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Case Report

Intensive Cardiopulmonary Rehabilitation Program for Patients with Severe Heart Failure and Acute Stroke: A Report of Two Cases

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Cardiovascular disease is a major factor restricting successful outcomes after stroke rehabilitation. While neurological recovery after stroke has been extensively investigated, cardiovascular adaptations to physical activities poststroke have received little attention. Severe heart failure patients have been well known for limitation of ambulation, but the influence over acute poststroke patients have rarely been investigated. Exercise testing has become a mainstay for the prognostic assessment of patients with heart failure. Various studies have shown that patients with impaired exercise capacity, as measured by low peak oxygen consumption ($V_{o2}$), have an unfavorable outcome, independent of other parameters. Whether parameters from submaximal test have prognostic value have recently been studied. Exercise capacity early after stroke has been known, but what has not been documented is exercise capacity during early poststroke with severe heart failure and the effect of exercise training on those patients. We present two cases of acute poststroke with New York Heart Association (NYHA) Class III heart failure and illustrate how the cardiopulmonary rehabilitation program has helped. Such treatment for this case supports the view that intensive exercise training should be established for acute poststroke with severe heart failure patients, although their comorbidity may be higher than that of stable poststroke patients. (Tw J Phys Med Rehabil 2007; 35(1): 33 - 40)

Key words: heart failure, stroke, cardiopulmonary rehabilitation

INTRODUCTION

It is well established that old age and severe impairment after stroke predict poor outcome, and the negative impact of heart failure on late mortality is well documented. Prestroke heart failure is associated with more severe strokes. The reason that heart failure is associated with more severe strokes remains unclear, although it may predispose to cardiac embolism, which gives rise to larger infarcts. During early poststroke period, physical rehabilitation usually takes place and the potential for functional improvement is maximized. However, cardiovascular and neuromuscular impairment, together with...
physical inactivity resulting from stroke, decrease adversely exercise capacity, which has detrimental effects on functional mobility and resistance to fatigue from rehabilitation training. Exercise testing during this period is thus critical to inform the clinician of the need for, and safe design of, cardiovascular exercise prescription. Unique features of acute poststroke with severe heart failure have not been well known, especially the exercise testing results and the training effect. The exercise testing mode including maximal, submaximal, and endurance tests has been used in congestive heart failure (CHF) patients, but we don’t select endurance tests for these patients in this paper. The preferred mode of measuring maximal oxygen consumption (VO2max), the definitive index of exercise capacity, is the treadmill. The potential to recruit sufficient muscle mass to elicit a maximal metabolic response is much more likely to be realized while walking than cycling, particularly in deconditioning populations. Therefore, this study aimed to evaluate the effect of intensive aerobic exercise training in acute poststroke patients with severe heart failure.

**CASES AND REHABILITATION PROGRAM**

Case I: A 59-year-old woman was known to have CHF, functional class (Fc) III for several years under regular medicine control. Unfortunately, left Middle Cerebral Artery (MCA) infarction with right hemiparesis was noted 3 months ago. Beside traditional rehabilitation training program, we performed graded exercise treadmill test (GXTT). A complete cardiopulmonary exercise training was emphasized according to the objective data. At the same time, blood lactate and lipid profiles were checked at resting and blood lactic acid was checked again at the time of maximal effort. After 12 weeks of training, She underwent GXTT and strength test again and all lab data were rechecked similar to those 12 weeks ago.

Case II: A 76-year-old men was known to have CHF, Fc III for 3 years under regular follow-up and treatment at our hospital. Right basal gangion lacunar infarction with left hemiparesis was noted for 4 months. Because of poor dynamic balance control when walking on treadmill, suspension with 15% body weight was given when undergoing GXTT and during training period. He received the same study protocol as that of Case I (Table 1).

