

# Simple Grading for Motor Function in Spastic Arm Paralysis: Hua-Shan Grading of Upper Extremity

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*Objective:* Spastic arm paralysis after central neurological injury has a long-term effect on the patient's quality of life. Effective neurosurgical treatment for this dysfunction has been described in our previous studies. It is of great significance to determine a set of unified and concise clinical standards for motor function grading in the neurosurgical treatment and management. *Methods:* We first conducted a retrospective study that included 51 hemiplegic patients from the Neurosurgery and Microsurgery outpatient database of Huashan Hospital. The neurosurgeons cooperated with rehabilitation experts to design and administer the new rating system (Hua-Shan Grading of Upper Extremity, H-S grading) after analyzing the scale scores and video records of these patients. We then randomly enrolled 64 patients with unilateral spastic arm paralysis after stroke or brain trauma. The Fugl-Meyer Assessment, the Ashworth scale and the new grading system were applied and analyzed to evaluate the participants' motor function. *Results:* Based on rehabilitation medicine scales and long-term follow-up, a feasible and concise grading system was applied that was based on the patients' characteristics and the examination experiences of neurosurgeons and rehabilitation experts in clinical practice. This method could effectively grade upper extremity motor function, usually in 3-5 minutes. A significant correlation was found between H-S grading and the Fugl-Meyer score by the Spearman test ( $r = .937, P < .01$ ). The mean difference between any two levels of the new grading system was significant ( $P < .05$ ). And good test-retest reliability, the Cronbach's alpha coefficient and the validity indices were presented. In addition, it was more sensitive to motor function compared with the Ashworth scale. *Conclusion:* As a supplement to the classic scales, H-S grading was

*Abbreviations:* ANOVA, analysis of variance; CNI, central neurological injury; FM-UE/FMA, Fugl-Meyer assessment for upper extremity; GMFM-88, gross motor function measure; H-S Grading, Hua-Shan grading of upper extremity; MAS, Modified Ashworth Scale; SD, standard deviation; TBI, traumatic brain injury; WMFT, Wolf Motor Function Test

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developed in the area of spastic hemiplegia treatment. It is standardized and simplified for patients in the chronic stage after central neurological injury.

**Key Words:** Spastic hemiplegia—upper extremity—motor disorder—grading—scale

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## Introduction

Spastic arm paralysis due to injury to a cerebral hemisphere or a central neurological injury (CNI) such as stroke, traumatic brain injury (TBI), or cerebral palsy is a cause of long-term disability.<sup>1,2</sup> The hands and upper extremities play an important role in activities of daily living, and at present, functional recovery of the affected limb is one of the most difficult problems in clinical practice.<sup>3,4</sup> In previous studies, we published our results of a new strategy for treating spastic arm paralysis, cervical nerve transfer procedure, to functionally connect to the contralesional hemisphere of patients after CNI. In our clinical trial, patients with more than 5 years post-CNI were assigned to the neurosurgical procedure, and a satisfactory outcome was observed: the mean increase in the Fugl-Meyer Assessment for Upper Extremity (FM-UE, or FMA as follows) was 17.7 points.<sup>5</sup> In our clinical practice, we found that the treatment and evaluation of motor function were both essential for the management of upper limb dysfunction.

However, there is a lack of clinical standards that are simple and applicable for the evaluation of upper limb motor function in patients, especially those at the chronic or plateau stage.<sup>6</sup> These patients had arm paresis for several years, and their limb function had ceased to improve after at least 6 months of rehabilitation. We performed the surgical procedure only for these patients.<sup>5,7,8</sup> In our practice, we use different assessment scales, such as the FMA,<sup>9</sup> the Wolf Motor Function Test,<sup>6</sup> the Gross Motor Function Measure (GMFM-88),<sup>10</sup> the House Functional Classification System,<sup>11</sup> and the Brunnstrom stages.<sup>12</sup> These scales are widely accepted for rehabilitation assessment and have high validity and reliability. However, they commonly contain a quantity of items and are designed especially for rehabilitation and neurological experts. To help neurosurgical department and perform the new operation procedure, a simplified and concise clinical grading standard should be available in addition to the classic scales mentioned above. For instance, more and more patients come to Neurosurgery and Microsurgery Clinic in our hospital. And some inpatients might refuse to cooperate with existing assessments due to the repeated examinations and amount of time they require. Additionally, for neurosurgeons or primary care doctors in the community without access to rehabilitation personnel and special venues, the classical scales are hard to implement and require professional training time. Other simplified scales, such as the Los Angeles Motor Scale<sup>13,14</sup> and the 3-Item Stroke Scale,<sup>15</sup> are prehospital evaluations designed for paramedic use

during the acute stage of the stroke and are not suitable for our patients at the plateau stage.

