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Wan-Ling Hsu

Yi-Chieh Lien

Wei-Hsiu Chang

Chi-Tzu Feng

Kuei-Yu Chou

See next page for additional authors

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Original Article

A Preliminary Evaluation on the Correlation between Severity of Hand Spasticity and Functional Recovery in Chronic Stroke Patients

Wan-Ling Hsu, Yi-Chieh Lien, Wei-Hsiu Chang, Chi-Tzu Feng, Kuei-Yu Chou, An-Fang Hsiao

Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, New Taipei City, Taiwan

Objective: This study is a secondary analysis of data from a previous project that attempts to analyze the correlation between severity of hand spasticity and functional recovery in chronic stroke patients.

Methods: A total of 21 chronic stroke patients who received hand-stretching device or functional training were analyzed. The evaluation of outcomes included the Modified Ashworth Scale (MAS) for assessing hand spasticity; Fugl-Meyer Assessment (FMA), the Action Research Arm Test (ARAT), the Functional Independence Measure (FIM), and Stoke Impact Scale (SIS) for evaluating functional recovery.

Results: Correlation was found between MAS and FIM scores (p=.029), but due to bias on age and severity of spasticity, we could not confirm that hand MAS correlated with activity of daily living (ADL). We also found a limited relationship between change in severity of hand spasticity and functional recovery, even in subjects with lower MAS scores who showed greater improvement in the post-test.

Conclusion: Although subjects with low hand spasticity benefited more from the intervention, we found limited correlation between hand spasticity and functional recovery. Further studies to clarify this actual correlation are required. (Tw J Phys Med Rehabil 2015; 43(3): 181 - 189)

Key Words: correlation, chronic stroke patients, hand spasticity, Modified Ashworth Scale, functional recovery

INTRODUCTION

Stroke survivors frequently have an upper motor neuron (UMN) injury that cause positive and negative features.[1] Negative features include the loss of muscle strength and dexterity, and slowness of movement; positive features include spasticity and abnormal postures. The above motor deficits exist in nearly half of all stroke patients.[2,3] Spasticity in particular is a motor control disorder. Lance (1980) described that it's a "velocity-dependent increase in tonic stretch reflex (muscle tone) with exaggerated tendon jerks"[4] and Pandyan et al.(2005) defined it as "intermittent or sustained involuntary activa-

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Correspondence to: Wan-Ling Hsu, Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, 5F., No.289, Jianguo Road, Xindian District, New Taipei City 231, Taiwan.
Tel：(02) 66289779 ext 3520 E-mail：mysalvia@gmail.com
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tion of muscles".[5-7] Spasticity develops most often in the upper limbs.[3,8] The level of spasticity may change according to the position of patients, intrinsic change of the muscles and the task being performed. The real influences of spasticity on motor impairments and activity limitation are therefore difficult to assess.[2]

Previous studies that used the Modified Ashworth Scale (MAS) to assess the severity of spasticity in stroke patients produced highly variable results with estimated prevalence ranging from 19% to 42.6%, and reaching as high as 65%.[2,3,6,8-10] The highly variable prevalence may be due to different lengths of time since the stroke, the lack of a universal standard of measurement and the small sample size in stroke subjects.[6]

Spasticity may cause some clinical manifestations such as muscle atrophy, contracture, fibrosis, weakness, skin breakdown, malodor, pain, abnormal posture and joint compression; it may also lead to motor deficit and limitations on activity of daily living (ADL) such as dressing and bathing.[6-8,11] Sommerfeld et al.(2004) found that stroke patients with spasticity had significantly lower performance on hand dexterity, mobility and ADL as well as higher risk of falling than those without spasticity.[2] As high as 78% of stroke patients had reported ADL limitation due to spasticity.[6]

Apart from the impact on motor function, activity performance and ADL, spasticity also affected health-related quality of life (QoL) and self-esteem.[3,6,8,12,13] Welmer et al. (2006) used the Short Form Health Survey (SF-36) to analyze the QoL in stroke patients and found significantly lower scores in the physical function domain of SF-36 in patients with spasticity.[12] Doan et al. (2012) also described how stroke patients with spasticity experienced greater disability in the hygiene, dressing and pain domains.[6,13] On the other hand, stroke patients with spasticity necessitated higher costs in hospital care, home help and residential care which were strongly associated with worsening functional ability.[14]