These two patients had the ability to walk independently on the floor for 9 m without using a walker or cane. The entry evaluation included a resting electrocardiogram, resting pulmonary function test, medical history, and physical examination. They then underwent a graded exercise testing with open-circuit spirometry. They were both provided informed consent of the study. Exclusion criteria including peripheral arterial disease with claudication, cancer, pulmonary or renal failure, unstable angina, uncontrol hypertension (>190/110 mmHg), moderate smoking (>1 pack/d), dementia, and aphasia were not found in these two patients. Functional ability was measured using the Barthe activities of daily living (ADL) scale, which is empirically based but has been validated and used in other studies on stroke.

Three days before exercise testing, each subject visited the exercise testing laboratory for orientation to weight-supported treadmill walking. The subject practiced breathing through a open-circuit mask which covers the nose and mouth tightly. Gas exchange was assessed breath by breath, calibrated before each test (Metamax 3B, Germany). These two patients walked on the treadmill at a set speed and grade progressed with or without 15% of body weight vertically displaced through the overhead support.

In preparation for the exercise test, subjects were requested to avoid food and smoking for at least 2 hours, to refrain from drinking caffeinated beverages for at least 6 hours, and to avoid heavy exertion or exercise for 12 hours. Medication schedules were not altered.

At first, the 6-minute walk, a submaximal treadmill exercise test was performed, in which patients were asked to walk as far as they can during a 6-minute period. Butland and coworkers recently demonstrated that a 6-minute walk, which has the advantages of being efficient and less stressful for the patient and corresponding more closely to the usual day-to-day activity of moderately or severely limited patients.

After one day, peak exercise capacity (VO2peak) was measured. The testing protocol for these two patients was the same. Initially, they walked at 0.5 mph, 0% incline followed by 1 mph, 0% incline, and with 1% incline increments adjusted every two minutes. The exercise
testing was terminated according to ACSM guidelines.\textsuperscript{[4]} The reason of termination for Case I was three continuous ventricular premature contractions (VPCs), and Case II was volitional fatigue. Criteria for attainment of VO$_2$-max included: (1) increase in VO$_2$ of less than 150mL in the final minute of exercise- a VO$_2$ plateau. (2) peak respiratory exchange ratio (RER) above 1.1. (3) peak systolic blood pressure (SBP) greater than 200mmHg, and (4) peak heart rate within 15 beats per minute of predicted maximal heart rate.\textsuperscript{[6]} Immediately after exercise testing and before, blood samples of patients were collected for blood lactic acid determination. In addition, the blood samples were also used to determine serum lipid profiles, including total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) concentration.

After baseline testing, all subjects participated in a 12–week supervised aerobic exercise program with three visits each week (total of 36 visits) for 1 hour. For the endurance activities, exercise intensity was maintained at 40-49% heart rate reserve (HRreserve) or a rating of perceived exertion 11 to 13 during treadmill walking at the first month, then progressing to the higher intensity of 50-80% HRreserve.\textsuperscript{[7]} Each training session included 5-minute warm-up and cool-down periods at approximately 30% HRreserve. Handrail support was provided during training periods. All exercise training was conducted under the direction and supervision of a physician and a physical therapist.

After exercise training, we found that VO$_2$peak, 6-minute walking test (6WT) distance, Barthel index, peak exercise HR, peak exercise lactic acid level, HDL level, and anaerobic threshold (AT) all increased. On the other hand, the total cholesterol level, LDL level, resting lactic acid level, TG level, resting HR, and resting SBP all decreased. Peak exercise SBP and respiratory exchange ratio showed no difference (Table 2).

There was no fatal response during exercise training, although the subjects occasionally stopped the training owing to personal reason or following the advice of the supervisor.

