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Clinical Treatment of Orthostatic Hypotension after Spinal Cord Injury with Standing Training Coupled with a Remote Monitoring System

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Background: The treatment for orthostatic hypotension (OH) after spinal cord injury (SCI) is an important part of rehabilitation in late-stage SCI. Electric uprise bed training is a relatively commonly used method in treating OH, and how to carry out uprise bed training safely and effectively is an urgent problem. In the early stage of SCI, we used a remote monitoring system to monitor the whole process of uprise bed training, and we explored a safe and efficient method of electric uprise bed training.

Material/Methods: The experimental group consisted of 36 patients diagnosed with orthostatic hypotension (OH) after SCI and who received training with an electric uprise bed coupled with remote monitoring system, and the control group of 18 subjects who used a traditional training method.

Results: There were no differences in baseline data between the 2 groups. There were no severe symptoms during training in the experimental group, but 3 patients had severe symptoms in the control group. Among the 32 enrolled subjects reaching upright training status within 30 days (17 subjects in the experimental group and 15 subjects in the control group), time interval of training from horizontal position to erect position in the experimental group was 18.00±3.12 days and 21.40±4.95 days in the control group. Time interval in the experimental group was significantly less than in the control group. However, among all 36 subjects, by combining results of follow-up, there was no significant difference of time interval of training from horizontal position to erect position between the experimental group and the control group. In the experimental group 90.52% of patients finished training compared to 78.19% in the control group ($P<0.01$). After training, values of OCs and OCd of the experimental group were lower than in the control group. There was no significant difference between groups in number of re-diagnosed OH.

Conclusions: Implementation of training with electric uprise bed coupled with remote monitoring system is generally safe for patients with OH after SCI. For patients who could reach standing training status within 30 days, implementation can improve efficiency of training by shortening time interval of training from horizontal position to erect position. It can increase orthostatic blood pressure change during position change.

MeSH Keywords: Blood Pressure • Electrocardiography • Hypotension, Orthostatic • Spinal Cord Injuries

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Background

Orthostatic hypotension (OH) is a clinical syndrome in which blood pressure in erect position decreases significantly compared with supine position. OH has a variety of causes and mostly occurs during postural changing, especially from supine position to erect position, which mainly causes symptoms of cerebral hypoperfusion and even syncope or sudden death [1]. Orthostatic hypotension (OH) is one of the most common complications of spinal cord injury (SCI) patients. In patients with SCI over the level of T6, the incidence rate of orthostatic hypotension is very high [2]. Illman et al. enrolled 14 acute SCI patients; 73.6% of patients had OH during rehabilitation, among whom 58.9% had symptoms, and rehabilitation was restricted in 43.2% of these patients [3]. OH severely impedes the process of rehabilitation after SCI. Treatment of OH after SCI has become an important part of rehabilitation in late-stage SCI [4].

Training with an electric uprise bed is a relatively common therapeutic method for OH [5,6]. By adjusting the tilt angle, the uprise bed can make patient tied to the bed generate their own gravity, which can help SCI patients in the following aspects: 1) Help patients complete the transition from supine to erect position and from low to high level of gravity, and fully adapt to standing position; 2) Increase weight-bearing ability of the trunk and lower limbs, and controlling ability of cervix, thorax, waist, and pelvis in erect position, so as to create a good foundation for independent standing and balance in the future; 3) Through squeezing joints and muscles by gravity, proprioception is effectively stimulated, the affected limbs are facilitated, and muscle tension in patients with low muscle tension is increased; 4) For drooping feet, varus, and other abnormal modes caused by high tension of the lower limb muscles, gravity was used to perform sufficiently strong and lasting traction of the Achilles tendon so as to exert corrective action. However, the most common adverse reaction of this method is OH, even an adverse cardiovascular event [7]. The mechanism of the head-up tilt test is in line with the mechanism of the uprise bed. Ditor et al. applied weight-decreased walking training to treat OH in SCI patients; they chose 8 patients with cervical SCI and conducted training 3 times per week for 6 months and found that blood pressure during the head-up tilt test did not change significantly before and after training, but heart rate changed significantly, indicating that patients could adapt to changes in posture better [8]. However, Engelke et al. used an arm-bending training test during the head-up tilt test; they enrolled 10 paraplegia patients with thoracic SCI and found that arm-bending training could enhance systolic blood pressure in head-up tilt tests significantly but had little effect on heart rate [9]. Lopes et al. chose 6 SCI patients and 6 normal controls to perform upper limb exercise during standing training and found that upper limb exercise had no significant effect on upright tolerance [10].

