

Immediate effects of scalp acupuncture with twirling reinforcing manipulation on hemiplegia following acute ischemic stroke: a hidden association study

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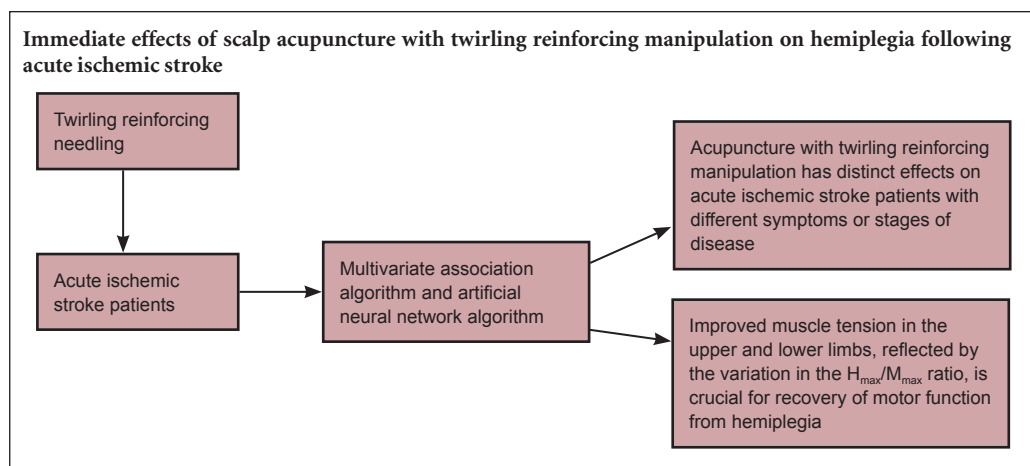
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Graphical Abstract



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Abstract

Data mining has the potential to provide information for improving clinical acupuncture strategies by uncovering hidden rules between acupuncture manipulation and therapeutic effects in a data set. In this study, we performed acupuncture on 30 patients with hemiplegia due to acute ischemic stroke. All participants were pre-screened to ensure that they exhibited immediate responses to acupuncture. We used a twirling reinforcing acupuncture manipulation at the specific lines between the bilateral *Baihui* (GV20) and *Taiyang* (EX-HN5). We collected neurologic deficit score, simplified Fugl-Meyer assessment score, muscle strength of the proximal and distal hemiplegic limbs, ratio of the maximal H-reflex to the maximal M-wave (H_{max}/M_{max}), muscle tension at baseline and immediately after treatment, and the syndromes of traditional Chinese medicine at baseline. We then conducted data mining using an association algorithm and an artificial neural network backpropagation algorithm. We found that the twirling reinforcing manipulation had no obvious therapeutic difference in traditional Chinese medicine syndromes of “Deficiency and Excess”. The change in the muscle strength of the upper distal and lower proximal limbs was one of the main factors affecting the immediate change in Fugl-Meyer scores. Additionally, we found a positive correlation between the muscle tension change of the upper limb and H_{max}/M_{max} immediate change, and both positive and negative correlations existed between the muscle tension change of the lower limb and immediate H_{max}/M_{max} change. Additionally, when the difference value of muscle tension for the upper and lower limbs was > 0 or < 0 , the difference value of H_{max}/M_{max} was correspondingly positive or negative, indicating the scalp acupuncture has a bidirectional effect on muscle tension in hemiplegic limbs. Therefore, acupuncture with twirling reinforcing manipulation has distinct effects on acute ischemic stroke patients with different symptoms or stages of disease. Improved muscle tension in the upper and lower limbs, reflected by the variation in the H_{max}/M_{max} ratio, is crucial for recovery of motor function from hemiplegia.