Based on the above, dealing with spasticity in stroke patients to improve their performance on ADL as well as QoL is very important. We currently adopt a multidisciplinary approach to reduce spasticity including pharmacologic intervention,[3,6,11] stretching exercises under rehabilitation intervention (including occupational therapy and physical therapy), hand-stretching device, repetitive transcranial magnetic stimulation (rTMS), neuromuscular electrical stimulation, anti-spastic brace, serial casting, splint, orthosis, and surgery.[6,9,10,15] Among these modalities, hand-stretching devices were recently developed to manage hand spasticity by stretching the subjects' wrist and fingers. Stroke patients benefit from such release of hand spasticity.[9,10]

Our study team also used the Reliver — one hand-stretching device from Daesung Maref company in Korea to evaluate the effect of hand-stretching devices on chronic stroke patients in 2015.[16] Reliver combines the intermittent pneumatic compression principle (IPC) using air gloves to extend the subject's wrist and fingers from the neutral position to the extension position (wrist extended 60°, fingers totally extended) then temporarily maintain this position to stretch the subject's hand. In our previous study,[16] we recruited 21 chronic stroke patients from a rehabilitation unit and randomly assigned them to the experimental group (EG) (11 patients) and the control group (CG) (10 patients); EG accepted Reliver intervention and CG accepted traditional occupational therapy. Our results showed that Reliver did actually reduce hand spasticity through the stretching procedure but the results also showed limited improvement in the motor function, daily living performance and QoL.[16] Previous studies [6-8,12,13] had described that spasticity might affect those functional outcomes. Why reducing hand spasticity could not improve chronic stroke patients' functional performances? This might be due to three possible reasons. First, longer onset time in our subjects (3.48 ± 1.88 years) might affect some improvement from the reduction of spasticity. Second, no patients with severe hand spasticity included might show limited improvement in the motor function, daily living performance and QoL. Third, there might be only a small correlation between hand spasticity and motor /activity performance, just like Sommerfeld el al.(2004) described that severe motor and activity problems were seen in almost the same number of non-spastic as spastic stroke patients.[2] Ada et al.(2006) also described that increasing strength could improve activity, but did not change spasticity.[17]

Because of the different opinions, the aim of our study was to further confirm the correlation between severity of hand spasticity and functional recovery in chronic stroke patients. Since we often deal with the spasticity problems in clinical practices, it is helpful for us to see whether a change in severity of spasticity improved functional performance or not as the knowledge will aid us in making clinical judgements.

METHODS

Participants

This study recruited 21 stroke patients from a rehabilitation unit. Participants were included if they met the following criteria: (1) first onset of stroke and the onset time was over 6 months; (2) aged between from 20 and 80 years; (3) hand spasticity with the MAS scores ≧1; Candidates were excluded if they had (1) history of peripheral nerve injury or musculoskeletal disease in the affected upper extremity; (2) contracture of the affected wrist and fingers; (3) history of any invasive therapy such as Botox injection in the upper limb at least 6 months before the start of this study; (4) unable to follow the instructions of the Mini-Mental State Examination < 23.[18] All participants provided written informed consent prior to the study.

Research Design

Design

This study is a secondary analysis of our previous study in 2015[16] with a randomized pre-test and post-test control design. The 21 participants were randomly assigned to an experimental group (EG) (11 patients) and a control group (CG) (10 patients). The interventions were administered during routine occupational therapy sessions by two certified occupational therapists trained to perform the EG and CG protocols. Before and after the 3-week intervention period, clinical outcome measures were administered by one certified and trained occupational therapist and one doctor both blind to the groups.

Interventions

Both groups received an equal amount of therapy (one hour daily for 5d/wk for 3 consecutive weeks). EG used Reliver to release hand spasticity of the affected hand for about 20 minutes then received traditional occupational therapy (functional training in upper limbs, including reaching, grasping and picking up pegs) for the remaining 40 minutes. In the Reliver protocol, we fixed the participants' forearm, wrist and five fingers to the air glove, and set the air pressure to 300 mmHg with one circle every 20 seconds to regularly stretch the hand. Except during the first inflation, for most of time we could keep the subjects' wrist and fingers in the total extension position (wrist extended 60°, fingers totally extended) (Figure 1).

