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Predictive ability of 2-day measurement of AROM on 3-month UE motor function in people with post-stroke hemiparesis

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Abstract

Objective—We determined: 1) if active range of motion (AROM) of shoulder flexion and wrist extension measured at the initial therapy evaluation in the acute hospital predicted upper extremity (UE) motor function three months after stroke and 2) if the presence of non-motor impairments influenced this prediction.

Methods—We collected AROM data from 50 people with stroke during their initial, acute hospital, therapy evaluation and UE motor function data 3 months later. Multiple regression techniques determined the predictive ability of initial AROM on later UE motor function.

Results—Initial AROM explained 28% of the variance in UE motor function 3 months post stroke. Non-motor deficits did not contribute to the variance.

Conclusions—Compared to later AROM measurements, initial values do not adequately predict UE motor function 3 months after stroke. Clinicians should use caution when informing clients of UE functional prognosis in the early days after stroke.

Keywords

Rehabilitation; Stroke; Upper extremity; Activities of daily living; Linear regression

INTRODUCTION

The ability to predict upper extremity (UE) motor function post stroke is important for planning rehabilitation service needs and patient discharge. For the purposes of this paper, UE motor function is defined as the capacity to use the UE for skilled actions, such as reaching, grasping, and manipulating objects used in daily life. UE motor function is frequently determined via performance of various skilled actions in the clinic and/or by self-report of performance. Prediction of future UE motor function can provide prognostic information about functional motor activities achievable by the individual at the end of the rehabilitation process. This information would assist clinicians with selecting appropriate interventions, setting goals, and educating the individual with stroke and their caregivers. A handful of studies have investigated the predictive validity of various assessment tools on UE motor function (de Weerd, Lincoln, & Harrison, 1987; Feys et al., 2000; Katrak et al., 1998; Kwakkel, Kollen, van der Grond, & Prevo, 2003; Loewen & Anderson, 1990; Smania et al., 2007). Interpretation of the collective data is challenged by the use of various

predictor variables, outcome variables, prediction time points, and analytical models. One general conclusion can be drawn from these data: people with less severe impairments, particularly less motor loss (i.e. milder paresis) early, achieve better UE motor function later. This general conclusion however, does not provide the depth of information necessary to inform the clinician about potential level of independence, achievable activities, appropriate interventions, goal setting, or individual and caregiver education.

In a sample of people with relatively pure motor hemiparesis, we recently showed that the simple measurements of UE active range of motion (AROM) measured 3 weeks after stroke was predictive of UE motor function three months after stroke (Beebe & Lang, 2009a). AROM measurements of shoulder flexion and middle finger flexion/extension taken an average of 3 weeks post stroke explained 71% of the variance in UE motor function 3 months later, where UE motor function was measured with a comprehensive test battery quantifying the motor capacity of the affected upper extremity. AROM measures can be conceptually considered as a measure of the ability to voluntarily activate the spinal motoneuron pools that move a given segment, and thus an index of paretic severity (Hislop & Montgomery, 2002). Since AROM measures are predictive of later UE motor function, they may be a quick, inexpensive way to obtain prognostic data regarding UE motor function near the end of the rehabilitation process.

Two issues need further refinement however: the timing of the measurements and the sample of people in which they are evaluated. With respect to the first issue, people with stroke typically enter the rehabilitation system within the first day or first few days after stroke, not at 3 weeks. With respect to the second issue, people with stroke experience deficits in non-motor domains, not just in the motor and somatosensory domains as was tested previously (Beebe & Lang, 2008, 2009a; Lang & Beebe, 2007). Of the many non-motor deficits seen after stroke, three are particularly common and debilitating: aphasia, neglect, and cognitive deficits (Cherney & Halper, 2001; Wade, Hower, David, & Enderby, 1986; Zinn, Bosworth, Hoenig, & Swartzwelder, 2007). The purpose of this study, therefore, was to determine if AROM at a proximal and distal joint taken at the initial therapy evaluation in the acute hospital was predictive of UE motor function 3 months later in people with deficits in motor and non-motor domains. Shoulder flexion and wrist extension were chosen as the representative proximal and distal movement assessed in the current study because they had high zero-order correlations with function in the earlier studies (Lang & Beebe, 2007) and were easy to measure systematically in the acute care hospital. Our hypotheses were: 1) initial AROM measurements of the shoulder flexion and wrist extension would predict UE motor function 3 months post stroke; 2) non-motor deficits of aphasia, neglect, and cognitive deficits would not influence the predictive relationship between initial AROM measurement and UE motor function 3 months post stroke.