Key Words: nerve regeneration; traditional Chinese medicine; needling; reinforcing manipulation; hemiplegia due to acute ischemic stroke; immediate effect; association algorithm; artificial neural network algorithm; neurological deficit score; simplified Fugl-Meyer assessment; H_{max}/M_{max} ; traditional Chinese medicine syndromes; scalp acupoints; neural regeneration

Introduction

Scalp acupuncture has a remarkable immediate therapeutic effect on some post-stroke hemiplegia patients. In these patients, researchers have observed a rapid increase in the muscle strength of hemiplegic limbs by two grades or more after 10–30 minutes of acupuncture, often accompanied by varying degrees of improvement in muscle tension (Yu et al., 1991; Zheng et al., 1999; Dai et al., 2008). The immediate effects of scalp acupuncture may be explained by the inhibitory generalization theory for neural networks (Dong et al., 1994a, b), which has been supported by a series of animal studies (Dong et al., 2006; Cao et al., 2007).

The immediate effects of acupuncture are dependent on both the puncture site and the type of acupuncture manipulation. Acupuncture at the precise line between the *Baihui* (GV20) and *Taiyang* (EX-HN5) positions on the lesion side is considered to be ideal for treating individuals with post-stroke hemiplegia, although bilateral acupuncture is optimal. Moreover, the use of proper acupuncture manipulation techniques is necessary for obtaining immediate effects. As previously reported (Yu et al., 1991; Zheng et al., 1999; Dai et al., 2008), 90 post-stroke hemiplegic patients who experienced immediate effects of acupuncture were screened and equivalently subjected to reinforcing-reducing needling, twisting reducing needling, and twirling reinforcing needling. Findings from these studies indicated that twirling reinforcing needling elicited stronger immediate effects compared with the two other kinds of acupuncture techniques.

The selection of acupoints, acupuncture manipulation technique, and treatment time (*i.e.*, acupuncture prescription) modulate the clinical efficacy of acupuncture. Thus, optimizing an acupuncture prescription is a major challenge faced by acupuncturists. To the best of our knowledge, no comprehensive and/or systematic reports have addressed acupuncture-related data collection, integration, and analysis. Although a number of studies have collected large data sets, many of these are missing data that are important for interpretation. Studies of the efficacy of acupuncture in comparison with traditional Chinese medicine (TCM) often place an emphasis on the pathogenesis of the meridian, *via* correlation analyses of body surface-meridian-viscera. In fact, the acupuncture syndrome system is a large, complex, nonlinear, multi-dimensional, and multi-level system that has an infinite number of combinations. Traditional statistical methods that are based on verification only, such as meta-analyses, are thus insufficient for investigating deeper correlations and conducting regularity analyses. Data mining is the computational process of discovering patterns in large data sets, and its overall goal is to extract information from data sets that are unknown, unpredictable, and may be even in conflict with human intuition (Yan et al., 2011).

Our ultimate goal was to provide decision support for improving clinical acupuncture strategies in the treatment of stroke. Thus, in this study, we used a multivariate association algorithm and artificial neural network algorithm to investigate the multivariate association rules between events in a

data set, such as therapeutic efficacy (Ye et al., 2014).

Subjects and Methods

Participants

For participation in this study, we recruited 30 patients with acute ischemic stroke who were hospitalized in the Stroke Unit of the Yueyang Hospital of Integrated Medicine, Shanghai University of Traditional Chinese Medicine in China. The sample included 12 males and 18 females, with an average age of 71.5 ± 10.4 years (40–49 years in 1 case, 50–59 years in 2 cases, 60–69 years in 10 cases, 70–79 years in 7 cases, 80–89 years in 10 cases). The study protocol was approved by the ethics committee, Yueyang Hospital of Integrated Medicine, Shanghai University of Traditional Chinese Medicine (approval No. 09048).

Diagnoses of cerebral infarction were confirmed according to the diagnostic criteria for cerebral infarction, formulated at the Fourth China Cerebrovascular Disease Conference.

TCM syndromes for stroke were confirmed according to the *Diagnostic Criteria for Stroke Syndromes*, released by the State Administration of Traditional Chinese Medicine of China (Scientific Research Group of Encephalopathy and Emergency in the State Administration of Traditional Chinese Medicine, 1991).