Therefore, the new grading system, as a standardized guideline, can be used by clinical practitioners for rapid examinations, screening, or the management of patients at the chronic stage whose physical condition will not change significantly in the short term.

## Methods

### *The Design of the Assessment*

### Retrospective Study

The first part of this study was based on a review of the history and examination data of 58 post-CNI patients from the outpatient database of the Neurosurgery and Microsurgery Clinic of Huashan Hospital, Shanghai, China, from November 2016 to November 2017. The patients all had arm hemiparesis because of stroke or TBI and a clear diagnosis of unilateral brain lesion by CT or MRI. Seven patients did not have scale data because they refused to complete examinations for physical or personal reasons. The other patients, a total of 51, completed the scale assessments and video records (refer to Results and Discussion). Based on the patients' characteristics and clinical examinations by neurosurgeons and rehabilitation experts, a new functional assessment called the Hua-Shan Grading of Upper Extremity (H-S grading) was developed for patients with spastic hemiplegia after CNI. The assessment scheme is described below, and the grading criteria are provided in the online supplement.

### Assessment Scheme

This grading system (Table 1, Supplemental material of the criteria, Supplemental material of the rating sheet) is a measure of hand and upper extremity motor impairment in patients with spastic hemiplegia at the chronic or plateau stage after CNI. The assessment includes 4 grades (I-IV) and 6 levels (grade II is divided into II-a, II-b, and II-c). The grades are determined by the completion of the main and secondary test indicators, which are based on the main motions of the hand and upper extremity. Five main indicators and 3 secondary indicators were established by the consensus of neurosurgeons and rehabilitation experts. The main indicators included the motions of the wrist and hand, and the secondary indicators comprised the motions of the shoulder and elbow.

**Table 1.** Hua-Shan grading of upper extremity (H-S grading)

Level	Grade	Number of main indicator*	Number of secondary indicator <sup>†</sup>	Description
1	I	≤2	0	Nearly complete palsy
2	II-a	≤2	1	Severe dysfunction
3	II-b		2	
4	II-c		3	
5	III	3-4		Moderate dysfunction
6	IV	5		Mild dysfunction

\*Main indicators: 1. grasp and lift; 2. open hand; 3. pinch; 4. wrist extension ( $\geq 15^\circ$ ); and 5. forearm rotation ( $\geq 45^\circ$ ).

<sup>†</sup>Secondary indicators: 1. shoulder flexion ( $\geq 90^\circ$ ); 2. elbow extension ( $\geq 60^\circ$ ); and 3. hand touching the lower jaw.

The assessment instruments include a chair, a table, a cone, A4 paper, and a protractor. The cone is made of wood or a similar material and is 4 cm in diameter and 12 cm high (Supplement Fig 1). The assessment is performed in a quiet area when the patient is maximally alert and is in a sitting or standing position. The combination of indicators determines the patient's final grading. It usually takes 3 minutes to complete the assessment.

Functional motions of the hand and wrist were selected as the main indicators. These motions included grasping; suspending and lifting an object; opening the hand: volitionally opening the hand to let the object fall onto the table; pinching: holding a piece of paper firmly with the thumb and index finger and resisting a slight tug; wrist extension ( $\geq 15^\circ$ ); and forearm rotation ( $\geq 45^\circ$ ). After the development and adjustment of our scale test by surgeons and rehabilitation experts, Grades I-II were determined to reflect an inability to complete the main indicators and represented patients with FMA scores below 35 (Discussion). Grades III-IV reflected the ability to complete the main indicators (more than 2 items attained). This was the primary stratification used in our grading system. Regarding shoulder and elbow function, relatively simple motions such as shoulder flexion, elbow extension and lower jaw touching were selected as secondary indicators and sources of secondary stratification in our grading system. There are 5 main indicators and 3 secondary indicators in the new grading system. The item selection conformed to the common clinical patterns of motor dysfunction in the upper extremity after CNI, including adduction, internally rotated shoulder, flexed elbow, pronated forearm, flexed wrist, clenched fist, and thumb-in-palm.<sup>16</sup> The combination and number of indicators determine the patients' level. This classification was tested and verified in the next part of this study.