The mechanism of standing training was encouraging because long-term training had good effects on patients with orthostatic hypotension syncope [11], but the effects of short-term training were unclear [12,13]. Huang et al. treated patients with OH after SCI with twice-daily standing training, and found the incidence of re-diagnosed OH was 12.5% in the treatment group and 50% in the control group after 30 days of treatment [14]. Chen et al. treated OH patients after incomplete SCI with an electric uprise bed at the early stage and reported that the time from supine position to upright position was 12.8±1.2 days in the experiment group and 21.2±2.8 in the control group [15].

How to safely and effectively carry out uprise bed training is an issue that urgently needs to be solved. During cardiac rehabilitation process, we used the remote monitoring system for monitoring the exercise training process to ensure the safety and high efficiency of exercise training. Therefore, we assume that a remote monitoring system can play a similar role in uprise bed standing training for SCI patients. The purpose of our study was to use a remote monitoring system to monitor patient responses to electric uprise bed training and to compare training efficiency and percentages of patients completing this training to traditional uprise bed training without telemetric monitoring.

Material and Methods

Study subjects

Inclusion criteria included: Patients with complete data received rehabilitation therapy after spinal trauma or spinal surgery in our hospital from January 2013 to February 2014; Patients were definitively diagnosed as SCI by CT or MRI; patients were awake with spontaneous breathing; According to American Spinal Injury Association (ASIA) standard [16], the spinal cord dysfunction was in grade A-D; Patients had no water, electrolyte disorders, acid-base imbalance, and had basically normal blood sugar, liver and kidney function, blood and urine routine levels; The SCI had lasted for 2 to 4 weeks; Before uprise bed training, 3 orthostatic blood pressure measurements were performed and OH diagnostic criteria were reached once or more. A total of 36 patients were enrolled and randomly divided into the experimental group and the control group (n=18). All enrolled subjects participated in this trial voluntarily, understood the purpose and significance of this trial and signed written informed consents. This trial was approved by Medical Ethics Committee in Guangzhou General Hospital of Guangzhou Military Region.

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OH diagnostic criteria

The 1996 diagnostic criteria of American Autonomic Society (AAS) and American Academy of Neurology (AAN) [17] was used: Within 3 min after a patient turned from the supine position to the upright position, systolic blood pressure decreased ≥20 mmHg and/or diastolic blood pressure decreased ≥10mmHg with or without a clinical syndrome including a variety of low perfusion symptoms. We performed orthostatic blood pressure measurements 3 times in 3 days before the treatment and 3 times in 3 days after the treatment; if at any of the 3 times, OH criteria were reached 1 or more times, OH could be diagnosed.