To screen the patients who exhibited an immediate response to acupuncture, individuals who met the above-mentioned criteria were enrolled and subjected to scalp acupuncture. Acupuncture was applied at the precise line between the bilateral *Baihui* and *Taiyang* positions, three times in succession. This was followed by the twirling reinforcing manipulation with a twirling angle of 360° and a twirling frequency of about 100 r/min, once for 1 minute. The needle was retained for 30 minutes, during which the same twirling reinforcing manipulation was performed three times with an interval of 10 minutes. If we observed a rapid increase in the muscle strength of the hemiplegic limbs by at least two grades, we considered the patient to exhibit an immediate response to scalp acupuncture.

Patients who fulfilled the criteria detailed below were recruited to the study: (1) cerebral infarction in the internal carotid confirmed by brain MRI; (2) within 1–14 days after first onset of stroke; (3) muscle strength of the affected upper and lower limb was grade 0–II and 0–III, respectively; (4) an immediate response to scalp acupuncture; (5) 40–90 years of age; (6) conscious with stable vital signs and no speech disorders.

Patients who presented with one of the following criteria were ineligible: (1) transient ischemic attack or reversible ischemic neurological deficits; (2) neurological deficits caused by brain tumor, brain trauma, brain parasites, heart disease, metabolic disorders, and other diseases; (3) hemorrhagic cerebrovascular disease; (4) pregnant or lactating women; (5) severe primary heart, liver, kidney, hematopoietic system, and endocrine system diseases, and psychosis.

The patients in this study were discontinued if one of the following occurred: (1) misdiagnosis; (2) meeting the exclusion criteria; (3) non-compliance; (4) voluntary withdrawal

from the study; (5) adverse events rendering the patient no longer suitable for further treatment.

Randomization

We generated random allocation sequences for each patient using SPSS software, and thus randomly assigned 30 patients fulfilling the inclusion criteria to receive twirling reinforcing manipulation. Muscle strength of the upper limb was graded 0 in 10 cases, I in 10 cases and II in 10 cases.

Indicator detection

Changes in muscle tension were assessed by measuring resting tension and the ratio of the maximal H-reflex to the maximal M-wave (H_{\max}/M_{\max}), shown *via* electromyography (EMG).

We assessed the resting tension of the biceps and rectus femoris muscles using a soft tissue tension testing system (Tianjin Mingtong Century Technology Co., Ltd., Tianjin, China). The patients held a test sensor in the right hand, pressing a moving section of the device vertically at an even speed for 2–3 seconds, and then released the hand uniformly within 2–3 seconds. A complete test trial comprised pressing and releasing with no noticeable pause.

We used a 5-channel Medelec Synergy system (Oxford Instruments Medical, Inc., Woking, UK) to test the H-reflex and observe the H_{\max}/M_{\max} at baseline and immediately after acupuncture. A recording electrode was placed at the upper 1/3 segment of the line between the medial epicondyle of the humerus and the radial styloid; a reference electrode was placed on the vertical axis of the flexor carpi radialis, located 2–4 cm from the record electrode; a stimulating electrode was positioned at the cubital fossa for transcutaneous stimulation of the median nerve; and a ground electrode was placed at the midpoint between the recording and reference electrodes. The stimulation pulse was set to have a width of 0.5 ms and a frequency of 1 Hz. After EMG debugging, the patients were positioned properly for muscle stimulation. The recording, reference, and ground electrodes were fixed and the stimulating electrode was located at the elbow fossa, following skin degreasing using acetone. The stimulation current was initially set at 0.5 mA, and increased gradually during scanning. During scanning, the amplitude of the H wave began to increase gradually with the presence of the M wave. If the stimulation current was further increased, the amplitude of the H wave would decrease, but the M-wave amplitude would continue to increase. The maximum amplitude of the H wave was recorded automatically by a computer. With the increase of stimulation current, the amplitude of the M wave would begin to show a ceiling effect, which could be eliminated by reducing the sensitivity. Then, the stimulation current could be increased gradually until there was no longer an observed increase in the M wave amplitude. The maximum amplitude of the M wave was automatically recorded by a computer.

