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Original Article

Therapeutic efficacy of intensified walk training under the electrocardiogram telemetry in stroke induced lower limb dysfunction patients with heart failure

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Abstract: Objectives: This study aimed to explore the therapeutic efficacy of intensified walk training under the electrocardiogram (ECG) telemetry in stroke induced lower limb dysfunction patients with heart failure. Material and Methods: A total of 40 patients with stroke induced lower limb dysfunction and heart failure were randomized into control group and walk training group (n=20 per group). Besides comprehensive rehabilitation, patients in walk training group received intensified walk training under the ECG telemetry and patients in control group received traditional training. After 5-week treatment, the FMA score of lower limbs, ADL score, 6-min walking distance and left ventricular ejection fraction (EF) by heart ultrasonography were determined. Results: There were no marked differences in the demographics between two groups at baseline, and no severe complications were observed during training in the walk training group. In control group, 6 patients developed lung edema which required further therapy. After 5-week training, the FMA score of lower limbs, ADL score and 6-min walk distance were improved to different extents, but the improvement was more obvious in walk training group ($P<0.05$). The left ventricular EF remained unchanged in both groups. Conclusions: In patients with stroke induced lower limb dysfunction and heart failure, routine rehabilitation in combination with additional walk training under the ECG telemetry is helpful to increase the training efficiency and training intensity and improve the low limb function and walk distance when the safety is assured.

Keywords: Stroke, heart failure, exercise, electrocardiogram telemetry

Introduction

Stroke has high morbidity, high disability and high recurrence rate and has been one of major diseases causing death and disability in China. About 75% of stroke survivors may develop disability of different severities, which significantly influences the daily life and quality of life and increase the economic burden [1]. A large amount of studies have confirmed that rehabilitation is an effective strategy to increase the daily activities and quality of life and return the patients to the society [2]. Walking disorder has a significant influence on the activities of daily life (ADL) of stroke patients and also markedly affects the quality of life. Thus, to promptly recover and improve the walking ability is one of major goals of therapy for the majority of stroke patients, and to achieve the walking ability again has been a widely accepted goal in the therapy of stoke [3]. However, heart disease is a major complication of stroke, and especially coronary atherosclerotic heart disease shares some risk factors with stroke. Moreover, being bedridden due to stroke may cause severe cardiovascular dysfunction and frequently result in adverse cardiac events during rehabilitation, which may significantly compromise the efficacy of rehabilitation [4]. In early stage of stroke, it is crucial to assure the safety and efficiency of training, especially for patients with heart failure. In the present study, patients received intensified walk training and were simultaneously monitored by dynamic electrocardiogram (ECG) telemetry during training. Herein, we reported our findings as follows.

Table 1. Characteristics of patients recruited at baseline

Variables	Walk training group (n=20)	Control group (n=20)	P
Age (yr)	62.19±11.08	56.44±12.19	>0.05
Days after stroke	35.14±18.77	40.70±16.78	>0.05
BMI (Kg/m^2)	23.39±2.53	24.17±2.76	>0.05
Female (%)	8 (40%)	7 (35%)	>0.05
Cerebral hemorrhage (%)	5 (25%)	6 (30%)	>0.05
Cerebral infarction (%)	15 (75%)	14 (70%)	>0.05
Hypertension (%)	14 (70%)	15 (75%)	>0.05
Coronary heart disease (%)	15 (75%)	13 (65%)	>0.05

Material and methods

Patients

Hospitalized patients who received rehabilitation therapy due to stroke and had complete medical record were recruited from our hospital between January 2013 and February 2014. Stroke was diagnosed according to the diagnostic criteria developed in the Forth National Cerebrovascular Disease Conference [5], and cranial CT or MRI confirmed the first onset of stroke. Inclusion criteria included (1) patients developed stroke 15-90 days ago and had a stable disease condition; (2) chronic heart failure was diagnosed according to the diagnostic criteria of WHO and China, Grade II/III (NYHA) heart failure was present, and left ventricular ejection fraction (LVEF) was ≥35%; (3) the affected lower limb was scored ≥ Brunnstrom stage III, lower extremity muscle strength was scored ≥ grade III, and the strength of iliopsoas, quadriceps and biceps femoris was scored ≥ grade III; (4) patients could stand and walk 16 m with the help of one caregiver; (5) patients were aged 35-75 years; (6) patients were willing to participate in this study, and informed consent was obtained from patients or their relatives. Exclusion criteria: (1) patients had severe cognition disorder; (2) patients had logagnosia or disturbance of understanding; (3) patients had severe pulmonary insufficiency; (4) patients had acute coronary syndrome and malignant arrhythmias; (5) patients had severe liver and kidney failure or acute attack of other systemic diseases; (6) patients were unable to cooperate with training.