### Test and Correlation Analysis

#### Subjects and Methods

Thirty-two poststroke patients and 32 post-TBI patients, a total of 64, from the Neurosurgery and Microsurgery Clinic of Huashan Hospital were randomly enrolled from February to July 2018. Inclusion criteria: no gender

preference; between 15 and 69 years of age; spastic hemiplegia caused by stroke or TBI; diagnosis confirmed by MRI or CT<sup>17</sup>; unilateral arm paralysis; at the chronic or plateau stage; extremity function that ceased to improve after at least 6 months rehabilitation; Modified Ashworth scale (MAS)<sup>18</sup> score greater than or equal to 1 for the elbow joint; stable mental state and physical condition; willingness to cooperate, and good compliance. The Mini-Mental State Examination<sup>19</sup> score was used to exclude patients with serious cognitive disorders; additionally, patients with vision and hearing impairment and a history of congenital or psychiatric disorders were excluded. The patients were assessed by professional rehabilitation doctors using a battery that included H-S grading, the MAS and the FMA, and the time required to complete the test was recorded. Specifically, the H-S grading was stipulated to be evaluated by the same assessor for all patients as well as the second H-S assessments 2 weeks later, which was for the test-retest reliability of the new grading system. Data from the 64 cases were fully recorded and sent for statistical analysis.

#### Statistical Analysis

The results were processed with SPSS 23 software. As a rank variable, the H-S grading and MAS data were compared with the FMA scores using the Spearman correlation test. One-way analysis of variance (ANOVA) was chosen to analyze the differences among the levels of each scale. The reliability of the grading was tested by the test-retest reliability analysis and the Cronbach's alpha coefficient as interitem reliability. The validity of the grading was evaluated by the correlation analysis between H-S grading and FMA which equaled the convergent validity in our research, for the FMA was considered a golden standard of motor function test for upper extremity.

#### Statement

The ethical approval of this research was given by the medical ethics committee of Huashan Institutional Review Board, Fudan University. And the written informed consent was obtained for each participant according to federal and institutional guidelines.

**Results**

First, a retrospective study was performed that included hemiplegic patients after CNI from the Neurosurgical Outpatient Database of Huashan Hospital who were recruited over a 1-year period as the Reviewed group. This portion of the study formed the basis of the design of the scale (Table 1 and Discussion). There were 51 patients in the Reviewed group, including 30 post-stroke patients and 21 post-TBI patients (41 males and 10 females); the average age was  $34.06 \pm 13.98$  years. In the test part of this study, 64 patients with spastic hemiplegia after stroke or trauma were recruited to test and evaluate the new grading system. There were 53 males and 11 females in the Test group; their average age was  $47.97 \pm 13.77$  years. The general patient information is shown in Supplemental Table I.

The distribution of the FMA scores among the patients in the Reviewed group and the Test group was analyzed. In the Reviewed group, 44 patients had scores of 0-35, accounting for 86.27%; 7 patients had scores greater than or equal to 36, accounting for 13.73%. Among the patients with an FMA score of 0-35, the wrist and hand total scores (upto 24 possible) commonly did not exceed 10, and the average scores were  $2.95 \pm 2.55$  average score (range 0-8). Among the patients with FMA greater than or equal to 36, the wrist and hand scores exceeded 10. Similar results were revealed in the Test group (Table 2).

In the test part, the patients were evaluated by using H-S grading and the FMA (Supplemental Table II). The correlation between the H-S and FMA scores was determined (Table 3 and Fig 1); it was .937 for the poststroke and TBI patients according to the Spearman test, and the difference was statistically significant ( $P < .01$ ). Therefore, the results of H-S grading and the FMA are relevant to these patients. Moreover, compared with the mean FMA score,

there were statistically significant differences within the groups between any 2 H-S levels (Fig 2). Furthermore, the average time required to complete H-S grading was  $3.77 \pm 1.58$  minutes (range 2-9 minutes).