Acupuncture interventions

A disposable stainless steel acupuncture needle (Brand Hwa-

to, Suzhou Hua Tuo Medical Instruments Co., Ltd., Suzhou, China), $\phi 0.25 \times 40.00$ mm, was used for scalp acupuncture. After disinfection with 75% ethanol, the needle was inserted rapidly at a 30° angle into the galea aponeurosis at the specific lines between the bilateral *Baihui* and *Taiyang* positions, followed by further rapid insertions in triplicate with no twirling at an angle of 15° and a depth of 30 mm.

The patients were then subjected to scalp acupuncture with the twirling reinforcing manipulation at a twirling angle of 360° and a twirling frequency of about 100 r/min, once for 1 minute, three times separated by a 10-minute interval during the 30-minute needle retention period.

Data analysis

We used Microsoft SQL Server 2012 software (Microsoft, Silicon Valley, San Francisco, CA, USA) for data mining with an association algorithm that examined implicit associations between TCM syndromes and neurologic deficit scores (NDS) at baseline, between simplified Fugl-Meyer assessment (FMA) scores and changing values in the muscle strength of the proximal and distal ends of the hemiplegic limbs at baseline and immediately after acupuncture, and between the changing values in H_{\max}/M_{\max} and muscle tension of the hemiplegic limbs at baseline and immediately after treatment. Given the complexity of the data, we employed an artificial neural network backpropagation (BP) algorithm to verify whether the scalp acupuncture had a bidirectional effect.

The NDS evaluation is a rating tool for the comprehensive assessment of post-stroke functional disorders, involving level of consciousness, horizontal gaze, facial paralysis, speech, muscle strength of the upper limb, hand and lower limb, and walking ability. The NDS score is positively correlated with the degree of neurological deficits. Additionally, NDS can be used to assess the clinical efficacy of a treatment with respect to neurological deficits, that is, the lower the NDS score, the better the clinical efficacy. NDS scoring is a simple, easy, and accurate method for rapidly evaluating neurological function in acute stroke patients.

FMA is a method for evaluating physical performance, and FMA scores are positively correlated with limb motor function. In this study, a great variation in FMA scores before and immediately after acupuncture indicated improvement in limb motor function.

Association natural combination is an important feature of association rules, which is useful to find existing subset modes of all attributes. Apriori is a classical association algorithm designed for frequent item set mining and association rule learning. Apriori has two main stages: first, identify all frequent item sets that appear sufficiently often, at least in line with the minimum support; second, generate strong association rules from frequent item sets that satisfy both a minimum support threshold and a minimum confidence threshold (Yang et al., 2012). To control for the mechanism and therapeutic efficacy of acupuncture in the data mining technology, we adopted a modified Apriori to identify the hidden patterns between TCM syndromes and NDS change values, between FMA change values and variation in the

muscle strength of proximal and distal limbs, and between H_{max}/M_{max} change values and variation in the muscle tension of the upper and lower limbs.

The artificial neural network BP consists of an input layer, a hidden layer, and an output layer (the hidden layer may comprise multiple layers), and generally, the sigmoid function is used in the hidden layer. In the artificial neural network BP, a large number of samples are used to train the network in a forward propagation mode: the input layer → hidden layer → output layer. To minimize the loss function, the error is propagated back from the output layers to update the weights in the network using a gradient descent method (Yang et al., 2012).

