

Clinical Assessments for Predicting Functional Recovery after Stroke

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Abstract

Despite on-going technological developments, clinical assessment remains an essential tool to evaluate the effects of rehabilitation treatment and to predict functional recovery. This paper provides a review of clinical assessment for stroke patients focusing on predictive value of motor, function and participation assessment, taking into consideration some specific evaluations for upper and lower limb function, trunk control, balance and walking. In the future an increased integration between clinical assessment, neurophysiology and neuroimaging will be required, in order to apply specific evaluation pathways to reach a more accurate and customized prognostic stratification.

Keywords: Stroke; Functional recovery; Neurorehabilitation; Clinical assessment

Introduction

Functional recovery could be defined as the restoration of function with resumption of the previous activity with characteristics comparable to those pre-stroke [1]. Knowing that recovery is a dynamic and modifiable concept, modern neurorehabilitation is aimed at improving functional recovery after stroke, taking advantage from the mechanisms of brain plasticity that occur after an acute event. The final objective is to reach the best recovery as possible in the single subject. To achieve this it is important to predict and stratify functional recovery, defining in early stages long-term individual functional recovery potential. Despite on-going technological developments, clinical assessment of functional recovery remains an essential tool to evaluate the effects of rehabilitation treatment and to predict functional recovery [1]. For instance, clinical evaluation is still crucial in the description of compensatory mechanisms distinguishing them from real motor recovery.

The study and assessment of stroke patients is linked to numerous outcome measures applicable to one or more of disease dimensions. The commonly used outcome measures in stroke rehabilitation have been classified in the WHO International Classification of Functioning, Disability and Health (ICF: WHO, 2001, 2002), a multi-dimensional framework for health and disability. The ICF framework (2001, 2002) provides the conceptual basis for measurement of three primary levels of human functioning: the body or body part, the whole person and the whole person in relation to his/her social context. In effect, behavioral functional recovery can be evaluated at different levels, referring to body functions/structure (impairment), activities (formerly conceived as disability) and participation (formerly referred to as handicap). Activity and participation are affected by environmental and personal factors (referred to as contextual factors within the ICF). The ICF provides a useful reference to identify and quantify the concepts contained in outcome measures used in stroke trials [2].

In the following chapters, our discussion follows this classification providing an overview of clinical assessment for stroke patients. The focus is on predictive value of motor, function and participation assessment taking into consideration specific evaluations for upper and lower limb function, trunk control, balance and walking.

Properties of Clinical Assessment Tools

Before describing in detail clinical tools, it is necessary to analyse their psychometric properties. The knowledge of the properties of these tools is useful also to guide the selection of the most appropriate outcomes measure. In particular, reliability, validity, responsiveness to

change, sensibility and minimal clinically important difference have widespread usage and are discussed as being essential to the evaluation of outcome measures [3].

Reliability refers to the reproducibility and internal consistency of the instrument [4]. Reproducibility addresses the degree to which the score is free from random error. Test re-test & inter-observer reliability both focus on this aspect of reliability. Internal consistency assesses the homogeneity of the items of the scale. Validity is the actual capacity of an instrument to measure what it is intended and presumed to measure. Forms of validity include face, content, construct and criterion. Concurrent, convergent or discriminative, and predictive validity are all considered as forms of criterion validity. Though, concurrent, convergent and discriminative validity all depend on the existence of a "gold standard" to provide a basis for comparison. If no gold standard exists, they represent a form of construct validity in which the relationship to another measure is hypothesized [5]. Responsiveness reflects the sensitivity to detect clinical changes within patients over time (which might be indicative of therapeutic effects). Responsiveness is most commonly evaluated through correlation with other change scores, effect sizes, standardized response means, relative efficiency, sensitivity & specificity of change scores and Receiver Operating Characteristic (ROC) analysis. Assessment of possible floor and ceiling effects indicate limits to the range of detectable change beyond which no further improvement or deterioration can be detected. Sensibility refers to the overall appropriateness, importance and ease of use of the instrument [6].

Minimal clinically important difference is a parameter to define a threshold that is considered to be an important improvement for the patient [7]. For each outcome measure mentioned in this article, reliability, validity and responsiveness of are reported (Table 1).

