement in the 6MWT might also be attributed to the improved cardiac output delivered by the LVAD. By the third 6MWT, patients were approximately 6-8 weeks post surgery. The relatively improved score of 307 meters achieved by the early rehabilitation protocol might have a benefit on survival beyond the obvious improved functional capacity as suggested in a recent paper by Hasin et al. [29] demonstrating improved survival of the patients supported by an LVAD who were able to walk more than 300 meters on the 6MWT.

The patient's prolonged poor aerobic exercise capacity prior to the LVAD implantation, typical to patients with advanced heart failure, is due to the reduced blood supply to the exercising muscles leading to anaerobic metabolism and low functional capacity [30]. LVAD implantation results in improved blood supply to the exercising muscles, improving their performance and oxygen consumption leading to improved aerobic capacity [31]. This could explain the steeper slope of the 6MWT performance observed between the first and second 6MWT compared to the slope between the second and third. From the first treadmill session and onwards the patient's resting periods were gradually shortened and some patients did find it difficult to walk continuously for six minutes. In those cases, we "regressed" to another two interval session of four minutes each, gradually shortening the recovery period in between. The low exercise capacity of those patients despite clinical stability as assessed by the stable oxygen saturation and heart rate, suggests the presence of another limiting factor. Patients with prolonged severe heart failure, were not able to and thus were not used to, walk for "such a long time" and consequently might have developed a fear from continuous aerobic exercise. The ability to walk continuously on the treadmill for six minutes is of crucial importance. From this point on, the emphasis of the program was on increasing the intensity of the exercise by constantly increasing the treadmill's speed in order to improve the aerobic capacity of the training patient.

Another unique difficulty faced by patients supported by the LVAD in the early post operative rehabilitation period is posed by the batteries and the controller. Those objects become a part of the patient's body who must adapt to them both physically and psychologically. The physical burden of carrying the two batteries and the controller weighing approximately 2-2.5 kilograms is not simple for the debilitated HF patient and in particular for those patients with low BMI. Due to the novel surgical approach of the LVAD implantation intended at reducing the rates of the infectious complications, the sub-cutaneous tract of the drive line is extended exposing it at the left abdominal wall. Performing this procedure shortens the length of the cable forcing the patients to carry the batteries and controller on their shoulder and not on their back. Other battery carrying options are not practical for most of the common BMI patients. This issue should be carefully addressed because of the upper body asymmetry that results from carrying the relatively heavy weight on the shoulder. Such a body asymmetry, particularly in the low BMI patients undergoing thoracic surgery, can lead to shoulder, neck and thoracic pain in addition to balance and posture problems and to prolonged post operative recovery. Orthopedic and physiotherapist evaluation should be considered (when possible) prior to the surgery of LVAD implantation and any shoulder girdle and thoracic problem should be treated.

In the early rehabilitation process, during the first post-operative week, the physiotherapist should re-evaluate the LVAD recipients. Most of the LVAD supported patients will need some specific exercises for improving their balance and body posture.

It should be emphasized that carrying the batteries and controller pack, either on the back or on the shoulder, is inconsistent with the common recommendations given to all patients undergoing mid-sternotomy operation [32].

Controversy exists regarding the clinical significance of carrying the 2-2.5 kilograms' pack on one shoulder. On one hand, it might cause upper body asymmetry, sternal instability and prolonged healing time but on the other hand, it has been recently shown that the common post-operative sternal precautions might be somewhat too strict, especially in LVAD recipients, who are unable to follow those precautions [32].

On the first sessions patients exercised on the cross-trainer with the battery pack hanging on the side of the chair of the cross-trainer so they did not have to carry the relative heavy pack. This method of exercising without the burden of the batteries which are connected to the body by the cable can be problematic in the event of an unexpected fall. Only after the patients' has achieved a significant improvement in their aerobic capacity were they instructed to start carrying the battery pack. In most cases, this happened on the third training session. Even then, the patients' carried the battery pack for only the first of the two walking intervals (of two minutes each). On the fourth training session, when the intervals were increased to three minutes each, most of the patients were able to carry the battery pack during both intervals. From the seventh training session onwards, the patients carried the batteries during all the training exercises. (Another explanation for the physiological difficulty experienced by the patients on the seventh training session would be the combination of a relatively prolonged continuous walk of 6 minutes and the load of the battery pack. On the sixth training session, patients were instructed to walk for two intervals of four minutes with minimal rest time in between the intervals. The overall increase in the exercise time to eight minutes had a beneficial psychological effect on the patients' sense of accomplishment. Although exercise training has been shown to improve QOL of patient patients whom are supported with a LVAD [20], the feasibility of training LVAD supported patients in the very early post operative period has not been examined yet.