As for the validity and reliability properties, the correlation analysis between H-S grading and Fugl-Meyer assessment is the convergent validity in our research, which is .937 demonstrated above. On the other hand, the test-retest reliability:  $r = .971$ ; and the mean of the differences of the first and second test  $\bar{d} = .156$ ,  $t = .331$ ,  $P = .742$ . The result of Cronbach's alpha coefficient between the main indicators and the secondary indicators was .722.

In our general outpatient population, 94.00% of the patients had a MAS score greater than 1 (range 0-4). For the 64 patients with MAS greater than 1 in the Test group, the correlation coefficient for the MAS and the FMA was  $-.251$  according to the Spearman test, and this value was not statistically significant. Moreover, compared with the mean FMA scores, there were no statistically significant differences between any 2 levels of the MAS between 1 and 3. In contrast, the mean plot of the FMA score to the MAS is shown in Figure 3, A, and the plot of H-S grading is shown in Figure 3, B.

**Discussion**

In our surgical clinical practice, most hemiplegic patients present with severe loss of limb function, a finding that is also reported in related studies.<sup>1,20</sup> Effective neurosurgical treatments for this dysfunction have been described in our previous studies.<sup>5</sup> It is of great significance to determine a set of unified and concise clinical standards for evaluating motor function in patients with spastic hemiplegia during treatment and management as a supplement to the classic scales. A new grading system (Table 1) was designed and tested with the consensus of

**Table 2.** FM-UE distribution analysis

	FM = 0-35		FM ≥ 36	
	Reviewed group	Test group	Reviewed group	Test group
Number (percentage)	44 (86.27%)	46 (71.90%)	7 (13.73%)	18 (28.10%)
Wrist & hand* (range)	$2.95 \pm 2.55$ (0-8)	$2.39 \pm 2.01$ (0-7)	$14.29 \pm 4.68$ (9-22)	$15.94 \pm 4.19$ (9-24)
Shoulder & elbow† (range)	$15.75 \pm 5.98$ (0-25)	$12.24 \pm 5.97$ (2-27)	$28.71 \pm 3.99$ (23-34)	$27.00 \pm 5.26$ (16-36)

FM-UE = FM = Fugl-Meyer Assessment for upper extremity.

\*FMA scores a maximum of 24 for the motor function of wrist and hand (mean ± SD).

†FMA scores a maximum of 36 for the motor function of shoulder and elbow (mean ± SD).

**Table 3.** Correlation test between H-S and FM-UE

	Total(n = 64)	Stroke(n = 32)	Trauma(n = 32)
Age, mean ± SD (range)	$48.0 \pm 13.9$ (15-73)	$50.8 \pm 9.5$ (33-69)	$45.3 \pm 16.9$ (15-73)
H-S *, mean ± SD (range)	$3.5 \pm 1.6$ (1-6)	$3.3 \pm 1.6$ (1-6)	$3.6 \pm 1.6$ (1-6)
FM-UE, mean ± SD (range)	$24.8 \pm 16.1$ (2-61)	$23.9 \pm 15.8$ (3-61)	$25.7 \pm 16.6$ (2-61)
r Value	.941 <sup>†</sup>	.937 <sup>†</sup>	.937 <sup>†</sup>

\*The H-S assessment includes 4 grades with 6 degrees, transforming the assessment results into 1-6 levels for statistical analysis.

† $P < .001$ .