On the other hand, CG received 60 minutes to the same occupational therapy that EG underwent. During the 3-week intervention period, we didn't change any of the participants' daily activities and other rehabilitation programs (including physical therapy and speech therapy), and all the participants were able to complete our study protocol.

Outcome Measures

We used multiple methods to evaluate the functional recovery of our participants. Hand spasticity was measured by the MAS; motor function was measured by the Fugl-Meyer Assessment (FMA) and the Action Research Arm Test (ARAT); ability of daily life was measured by the Functional Independence Measure (FIM); quality of life was measured by the Stoke Impact Scale (SIS).

MAS was used to evaluate the severity of hand spasticity: 0 (no spasticity); 1 (slight increase in spasticity, manifested by catch and release or by minimal resistance at the end of the range of motion (ROM); 1+ (slight increase in spasticity, manifested by a catch and followed by minimal resistance throughout the remainder of the ROM); 2 (more marked increase in spasticity through most of the ROM, but the affected part(s) is easily moved); 3 (considerable increase in spasticity, difficult passive movement); 4 (affected part(s) rigid).[9,10,15,19] In our study, we evaluated all subjects' wrist flexion/extension and fingers flexion/extension performances, then calculated their average value to represent their hand spasticity; we also used a score of 1.5 to represent 1+ for analysis.

Fugl-Meyer Assessment (FMA) is a widely used quantitative measure of motor impairment in both clinical and research settings.[20] The Upper-Extremity (UE) subscale of the FMA (FMA-UE) consists of 33 items to measure UE movement, coordination and speed on a 3-point scale (0=cannot perform to 2=can perform fully). Higher scores indicate better recovery.

Action Research Arm Test (ARAT) is a 19-item measurement that includes 4 subtests (grasp, grip, pinch and arm gross movement) rated on a 4-point scale (0=can perform no part of test to 3=performs test normally) with higher scores indicating better UE function.[20]

Functional Independence Measure (FIM) was developed to evaluate the level of disability and to measure how much assistance is required to carry out ADL. It consists of 18 items rated on a 7-point scale (0=complete dependence to 7=complete independence).[15,21]

Stoke Impact Scale (SIS) is a self-reported QoL measurement used to assess the difficulty level in performing activities.[22] It consists of 8 domains (strength, hand function, etc.) with a total of 64 items rated on a 5-point scale. Higher scores indicate better QoL.

Data Analysis

SPSS statistics (version 18.0) (SPSS, Inc., Chicago) was used to analyze the collected data in this study. For the correlation analysis, we first used the baseline scores from both groups to test the relationship between severity of hand spasticity (hand MAS scores) and functional performances (FMA-UE, ARAT, FIM and SIS scores); second, we calculated the difference between pretest and post-test hand MAS scores (pretest minus post-test = progressed MAS scores) and defined this variable as the change in severity of spasticity to our database. We then assessed the correlation between change in severity of hand spasticity and functional recovery (change in scores between pre- and post-test on the FMA-UE, ARAT, FIM and SIS). Both steps used Spearman's rank correlation coefficient to measure the relationship among these variables.

Moreover, we used the median score of pretest hand MAS scores (median=1.5) from all subjects (21 participants) to regroup our data into two separate new groups; subjects with higher scores (hand MAS score $\geqq 1.5$) formed one group (H-MAS), and subjects with lower scores (hand MAS score < 1.5) formed the other group (L-MAS). We then analyzed whether hand spasticity influenced the patients' functional performances or not. Nonparametric statistical methods including the Mann-Whitney U test and Wilcoxon's test were used to analyze all the variables due to the small sample size and non-standardized normal distribution. Our Null hypothesis was that no difference would be rejected if p-values were less than 0.05.