All the patients recruited into present study were randomly assigned into 2 groups: control group and walk training group (n=20 per group) (**Table 1**).

Methods

Common treatments of patients recruited [6]: 1. Routine managements for chronic heart failure and secondary prevention of stroke were performed (such as pressure-lowering therapy, lipid-lowering therapy, glucose-controlling therapy and anti-platelet therapy, excise, smoking abstinence and alcohol restriction and rational diet). Etiological therapy and cardiac function modulating therapy (β-blockers, digoxin, angiotensin converting enzyme inhibitors and diuretics) were employed to stabilize the cardiac function. 2. Routine rehabilitation: measurements such as Bobath, Brunnstrom, Rood and motor relearning were employed for nerve facilitation. (I) training of placing the intact limbs (anticonvulsant position) and position conversion (turn the body over); (2) passive and active training on the bed; (3) bridge-like movement; (4) standing/sitting and sitting balance training; (5) training of gravity center shifting at sitting; (6) sitting/standing shifting training; (7) sitting balance, side walking, cross step walking and stair activity; (8) occupational therapy. Different techniques and exercise methods were used on the basis of the disease condition, and training was done once daily. 3. Training was not allowed in a fasting status, or after a heavy meal, aiming to avoid gastrointestinal discomfort and Hypoglycemia. The safety and thermal protection should be emphasized during training; 4. Treatment continued for 5 weeks, 5-6 days per week.

Walk training group: Intensified rehabilitation therapy was performed. During the above training, patients received ECG telemetry (Hailiying TE-4000Y wireless multi-parameter dynamic monitoring system, Beijing Hailiying Medical Technology Co., Ltd.), and training intensity and time should be guaranteed. When the mild to moderate symptoms of discomfort were unable to determine the training discontinuation, physicians should encourage patients to continue until the training completes. During the walk training, the training intensity increased gradually according to the physical capacity and lower extremity muscle strength (the walk intensity and frequency increased gradually, the longest distance of tolerance was 2-3 km [3000-5000 steps] and the accumulative time of training was 40-60 min). Conditions for train-

Table 2. Rehabilitation completed in two groups

	Training performed	Training completed	Proportion
Walk training group (n=20)	5261	4752	90.33%*
Control group (n=20)	4728	3561	75.32%

Footnotes: *P<0.001 vs. control group.

ing discontinuation: (1) The discomfort symptoms were obvious (chest tightness, shortness of breath, chest pain, dizziness, nausea and palpitations), or syncope was present. (2) Systolic blood pressure was ≥180 mmHg or ≤90 mmHg, or reduced by ≥20 mmHg as compared to that at rest; diastolic blood pressure was ≥110 mmHg or ≤60 mmHg, or reduced by ≥10 mmHg as compared to that at rest. (3) The heart rate increased or decreased by 30% as compared to that in a supine position; (4) Malignant arrhythmias or evident ST-T change were observed. Once above conditions were present, training should be stopped immediately, and patients lied in a supine position. Liquid supplement and symptomatic therapy were administered, and further managements were performed according to the disease condition.

Control group: Above measures were taken for rehabilitation. During the training, the patients were closely monitored (such as consciousness, facial expression and discomfort symptoms [chest tightness, shortness of breath, chest pain, dizziness, nausea and palpitations]). Once evident symptoms above were present, training should be stopped immediately and measures were taken for the management of the discomfort.

Evaluation and data collection

Fugl-Meyer Assessment (FMA) was employed to evaluate the function of lower limbs: Reflex activity (supine), flexor synergy (supine), extensor synergy (supine), movement combining synergies (sitting), movement out of synergy (standing), normal reflexes (sitting), coordination/speed (sitting), and the total score was 34.

6-min walk test: The 6-min walk test was conducted 2 h after a meal. A 100-m straight line was marked on the floor, and a chair was placed at both ends. Before test, patients were informed the significance and cautions of this test and allowed to accommodate to the surrounding environment. After resting for 15 min, patients were asked to walk back and forth along the line and the walk speed was determined according to patients' physical ability. Patients were encouraged to walk within 6 min. Restricted movement was employed: walk was stopped and patients should rest once angina, dyspnea, dizziness or muscle ache was present. When the physical ability did not allow further walking, patients should rest or the test was transiently discontinued. Finally, the total walk distance was calculated as meters.

LVEF: The heart was examined by an experienced physician by using Color Doppler Ultrasound, and the LVEF was recorded.