Motor Impairment Assessment

The first level or category of the ICF classification system, Body Structure/Impairment, includes the identification or assessment

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Outcome Measure	Reliability		Validity		Responsiveness		
	Rigor	Results	Rigor	Results	Rigor	Results	Floor/ceiling
Body Structure-Impairment							
Fugl-Meyer Assessment	+++	+++ (TR) +++ (IO) ++ (IC-balance)	+++	+++ (problems balance & sensation sections)	++	++ (UE) + (sensation)	+ (sensation)
Mini Mental State Examination	+++	+++ (TR) ++ (IO) ++ (IC)	+++	++	n/a	n/a	n/a
Modified Ashworth Scale	+++	++ (TR) ++ (IO)	+	++	+	++	n/a
National Institutes of Health Stroke Scale	++	++ (TR) ++ (IO) + (IC)	+++	+++	+	+	+
Activity/Disability							
Action Research Arm Test	++	+++ (TR) +++ (IO)	++	+++	++	+++	+
Barthel Index	+++	+++ (TR) +++ (IO) +++ (IC)	+++	+++	+++	++	varied
Berg Balance Scale	++	+++ (TR) +++ (IO) +++ (IC)	+++	+++	+++	+++	varied
Box and Block Test	++	+++ (TR) +++ (IO)	++	+++	++	++	n/a
Chedoke-McMaster Stroke Assessment Scale	+	+++ (TR) +++ (IO) +++ (IC)	+	+++	+	+++	n/a
Functional Ambulation Categories	+	+ (TR) +++ (IO)	++	+++	+	+++	+
Functional Independence Measure	+++	+++ (TR) +++ (IO) +++ (IC)	+++	++	+++	++	++
Frenchay Activities Index	+++	++ (TR) ++ (IO) +++ (IC)	+++	+++	+	++	+++
Rivermead Motor Assessment	+	++ (TR) + (IO) +++ (IC)	++	++	+	++	Possible floor effect
Six-Minute Walk Test	++	+++ (TR) +++ (IO)	+++	+++	++	++	n/a
Nine Hole Peg Test	++	+++ (TR) +++ (IO)	++	+++	+	+	+
Rivermead Mobility Inventory	+++	+++ (TR) +++ (IO) +++ (IC)	+++	+++	+++	+++	varied
Timed "Up & Go"	++	+++ (TR) +++ (IO)	+++	+++	+	++	+ (floor, pts unable to)

							complete)	
Wolf Motor	+	+++ (TR)	+	+++	++	++	+	
Function Test		+++ (IO)						
		++ (IC)						
			Participation					
Medical Outcomes	+++	+++ (TR)	+++	+++	++	+++	+++ (total score –	
Study Short Form		+++ (IC)					floor/ceiling)	
36							++ (individual	
							domains – floor)	
							+ / ++ (individual	
							domains - ceiling)	
Stroke Impact Scale	+	++ (TR) +++ (IC)	++	+++	++	+	varied	

NOTE: +++=Excellent; ++=Adequate; +=Poor; n/a = insufficient information; TR=Test re-test; IC= internal consistency; IO = Interobserver; varied (re. floor/ceiling effects; mixed results); UE=upper extremity.

Table 1: Reliability, validity and responsiveness of outcome measure mentioned in the article. [Taken from: Matthew Moses B. A., & Teasell R. Outcome Measures in Stroke Rehabilitation. Evidence-Based Review of Stroke Rehabilitation, 2013].

of impairments in body function, structure or system (including psychological).

Among the tools to assess motor impairment, Fugl-Meyer Assessment (FMA) scale [8] is one of the most widely used and internationally accepted [9]. The scale is divided in five different items: sensibility, pain, passive motion, active motion and balance, providing a global assessment of motor recovery after stroke. FMA is a feasible, well-designed and very efficient quantitative measure [9], to be administered by a trained physical or occupational therapist. It should take approximately 30 – 45 minutes to administer the scale, but a limitation is that it may take considerably longer [10]. Other limitations of the motor domain include a ceiling effect, omission of some potentially relevant items and weighting of the arm more than the leg [9]. Anyhow, it requires no specialized equipment and can be administered across a variety of settings and has been tested for use in longitudinal assessments.

Motricity Index (MI) is a test able to provide a rapid overall indication of a patient's limb impairment [11]. The total score of MI derives from the evaluation of one movement at each joint. The arm scores of MI measure strength in pinch grip, elbow flexion (from 90°) and shoulder abduction. The leg scores of MI evaluate strength in hip flexion, knee extension and ankle dorsiflexion [11,12].

Modified Ashworth Scale (MAS) is a clinical tool to assign a rating of the amount of resistance or muscle tone perceived by the examiner moving the limb through its full range of motion. The original Ashworth scale consisted of 5 grades from 0 to 4 [13]. More recently, Bohannon and Smith added one grade (1+) and revised the wording of the scale in an attempt to make the scale more sensitive. MAS is widely used and accepted even if ambiguity of wording and lack of standardized procedures limit the scale's usefulness for comparison across studies as well as lower levels of reliability instrument [4] (Table 1).

