High-Intensity Interval Training for Severe Left Ventricular Dysfunction Treated with Left Ventricular Assist Device

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Summary
Aerobic training based on anaerobic threshold (AT) is well-known to improve cardiac function, exercise capacity, and long-term outcomes of patients with heart failure. Recent reports suggested that high-intensity interval training (HIIT) for patients with cardiovascular disease may improve cardiopulmonary exercise capacity. We present a 61-year-old male patient of severe left ventricular dysfunction with left ventricular assist device (LVAD). Following HIIT for 8 weeks, exercise capacity and muscle strength have improved without worsening left ventricular function. Our case showed the possibility that HIIT was feasible and effective even in patients with LVAD.

Key words: Exercise training, Left ventricular assist device, Peak oxygen uptake, Muscle strength

Several controlled trials have demonstrated that exercise training improved exercise capacity and quality of life of patients with heart failure. And a meta-analysis of randomized trials showed that exercise training for patients with heart failure improved exercise capacity and reduced cardiovascular events. However, continuous moderate-intensity aerobic training is only limited to patients with preserved exercise capacity and muscle strength. Patients with severe deconditioning or muscle weakness are intolerant to continuous moderate-intensity aerobic training.

Recently high-intensity interval training (HIIT) has been reported to improve exercise capacity of patients with severely impaired left ventricular function. HIIT may be feasible for patients who are intolerant to continuous moderate-intensity aerobic training because of deconditioning. It may be difficult for the patient with implantable left ventricular assist device (LVAD) to perform continuous moderate-intensity aerobic training because of longstanding deconditioning, but the patient with LVAD may be a good candidate for HIIT. We present a case of patients with LVAD that was treated by HIIT.

Case Report
A 61-year-old male, who was diagnosed with dilated cardiomyopathy (DCM) and treatment-refractory heart failure dependent on inotropic agent, was transferred to our institute for left ventricular assist device (LVAD) implantation. During admission, the patient was 166.3 cm tall and weighed 68.5 kg, with a BMI of 24.9, blood pressure 94/74 mmHg, resting heart rate 105/minute, and body temperature of 36.2°C. Blood biochemistry showed T.P. 7.1 g/dL, albumin 3.8 g/dL, T-bil 3.7 mg/dL, D-bil 2.5 mg/dL, AST 43 IU/mL, ALT 35 IU/mL, LDH 378 mg/dL, CK 168 mg/dL, ALP 324 mg/dL, gamma-GTP 60 mg/dL, CRP 0.69 mg/dL, Na 137 mEq/L, K 4.4 mEq/L, Cl 97 mEq/L, BUN 43 mg/dL, Cr 1.45 mg/dL, UA 10.7 mg/dL, T-chol 154 mg/dL, HDL-C 34 mg/dL, TG 83 mg/dL, WBC 4930/mm³, RBC 493 × 10⁶/mm³, Hb 15.5 g/dL, Ht 48%, Plt 15.7 × 10⁴/mm³. The plasma glucose level was 210 mg/dL and the BNP level was 3085 pg/mL. Chest X-ray on admission showed slight pleural effusion and cardiomegaly. Echocardiography (ECG) on admission showed sinus tachycardia with a heart rate of 110 BPM, left axis deviation, low voltage, and negative T-wave in V6 lead. Echocardiography showed diffuse severe hypokinesis of left ventricle (left ventricular ejection fraction [LVEF] 15%, left ventricular diastolic diameter[LVDd] 61 mm). Clinical course of medication, exercise prescription, line chart of plasma BNP level, and LVEF are described in Figure 1. In addition to medical treatment and continuous venous infusion of inotropic agent, aerobic exercise training of 15 watt, 15 minutes of ergometer was performed before LVAD implantation and this load made him feel Borg 9. After the implantation of an LVAD (Heart Mate II, Thoratec, USA), cardioprotective drug and diuretics were stopped and we continued warfarin, aspirin, proton pump inhibitor, and DPP4 inhibitor. We tried to restart and titrate administration of beta blockers and angiotensin converting enzyme inhibitors; however, he developed cerebral infarction due to thrombus originating from...
Figure 1. Clinical course of the case. We started moderate continuous exercise at 4 weeks after LVAD implantation. However, the patient felt strong fatigue after exercise training. We performed CPX for arranging to HIIT program and followed CPX reevaluation after performing 8 weeks HIIT program.