Results

Association analysis results of TCM syndromes and NDS change values immediately after acupuncture

We used the association algorithm with the TCM syndrome as the input and the immediate change in NDS as a predictable variable to extract eight association rules, listed as follows from strongest to weakest:

- (1) TCM syndrome = Wind fire causing mental confusion → NDS change interval [9.6, 10.5].
- (2) TCM syndrome = Wind stirring due to *yin* deficiency → NDS immediate change interval [7.6, 9.6].
- (3) TCM syndrome = Wind phlegm and blood stasis → NDS immediate change interval [10.5, 12.2].
- (4) TCM syndrome = *Qi* deficiency and blood stasis → NDS immediate change interval [7.6, 9.6].
- (5) TCM syndrome = Wind phlegm and fire heat → NDS immediate change interval [7.6, 9.6].
- (6) TCM syndrome = *Qi* deficiency and blood stasis → NDS immediate change interval [10.5, 12.2].
- (7) TCM syndrome Wind phlegm and fire heat → NDS immediate change interval [9.6, 10.5].
- (8) TCM syndrome = *Qi* deficiency and phlegm stagnation → NDS immediate change interval [10.5, 12.2].

As described above, the pattern of wind fire causing mental confusion had the strongest effect on the NDS change value, which was subsequently followed by patterns of wind stirring due to *yin* deficiency, wind phlegm and blood stasis, *qi* deficiency and blood stasis, wind phlegm and fire heat, *qi* deficiency and phlegm stagnation. The immediate change interval of NDS was highest ([10.5, 12.2]) in patients with wind phlegm and blood stasis, *qi* deficiency and blood stasis, and *qi* deficiency and phlegm

stagnation, followed by patients with wind fire causing mental confusion and wind phlegm and fire heat ([9.6, 10.5]), and lowest ([7.6, 9.6]) in patients with wind stirring due to *yin* deficiency. In addition, we found different NDS change intervals in patients with the same TCM syndromes. For example, *qi* deficiency and blood stasis pattern was strongly associated with the NDS change value at a range of [7.6, 9.6], and weakly associated at a range of [10.5, 12.2]; wind phlegm and fire heat pattern showed a strong or weak association with the NDS change value at a range of [7.6, 9.6] or [9.6, 10.5], respectively. That is to say: scalp acupuncture has different therapeutic effects on patients with the different TCM syndromes, but has no therapeutic difference on the same TCM syndromes of “Deficiency and Excess” (Table 1).

Association analysis results of FMA change values and change values in the muscle strength of proximal and distal limbs

The results of association analysis between the FMA change values and the change values for the muscle strength of proximal and distal upper limbs are as follows. Two association rules were extracted using the association algorithm. These are listed according to dependency network, *i.e.*, from the strongest to weakest link:

- (1) Change value of the muscle strength of the distal upper limb < 0.95 → FMA change value = 37.51–44.29.
- (2) Change value of the muscle strength of the distal upper limb < 0.95 → FMA change value = 44.29–55.64.

As described above, when the change in the muscle strength of the distal upper limb was < 0.95, the immediate change in FMA was at the interval of [37.51, 55.64]. There was a hidden rule between the change value of the muscle strength of the distal upper limb and the immediate FMA change value, but not between the change value of the muscle strength of the proximal upper limb and the immediate FMA change value. An increase in the muscle strength by a grade of 0, 1, 2, 3 is considered to be invalid, effective, moderately effective, or extremely effective, respectively. Therefore, as the change value for the muscle strength of the distal upper limb was < 0.95, this was approximated to 1 and considered to be effective. This was one of the main factors affecting the immediate change in FMA.