The National Institutes of Health Stroke Scale (NIHSS) is an instrument for broader assessment of patient's impairment. In fact, NIHSS is a general measure of the severity of symptoms associated with stroke and it is used as a quantitative measure of neurological deficit after the acute event. It is widely used and can be administered rapidly following acute admission [14].

Functional Assessment

The most used scales for function assessment could be divided

between those scales that assess global aspects, such as the improvements in ADLs (i.e. the Barthel Index), and those that assess specific limitation in the execution of a task (as Action Research Arm Test or Wolf Motor Function Test for upper limb).

ADL evaluation

The evaluation of ability in ADLs has been widely used as a main outcome measure after stroke [15] and reducing the degree of dependence in ADLs is one of the central aims of rehabilitation treatment in stroke patients. The prediction of ADL function at an early stage enables clinicians to select the best treatment programs and goals for these patients [16]. ADLs could be divided in basic ADL (BADL) and instrumental ADL (IADL). BADL include self-care activities and the ability to live independently. Barthel Index (BI) and Functional Independence Measure (FIM) are reliable and valid scales (Table 1) to evaluate patient's ability to carry out BADL and are among the most used assessment scales in stroke rehabilitation.

BI is a very simple test consisting in 10 items to investigate independence/dependence in common ADL, to be administered through direct observation. BI proved to be a useful instrument with high inter-rater reliability, internal consistency, convergent and predictive validity [17]. A relative insensitivity and a lack of responsiveness (with significant ceiling and floor effects) have been reported [18].

Developed in part as a response to the highlighted criticism of BI, FIM assesses physical and cognitive disability in terms of burden of care. FIM contains 13 items related to motor score (self-care, bowel and bladder continence, mobility and ambulation) and 5 items related to social/cognition score [19]. Many studies have evaluated its reliability, validity and sensitivity to change. In an evaluation of responsiveness, FIM, motor FIM and the BI were all found to have similar effect sizes, while the total-FIM was reported to exhibit no ceiling effect (0% as compared to the BI's 7%). This would suggest that the FIM might have no real advantage in terms of responsiveness to change despite having more items and a more precise scoring range for each item. Nevertheless, it has been demonstrated a high concordance between FIM and BI [20] and it has also been shown that the BI was used more often than the FIM in randomized controlled trials and that it was cited in trials of superior quality [21]. Even if BADL evaluation has been widely used as outcome measure in stroke patients, BADL evaluation does not take into account of significant impairment in higher levels of

physical functions or activities necessary for independence at home and in community [15]. This is the field of application of IADL evaluation scales, among which the most used are Frenchay Activities Index [22] and Philadelphia Geriatric Center (PGC) Instrumental ADL Scale [23,24]. In these scales, domestic, leisure/work and outdoor activities assessment are included. For the reasons previously submitted, some author [25,26] recommended to combine the IADL and BADL evaluation in order to measure ADL function in a more comprehensive way.

Upper limb assessment

Partial or complete motor recovery of upper limb, even after initial paralysis, represents an important example of the recovery potential of the brain [27]. The initial measurement of upper limb impairment and function were found to be the most significant predictors of upper limb recovery [28]. In particular, the evaluation of active finger extension proved to be a strong and reliable early predictor of recovery of arm function in stroke patients [29]. Initial shoulder shrug predicted good hand movement and hand function at 1, 2, and 3 months, respectively [30]. Initial presence of synergistic hand movement predicted good hand movement at 1, 2, and 3 months and hand function at 1 and 2 months. Initial active shoulder abduction predicted good hand movement at 1 month and hand function at 1 and 2 months only.

Combining the early assessment of the movements of the hand and shoulder, the Early Prediction of Functional Outcome after Stroke (EPOS) cohort study [31] found that the evaluation of voluntary extension of the fingers and abduction of the hemiplegic shoulder within 72 hours after stroke predict upper limb function at 6 months (measured with the ARAT scale). Moreover, Stinear et al. [32] outlined the predicting recovery potential (PREP) algorithm to predict upper limb motor recovery including as a key factor the SAFE (Shoulder Abduction, Finger Extension) score. This score is a measure of shoulder abduction and finger extension evaluated with MRC scale 72 hours after stroke onset. With this algorithm, they tried to stratify various levels of functional recovery according to clinical and neurophysiological evaluations and trying to define the goals of rehabilitation basing on that prediction. The PREP algorithm is currently the only sequential algorithm that combines clinical, neurophysiological and neuroimaging assessment at the sub-acute stage to predict the potential for subsequent recovery of upper limb function [33].