Conclusion

Our study suggests that well constructed exercise training program performed on patients supported with a LVAD in the very early post operative period is safe and can lead to improved functional capacity prior to hospital discharge. The impact of exercise training on the survival of patients supported with a LVAD needs to be studied in larger groups of patients. We believe that better functional capacity of the LVAD supported patient at discharge will improve their adaptation to the needs of their new life. Further work must be done in order to prove the efficacy and applicability of our protocol in a larger group of LVAD supported patients.

Limitations

The major limitation of our study is the small sample size therefore it should be considered as a "hypothesis generating" study. The lack of a control group is another obvious limitation. During the process of the study we were faced with novel and complicated challenges that needed prompt and creative responses like how to enable the patients to practice without the need to carry the batteries and the controller. Those challenges were not addressed previously. This limitation can also be considered positively since it raises issues that will have to be dealt in further studies.

References

1. Roger VL, Weston SA, Redfield MM, Hellermann-Homan JP, Killian J, et al. (2004) Trends in heart failure incidence and survival in a community-based population. below JAMA 292: 344-350.
2. Lee WC, Chavez YE, Baker T, Luce BR (2004) Economic burden of heart failure: a summary of recent literature. below Heart Lung 33: 362-371.

3. Thom T, Haase N, Rosamond W, Howard VJ, Rumsfeld M, et al. (2006) Heart disease and stroke statistics-2006 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 113: e85-151.
4. Ambrosy AP, Fonarow GC, Butler J, Chioncel O, Greene SJ, et al. (2014) The global health and economic burden of hospitalizations for heart failure: lessons learned from hospitalized heart failure registries. below J Am Coll Cardiol 63: 1123-1133.
5. Dickstein K, Cohen-Solal A, Filippatos G, McMurray JJ, Ponikowski P, et al. (2008) ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: the Task Force for the diagnosis and treatment of acute and chronic heart failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM). Eur J Heart Fail 10: 933-989.
6. Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, et al. (2009) 2009 Focused update incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines Developed in Collaboration With the International Society for Heart and Lung Transplantation. J Am Coll Cardiol 53: e1-e90.
7. Heart Failure Society of America, Lindenfeld J, Albert NM, Boehmer JP, Collins SP, et al. (2010) HFSA 2010 Comprehensive Heart Failure Practice Guideline. below J Card Fail 16: e1-194.
8. Morrone TM, Buck lA, Catanese KA, Goldsmith RL, Cahalin LP, et al. (1996) Early progressive mobilization of patients with left ventricular assist devices is safe and optimizes recovery before heart transplantation. J Heart Lung Transplant 15: 423-429.
9. Starling RC, Naka Y, Boyle AJ, Gonzalez-Stawinski G, John R, et al. (2011) Results of the post-U.S. Food and Drug Administration-approval study with a continuous flow left ventricular assist device as a bridge to heart transplantation: a prospective study using the INTERMACS (Interagency Registry for Mechanically Assisted Circulatory Support). J Am Coll Cardiol 57: 1890-1898.
10. Mikus E, Stepanenko A, Krabatsch T, Loforte A, Dandel M, et al. (2011) Reversibility of fixed pulmonary hypertension in left ventricular assist device support recipients. Eur J Cardiothorac Surg 40: 971-977.
11. Liden H, Karason K, Bergh CH, Nilsson F, Koul B, et al. (2007) The feasibility of left ventricular mechanical support as a bridge to cardiac recovery. below Eur J Heart Fail 9: 525-530.
12. Park SJ, Milano CA, Tatooles AJ, Rogers JG, Adamson RM, et al. (2012) Outcomes in advanced heart failure patients with left ventricular assist devices for destination therapy. Circ Heart Fail 5: 241-248.