The results of the association analysis for the association between the FMA change value and the change in the muscle strength of the proximal and distal lower limbs are as follows. Three association rules were extracted using the association

Table 1 TCM syndromes and change values of NDS immediately before and after acupuncture in two cases

No.	Group	Sex	Age (year)	Recruitment date	TCM syndrome	NDS score		Change value of NDS
						Before	After	
1	Reinforcing	Male	62	2010.10.11	Wind-phlegm syndrome	22	13	9
2	Reinforcing	Male	54	2010.11.01	Wind-fire syndrome	21	11	10

TCM: Traditional Chinese medicine; NDS: neurological deficit score.

algorithm. These are listed according to dependency network, *i.e.*, from the strongest to weakest link:

- (1) Change in the muscle strength of the proximal lower limb $\geq 2.26 \rightarrow$ FMA immediate change value ≥ 55.64 .
- (2) Change in the muscle strength of the proximal lower limb $< 1.04 \rightarrow$ FMA immediate change value < 26.44 .
- (3) Change in the muscle strength of the proximal lower limb $\geq 2.26 \rightarrow$ FMA immediate change value = 44.29–55.64.

As described above, when the change in the muscle strength of the proximal lower limb was < 1.04 , the immediate change in FMA was less than 26.44; and when the change in the muscle strength of the proximal lower limb was ≥ 2.26 , the immediate change in FMA was in a range [44.29, 55.64] or > 55.64 . The change in the muscle strength of the proximal lower limb was positively correlated with the immediate change in FMA. Based on the immediate change in FMA, changes in the muscle strength of the proximal lower limb that approached 1 or 2 were classified as “effective” or “moderately effective”, respectively. Therefore, the change value of muscle strength for the proximal lower limb was one of the main factors influencing the immediate change in FMA.

In summary, the main factors influencing immediate FMA change were: a change value of muscle strength for the distal upper limb that was maximally approximate to 1, *i.e.*, “effective” and a change value of muscle strength for the proximal lower limbs that was > 2 , *i.e.*, “moderately effective”.

Association analysis results of H_{max}/M_{max} immediate change value and change in the muscle tension of upper or lower limbs

We used the H_{max}/M_{max} change value as the predictable variable and change in the muscle tension of upper or lower limbs as the input to extract 10 association rules, which are listed from strongest to weakest as follows:

- (1) Change in the muscle tension of the lower limb = 0.16–0.63 $\rightarrow H_{max}/M_{max}$ immediate change value < -44.12 .
- (2) Change in the muscle tension of the lower limb = 0.63–0.98 $\rightarrow H_{max}/M_{max}$ immediate change value = -27.24 to 11.60.
- (3) Change in the muscle tension of the lower limb = -0.71 to 0.16 $\rightarrow H_{max}/M_{max}$ immediate change value = 11.60–46.53.
- (4) Change in the muscle tension of the lower limb $< -0.71 \rightarrow H_{max}/M_{max}$ immediate change value ≥ 46.53 .
- (5) Change in the muscle tension of the upper limb = -1.53 to -1.33 $\rightarrow H_{max}/M_{max}$ immediate change value = 11.60–46.53.
- (6) Change in the muscle tension of the upper limb = -1.53 to -0.09 $\rightarrow H_{max}/M_{max}$ immediate change value = 11.60–46.53.
- (7) Change in the muscle tension of the upper limb = -0.09 to 0.60 $\rightarrow H_{max}/M_{max}$ immediate change value ≥ 46.53 .
- (8) Change in the muscle tension of the upper limb $< -1.53 \rightarrow H_{max}/M_{max}$ immediate change value = 11.60–46.53.
- (9) Change in the muscle tension of the lower limb = 0.63–0.98 $\rightarrow H_{max}/M_{max}$ immediate change value = 11.60–46.53.

- (10) Change in the muscle tension of the lower limb = 0.16–0.63 $\rightarrow H_{max}/M_{max}$ immediate change value ≥ 46.53 .

When the change value of muscle tension for the upper limb was between -1.53 and -0.09, the H_{max}/M_{max} immediate change was at the interval of [11.60, 46.53]; and when the change value of muscle tension for the upper limb was between -0.09 and 0.60, the H_{max}/M_{max} immediate change was larger or equal to 46.53. Therefore, there was a positive correlation between the muscle tension change for the upper limb and H_{max}/M_{max} immediate change. Additionally, both positive and negative correlations existed between the muscle tension change for the lower limb and H_{max}/M_{max} immediate change. These were relatively complex, according to the six association rules.