Figure 2. Protocol of HIIT. Exercise training was carried out by using ergometer. 10 minutes of warm up was followed by program No.1 that consisted of repetition of 4 minutes of 90% of peak heart rate, and 3 minutes of 50% of peak heart rate, 21 minutes in total. Program No.2 consisted of repetition of 1 minute of 90%, and 2 minutes of 50%, 30 minutes in total.
HIIT on 2 weeks after LVAD implantation. The symptom was moderate cognitive and attention disorder without motor and sensory paralysis. After stabilization of cerebral infarction, his systolic blood pressure was under 100 mmHg and he was considered to be intolerant to administration of cardioprotective drug. Administration of aspirin and warfarin was stopped temporarily until stabilization of cerebral infarction and cerebral hemorrhage. He underwent continuous moderate exercise training based on Karvonen formula at 50% intensity level for 5 weeks from 4 weeks after LVAD implantation. Cardiopulmonary exercise test (CPX) on 8 weeks after LVAD implantation showed a peak oxygen uptake of 13.1 mL/kg/minute, minute ventilation (VE) versus carbon dioxide output (VCO2) slope of 35.5, and max load 66 watts. Grip strength of right and left was 26.3 kg and 26.5 kg, respectively. Quadriceps strength of right and left was 23.7 kg and 26.6 kg, respectively. In measuring grip strength, grip dynamometer was used with standing posture. Three measurements were made and we used the maximal value obtained from each hand. Quadriceps strength was measured by using μTAS F1 (ANIMA Corp., Tokyo) in sitting posture. Although he tried continuous aerobic ergometer training (30 minutes) at aerobic threshold (AT) level for 18 days, he could not continue the exercise program targeted to AT level (8.3 mL/kg/minute, 23 watt of load on AT per minute) due to heavy peripheral skeletal muscle fatigue caused by the increase in the intensity of exercise from mild to AT level and intolerance to continuous exercise caused by attention disorder. Exercise prescription was arranged to high-intensity interval training according to previous report. (program No.1, HIIT: 90% of peak heart rate: 4 minutes, 50% of peak heart rate: 3 minutes, Figure 2). We used peak heart rate obtained from CPX as peak heart rate of HIIT program. HIIT and resistance training of lower extremities for muscle strength were started to obtain higher level of exercise capacity before LVAD implantation. Training session were performed 5 times a week and, consisted of 10 minutes stretching and warming-up exercise, resistance exercises which consisted of 30 circuits of single seated calf raise without load and 30 circuits of standing-up from sitting position on a 25-cm high table, and HIIT program.

He continued HIIT and resistance training program for a week without worsening heart failure, but he felt strong fatigue and was reluctant to do other activities. We rearranged HIIT program to 90% of peak heart rate: 1 minute, 50% of peak heart rate: 2 minutes (program No.2, Figure 2). At 15 weeks after LVAD implantation, CPX was performed again for evaluation of improvement extent of exercise capacity followed by 8 weeks HIIT program and resistance training. CPX showed a peak oxygen uptake of 17.3 mL/kg/minute, VE versus VCO2 slope of 31, and max load 84 watts. Grip strength of right and left was 31.4 kg and 31.4 kg, respectively. Quadriceps strength of right and left was 31.9 kg and 40 kg, respectively. As compared with CPX parameters, grip strength and quadriceps strength before HIIT, all parameters including peak oxygen uptake, VE versus VCO2 slope, peak load, grip strength and quadriceps strength, have improved after 8 weeks HIIT. Echocardiogram before discharge showed 25% of LVEF, and BNP before discharge was 84 pg/mL without worsening LVEF. After 17 weeks of implantation, he was discharged safely on his foot.

**Discussion**

To our knowledge, this is the first case report about HIIT for a patient with LVAD. The case suggested that HIIT might be safe and feasible for severely deconditioned patients with LVAD, and HIIT might improve exercise capacity in patients with LVAD. Generally, patients with heart failure depending on inotropic agent are presented with skeletal muscle deconditioning and poor exercise capacity. Also, exercise capacity is usually still poor after LVAD implantation. Kugler previously reported that predicted value of peak oxygen consumption adjusted by age, gender, and BMI was only 60% at 6 months after LVAD implantation. Therefore, it is important for LVAD patient to improve their exercise capacity. While a basic aerobic training composed of 30-60 minutes of moderate-intensity continuous training, HIIT has intermittent low load parts as shown in Figure 2. It is usually difficult for LVAD patients to continue moderate continuous exercise training based on AT, whereas it may be feasible for LVAD patients with low exercise capacity to continue HIIT, which is composed of intermittent low load part to recover from leg fatigue.

Earlier literatures including meta-analysis showed that HIIT improved peak oxygen uptake in patients with cardiovascular disease. Wisloff, et al. reported that improvement of peak oxygen uptake was greater in HIIT as compared with moderate aerobic training in patients with heart failure after myocardial infarction. The improvement of peak oxygen uptake following HIIT was also observed in the present case. In moderate aerobic exercise, the rate of complication (the number of patient-exercise hours) was 1 nonfatal and 1 fatal cardiovascular complication per 34,673 and 116,402 hours, respectively. In HIIT, the rate of complication was 1 nonfatal per 23,182 hours, which were in line with the rate of complication that was previously reported in moderate exercise training.

In summary, HIIT may be useful and safe even for severely deconditioned LVAD patients in order to improve peak oxygen consumption effectively. We need further investigation on HIIT for deconditioned patients with implantable LVAD.

**Disclosures**

**Conflicts of interest:** None.

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