Many tools are available for the assessment of arm function. Together with FMA, Wolf Motor Function Test (WMFT) is one of the most widely used test to quantify possible changes of arm function in response to rehabilitation therapy [34]. WMFT is a time-based method to evaluate upper extremity function while providing insight into joint-specific and total limb movements [34]. WMFT consists of 17 items or tasks, arranged in order of complexity and progress from proximal to distal joint involvement. Functional scores for the WMFT are derived via the application of a 6 point scale, ranging from 0 (does not attempt with involved upper extremity) to 5 (arm does participate and movement appears to be normal). Functional ability scale (FAS) scores are expressed as the mean of item scores [34]. The WMFT is an instrument with high interrater reliability, internal consistency, test-retest reliability and adequate stability [34].

Even if Hsieh et al. [35] demonstrated moderate associations between total and motor FIM scores and timed performance scores at WMFT, the relationship between quality of movement (FAS) and FIM scores was substantially weaker. In addition, only timed task completion was predictive of functional outcome as assessed on the FIM.

The short forms of the FMA and WMFT had comparable psychometric properties to their own original assessments and demonstrate sound clinical utility [36] made a psychometric comparison of the shortened FMA and the streamlined WMFT. The streamlined FMA demonstrated greater responsiveness, better concurrent and predictive validity compared with the streamlined WMFT in subacute stroke patients. The streamlined FMA, for its better psychometric properties, is more practical for use in the assessment of arm function in patients with subacute stroke.

Another method of assessment of upper limb function is Action Research Arm Test (ARAT). It consists of 19 items divided into 4 subscales: grasp, grip, pinch, and gross movement. The items are scored on a 4-level ordinal scale [37]. The ARAT is a responsive and valid instrument to measure upper-extremity functional limitation [38].

Hsieh et al. [35] examined and compared the responsiveness, construct validity and predictive validity of FMA, ARAT and WMFT in stroke rehabilitation trials. The FMA confirmed a large degree of responsiveness, along with good construct and predictive validity properties. Moreover, the ARAT showed good responsiveness and construct validity, but its predictive validity was low. The construct validity of the 2 measures of the WMFT was supported; the WMFT-FAS had a large responsiveness, and the WMFT-TIME had moderate predictive validity. Nevertheless, the responsiveness of the WMFT-TIME was small, and the predictive validity of the WMFT-FAS was low.

Thus, compared to the ARAT and the WMFT, the FMA is a relatively complete outcome measure of motor function after stroke rehabilitation.

At last, other clinical instruments widely used are: Jebsen Taylor Hand Function Test, a well validated test for functional motor assessment of a broad range of hand functions used in ADL, Box and Block Test, a unilateral assessment of gross manual dexterity, and Nine Hole Peg Test, a simple and quick assessment for finger dexterity (Table 1).

Lower limb evaluation, balance and walking

For most of stroke patients the primary aim of rehabilitation treatment is the recovery of walking ability. For this reason, along with motor function evaluation of lower limbs, it is important to evaluate walking ability. As we already stated, lower limb assessment can be performed with lower extremity subscores of FMA and MI; walking performance measurement is instead based on simple tests like 6-minute walk test (6MWT) (alternatively replaced by 2- and 12- minute walk test) and 10-meter walk test (10mWT) (sometimes replaced by 5- or 8- meter distances) [5].

The 6MWT is a widely used tool that provides a quantitative measure of submaximal exercise capacity. Subjects are instructed to "walk as far as possible in six minutes", without encouragement [39].

Initially 6MWT was predominantly used to assess outcomes in individuals with cardiac and pulmonary diseases, while subsequently its use was introduced also in stroke population [39]. In 10mWT participants are asked to walk for 10 meters while being timed so that their walking speed may be calculated. All these walking tests are brief, inexpensive and simple to administer.

A study compared the change in 2-, 6- and 12-minute walk test scores to change in FIM walking subscores during inpatient rehabilitation following stroke [40], finding that serial 6- and 12-minute walk tests were more sensitive to change and more useful in gait outcome documentation than FIM walking subscores.

Repeated comfortable walking speed measurements are sensitive enough to detect clinically important changes in physically independent gait in people severely affected by stroke [41]. In a recent study [42] 5-meter walk test and 6-minute walk test were used to assess gait speed and walking distance in stroke patients. Both gait speed and walking distance were found to be strongly associated with community walking. Community walking after stroke is an equally accurate predictor for community walking as walking distance in mildly to moderately affected patients approximately 9 months post-stroke.