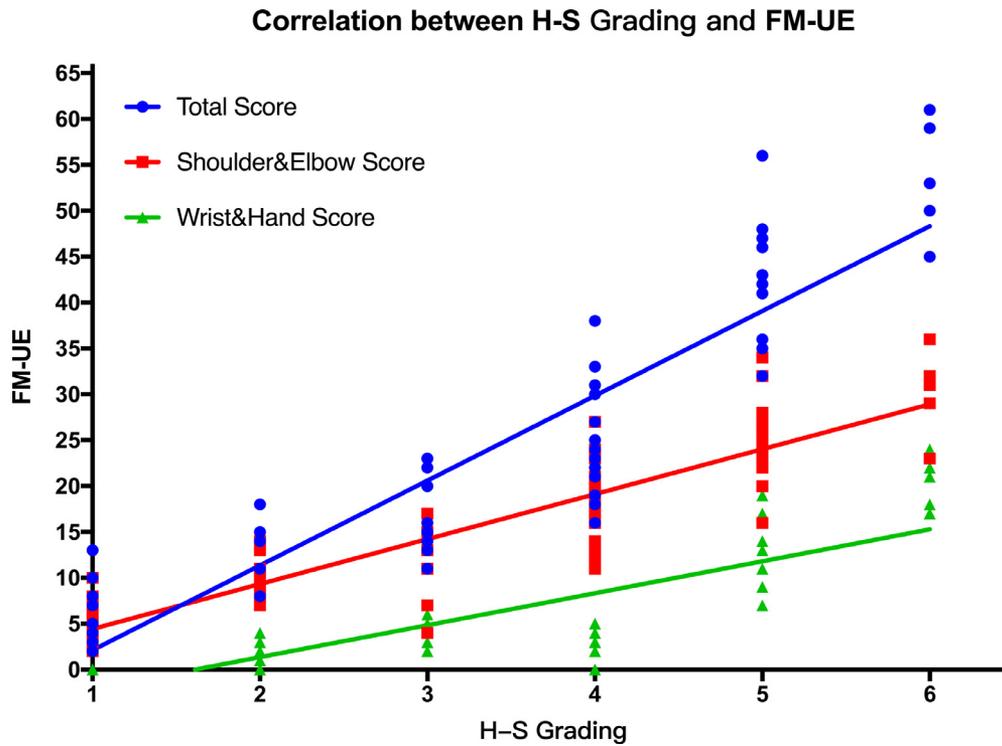


Figure 1. The correlation between H-S grading and FM-UE score. Abbreviation: FM-UE, Fugl-Meyer assessment for upper extremity.

neurosurgeons and rehabilitation experts in a retrospective study that summarized the scale data and video records of patients at Huashan Hospital with spastic hemiplegia. Next, the feasibility and effectiveness of the

new grading system was tested by enrolling a new group of hemiplegic patients at the chronic or plateau stage.

Patients with FMA scores below 35 represent most of the patients in our surgical department clinic; 86.27% of

