Acta Neurol Belg (2014) 114:125–129
DOI 10.1007/s13760-014-0279-x

ORIGINAL ARTICLE

Clinical efficacy and sEMG analysis of a new traditional Chinese medicine therapy in the treatment of spasticity following apoplectic hemiparalysis

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Received: 14 August 2013 / Accepted: 9 December 2013 / Published online: 11 February 2014

Abstract To investigate the clinical effect and surface electromyography (sEMG) of rehabilitation exercise therapy in combination with total glucosides form Shaoyao Gancao decoction in treating spasticity after apoplectic hemiparalysis. Composite spasticity scale (CSS), Fugl-Meyer assessment (FMA) and modified Barthel index were compared between the exercise only group and the combined therapy group before and 1 month after the treatment to scale muscular tension, function and activities of daily living. Meanwhile, integrate EMG and root mean square (RMS) were used to detect the tension of upper limbs (biceps brachii) and ankles (tibialis anterior muscle and gastrocnemius) after the 1-month treatment. In the combined therapy group, the Ashworth and CSS scales were significantly improved compared to before the treatment ($P < 0.05$) and compared to the patients in the control group ($P < 0.05$). After the 1-month treatment, the combined therapy group showed significantly higher FMA and BI scores ($P < 0.05$) compared to the control group. For the combined therapy group, the sEMG was significantly improved at 1 month after the treatment ($P < 0.05$), while the control group only showed relatively slight improvement in the RMS of the tibialis anterior muscle and the gastrocnemius. The total glucosides form Shaoyao Gancao decoction could significantly improve the efficacy of the rehabilitation exercise therapy in the treatment of spasticity after apoplectic hemiparalysis, and its mechanism might involve the decrease of muscular tension.

Keywords Spasticity · Apoplectic hemiparalysis · Glucosides form Shaoyao Gancao decoction · IEMG · RMS

Introduction

Patients with cerebrovascular disorders usually show a high incidence of spasticity due to the hemiparalysis, and the ipsilateral spasticity can deteriorate by varying degrees if without timely and effective rehabilitation treatment, which would eventually result in slow recovery or even loss of ipsilateral limb function. The symptoms of cerebral apoplexy are described in detail in Treatise on Febrile Diseases, which further points out that the symptoms can be relieved by Shaoyao Gancao decoction. Gancao (Glycyrrhiza) and Shaoyao (*Paeonia lactiflora*), the two main components of the decoction, may take spasmolysis and analgesia effects [1]. The decoction has been used for the treatment of hemifacial spasm, gastrocnemius spasm and gastrointestinal smooth muscle spasm, which has achieved ideal efficacy. Biological research has suggested that the decoction can increase the activity of inhibitory

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neurotransmitters such as Gly and GABA, but not excitatory neurotransmitters Glu and Asp, in the brain and spinal cord, and can improve muscular tension.

In the present study, we applied a combined therapy of rehabilitation exercise and total glucosides form Shaoyao Gancao decoction to treat spasticity, and achieved satisfactory results. Our results indicated that the supplement of conventional rehabilitation exercise therapy with total glucosides form Shaoyao Gancao decoction can efficiently relieve the limb hypertonia and consequently the spasticity of the patient, which would benefit the functional recovery of the hemiplegic limbs.

Subjects and methods

Research subjects

All experiments have been approved by Wenzhou Chinese Medicine Hospital ethics committee. Informed consent has been obtained from the subjects before study. Sixty patients with spasticity after apoplectic hemiparalysis admitted in our hospital between February 2010 and February 2012 were randomly divided into a control group and a test group with 30 patients per group. The two groups did not show significant difference in gender, age, disease course or hemiparalysis side ($P > 0.05$) (Table 1).

Inclusion criteria: (1) the patient should meet the stroke diagnostic criteria set by the Fourth National Conference on Cerebrovascular Disease [2]; (2) the patient should be 40–80 years old; (3) the patient was conscious and showed spasticity after apoplectic hemiparalysis; (4) the upper limb spasticity was focused on the flexor, and the lower limb spasticity was focused on the extensor; (5) the spasticity degree was Ashworth grade I–III; (6) the Brunnstrom staging was stage II or III; (7) informed consent was obtained from the patients and their families.