Research methods

All selected objects were commonly managed [18]: 1). All of them received comprehensive rehabilitation treatment, including: application of neurotrophic drugs, turning expectoration, preventing bedsores, stool and urine management, strengthening exercise therapy and occupational therapy, and physiotherapy and other therapies in supine and sitting positions. 2). An electric uprise bed was used to train. At first, the training was at 25~30° for 60 min twice daily; 5° was increased daily until the patient was erect. A patient who had developed OH or could not tolerate the training received training at an angle at which OH would not emerge and the patient could tolerate the training for 1–3 days; relying on the patient's adaptability, the angle was gradually increased until the upright position was reached. 3). Before training, good explanation to the patient was provided; the blood pressure and heart rate were measured when the patient was lying down after 5 min of resting. In the bed the patient underwent active and passive joint exercise of the 2 lower limbs to improve blood circulation; then, with the patient in the supine position in the uprise bed, the patient's back was tight to the bed surface, both feet were placed on the pedals shoulder width apart, all key positions (underarm, pelvis, knees) were fixed belts with 10~15 cm width, and the legs were secured by elastic bandages. 4). Standing after a meal or during fasting was avoided so that gastrointestinal reactions, hypoglycemia, and other discomforts could be avoided; during standing training, the chest-protecting belt could not be tied too tightly to affect breathing and avoid discomfort; being sure to keep the patient warm and safe; 5). During the trial, a total of 30 days was needed for treatment. This was mainly because most of the hospitalized patients with acute SCI had a rehabilitation time of less than 30 days and patients with rehabilitation time of more than 1 month selected discharge or were transferred to a lower level rehabilitation facility for continuing treatment; they failed to extend our above treatment systematically. After systemic training for 30 days, all subjects withdrew from the trial, and continued comprehensive OH treatments, including a variety of intermittent exercise training and drug therapies, and insistence on follow-up and regular re-checking.

Experimental group

When a patient underwent electric uprise bed training, the patient would wear the remote monitoring system (Beijing Hailiying Medical Technology Co., Ltd. Hailiying TE-4000Y wireless multi-parameter dynamic monitoring system) if they met the following conditions: 1). Dizziness, nausea, palpitations, chest tightness and other obviously intolerable symptoms, even syncope emerged. 2). Blood pressure change reached the decreasing magnitude defined by OH diagnostic criteria. 3). Heart rate (increased or decreased) by over 30% from that in the supine position. 4). Malignant arrhythmia occurs and obvious ST-T change emerged. The patient should immediately stop training, rest in the supine position, and receive appropriate rehydration, symptomatic treatment, and other treatments. Further treatments would be performed depending on the conditions of the patient. If the patient had mild to moderate dizziness, nausea, heart palpitations, chest tightness, and other symptoms, but the changes of ECG and blood pressure did not meet the above conditions, the patient would be encouraged to exercise and received close observation.

Control group

the patients underwent electric uprise bed training according to conventional method, and blood pressure was measured in the first minute and the third minute during training and 2 min after body position change. During uprise training, patient conditions were closely observed, such as consciousness, complexion change, dizziness, nausea, palpitations, chest tightness, and other uncomfortable symptoms. Once the patient had mild dizziness, nausea, or complexion change and other conditions, the angle of standing was immediately reduced. If a patient had relatively obvious symptoms or at the time the measured blood pressure and heart rate greatly changed, the patient's training was suspended and the patient was returned to supine position to receive treatment.

Data collection

When a subject finished training in accordance with the plan, it was calculated as 1 person-time of training completion; if training time of uprise bed lasted for more than 30 min every time, it was recorded as 1 person-time of training completion; if less than 30 min, it was recorded as not completing 1 person-time of training. We recorded the time when a patient turned from the supine position to the upright position (the standard was the completion of upright position training for the first time), and the completion rate of arranged uprise bed training. After completion of 30-day treatment, the records

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Table 1. Basic data of study subjects.

General conditions	Experimental group (n=18)	Control group (n=18)	P value
Age (years, means ±SD)	29.19±11.01	36.44±9.19	0.42
Number of days after injury (day, means ±SD)	18.14±8.77	20.70±6.78	0.33
Body mass index BMI (Kg/m^2, means ±SD)	22.39±2.30	22.17±2.73	0.82
Proportion of female (%)	3 (16.7%)	2 (11.1%)	1.00
Cervical SCI (%)	9 (50.0%)	8 (44.4%)	1.00
Thoracic SCI (%)	4 (22.2%)	5 (27.8%)	1.00
Lumbar SCI (%)	5 (27.8%)	5 (27.8%)	1.00
Full injury (%)	5 (27.8%)	4 (22.2%)	1.00

included OH incidence rates of the 2 groups, blood pressure values in the supine position and in the upright position before and after treatment, and the blood pressure change values calculated following 2 values: orthostatic change in systolic blood pressure (OCs) was supine systolic blood pressure value minus systolic blood pressure value immediately after turning to the upright position, and orthostatic change in diastolic blood pressure (OCd) was supine diastolic blood pressure value minus diastolic blood pressure value immediately after turning to the upright position [19]. The records also included blood pressure values in the first min and the third min, and included the maximum OCs and OCd. Orthostatic blood pressure measurements were performed 3 times before and 3 times after treatment, and the mean of 3 OCs and the mean of 3 OCd were used as OCs value and OCd value in the statistics.