To verify the existence of “bidirectional regulation of acupuncture”, we used a BP algorithm of artificial neural networks to extract the manipulating factors in each classification. Specifically, we mined the association rules between H_{max}/M_{max} immediate change and change in muscle tension for the upper and lower limbs before and after acupuncture treatment. If independent functional dependencies exist, ordered derivatives (the mathematical basis of the BP algorithm) can be used to determine the relationship between dependent and independent variables according to the chain rules. Immediate differences in the H_{max}/M_{max} ratio before and after treatment referred to the H_{max}/M_{max} change value. If positive, the H_{max}/M_{max} change value was set to “P”, and if negative, it was set to “N”. Then, “P” and “N” were assigned as the predicted variable, and the change in the muscle tension of the upper and lower limbs was set as the input. As shown in **Table 2**, when a value is specified for the input variable, it affects the interval of the output variable; the “score” represents the contribution of input variables to output variables. We found that when the change value of muscle tension for the upper and lower limbs was > 0 or < 0 , the H_{max}/M_{max} immediate change value was correspondingly positive or negative, indicating that scalp acupuncture has a bidirectional effect on the muscle tension of hemiplegic limbs.

Table 2 Data analysis of input and output variables using the artificial neural network backpropagation algorithm

Score	H_{max}/M_{max} change value	
	N	P
Δ Muscle tension of the upper limb = -0.990 to -0.020	100	
Δ Muscle tension of the lower limb = -1.330–0.122	61.85	
Δ Muscle tension of the upper limb = 1.304–2.200		59.89
Δ Muscle tension of the upper limb = -0.020–0.642	31.54	
Δ Muscle tension of the upper limb = 0.642–1.304		24.46
Δ Muscle tension of the lower limb = 0.793–0.830		21.26
Δ Muscle tension of the lower limb = -1.220–0.336	12.33	
Δ Muscle tension of the lower limb = 0.336–0.793		10.99

H_{max}/M_{max} : ratio of the maximal H-reflex to the maximal M-wave; N: negative; P: positive.

Discussion

Studies have shown that NDS scoring has good inter-rater reliability, test-retest reliability, internal consistency, and common validity as well as a certain degree of predictive validity. In this study, we mainly observed the motor function of hemiplegic limbs after acupuncture, and all participants were classified as conscious with no language disorders. Therefore, the following aspects were not included in the NDS scoring: level of consciousness, horizontal gaze, facial paralysis, and speech. Here, NDS score was only used to assess the neurological recovery of affected limbs after acupuncture with different manipulations. Using the association and BP algorithms to dig the hidden rules between acupuncture manipulation and therapeutic effects in hemiplegic patients, we found that scalp acupuncture with twirling-reinforcing manipulation was effective for all the TCM syndromes, either Deficiency or Excess syndromes, in our participant group. Clinical studies addressing acupuncture mainly focus on the severity of disease, but little has been reported with respect to TCM syndromes. Our findings suggest that evaluating TCM syndromes at baseline can help clinicians improve acupuncture strategies and thus therapeutic effects.

Clinicians generally focus on improving muscle strength in hemiplegic limbs, but neglect motor function recovery. While recovery of limb motor function is based on improved limb muscle strength, recovery of limb motor function does not always follow such improvement. In this study, we conducted data mining using an association algorithm, and found that the change in the muscle strength of the distal upper limb and proximal lower limbs (as the inputs) was one of the main factors influencing immediate change in FMA before and after treatment (as the predictable variable). These findings may result from the functional division of the upper and lower limbs: the upper limbs are more frequently engaged in fine motor behaviors, and the lower limbs are mainly responsible for weight-bearing and walking. After acupuncture, the maximum change value for the muscle strength of the distal upper limb or proximal lower limb was identified as approximately “effective” or certainly “moderately effective”, respectively. Thus, improvement in the muscle strength of the distal upper and proximal lower limbs is strongly associated with motor function recovery in hemiplegic patients.