### DISCUSSION

Cardiac disease reduces the long-term survival of stroke patients and increases the likelihood of intercurrent medical illness during the rehabilitation phase. It remains controversial whether heart disease affects negatively functional capabilities after stroke, but most studies agree that associated cardiac disease, especially congestive heart failure, affects adversely functional outcomes after stroke rehabilitation.\textsuperscript{[8]}

Cardiac disease is a major factor for stroke, ranking third following age and hypertension. Atrial fibrillation is the most frequent cardiac disorder associated with stroke, carrying a fourfold relative risk. Congestive cardiac failure ranks second in cardiogenic stroke risk, with a twofold to threefold relative risk.\textsuperscript{[9]} Congestive heart failure is a clinical syndrome characterized by varying degree of dyspnea, abnormal fluid accumulation, and fatigue. Traditionally, classification following the severity of functional impairment caused by heart failure in

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clinical studies is the New York Heart Association (NYHA) classification. NYHA class 4 refers to heart failure symptoms at rest, class 3 patients have symptoms on mild exertion, class 2 implies that symptoms arise with moderate effort, and class I refers to patients being asymptomatic except at extremes of effort. Peripheral vasoconstriction often develops to a degree which requires compensating for the fall in cardiac output and maintaining the blood pressure. Furthermore, the reduced stroke volume creates a condition of relative stasis within the left ventricle that may activate coagulation processes and increase the risk of thromboembolic events.

Historically, excessive muscle fatigue and shortness of breath were felt as a result of inadequate perfusion of skeletal muscle and end organs due to impaired cardiac output. Recent studies have revealed intrinsic changes in skeletal muscle fibers which may be responsible for impaired metabolism and result in early muscle fatigue. These changes include reduced mitochondrial density, reduction in lipolytic oxidative enzymes, and fiber atrophy. In addition to these intrinsic changes, underperfusion secondary to impaired regional blood flow in CHF may be a contributing factor. At a previous animal study, regional underperfusion, especially at brain area, was discussed. Underperfusion over brain stem area and parietal region at CHF (pig) which influences motor control and heart rate response to exercise could be fatal. We should be careful because our patients had stroke with CHF, if regional underperfusion happened in human being, the result of intensive exercise training could be fatal.

Several excellent papers provide an overview of the published trials evaluating exercise training in patients with heart failure. Patients with CHF have made significant improvements during rehabilitation. Congestive heart failure is not a reason to deny rehabilitation services, but only serves as a marker for the clinician to use extra caution and care. Review of these trials shows encouraging results, but also serious methodological limitations. Recognition of the presence and potential impact of concomitant cardiac disease in disabled stroke patients is particularly important because physical activities exert extra energy demand on the heart in hemiplegic patients.
compared with able-bodied subjects. Energy expenditure during hemiplegic gait varies with degree of weakness, spasticity, and bracing, but in general, the oxygen rate (ie, energy consumption per minute) is comparable to that in normals, whereas the oxygen cost (ie, energy consumption per meter) is greatly elevated in hemiplegic patients from 0.15 to 0.54 ml/kg-m.\[8\]

Exercise training decreases dramatically central sympathetic nerve outflow measured directly. All pharmacologic therapies with beneficial effects on the neurohumoral system in patients with CHF have also been shown to reduce mortality.\[13\] Therefore, it may be one of the reasons why resting heart rate decreases after exercise training. Increasing evidence suggests that aerobic exercise training using a variety of modalities can improve cardiovascular fitness in chronic hemiparetic stroke patients. In a controlled study, Potempa et al.\[14\] demonstrated a 14% improvement in maximal VO2 among young stroke patients after a bicycle training program. Beside improving aerobic ability, treadmill training in chronic stroke patient’s increases quadriceps strength, decreases hamstring spasticity, and improves ambulatory and dynamic balance performance. Thus, there is a strong rationale for using treadmill training in older hemiparetic stroke patients, given that it improves mobility and facilitates locomotor learning.\[14\]