Statistical analysis

After quality check of the survey data, the data were entered and SPSS 19.0 was used to establish a database. Qualitative data were described by percentage and quantitative data were described by mean and standard deviation. χ^2 test was used for comparison of qualitative data. The t test was used in the comparison between groups, while paired t test was used to compare the same indicators within a group. Repeated 1-way ANOVA was used to analyze blood pressure value changes. $P<0.05$ was considered statistically significant.

Results

Basic data

Characteristics of the subjects in this study are presented in Table 1. According to the trial design, there was no significant difference in baseline data between the experimental group and the control group.

The situation of training from the supine position to the upright position

After completion of 30-day training, there were still 4 subjects who had not gone in the upright training phase, including 1 in the experimental group (complete cervical SCI) and 3 in the control group (2 subjects with complete cervical SCI, 1 subject with complete thoracic SCI). There were no significant differences in age, number of days after injury, or basic diseases between the 4 subjects and other subjects, but all 4 subjects were complete SCI above thoracic spinal cord level. The 4 subjects together with all other enrolled subjects withdrew from the trial after training for 30 days. Then the 4 subjects tried standing training every day and kept re-visiting 1–2 times a week. The time to reach standing training status of the subject in the experimental group was 78 days, while the time for 3 subjects in the control group were 56 days, 89 days, and 102 days. Among 32 subjects who reached standing training status within 30 days, the number of training days from supine position to erect position in the experimental group was significantly shorter than that in the control group. The reasons why subjects were unable to complete training are listed in Table 2. However, by combining results of follow-up, there was no significant difference of time interval of training from horizontal position to erect position between the experimental group and the control group (Table 3). After training from the supine position to the upright position, the 90.52% training completion rate in the experimental group was also significantly higher than the 78.19% in the control group, as shown in Table 4. No subjects in the experimental group had syncope, vomiting, shock, or other severe symptoms during the training process, among which 58 person-times did not complete training and included: 44 person-times (75.86% of person-times of not completing training) of training were terminated because the remote monitoring system indicated obvious abnormalities of blood pressure, ECG, and heart rhythm, and 14 person-times (24.13%) of training were terminated because the symptoms were intolerable. There were 157 person-times (24.13% of total training person-times) of training in the

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Table 2. Comparison of situations of not completing training.

		Experimental group person-time (%)		Control group person-time (%)	
Person-time of not completing training		58	(100%)	157	(100%)
The main symptoms for discontinuation of training	syncope	0	(0%)	1	(1%)
	Vomiting	0	(0%)	2	(1%)
	Dizziness or vertigo	5	(9%)	64	(41%)
	Blurred vision	1	(2%)	8	(5%)
	Weakness or fatigue	2	(3%)	6	(4%)
	Headache, neck pain	3	(5%)	8	(5%)
	Difficult breathing or chest pain	3	(5%)	10	(6%)
The main examination abnormalities for discontinuation of training	Blood pressure abnormality	39	(67%)	45	(29%)
	Arrhythmia	4	(7%)	13	(8%)
	ECG ST-T change	1	(2%)	0	(0%)
The main reason for discontinuation of training was symptoms		14	(24%)*	99	(63%)
The main reason for discontinuation of training was examination abnormalities		44	(76%)*	58	(37%)

Compared with control group, * P<0.001.

Table 3. Comparison of number for days from supine to standing position training.

	Subjects reaching the standing training within 30 days		All enrolled subjects	
	Experimental group	Control group	Experimental group	Control group
	n=17	n=15	n=18	n=18
Number for days from supine to standing position training (means ±SD)	18.00±3.12	21.40±4.95	21.33±14.46	31.56±25.15
Comparison between groups	P=0.032		P=0.144	

Table 4. Comparison of the training situations from the supine position to the upright position.