Before recruitment and 5 weeks after therapy, FMA and modified Barthel index of lower limbs were used to evaluate the function of lower limbs and the daily activities. The 6-min walk distance and LVEF were employed to evaluate the walk ability and cardiac function. Evaluation was initiated one day before therapy and the last evaluation was done at 1 day after therapy. All the evaluations of these patients were done by a trained and experienced rehabilitation physician who was not involved in the rehabilitation therapy and also blind to the grouping. Scores and walk distance were recorded in detail.

Statistical analysis

Data were input after quality assessment, and statistical analysis was done with SPSS version 19.0. Enumeration data were expressed as percentage, and measurement data as means plus standard deviation. Enumeration data analyses were performed by chi square test, and measurement data by test or paired t test. A two-tailed P<0.05 was considered statistically significant.

Results

Completion of rehabilitation therapy

During the 5-week rehabilitation therapy, 90.33% of patients completed the training, and this proportion was significantly higher than that in control group (75.32%) (**Table 2**). During the training, severe symptoms such as syncope, pulmonary edema and shock were not

Table 3. Comparison of FMA score of lower limbs and ADL score before and after training

	FMA score of lower limbs		ADL score	
	Before	After	Before	After
Walk training group (n=20)	12.38±3.42	28.24±3.12[a,b]	36.71±8.42	79.24±14.80[a,b]
Control group (n=20)	12.44±3.14	20.60±2.37[a]	35.88±9.05	57.05±13.03[a]

Footnotes: [a]P<0.05 vs. before training; [b]P<0.05 vs. control group.

Table 4. LVEF and 6-min walk distance before and after training

	LVEF (%)		6-min walk distance (m)	
	Before	After	Before	After
Walk training group (n=20)	45.38±5.42	52.24±6.12	213.7±109.2	454.24±128.8[a,b]
Control group (n=20)	46.44±6.14	50.60±7.37	228.8±116.0	367.05±145.3[a]

Footnotes: [a]P<0.05 vs. before training; [b]P<0.05 vs. control group.

observed in walk training group. In addition, 509 person-time training was stopped: 384 person-time training (75.44%) was stopped due to abnormality in blood pressure and/or ECG, and 125 training (24.56%) was stopped due to intolerable symptoms. In control group, 1167 person-time training was stopped due to intolerable symptoms, and 6 patients required emergent therapy due to lung edema.

FMA score of lower limbs and ADL score before and after training

After 5-week training, paired t test showed the FMA score of lower limbs and ADL score were improved to different extents, but the improvement was more obvious in walk training group as compared to control group (P<0.05) (**Table 3**).

LVEF and 6-min walk distance before and after training

After 5-week training, paired t test showed the 6-min walk distance improved, but the improvement was more obvious in walk training group as compared to control group (P<0.05). However, LVEF remained unchanged after training, and the LVEF was comparable between two groups (**Table 4**).

Discussion

Stroke has been a common disease with high morbidity. Moreover, stroke patients are becoming younger with the elevation of living standard. In the determination of a goal for rehabilitation, to improve the living skills is of great importance, of which walk ability is a basic one. After stroke, to recover the walk ability is a preferred goal for 85% of patients and also the most urgent need and desire for hemiplegia patients. The theoretical basis of rehabilitation is the brain plasticity, and repeated training is able to improve the neurological function [6]. Our study also confirmed that nerve facilitation techniques (such as Bobath, Brunnstrom, Rood and motor relearning) for motor training were helpful to improve the function of lower limbs of a majority of stroke patients. Cardiovascular and cerebrovascular diseases have been major causes of death and disability in humans, and they share pathogenic factors. Some patients may be even affected by both cardiovascular and cerebrovascular diseases which may interact with each other. Meta-analysis have shown adaptive training after stroke (especially the treadmill walking training, Spa training and family intervention) is beneficial for stroke patients [4]. Another meta-analysis supports that post-stroke adaptive training may increase the workload, walk speed and walk distance [7]. However, there is no sufficient evidence supporting the increase in aerobic metabolism after training. Walking in the community usually fails to increase the cardiovascular adaptability. It has been reported that training according to the American College of Sports Medicine Guideline may not increase or reduce the attack of heart diseases [8]. Nevertheless, for stroke patients with chronic heart failure, there is still controversy on the side effects of rehabilitation at routine intensity, and the training safety is more dependent on the pre-training evaluation and the monitoring of physicians during training.