13. Kirklin JK, Naftel DC, Kormos RL, Stevenson LW, Pagani FD, et al. (2013) Fifth INTERMACS annual report: risk factor analysis from more than 6,000 mechanical circulatory support patients. below J Heart Lung Transplant 32: 141-156.
14. Ades PA, Keteyian SJ, Balady GJ, Houston-Miller N, Kitzman DW, et al. (2013) Cardiac rehabilitation exercise and self-care for chronic heart failure. below JACC Heart Fail 1: 540-547.
15. Naci H, Ioannidis JP (2013) Comparative effectiveness of exercise and drug interventions on mortality outcomes: metaepidemiological study. below BMJ 347: f5577.
16. Cipriano G, Cipriano VT, da Silva VZ, Cipriano GF, Chiappa GR, et al. (2014) Aerobic exercise effect on prognostic markers for systolic heart failure patients: a systematic review and meta-analysis. below Heart Fail Rev 19: 655-667.
17. Keteyian SJ, Fleg JL, Brawner CA, Piña IL (2010) Role and benefits of exercise in the management of patients with heart failure. below Heart Fail Rev 15: 523-530.
18. O'Connor CM, Whellan DJ, Lee KL, Keteyian SJ, Cooper LS, et al. (2009) Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. below JAMA 301: 1439-1450.
19. Hayes K, Leet AS, Bradley SJ, Holland AE (2012) Effects of exercise training on exercise capacity and quality of life in patients with a left ventricular assist device: a preliminary randomized controlled trial. below J Heart Lung Transplant 31: 729-734.
20. Laoutaris ID, Dritsas A, Adamopoulos S, Manginas A, Gouziouta A, et al. (2011) Benefits of physical training on exercise capacity, inspiratory muscle function, and quality of life in patients with ventricular assist devices long-term postimplantation. below Eur J Cardiovasc Prev Rehabil 18: 33-40.
21. Nicholson C, Paz JC (2010) Total artificial heart and physical therapy management. below Cardiopulm Phys Ther J 21: 13-21.
22. Perme CS, Southard RE, Joyce DL, Noon GP, Loebe M (2006) Early mobilization of LVAD recipients who require prolonged mechanical ventilation. below Tex Heart Inst J 33: 130-133.
23. English ML, Speed J (2013) Effectiveness of acute inpatient rehabilitation after left ventricular assist device placement. below Am J Phys Med Rehabil 92: 621-626.
24. Humphrey R (1997) Exercise physiology in patients with left ventricular assist devices. below J Cardiopulm Rehabil 17: 73-75.
25. Martina JN, de Jonge, Rutten M, Kirkels JH, Klopping C, et al. (2013) Exercise hemodynamics during extended continuous flow left ventricular assist device support: the response of systemic cardiovascular parameters and pump performance. Artif Organs 37: 754-762.
26. Ueno A, Tomizawa Y (2009) Cardiac rehabilitation and artificial heart devices. below J Artif Organs 12: 90-97.
27. de Macedo RM, Faria-Neto JR, Costantini CO, Casali D, Muller AP, et al. (2011) Phase I of cardiac rehabilitation: A new challenge for evidence based physiotherapy. below World J Cardiol 3: 248-255.
28. Schibilsky D, Benk C, Haller C, Berchtold-Herz M, Siepe M, et al. (2012) Double tunnel technique for the LVAD driveline: improved management regarding driveline infections. below J Artif Organs 15: 44-48.
29. Hasin T, Topilsky Y, Kremers WK, Boilson BA, Schirger JA, et al. (2012) Usefulness of the six-minute walk test after continuous axial flow left ventricular device implantation to predict survival. below Am J Cardiol 110: 1322-1328.
30. Adamopoulos S, Coats AJ, Brunotte F, Arnolda L, Meyer T, et al. (1993) Physical training improves skeletal muscle metabolism in patients with chronic heart failure. below J Am Coll Cardiol 21: 1101-1106.
31. Bellotto F, Compostella L, Agostoni P, Torregrossa G, Setzu T, et al. (2011) Peripheral adaptation mechanisms in physical training and cardiac rehabilitation: the case of a patient supported by a CardioWest total artificial heart. J Card Fail 17: 670-675.
32. Cahalin LP, Lapier TK, Shaw DK (2011) Sternal Precautions: Is It Time for Change? Precautions versus Restrictions - A Review of Literature and Recommendations for Revision. below Cardiopulm Phys Ther J 22: 5-15.