	Times of implementing training	Times of completing training	Proportion of completion
Experimental group (n=18)	612	554	90.52%*
Control group (n=18)	720	563	78.19%

Compared with control group, * P<0.001.

control group were terminated and included: 58 person-times (36.94% of person-times for not completing training) of training were terminated because mild symptoms emerged and abnormal blood pressure and heart rate were found by measurements; because the symptoms were obvious, 99 person-times (63.06% of person-times for not completing training) of training were terminated, of which 3 person-times had syncope and vomiting and after they were in the supine position and received further treatment, their symptoms were improved (Table 2).

OH morbidity rate and orthostatic blood pressure change after completion of training

After completion of 30-day training, 2 subjects in the experimental group and 5 subjects in the control group were definitively diagnosed as OH again, and the χ^2 test was used to compare the 2 groups (P=0.201). There was no significant difference in OCs and OCd between the 2 groups before training. After training, OCs and OCd in the experimental group were all

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Table 5. The OH morbidity rate and orthostatic blood pressure changes after completion of training.

	Number of subjects with confirmed OH after completion of training	Before training		After training	
		OCs (mmHg, means ±SD)	OCd (mmHg, means ±SD)	OCs (mmHg, means ±SD)	OCd (mmHg, means ±SD)
Experimental group (n=18)	2 (11.11%)*	22.38±8.42	11.24±10.90	13.71±9.42**	4.24±8.80**
Control group (n=18)	5 (27.78%)	21.44±10.14	10.60±8.37	18.88±6.05	7.05±5.03

Compared with control group, * P=0.261; ** P<0.05.

lower than those in the control group; paired t test results indicated that the change values in OCs and OCd in the experimental group before and after training, compared with control group, were statistically significant, and change values of OCs and OCd in the experimental group were relatively large. OCs after training in the experiment group was 13.71±9.42 mmHg, which was significantly less than that before training (22.38±8.42 mmHg) as well as that after training in the control group (18.88±6.05 mmHg). ODs after training in the experiment group was 4.24±8.80 mmHg, which was also significantly less than that before training (11.24±10.90 mmHG) and that after training in the control group (7.05±5.03 mmHg) (Table 5).

Discussion

OH can be symptomatic or asymptomatic [20], and some patients will develop recurrent vasovagal syncope [21]. OH diagnosis appears to have poor reproducibility; therefore, if a patient has a history of SCI, orthostatic blood pressure should be repeatedly measured [7]. In this trial, orthostatic blood pressure measurements were performed multiple times before and after training, and as long as 1 or more measurements met the criteria, the diagnosis could be confirmed so as to improve the detection rate of OH. Even after the uprise bed training, among the patients who could complete upright standing training, some patients met OH diagnostic criteria in subsequent orthostatic blood pressure measurements. In other words, reproducibility of OH diagnosis was poor, and from another point of view, we should allow the patients to properly strengthen stimulation intensity of the body position training. And, because of the same reason, some patients could be "cured" without any treatment. The cure rate from clinical observation has some deviation.