RESULTS

We analyzed data from 21 participants (14 men), with a mean age of 53.48 years. Mean stroke onset was 3.48 years, 10 patients had ischemic stroke, and 10 patients had right hemisphere lesion. The severity of hand spasticity was represented by the pretest hand MAS scores (Table 1). Most patients in our study had slightly increased spasticity (MAS=1-1.99) and none had a severe degree of hand spasticity (MAS$\geqq$3) as previously mentioned. Table 2 summarized the correlations between hand MAS scores and functional performance in the pretest and showed that hand MAS scores correlated with FIM scores (correlation coefficient=0.476, p=.029).

As for the correlation between change in severity of hand spasticity (change in score between pre- and post-test hand MAS scores) and functional recovery (change in score between pre- and post-test on FMA-UE, ARAT, FIM and SIS), we did not find any statistically significant correlation between these variables (Table 3). Finally, the results of regrouping analysis were showed in the Table 4. There was no significant difference found in pretest. After comparing two groups (H-MAS and L-MAS), there was no between group difference in posttest, but we found that the group with lower hand MAS scores (L-MAS) in pretest had a within group difference. Their post-test ARAT is higher than the pretest ARAT (pretest ARAT=13.46, posttest ARAT=15.23, p=.038).

Table 1. Hand MAS scores of pretest in 21 chronic stroke patients

Mean MAS scores	n(21)	Cumulative percentage
≦0.99	3	14.3
1-1.99	16	90.5
2-2.99	2	100
3-3.99	0	
≧4	0	
Total	21	

Table 2. Correlations between the hand MAS scores and the functional performance of chronic stroke patients in pretest (Spearman's rank correlation coefficient)

	Functional Performance			
	FMA-UE	ARAT	FIM	SIS
MAS	-0.419	-0.286	0.476*	0.221

Note: MAS= Modified Ashworth Scale; FMA-UE= The Upper-Extremity subscale of Fugl-Meyer Assessment; ARAT= The Action Research Arm Test; FIM =Functional Independence Measure; SIS=Stoke Impact Scale, all scores are pretest scores.

*correlation with $p<.05$

Table 3. Correlations between the change in severity of the hand spasticity (progressed MAS scores) and the functional recovery in the chronic stroke patients (Spearman's rank correlation coefficient)

	Functional Recovery (change in score between pre- and post-test)			
	FMA-UE	ARAT	FIM	SIS
progressed MAS scores	0.290	-0.113	0.218	0.137

Note: MAS= Modified Ashworth Scale; FMA-UE= The Upper-Extremity subscale of Fugl-Meyer Assessment; ARAT= The Action Research Arm Test; FIM =Functional Independence Measure; SIS=Stoke Impact Scale, all scores are pretest scores.

Table 4. The regrouping analysis results with the median score of hand MAS scores in Pretest:

Outcome	H-MAS(n=8)			L-MAS(n=13)		
Measures	Pretest	Posttest	p value	Pretest	Posttest	p value
FMA-UE	22.37±6.82	24.00±7.45	.361	29.62±15.12	29.92±15.67	.663
ARAT	10.13±7.26	9.38±6.48	.596	13.46±15.86	15.23±17.39	.038*
FIM	113.50±9.27	115.75±5.39	.270	104.54±16.73	102.54±15.14	.414
SIS	196.60±23.08	203.13±30.38	.327	191.00±36.26	196.54±38.10	.456

Note: MAS= Modified Ashworth Scale; FMA-UE= The Upper-Extremity subscale of Fugl-Meyer Assessment; ARAT= The Action Research Arm Test; FIM =Functional Independence Measure; SIS=Stoke Impact Scale; H-MAS=Higher MAS in pretest; L-MAS=Lower MAS in pretest; regrouping based on the median score of MAS in pretest (MAS=1.5); p value = the p value of within group; *$p<.05$.