Exclusion criteria: (1) the patient has severe primary disease in the heart, liver, lungs, kidneys, hematopoietic system or endocrine system; (2) the patient has secondary epilepsy; (3) the patient has mental illness; (4) the patient is a pregnant or lactating woman; (5) the patient has physical weakness and mental retardation, as well as aphasia, agnosia, apraxia and visual field defects. (6) The patient is being treated with anticonvulsants.

Treatment methods

The 60 patients were randomly divided into the control group and the test group with 30 patients per group. The patients in the control group were treated with rehabilitation exercise therapy only, while the patients in the test group received an additional treatment with total glucosides form Shaoyao Gancao decoction. Muscle relaxant treatment was terminated in both groups to avoid possible variation. If symptoms of infection, high pressure or high blood sugar appeared during treatment, the patients were treated accordingly.

Rehabilitation exercise therapy

The patients received one-to-one exercise training. The training program was as follows: (1) the muscle with spasm received slow continuous passive stretching. The maximal stretching was maintained for 5–10 s, and the muscle was slowly returned after the spasm was slightly relieved. The spasm control started from relieving trunk muscle tension and extended from the proximal joint to the distal joint. (2) The patient took a weight-bearing position to improve muscle spasm. For instance, at the sitting position, the ipsilateral upper limb received weight-bearing training; at the standing position, the ipsilateral lower limb received the training. (3) During training, spasm should be carefully controlled. For instance, the lower limbs should not be at a flexibility posture when the ipsilateral upper limb is receiving weight-bearing training. (4) Spasm antagonistic muscle contraction was promoted using a slight brushing method. The training program was performed 30 min per day, 6 days per week, for 4 weeks.

Total glucosides form Shaoyao Gancao decoction

The Gancao (Glycyrrhiza) and prepared slices of Shaoyao (*Paeonia lactiflora*) were purchased from Bozhou Medicinal Herb Company (Anhui, China). 2 kg Gancao and 2 kg Shaoyao were decocted twice in ten volumes water for 1 h per each, and concentrated to 10 L. After centrifugation at 12,000 r/min, the supernatants were passed through AB-8 macroporous adsorbent resins (Nankai Hecheng S&T, Tianjin, China) and rinsed with water for purification, followed by washing with 30–70 % ethanol. After the

Table 1 General information of the patients

Group	Case number	Age (years)	Gender (case)		Disease course (days)	Hemiparalysis side (case)	
			M	F		L	R
Control	30	65.53 ± 8.64	16	14	8.46 ± 5.14	17	13
Test	30	63.17 ± 9.50	15	15	7.86 ± 6.62	16	14

ethanol eluates were combined and the ethanol was recycled through pressure reduction, the eluates were air-dried to obtain 297 g total glucosides form Shaoyao Gancao decoction (13.5 g crude drug per 1 g glucoside). In addition to the regular rehabilitation exercise, the patients in the test group received postprandial administration of 10 mL total glucosides, three times per day (30 mL daily). In addition, the total glucosides were also used for spasm muscle rubbing, four times per day for 30 days.

Clinical efficacy evaluation

Before and 1 month after the treatment, we used the modified Ashworth scale [3], composite spasticity scale (CSS) [4], Fugl-Meyer assessment (FMA) [5] and modified Barthel index (MBI) [6] to assess the spasm degree of the ipsilateral upper and lower limbs, muscular function and activities of daily living (ADL) of the two patient groups.

The surface electromyography (sEMG) data were acquired using a ten-channel FlexComp Infiniti™ System (Thought Technology, Canada). Before treatment, the patient sat in a chair with armrests in a room with 22–28 °C temperature to measure the sEMG. The ipsilateral upper limb was put onto the isokinetic testing system to accomplish a passive elbow joint exercise at an angular velocity of 120°/s, and the sEMG of the first four biceps brachii stretching was recorded. In the next step, the ipsilateral lower limb was put onto the system to accomplish a passive ankle joint exercise at the same velocity, and the sEMG of the first four stretching of the tibialis anterior muscle and the gastrocnemius was recorded. The patient should always keep relaxed during measurement. The ankle range was between plantar flexion 30° and dorsiflexion 15°, and the elbow range was 120°–0°. All exercises were repeated five times with an interval of 1 min, followed by a 3 min rest before the second measurement. The integrated electromyography (IEMG) data of the muscles were analyzed using Infinite 3000 software, and the root mean square (RMS) was used as an indicator.