The mechanism of orthostatic hypotension after SCI is not yet clear, related diagnosis and measurement have no uniform criteria, and there is no specific therapeutic method [18]. It is generally considered that sympathetic preganglionic neurons are the neural information last common pathway from vasomotor center to cardiovascular sympathetic nerves, and SCI can cause disruption of the conduction pathway between vasomotor center and sympathetic preganglionic neurons, resulting in dysfunction of the normal central nervous system short-term blood pressure regulation mechanism [22]. Therefore, in the early stage of SCI, duo to sympathetic response loss, vein dilation, and abdominal muscle paralysis, intra-abdominal pressure decreases; meanwhile, in upright or sitting positions catecholamine, cortisol, and aldosterone are released insufficiently or too slowly; therefore, when a patient moves from the supine position to the upright position, blood pressure drops suddenly and is often accompanied with increased heart rate, causing transient brain ischemia leading to dizziness, vertigo, or sudden loss of consciousness [23]. The incidence rate is related to the position of the damaged spinal cord segment, the degree of injury, length of time confined to bed, and physical quality; higher paraplegia level is associated with higher incidence rate [2]. When patients undergo electric uprise bed training, they should lie on the tilted flat surface in a straight line, and the angle is adjusted daily depending on the degree of tolerance, gradually becoming close to the upright position. This method has the advantage that the links of the intermediate body position change between sitting position and upright position are reduced, so that quick excessive expansion of the lower limb vascular bed is avoided and the brain tissue can adapt to ischemia, thus solving the above problem [6]. As time goes on, the cooperation of SCI distal sympathetic preganglionic neuron conduction pathway is reestablished, and partial rehabilitation of sympathetic nerve function, long-term regulation, and vasoconstriction hormone secretion increase; increased sensitivity of these hormones and muscle spasm, cause orthostatic hypotension symptoms to improve and disappear [24]. The study also confirmed that on the basis of comprehensive treatment, the majority of OH after SCI is rehabilitated by undergoing electric uprise bed training. Uprise bed training is an important therapeutic means for a patient to turn from the supine position to the sitting position and then to the upright position, and can prevent orthostatic hypotension, pneumonia, bed sores, urinary tract infection, osteoporosis, and other long-term bedridden complications, so that the patient can regain good condition as soon as possible and the training can play a positive role in rehabilitation.

However, uprise bed training is essentially the body position stimulation under laboratory conditions, and moderately

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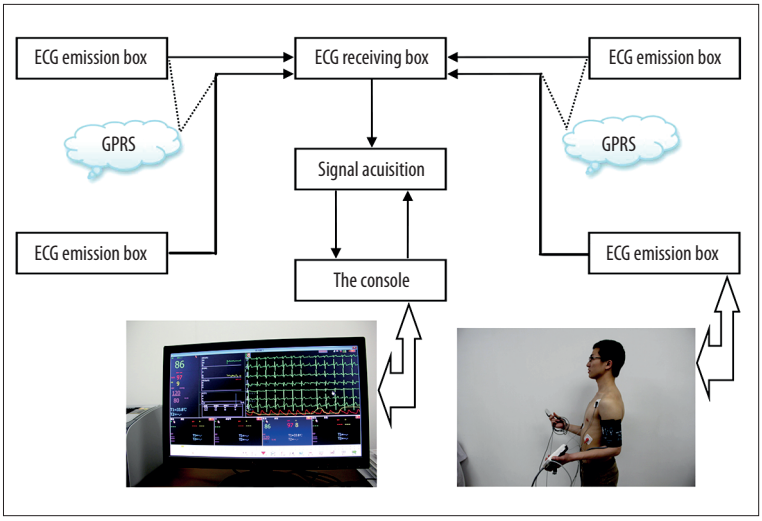

Figure 1. Diagram of remote monitoring system.