Balance is another clinical factor to evaluate stroke patients: the risk of falls after stroke is high and balance is important to prevent falls [43]. The measurement of balance function with scales like Berg Balance Scale (BBS) can predict falls [44]. BBS is a scale to assess the ability to maintain balance, either statically or while performing functional movements, and to evaluate fall risk. It comprises 14 tasks common to everyday life [45].

Furthermore, an objective measure of basic mobility and balance maneuvers can be performed using the Timed "up & go" (TUG). TUG assesses the ability to perform sequential motor tasks relative to walking and turning [4]. TUG requires subjects to stand up from a chair, walk for a distance of 3 meters, turn around, walk back to the chair and seat themselves. This activity is timed and the test is administered through direct observation of task completion. TUG is quick and easy to administer with high inter- and intra-reliability, demonstrating consistent and reliable results [46].

Trunk control

Trunk Control Test (TCT) is a clinical method to examine some aspects of trunk movement and it is performed in four different positions (rolling to weak side, rolling to strong side, sitting up from lying down and sitting in a balanced position on the edge of the bed, with the feet off the ground). TCT is sometimes administered together with MI scores of arm and leg: when the scores are added, an overall evaluation of motor function is reached. Anyway, the TCT alone resulted to have a good predictive value when related to eventual walking ability [47].

A good correlation was found between trunk control at an early stage and comprehensive ADL function in stroke patients 6 months after stroke event [48]. As we previously stated, early prediction of ADL function at 6 months after stroke is critical, but the addition of TCT to early evaluations may be important.

Participation Assessment

Participation represents the involvement of an individual in a life situation [21]. Restrictions to participation describe difficulties experienced by the subject in a life situation or role. Social context may take longer to stabilize than the impaired body structure [49], so suggested time frame for assessment should be delayed compared to body function and activity. The main instruments are: Canadian Occupational Performance Measure, EuroQol Quality of Life Scale, Assessment of Life Habits, London Handicap Scale, Medical Outcomes Study Short-Form 36 (SF-36), Nottingham Health Profile, Reintegration to Normal Living Index, Stroke Adapted Sickness Impact Profile, Stroke Impact Scale and Stroke Specific Quality of Life.

SF-36 is an assessment tool divided in two domain: physical component subscale and Mental component subscale, each ranging from 0 to 100 [50]. The SF-36 questionnaire can be administered by self-completion questionnaire or by interview (either on the telephone or in-person). Higher rates of missing data have been reported among older patients when using a self-completed form of administration [51].

Instrumental Neurophysiological/Imaging Parameters

There is a substantial unexplained inter-individual variability in the capacity for motor recovery that cannot be explained only with clinical assessment. Prabhakaran et al. assessed motor recovery in 41 stroke patients administering FMA Motor Score within 72 hours after stroke onset and at 3 and 6 months follow-ups. They found that clinical variables could explain only 47% of the variance in recovery.

In this light, clinical assessments could be combined with neurophysiological and neuroimaging parameters helping to predict functional recovery. Stinear et al. [52] proposed an algorithm the prediction of functional potential initially considering only instrumental neurophysiological and neuroimaging measures. Through these parameters the structural integrity of the corticospinal tracts was assessed. The parameters included were the presence or absence of motor evoked potentials in the affected upper limb (assessed using transcranial magnetic stimulation) and the lateralization of cortical activity during affected hand use at functional MRI. Furthermore, diffusion tensor imaging was used to measure the asymmetry in fractional anisotropy of the internal capsules. They proposed to use the level of predicted recovery obtained for the selection of individualized rehabilitation strategies. Anyway, in a subsequent study [32] the same group outlined the importance of clinical evaluation 72 hours after stroke onset adding the measure of shoulder abduction and finger extension (evaluated with MRC scale) in the predictive algorithm.

Conclusion

In the future it is expected that the clinical assessment will continue to play a vital role in the evaluation and prognostic definition of post-stroke patients.

Anyway, there is still no consistency in the selection of outcome measures or the timing of assessments. There is also remarkable heterogeneity of patients enrolled in different trials without adequate adjustment for expected outcomes [49,53]. This methodological variability makes quite difficult a results comparison across various studies and consequently the thorough understanding of the efficacy of the rehabilitative intervention. In fact, the choice of a given outcome measure (rather than another one) can significantly influence the results of a study. A way to minimize this problem might be the definition of feasible clinical guidelines, that should be universally accepted and followed. This would help in improving post-stroke clinical assessment in order to increase comparability between research articles. Furthermore, an increased integration between clinical assessment, neurophysiology and neuroimaging will be required to apply specific evaluation pathways. The introduction of integrated algorithms for evaluation may allow a more accurate and customized prognostic stratification, defining an individual functional recovery potential for the single subject.

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