Statistical analysis

Data analysis was performed using SPSS 13.0 software. Measurement data was shown as $\bar{x} \pm s$. Comparison between groups was conducted using one-way analysis of variance (ANOVA), and comparison within one group was conducted using paired t test. Count data were analyzed using Chi-square test.

Results

Assessment of spasm in the upper and lower limbs before and after treatment

In the test group, after the 1-month treatment, the Ashworth scale was 6 patients at grade 0 and 8 patients at grade I, and the CSS scale was 9 patients in grade 0 and 11 patients in grade I. These results indicated that the spasm was significantly improved for both upper and lower limbs, compared to before the treatment ($P < 0.05$). Moreover, after the treatment, the numbers of the test group patients at Ashworth/CSS grade 0 and I were significantly higher compared to the control group ($P < 0.05$) (Table 2).

Assessment of muscle function and ADL before and after treatment

For the test group, after the 1-month treatment, the FMA and BI scores of the upper limbs were significantly improved to 82.40 ± 31.53 and 49.61 ± 6.18, respectively, ($P < 0.05$); and the FMA and BI scores of the ankles were also significantly improved to 79.58 ± 26.34 and 42.57 ± 4.92, respectively ($P < 0.05$). For the control group, after the 1-month treatment, the FMA and BI scores

Table 2 Upper and lower limb spasticity grading of the patients before and after treatment

Group	Case number	Upper limb					Lower limb				
		0	I	II	III	IV	0	I	II	III	IV
Test											
Before	30	0	4	12	14	0	0	6	15	9	0
1 month after	30	6[ac]	8[ac]	9	7	0	9[bd]	11[bd]	8	2	0
Control											
Before	30	0	3	10	17	0	0	4	12	14	0
1 month after	30	2[a]	6[a]	8	14	0	2[b]	7[b]	10	11	0

[a] $P < 0.05$, [b] $P < 0.05$, compared to the control group before treatment; [c] $P < 0.05$, [d] $P < 0.05$, compared to the control group after 1-month treatment

Table 3 Scores of the muscle function and ADL of the patients before and after treatment ($\bar{x} \pm s$)

Group	Case number	Upper limb		Lower limb	
		FMA score	BI score	FMA score	BI score
Test					
Before	30	68.15 ± 24.61	35.57 ± 5.64	62.16 ± 30.75	25.36 ± 3.20
1 month after	30	82.40 ± 31.53[ac]	49.61 ± 6.18[ac]	79.58 ± 26.34[bd]	42.57 ± 4.92[bd]
Control					
Before	30	64.81 ± 20.33	32.05 ± 4.33	60.79 ± 31.09	24.83 ± 4.63
1 month after	30	73.63 ± 27.49[a]	40.57 ± 5.02[a]	69.56 ± 28.83[b]	33.81 ± 4.94[bd]

[a] $P < 0.05$, [b] $P < 0.05$, compared to the control group before treatment; [c] $P < 0.05$, [d] $P < 0.05$, compared to the control group after 1-month treatment

Table 4 IEMG and RMS of the patients before and after treatment ($\bar{x} \pm s$)

Group	Case number	IEMG (μV s)			RMS (μV)		
		Biceps brachii	Tibialis anterior muscle	Gastrocnemius	Biceps brachii	Tibialis anterior muscle	Gastrocnemius
Test							
Before	30	46.57 ± 3.98	33.51 ± 3.38	35.27 ± 4.20	3.76 ± 0.81	5.49 ± 1.20	5.72 ± 1.01
1 month after	30	32.32 ± 12.58[ac]	19.72 ± 7.61[ac]	43.85 ± 6.63[ac]	1.91 ± 0.33[bd]	3.03 ± 0.86[bd]	8.95 ± 0.77[bd]
Control							
Before	30	42.86 ± 4.02	46.09 ± 4.55	34.02 ± 4.82	4.07 ± 1.07	5.79 ± 1.37	5.56 ± 0.91
1 month after	30	48.35 ± 10.39	49.16 ± 8.13	31.26 ± 5.51	4.53 ± 1.21	6.27 ± 1.56[b]	5.13 ± 0.72[b]

[a] $P < 0.05$, [b] $P < 0.05$, compared to the control group before treatment; [c] $P < 0.05$, [d] $P < 0.05$, compared to the control group after 1-month treatment

of the upper limbs were 73.63 ± 27.49 and 40.57 ± 5.02, respectively ($P < 0.05$), and the FMA and BI scores of the ankles were 69.56 ± 28.83 and 33.81 ± 4.94, respectively ($P < 0.05$). Compared to the control group, the test group showed significantly greater recovery of muscle function and ADL ($P < 0.05$) (Table 3).