These two patients accepted both exercise test, the six-minute walk test and graded-exercise treadmill maximal test. They also rechecked ejection fraction. No adverse events occurred during or after symptom-limit maximal graded-exercise treadmill test. Case II reported that the body-weight support vest was comfortable and reduced anxiety due to fear of falling. Marilyn et al. devised a treadmill exercise protocol using partial body-weight suspension that would permit testing earlier poststroke patients that would otherwise be infeasible. They found that using 15% body-weight support did not affect the endpoints of the principal respiratory gas exchange variables of the exercise test, and thus did not confound interpretation of VO2max data.\[15\] Both subjects do not attain the minimum criteria for VO2max at first, reinforcing the notion that attaining VO2max in deconditioned and elderly subjects is often an unrealistic goal.\[2\] Our individualized protocol of incremental increases in treadmill grade, followed by incremental in speed to 1 MPH, was well tolerated by the subjects. We did not encounter adverse incidents during testing, in contrast to previous speculation that cardio-respiratory response such as hypotension and cardiac dysrhythmia might occur during exercise testing of patients less than 6 months poststroke. Continuous electrocardiogram monitoring and frequent blood pressure monitoring in our protocol reduced the possibility of these untoward events. The use of body-weight support mitigated against the possibility of falls during treadmill.

A previous study had shown that peak treadmill testing is highly reproducible in older chronic hemiparetic stroke patients,\[14\] but there were no evidence in post-stroke period for only three or four months. The mechanisms underlying the reduction in exercise capacity poststroke with CHF cannot be ascertained from previous report and this study. The observation that VO2peak values of the subjects in our study are lower than poststroke patients without CHF and only heart failure diseases reported before.\[5,11\] A previous investigation\[5\] of the effect of cardiac involvement on response to submaximal exercise poststroke reported evidence of greater use of anaerobic processes during exercise in patients with cardiac comorbidity.

However, only 9% patients of this study achieved a true VO2max with RER greater than 1.1 and reached the age-predicted HRmax.\[14\] Both of our patients failed to meet the criteria for attainment of VO2max which included: (1) increase in VO2 of less than 150mL in the final minute of exercise- a VO2 plateau, (2) peak RER above 1.1, (3) peak SBR greater than 200mmHg, and (4) HRpeak within 15 beats per minute of predicted maximal heart rate\[7\] at the first test before training except having RER>1.1. After 3 months of training, both patients still could not satisfy all criteria but RER >1.1 and increase in VO2 of less than 150mL in the final minute of exercise- a VO2 plateau were achieved. Medications, like ß-blocker used, cause HRmax to be lower than the predicted value. Peak VO2 might be underestimated because of reduced patient’s motivation as well as premature termination of exercise by the examiner. A peak VO2 of 14mL/kg/min is a widely used cutoff point to separate survivors from nonsurvivors, and is therefore commonly used to help select patients for transplantation.\[16\] However, for our patients with combined CHF and stroke, the criteria should be modified because VO2
was influenced much by stroke.

The anaerobic threshold measures the sustainable oxygen uptake and is an objective parameter of cardiopulmonary exercise capacity that can be derived from submaximal exercise testing and is therefore independent of the influences described above. However, there are no data showing its prognostic value in CHF.[17] The other submaximal test, the 6 WT, has not been shown to correlate closely with maximal test, but appears to be a better indicator of functional capacity with regard to activities of daily living. It has been repeatedly shown throughout the literature that ejection fraction is not a reliable predictor of functional capacity or survival.[11] Rather, exercise capacity is the result of complex physiological interactions which elude measurement by any single resting parameter.[18]

Respiratory function after hemispheric stroke is often only modestly affected, notwithstanding the relatively high occurrence of acute respiratory complications, but there was no enough evidence among those poststroke combined CHF patients. Thus, although the peak-minute ventilation and tidal volume of these two patients were substantially lower than normative values, it is unlikely that respiratory dysfunction was a primary factor limiting exercise capacity. The contribution of neurologic impairment to decreased exercise capacity is attributed to a reduction in motor unit recruitment during physical work, the extent of which depends on the location and severity of the cerebrovascular lesion. In previous study,[5] a significant relationship between VO2max and Barthel Index was noted, the latter indirectly reflecting the level of neuromuscular involvement. In a previous study,[19] the severely disabled stroke patients (Barthel Index ≤ 40) showed a considerable improvement over the first 3 months (p<0.001) and continuing (but statistically non-significant) improvement up to 6 months. The moderately disabled (Barthel Index 41-60) improved over the first 3 months (p<0.001) as did the mildly disabled (Barthel Index>61, p<0.001), but neither showed further improvement after 3 months. However, in our studies, the two moderately disabled patients (Barthel Index 41-60) could improve their overall function after stroke for 3 months combined with increase in VO2peak.