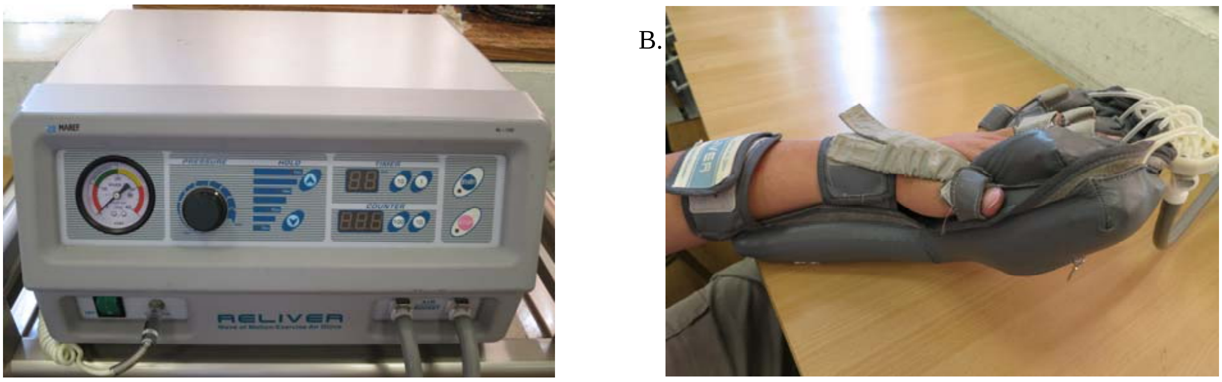

Figure 1. The Reliver (A) the control panel; (B) the air glove for stretching the subject's hand.

DISCUSSION

The aim of this study was to conduct a preliminary evaluation on the correlation between severity of hand spasticity and functional recovery using the data from our previous study. First, we used the baseline scores of all study participants (n=21) to investigate the relationship between hand MAS scores and functional performance on FMA-UE, ARAT, FIM and SIS. The results show that no statistically significant correlation existed between the hand MAS scores, motor function (FMA-UE, ARAT) and QoL(SIS). However, we found some negative trends between the hand MAS scores and the motor function. Subjects with higher hand MAS scores may have lower motor performance. As described in the previous study, spasticity was correlated with strength deficit in the agonist muscle[23] that may have possibly had a further effect the motor performance of patients.

For ADL function, we found that there was a correlation between hand MAS scores and FIM (correlation coefficient=0.476, p=.029). Why subjects with higher hand MAS scores have better ADL performance? As our subjects' hand MAS scores were mostly within the range of 1 to 1.99 (none had severe hand spasticity), we didn't include stroke patients with every level of hand MAS scores; as for chronic stroke patients like those we included, many factors might affect their functional performance such as age, stroke type, time since onset... etc. Correlation analysis was therefore conducted between the hand MAS score and other pretest data. We then found that there was a slight correlation between age and pretest hand MAS scores (the correlation coefficient= -0.42, p=.058). Our subjects with a younger age may have higher hand MAS scores, because age would influence the ADL performance (older adults with illnesses would have higher risk of losing independence during activities),[24] this meant that our subjects with a younger age might have higher hand MAS scores and better ADL performance, and these bias could affect the results of our analysis that caused positive correlation between hand MAS scores and FIM scores. We need to expand our sample size and do further studies to reduce these bias.

In addition, the FIM scale includes the upper limbs/lower limbs activity performance, bladder/bowel management and social interaction/cognitive ability. It does not represent pure upper limbs activity performance. In order to establish the actual correlation between hand spasticity and ADL function, further analysis and studies are necessary to clarify this finding.

As for the results of the second correlation analysis, we found that no significant relationship between the change in severity of hand spasticity and functional recovery; when our subjects' hand spasticity was reduced their functional performances did not change at the same time. This was similar to some previous studies [2,17] that found that regardless of having a spasticity problem or not, severe disability was seen in almost the same number of non-spastic as spastic patients. With no change in spasticity, stroke patients can still achieve some improvements in activity performance with strengthening interventions.[14] However the results of regrouping showed that subjects with lower hand MAS scores from the pretest (L-MAS) experienced improvements in their

ARAT performance after intervention. Based on this finding, we could speculate that subjects with lower hand spasticity in their baseline condition may derive greater benefits from the interventions like our study's occupational therapy and hand-stretching device intervention. This in turn influenced their motor recovery. As said in other previous studies,[2,3,6-8,11-13] the release of spasticity may improve functional performances.