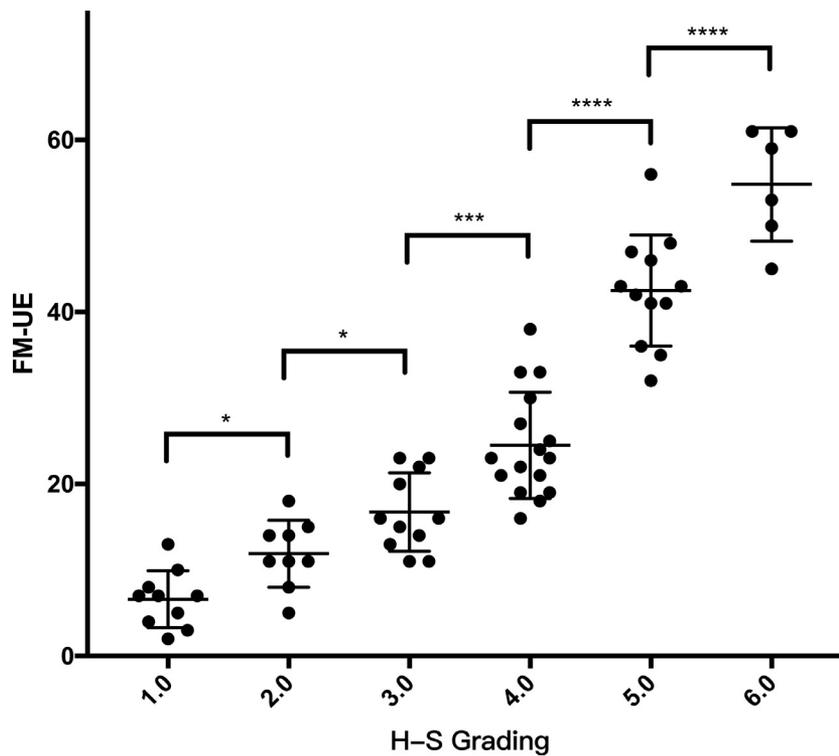
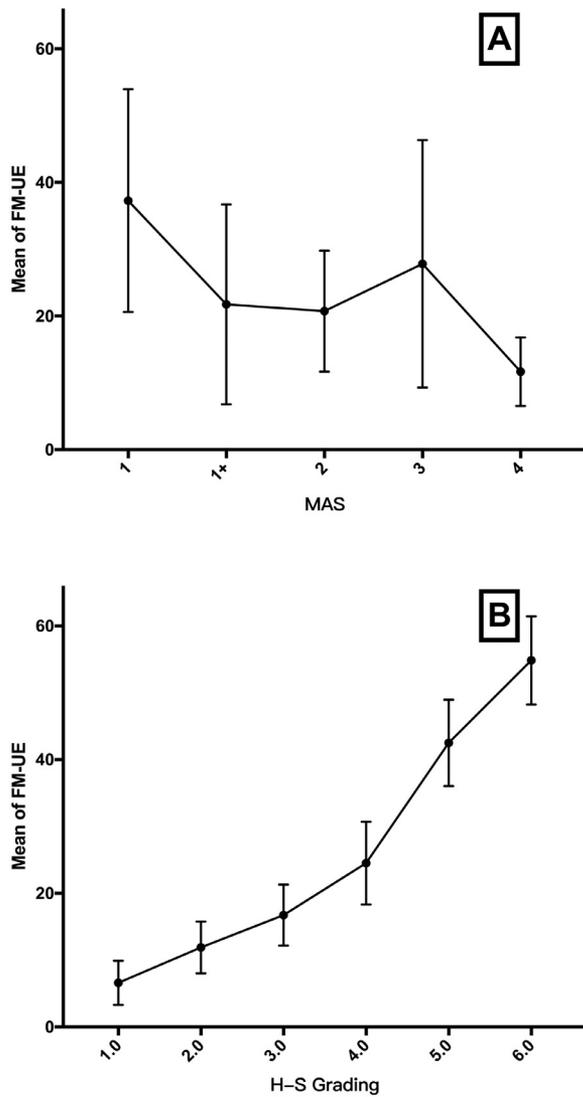


Figure 2. The ANOVA analysis of H-S grading and FM-UE score.



**Figure 3.** (A and B) The mean plot of FM-UE score (mean with SD) to MAS and H-S grading. MAS, Modified Ashworth Scale.

the patients in the Reviewed group and 71.90% in the Test group fell within this range. The percentage of the total patient group with scores in this range was 79.09%. The lower proportion of patients with FMA scores of 0-35 in the Test group might be due to the expansion of surgical treatment, which allowed more patients with better function to seek treatment at the surgical clinic. Further differentiating the function of these patient populations is an important goal. In our study, for patients with an FMA score of 0-35, the wrist and hand total scores (upto 24) did not exceed 10 and averaged  $2.95 \pm 2.55$  (range 0-8); in patients with FMA scores greater than or equal to 36, the wrist and hand scores commonly exceeded 10. Lindenberg<sup>21</sup> tested the correlations between motor impairment and diffusion tensor imaging-derived measures of motor tract integrity. His study revealed that nearly all the pyramidal tracts with the most alternate motor fibers were damaged in hemiplegic patients with an average FMA

score below 30. This score is similar to the scores determined in our study, and this imaging study provides a potential explanation for clinically observed poor volitional function of the hand and wrist.

The FMA is a classic scale that has been widely used for the functional evaluation and follow-up of patients with central hemiplegia.<sup>9</sup> The total FMA score for the upper extremity is 66 points, including 36 for the shoulder and elbow, 24 for the wrist and hand, and 6 for the finger-nose test. Our study found that for the wrist and hand, the Reviewed group had grades of  $2.95 \pm 2.55$  (range, 0-8), while the Test group had grades of  $2.39 \pm 2.01$  (range, 0-7) (Table 2), showing nearly complete loss of hand and wrist function at our clinic; these findings were confirmed by video recordings. Therefore, wrist and hand function can determine whether a patient's FMA score is likely to be 35 and higher or below 35; consequently, wrist and hand function was set as the primary stratification indicator in our grading system. The shoulder and elbow scores did not show such a distinct boundary; instead, they varied in proportion to the total score. For example, among the patients with FMA 0-35, the shoulder and elbow scores (upto 36) were  $15.75 \pm 5.98$  (0-25) in the Reviewed group and  $12.24 \pm 5.97$  (2-27) in the Test group (Table 2). In our study, shoulder and elbow function was set as the secondary indicator for the subdivision of Grades I-II. Relatively simple motions, such as shoulder flexion, elbow extension and lower jaw touching, were selected, and these were used as the secondary stratification in our grading system.