It is difficult to accurately measure limb muscle tension that is mainly evaluated by physical touch *via* the hand to assess muscle stiffness (elasticity), passive movement-induced joint resistance, and tendon reflexes. During passive movement, a decrease in muscle tension can reduce muscle stiffness, thereby lowering joint resistance and relaxing tendon reflexes, while increased muscle tension can promote muscle stiffness to increase joint resistance and activate tendon reflexes. Thus, muscle stiffness (elasticity) is a major aspect of muscle tension. In this study, we quantitatively measured muscle tension of hemiplegic limbs *via* a soft tissue tension analysis system. When uniform pressure is applied to soft tissue, a certain displacement will occur at the test site, and

this will vary according to the elasticity of soft tissue: good or poor elasticity results in a small or large displacement, respectively. Thus, displacement can reflect changes in the muscle tension.

The H_{\max}/M_{\max} ratio refers to the percentage of reflexively activated motor units, which reflect alpha motoneuron excitability in the spinal cord anterior horn (Chinese Nerve Science Association, 1996). As previously reported (Schiepati et al., 1987; Ansari et al., 2007), the H_{\max}/M_{\max} ratio is used to represent motoneuron excitability in hemiplegic patients, and is positively correlated with post-stroke spasticity in hemiplegic patients. In this study, we used the immediate difference in the H_{\max}/M_{\max} ratio before and after treatment as a reflection of change in spinal motoneuron excitability. We found that after acupuncture, hemiplegic patients with increased H_{\max}/M_{\max} had low or normal muscle tension, while those with decreased H_{\max}/M_{\max} had slightly elevated or normal muscle tension. These findings indicate that scalp acupuncture has a bidirectional effect on the regulation of muscle tension in hemiplegic patients.

By data mining using the associate algorithm, we found that the difference value of H_{\max}/M_{\max} was strongly and positively associated with the difference value of the muscle tension of the upper limb, indicating that H_{\max}/M_{\max} is an important indicator reflecting limb muscle tension. This is not fully consistent with the previous finding that the H_{\max}/M_{\max} ratio is directly proportional to the muscle spasticity of the hemiplegic limb. However, both positive and negative correlations, which are relatively complex, exist between the muscle tension change in the lower limb and immediate change in H_{\max}/M_{\max} . Because the EMG findings were collected from the affected upper limb of hemiplegic patients, the immediate change in H_{\max}/M_{\max} in this study was positively associated with the change value of muscle tension in the upper limb. However, we found complex associations between the immediate change in H_{\max}/M_{\max} and the change value of muscle tension in the lower limb. Further, using a BP algorithm, we found that when the difference value of muscle tension for the upper and lower limbs was > 0 or < 0 , the difference value of H_{\max}/M_{\max} was correspondingly positive or negative, indicating that scalp acupuncture has a bidirectional effect on muscle tension in hemiplegic limbs.

To conclude, findings from our association algorithm and BP algorithm analysis show that acupuncture with twirling reinforcing manipulation has unique but not specific effects on acute ischemic stroke patients with the same TCM syndromes of “Deficiency and Excess”, indicating the acupuncture treatment is effective for all TCM syndromes. Additionally, improvement in the muscle tension of the distal upper and proximal lower limbs, as represented by the variation in the H_{\max}/M_{\max} ratio, appears to be important for motor function recovery from hemiplegia. Furthermore, scalp acupuncture has a bidirectional effect on muscle tension in hemiplegic limbs.

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Author contributions: XZD, CLB and XMY collected and integrated the data. GRD, XZD, CLB and XMY conceived and designed the study. XZD and XMY analyzed the data, wrote and reviewed the paper, and were responsible for statistical analysis. GRD obtained the funding. XZD, GRD, CLB and XMY were research directors responsible for technical or data support. All authors approved the final version of this paper for publication.

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