The different findings in this study may be due to our biased hand MAS scores distribution (no one with severe hand spasticity) and the small sample size, so the impact of hand spasticity might be relatively small or couldn't be found. As for chronic stroke patients like those we included, many factors might affect their functional performance such as age, stroke type, time since onset, muscle strength, hand dexterity, having caregiver or not, side of stroke, and even motivation. In addition, earlier studies described that spasticity reached its maximum between 1 to 3 months after stroke onset. After 3 months, the increased resistance to passive stretching is possible due to intrinsic changes of the muscles.[2,7] MAS only measures the spasticity of relaxed muscles and not for activated muscles.[2] The use of MAS to reflect the values of hand spasticity may therefore be open to criticism.

Although we could not make any definite conclusions about the relationship between hand spasticity and functional recovery, we still arrived at the following implications for occupational therapy practice. First, hand spasticity seems to contribute to motor impairments and activity limitations that may be a problem for some stroke patients, but focusing only on the spasticity problem is unrealistic; we should analyze the relationship between the physical and functional changes induced by hand spasticity or other causes, and add ways of reducing hand spasticity as a supplemental method to our therapeutic program when necessary.

Second, although we used some functional training to treat our chronic stroke patients (onset time 3.48 years), the results showed only limited improvement. Previous studies showed the importance of early intervention.[6,8,17] The goal of rehabilitation is to help patients achieve maximal independence with the least environmental limitations. Careful and continued evaluation to find the causes of disabilities is essential before a decision is made. This will allow us to choose the proper rehabilitation approach and incorporate multidisciplinary methods to improve functional performances.

There are several limitations in our study, first, the small sample size due to including only 21 stroke patients; second, the limited time course and severity of hand spasticity in our patients may confine the explanation of our results and make them non-representative of all stroke patients. We need more concrete evidence, appropriate measures, more types of stroke patients (difference degree of spasticity, time course) and an increase in sample size to investigate the actual relationship between the severity of hand spasticity and functional recovery.

CONCLUSION

Although subjects with low hand spasticity benefited more from intervention, the biased hand MAS score distribution in this study meant that the severity of hand spasticity in chronic stroke patients may have limited correlation with their functional performance in terms of motor ability and ADL function. To confirm the necessity of including methods for releasing spasticity and to determine the actual relationship between hand spasticity and functional recovery in chronic stroke patients, further rigorous study is recommended. The findings will be very helpful to the field of rehabilitation of stroke patients.

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慢性中風患者手部痙攣嚴重度與功能性恢復的相關性探討

徐宛伶　連一潔　張維修　馮紀慈　周桂酉　蕭安芳

佛教慈濟醫療財團法人台北慈濟醫院

本研究爲再次分析之研究，目的爲探討慢性中風患者手部痙攣問題與其功能性恢復的相關性。分析之樣本爲 21 位慢性中風患者，且接受過手部拉筋設備或功能性活動之訓練；手部痙攣使用改良式艾斯渥氏量表來評量，而功能性恢復則使用傅格-梅爾評估量表、手臂動作調查測試表、功能獨立量表、中風影響量表等工具，並利用相關性分析來探討兩者的相關性。結果顯示改良式艾斯渥氏量表與功能獨立量表有顯著相關(p=.029)，但因本研究參與者的年齡與痙攣程度有所偏頗，可能會影響此結果之呈現；且痙攣問題有所改善之個案其功能性恢復評量並無明顯的相關性呈現，即使僅有輕微痙攣問題之患者於介入後有較明顯的進步。由上述結果可知，雖然當個案有較低的手部痙攣表現時，較能於介入後得到功能性的恢復，但受限於本研究未納入各痙攣程度之個案，慢性中風患者之手部痙攣嚴重度與功能性恢復的相關性分析卻不甚顯著，需要未來更多的研究才能真正了解兩者的相關性。（台灣復健醫誌 2015；43(3)：181 - 189）

關鍵詞：相關性(correlation)、慢性中風患者(chronic stroke patients)、手部痙攣(hand spasticity)、改良式艾斯渥氏量表(Modified Ashworth Scale)、功能性恢復(functional recovery)

通訊作者：徐宛伶職能治療師，佛教慈濟醫療財團法人台北慈濟醫院，新北市 231 新店區建國路 289 號
電話：(02) 66289779 轉 3520　　E-mail：mysalvia@gmail.com
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