stimulates the pathophysiological mechanism of OH; thus OH, bradycardia, or even cardiac arrest may appear due to the above mechanism. Therefore, during uprise bed training, a therapist generally pays attention to safety; when an adverse reaction emerges, the uprise bed is immediately placed flat, and blood pressure, pulse, and consciousness are observed. During the training, the symptoms observed generally determine the training process, but this kind of decision is prone to problems. First, subjective symptoms lead to termination of the training, affecting efficacy. Second, at the beginning, OH is asymptomatic and with training, further decrease of blood pressure causes a sudden syncope, shock, and other serious complications. Third, malignant arrhythmia, bradycardia, and even cardiac arrest, symptoms of which are not obvious in the short-term, cannot be found in time. Fourth, some patients participating in the training cannot accurately describe or show the symptoms emerging during the training. To solve the issue of the balance between safety and efficacy of uprise bed training, we used a remote monitoring system with the electric uprise bed training, and analyzed dynamic EEG, blood pressure, and other parameter changes that could be used as objective evidence to determine whether to continue the training, thus the training safety could be greatly improved [25]. With the remote monitoring system, among total person-times of terminating training, 75.8% of person-times were terminated because of significantly abnormal blood pressure or heart rhythm. No previous similar studies were retrieved. This datum showed there might be such situations (e.g., no discovery of significant blood pressure or heart rate abnormalities) during training without using remote monitoring system that result in increased risks. Remote monitoring system that measures ECG signals by several ECG telemetry boxes conducted to the console wirelessly, and the console converts the received data to visual signals and manages them. The instrument allows staff to observe multiple patients' condition changes simultaneously and can ensure staff make the right decisions and perform the correct actions in time so that the efficiency of hospital monitoring and care is greatly improved. The instrument reduces mortality rate and ensures the quality of medical care. The remote monitoring system consists of ECG emission boxes, the ECG receiving box, the signal acquisition card, and the console (Figure 1). Our trial results showed that compared with the control group, the experimental group had no serious adverse reactions, and the completion rate of training significantly increased because the number of patients who developed symptoms and had to stop training was also greatly reduced. The required training time from the supine position to the upright position was also significantly shortened, indicating that use of remote monitoring system can greatly improve the efficiency of electric uprise bed training by ensuring safety. The remote monitoring system has 5 advantages. First, for a patient who cannot communicate well and cannot express their disease condition, it can be used as an objective indicator of disease condition observation. Second, it can effectively reduce the patient's negative emotion, enhance the patient's confidence in rehabilitation, and increase the patient's training compliance. Third, it can significantly reduce termination of the training due to subjective symptoms. Fourth, the monitoring staff can quickly and accurately identify a variety of arrhythmias and blood pressure changes, and obtain objective evidence from the instrument to terminate the training, saving time helping plan subsequent training. Five, the instrument works easily and does not affect the exercise and training, allowing monitoring staff to efficiently monitor multiple patients simultaneously.

Our trial results showed that after completion of the training, there was no significant difference in proportion of patients definitively diagnosed as OH between the 2 groups; after training, OCs and OCd in the experimental group were significantly lower than those in the control group. OCs and OCd reflect the magnitude of blood pressure changes after

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body position changes. In normal populations without OH, OCs and OCd generally are negative; higher values are associated with greater magnitude of blood pressure decrease from the supine position to the upright position. The trial results showed that after 30-day comprehensive rehabilitation therapy, the use of the remote monitoring system did not significantly affect OH cure rate, but it affected the overall orthostatic blood pressure changes and, through affecting the training times, frequency, tilt angle, and other factors, it could increase the blood pressure change value from the supine position to the upright position. The trial results only indicated that, among the subjects who could reach standing training status within 30 days, number of days from supine to erect position was significantly reduced in the experimental group, which showed that treatment efficiency was higher in the experimental group. However, reaching standing position is not the same as cure of OH. With non-repeatability of OH, some subjects who reached standing training status also met OH diagnostic criteria in OH diagnosis tests later, which is called "not cured." Moreover, combining 1-month training plus follow-up, there was no significant difference in the time of reaching standing training status between the experimental group and the control group. Whether it can ultimately affect OH cure rate may be closely related to the sample size in trial design, the diagnostic timing of OH, and the training intensity adjustment, which need to be explored in a subsequent study. On one hand, as for SCI of different levels, the sample size should be expanded; based on the remote monitoring system, safety and effectiveness of different intensity training for treating OH should be investigated. On the other hand, standing training is one of many types of exercise training. Based on analysis of cardiovascular risk factors, in future research we will apply remote monitoring system more widely in a variety of exercise training regimens to explore safe and highly efficient exercise training methods for populations susceptible to OH or with high-risk of heart disease.

Conclusions

In summary, the remote monitoring system combined with electric uprise bed training for treatment of OH after SCI can ensure safety during training and it can substantially increase the efficiency of electric uprise bed training. Patients who could reach standing training status within 1 month for standing training could significantly shorten the training time required from the supine position to the upright position, and improve blood pressure change value from the supine position to the upright position. It is worth expanding the sample size in the next study, refining the exercise training project and time so as to further explore the remote monitoring system combined with exercise training rehabilitation.

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