A specific program design which will be best fit the heart failure patients with regard to the modality and intensity is yet unknown. Braith and Mills recommend screening of patient with ejection fraction of less than 30% for ischemia prior to implementing a training program. Further recommendations suggest that patients can exercise at 60-80% of their maximal heart rate or 50-70% VO2max if stable during the exercise test.[18] Home walking programs are often desirable for these patients, and can be encouraged with little concern regarding adverse events. Our patients not only had CHF, but also had stroke history. We prescribed exercise training with intensity maintained at 40-49% HRate or a rating of perceived exertion 11 to 13 during treadmill walking at the first months progressing to the higher intensity of 50-80% HRate later. The intensity and training mode had been shown to fit these two patients.

Lower blood cholesterol concentration have consistently been found to be strongly associated with lower risk of coronary disease but not with lower risk of stroke. Little association has been found in observational studies between blood total cholesterol concentration and the risk of any type of stroke, but there does appear to be a positive association with ischemic stroke risk (particularly at younger age). It has been suggested, however, that this might be counterbalanced by a weak negative association with hemorrhagic stroke risk (perhaps especially among people with higher blood pressure).[20] These two cases with decreased total cholesterol level and elevated HDL concentration indicate that intensive exercise training may safely produce substantial benefits among high-risk individuals in population (such as poststroke combined CHF) where the risks of ischemic stroke are relatively high.

Although the impact of coexistent heart disease on outcome after stroke rehabilitation remains controversial,[8] our studies showed significant improvement without adverse events. We need more data to confirm
our findings and eventually establish a standard rehabilitation protocol among those poststroke patients with previous CHF.

**DISCUSSION**

In this first investigation of intensive exercise training for post-stroke patients with CHF, we have found that cardiovascular adaptations to strenuous physical exercise were limited. However, we found that this training program was safe and beneficial. Although the extent to which this exercise protocol being applied during rehabilitation remains something unanswered, worthy of further investigation, we concluded that intensive exercise training for post-stroke patients with CHF is necessary and helpful.

**REFERENCES**

心臟血管疾病是造成中風後復健成果受限的一個主要原因。雖然中風後神經機能的恢復已被廣泛研究，但心臟血管機能如何因應中風後生理活動改變作調整，則很少受到注意。已知的是嚴重心臟衰竭病人行動能力受限，但尚無研究顯示在中風後早期這類病人會受何影響。運動測試是目前評估心臟衰竭病人預後的主流；各式研究已顯示病患以最高攝氧率來表示的運動能力較差者無論其他測試指標如何，都無很好預後。近來，已有幾研究在探討次大量運動測試檢查是否也有評估預後的價值。中風後早期的運動能力已被了解，但中風早期又合併有嚴重心臟衰竭的病人，其運動能力及接受運動訓練後的效果仍不清楚。雖然這類病患併發症發生的機會可能比一般穩定中風病人高，我們在此提出兩者合併有 New York Heart Association (NYHA) Class III 心臟衰竭的病例，如何在中風後早期經由心肺復健計劃獲得助益；由此治療計劃來驗證嚴重心臟衰竭病患於中風後早期接受積極運動訓練的觀點。（台灣復健醫誌 2007; 35(1): 33 - 40）

關鍵詞：心臟衰竭(heart failure)，中風(stroke)，心肺復健(cardiopulmonary rehabilitation)