Of note, rehabilitation is actually a physical activity in the laboratory condition. The heart failure patients are susceptible to dyspnea, tachycardia or even acute heart failure [9]. Thus, during the training, physicians should emphasize the safety, and training should be stopped once side effects are observed. In the training, physicians usually monitor the symptoms to determine whether training continues. However, this may cause following consequences: some subjective symptoms of patients may cause the training discontinuation, which may affect the therapeutic efficacy; patients have no discomfort at the beginning, but may develop severe complications such as acute heart failure and shock during training; the complications (such as malignant arrhythmia, bradycardia and even cardiac arrest) without evident symptoms and signs might be difficult to identify; several patients might fail to accurately depict or complain of discomforts during training. To balance the safety and efficacy of training, ECG telemetry was performed to monitor the training, and the parameters (such as ECG and blood pressure) were dynamically monitored and used as objective evidence for determining whether training continued. This significantly improves the training safety. In the ECG telemetry, electrocardiosignals from several ECG monitors are transmitted into a control panel and then transformed into visualized signals for further processing [10]. Thus, a physician may simultaneously monitor the disease conditions of several patients, which assures to promptly make judgment and take correct managements, significantly increases the efficiency of monitoring and is crucial to reduce mortality and assure the medical quality. Our results showed no severe adverse effects in walk training group as compared to control group and more patients in walk training group completed the training. Thus, training discontinuation was observed in only a few patients, and more patients received intensified training. These suggest that training under the monitoring by ECG telemetry may assure the training safety and also significantly improve the training efficiency. The advantages of ECG telemetry are as follows: (1) it provides objective parameters of disease condition for patients unable to correctly express; (2) it effectively reduces the negative emotions, increase the confidence of patients for rehabilitation and elevate the compliance to the training; (3) it significantly reduces the incidence of training discontinuation due to subjective symptoms; (4) physicians can promptly and accurately recognize different arrhythmias and change in blood pressure, which provides evidence for stopping training and subsequently planning for training; (5) the monitor is easy to ware and may not affect the excise and training, and one physician may simultaneously monitor several patients, suggesting high efficiency and favorable feasibility.

The effectiveness of rehabilitation has been confirmed for motor dysfunction in stroke patients [6]. However, whether intensified walk training is safe and has influence on the lower limb function, ADL and cardiac function are still unclear in stroke patients with heart failure. Studies on cardiac rehabilitation have confirmed that intermittent training may increase the tolerance of patients with heart failure to excise at a high intensity [11]. Some investigators propose that training may improve the cardiac contractility, which is characterized by reductions in heart rate and myocardial oxygen consumption and increase in cardiac functional reserve [12]. There is evidence showing that, after 4-week treadmill training, the vascular endothelial function is improved significantly in patients with chronic heart failure, suggesting that training of local muscles may affect the function of systemic endothelial cells [13]. Our study also found that, besides pharmacotherapy and routine rehabilitation, intensified walk training under the ECG telemetry for 5 weeks could markedly improve the lower limb function, ADL and 6-min walk distance as compared to control group. The improvement of ADL is close to that of lower limb function, but may not exclude the contribution of cardiac function improvement. 6-min walk test is one of tools used to evaluate the cardiac function and may be objectively assess the cardiac function. However, the lower limb function may influence the 6-min walk distance to a certain extent. 6-min walk distance is important for not only the evaluation of cardiac function, but the assessment of recovery of motor function [14]. Nevertheless, we failed to determine the specific contribution of each parameter (lower limb function and cardiac function) to the improvement of ADL and 6-min walk distance due to some limitations (such as small sample size and limited time of study). Of course, there are other objective parameters (such as EF, cardiac output, maximal oxygen uptake and BNP) used for the evaluation of cardiac function [15]. In the present study, LVEF was used as a parameter for the evaluation of cardiac function due to several limitations. Our results showed LVEF remained unchanged after 5-week training although the mean LVEF slightly increased in both groups. Of note, the sample size was small, the time of study was also limited, and LVEF has limited sensitivity to the change in cardiac function. Thus, we could not conclude the influence of training on the cardiac function. In our future studies, more patients will be recruited, the time of study will prolonged, and more parameters will be employed for the monitoring of cardiac function.

Our findings suggest that rehabilitation and intensified walk training under ECG telemetry for 5 weeks in heart failure patients with lower limb dysfunction is able to assure the training safety and significantly increase the intensity and efficiency of training, and improve the lower limb function, ADL and 6-min walk distance as compared to control group. We currently ascribe the therapeutic effectiveness to the comprehensive effect of rehabilitation and intensified walk training due to small sample size in this study. Whether the effectiveness is mainly attributed to the increased times of rehabilitation or to the intensified walk training, which type of training is more effective to improve the lower limb function/cardiac function, or which type of training is ineffective for the improvement of lower limb function/cardiac function are still poorly understood and required to be further studied.

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Disclosure of conflict of interest

None.

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