Assessment of sEMG before and after treatment

For the test group, after the 1-month treatment, the IEMG of the biceps brachii, tibialis anterior muscle and gastrocnemius was 32.32 ± 12.58, 19.72 ± 7.61 and 43.85 ± 6.63 μV s, respectively, and the RMS of the muscles was 1.91 ± 0.33, 3.03 ± 0.86 and 8.95 ± 0.77 μV, respectively. These results indicated that the sEMG was significantly improved compared to before the treatment ($P < 0.05$). However, for the control group, only the tibialis anterior muscle and the gastrocnemius showed significant difference in the RMS (6.27 ± 1.56 and 5.13 ± 0.72 μV, respectively) compared to before treatment ($P < 0.05$). After the 1-month treatment, the test group showed greater improvements in the IEMG and RMS of all muscles (i.e., biceps brachii, tibialis anterior muscle and gastrocnemius) compared with the control group ($P < 0.05$) (Table 4).

Discussion

Cerebral apoplexy patients often show a high incidence of hypermyotonia and consequently muscle spasticity during the recovery process, due to the lack of timely treatment. Clinically, the upper limb symptom is focused on flexor spasticity and the lower limb symptom is focused on extensor spasticity. As a result, the patients usually show upper limb hurdling action and lower limb hemiplegic gait [7]. The symptoms of cerebral apoplexy are described in detail in Treatise on Febrile Diseases, which further points out that the symptoms can be relieved by Shaoyao Gancao decoction. Gancao (Glycyrrhiza) and Shaoyao (*Paeonia lactiflora*) can have spasmolysis and analgesia effects [1]. The combination of Shaoyao and Gancao can produce synergistic effects. Co-administration of glucosides and acids can also relieve spasticity and acute pain. In the present study, our results indicated that the supplement of conventional rehabilitation exercise therapy with total glucosides form Shaoyao Gancao decoction can efficiently relieve the limb hypertonia and consequently the spasticity of the patient, which would benefit the functional recovery of the hemiplegic limbs.

In recent years, sEMG has been widely used to assess the post-stroke recovery of limb function [8, 9]. In sEMG, the bioelectrical signals of the neuromuscular system produced during voluntary and nonvoluntary activities were acquired by surface electrodes and enlarged to obtain a series of timing-voltage signals [10, 11]. The sEMG signals are usually weak when the muscle is slightly contracted but become greater if the muscle is intensively contracted. At present, the research on sEMG mainly focuses on the time domain and the frequency domain [12], and application of sEMG to the assessment of post-stroke neuromuscular function has become a hot spot in the research field of rehabilitation medicine. A previous study [13] has confirmed the reliability of sEMG. Qi et al. [14] analyzed the IEMG of the biceps brachii and triceps brachii of hemiplegia patients during the process of maximum isometric voluntary contraction, and found that the elbow spasm was mainly focused on the flexor. In the present study, we analyzed the IEMG and RMS in the time domain. The IEMG represents the total discharge of one muscle contraction unit within a certain period of time, and the RMS is the root mean square value of the amplitude of sEMG. The larger the IEMG and RMS values, the greater is the muscle tension. Onishi et al. [15] studied the relationship between IEMG and muscle tension and found that during voluntary contraction, IEMG and muscle tension show a certain level of positive correlation. Li et al. [16] also reported that sEMG combined with isokinetic test is a reliable quantification means to assess the spasticity degree of the patient.

In summary, our study indicated that the combined therapy of rehabilitation exercise and total glucosides form Shaoyao Gancao decoction obtained ideal efficacy in the treatment of spasticity after apoplectic hemiparalysis. Both the upper limb tension and lower limb spasticity of the patient were significantly relieved. As a result, the limb function of the patients such as active movement and the gait of the patients were well recovered, which could benefit the early rehabilitation and ADL improvement. Further research will focus on the elucidation of the relevant mechanisms.

Acknowledgments This study was supported by Scientific Research Foundation, Department of Health of Zhejiang Province, China (2010QNA020), and by Key Project of Traditional Chinese Medicine of Zhejiang Province, China (2012-XK-A30).

Conflict of interest None of the authors has any conflict of interest to disclose.

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