On the scale test, the Spearman correlation coefficients of H-S grading and the FMA score were .937 ( $P < .01$ ) among both the poststroke and post-trauma patients (Table 3 and Fig 2). The results showed a correlation between H-S grading and FMA scores. The correlation coefficient reflected the correctness of the scale measurement. In our test, H-S grading could rapidly spot the corresponding range of FMA scores. Grade I corresponded to estimated FMA about less than 10, Grade II corresponded to about less than 35, Grade III corresponded to about 35-55, and Grade IV corresponded to about greater than 50 (Fig 1). Furthermore, there were statistically significant differences between any 2 levels of H-S grades (Fig 2). Therefore, H-S grading could describe the different degrees of limb function impairment in patients with spastic hemiplegia, which is the responsiveness to different subjects.

The correlation coefficient, .937, was also the convergent validity in our research, for the FMA was considered a golden standard of motor function test for upper extremity. On the other hand, concerning for the reliability, the test-retest reliability:  $r = .971$ ; and the mean of the differences of the first and second test = .156,  $t = .331$ ,  $P = .742$ . And The result of Cronbach's alpha coefficient was .722 which was implicitly assumed that there was good inter-item reliability between the main and

secondary indicators. As the Cronbach's alpha coefficient can be viewed as the expected correlation of 2 tests that measure the same construct and normally the inter reliability is good when the Cronbach's alpha coefficient is more than .7.

For the evaluation of spasticity, the MAS is widely accepted and very simple to use, with good validity and reliability<sup>22</sup>; however, it is unclear whether the MAS performs comparably for motor function assessment. It was revealed that 94.00% of the patients in our clinical database had a MAS score greater than 1 (range 0-4). In the 64 patients (MAS > 1) in the Test group, the Spearman correlation coefficient of the MAS and the FMA was  $-.251$ , which was not statistically significant. Therefore, the MAS and the FMA were not considered relevant to each other for patients with MAS greater than 1. Furthermore, patients in 2 different levels of MAS 1-3 were not significantly different. In contrast, the mean plot of the FMA score to the MAS score and the H-S grade is shown in Figure 3; these plots show functional improvement accompanied by H-S grading rather than the MAS score. As the MAS score increased, the FMA score did not decrease over time. Instead, the FMA score sometimes increased during certain stages. This result is believed to conform with Brunnstrom's stage theory.<sup>12</sup> According to Brunnstrom's theory, spasticity is a type of compensation, and with an increase in spasms, motor function may be improved. The results from our database show that H-S grading was more sensitive to motor function than the MAS score, which performed well for spasticity.

The grading system required significantly less time to administer than other scales. The average time required to administer the H-S grading assessment was  $3.77 \pm 1.58$  minutes (range 2-9 minutes), while 10-20 minutes was required to finish the FMA after long-term professional training. It took more than 30 minutes to administer the Wolf Motor Function Test.<sup>6</sup>

In conclusion, H-S grading is an original and innovative method for rapidly assessing upper limb function in spastic patients at the chronic stage. It was designed by a consensus of neurosurgeons and rehabilitation experts based on the follow-up data of patients at Huashan Hospital. As a rapid and simplified test, it is user-friendly and easy to remember and implement. Therefore, it is easily used and accepted in clinical settings for the classification and management of motor function. One role of assessment scales is to provide information for future treatments. The H-S scale is a simplified method, and balancing simplicity and sensitivity is difficult. However, our original intention was to design this grading system as a supplement to the classic scales. We hope that this grading system can meet the needs of doctors and patients in specific situations and promote the clinical diagnosis and management of patients with spastic hemiplegia.

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## Disclosures

No potential conflicts are reported.

## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2019.04.006.

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