METHODS

This study used a prospective cohort design to evaluate the relationship between AROM measurements taken at the initial therapy evaluation at the acute hospital and UE motor function 3 months later. Fifty subjects provided data on post stroke recovery. Subjects were recruited from the Cognitive Rehabilitation Research Group and Brain Recovery Core Registries. The Registries are comprehensive databases of nearly all individuals admitted to Barnes Jewish Hospital with stroke; the only criterion to be entered into the Registries is a diagnosis of stroke or TIA. All subjects in the registries gave informed consent after admission to the hospital and the study was approved by the Washington University Human Research Protection Office. All eligible subjects were contacted first by written correspondence followed by a recruitment phone call. Inclusion criteria for participation in the study were: 1) adults with clinical diagnosis of ischemic or hemorrhagic stroke, meeting

ICD-9 criteria; 2) data from initial physical and occupational therapy assessments within 7 days post stroke; 3) unilateral UE paresis, as indicated by a score of 1-4 on the National Institutes of Health Stroke Scale (NIHSS) Arm item; 4) persistent deficits post stroke, as indicated by a total NIHSS score of 2 or higher; and 5) ability to follow 2-step commands. Exclusion criteria for participation in the study were: 1) history or current diagnoses of any other neurological or psychiatric conditions, including previous stroke; 2) current orthopedic condition involving the affected UE, 3) recent fall or UE surgery involving the affected UE; and/or 4) unavailable for 3 month follow-up assessment.

Data from the initial physical and occupational therapy evaluations were collected by acute care therapists just after admission to the hospital and were obtained by the research team by electronic medical record review. These data included: 1) two independent variables, AROM measurements of shoulder flexion and wrist extension of the affected, contralesional side using goniometric techniques (Gajdosik & Bohannon, 1987; Norkin & White, 2009); 2) UE Motricity Index score on the affected side (Collin & Wade, 1990), used as an additional descriptor of overall UE motor impairment; 3) the Short Blessed (Katzman et al., 1983), an executive functioning screening tool administered at the initial occupational therapy evaluation, used to index the presence and severity of cognitive deficits. Acute care therapists were trained to use standardized procedures for these and other measures by the research team. The therapists attended four training sessions and procedures were monitored monthly by research staff. Other descriptive items recorded from the medical record to characterize the sample include: 1) total scores from the NIHSS, used as a descriptor of overall stroke severity (Brott et al., 1989); 2) individual NIHSS item scores for aphasia and neglect, used as indexes of the presence and/or severity of stroke-related deficits in the language and attention domains. The NIHSS was administered by trained nurse practitioners on the acute hospital stroke service.

Three months after stroke onset, UE motor function of each subject was assessed in the laboratory by the research team. The dependent variable of UE motor function was assessed using a comprehensive battery, similar to the one described previously (Beebe & Lang, 2008, 2009a; Lang & Beebe, 2007). A battery was used instead of a single measure because no single tool adequately captures the breadth of UE motor function (Beebe & Lang, 2009b; Wade, Langton-Hewer, Wood, Skilbeck, & Ismail, 1983). A subject's results from the battery provide a thorough picture of what functional activities can be accomplished with the affected UE, including aspects of strength, coordination, functional range of motion, and subject perception of difficulty using the UE. The measures in this battery include: 1) Grip strength, assessed with a hand-held dynamometer (Mathiowetz et al., 1985; Schmidt & Toews, 1970); and reported as strength of the affected side as a percent of the unaffected side; 2) the Nine Hole Peg Test (Mathiowetz, Weber, Kashman, & Volland, 1985) reported as pegs placed/removed per second; 3) the Action Research Arm Test (De Weerdts & Harrison, 1985; Hsieh, Hsueh, Chiang, & Lin, 1998; Lang, Edwards, Birkenmeier, & Dromerick, 2008; Lang, Wagner, Dromerick, & Edwards, 2006; Lyle, 1981; van der Lee, Beckerman, Lankhorst, & Bouter, 2001; van der Lee et al., 2001; van der Lee, Roorda, Beckerman, Lankhorst, & Bouter, 2002); 4) and the Stroke Impact Scale, Hand Function subscale (Duncan et al., 1999; Duncan, Wallace, Studenski, Lai, & Johnson, 2001; Duncan et al., 2005). The results of the test battery were synthesized to yield a single measure of upper extremity motor function for each subject using principal component analysis (Lang & Beebe, 2007; Ward, Brown, Thompson, & Frackowiak, 2003a, 2003b), a statistical methodology in which the dimensionality of a data set is reduced to one or a few scores. All battery scores loaded onto the first principal component (eigenvalue = 2.96) explaining 74% of the variance in the test scores, and no other components yielded eigenvalues greater than 0.6. According to Kaiser's criterion, only eigenvalues greater than 1 are retained (Field, 2009), thus the first principle component was used as a score of relative magnitude of UE

motor function among subjects. The UE motor function score for each subject can be conceptualized as statistical composite of that subject's individual scores on the battery.

Statistical Analysis

SPSS version 17.0 software was used for analyses, with 2-tailed significance criterion of $p < 0.05$. Normal distribution of variables was confirmed and descriptive statistics were generated appropriately. Pearson's Product Moment correlations were used to evaluate relationships between initial assessment measures and UE function. Initial assessment measures with Pearson Product Moment correlation coefficients greater than 0.25 were entered into a regression model to determine if they were predictive of UE motor function 3 months later. Coefficients less than 0.25 were excluded because they would contribute less than 6% of the total variance. Model diagnostics were evaluated and a sensitivity analysis was performed on all outliers. All subjects were included in the regression model.

RESULTS

Sample characteristics and measurement time points are provided in Table 1. Descriptive statistics for the impairment measurements at the time of initial therapy evaluation and the UE motor function measurements 3 months after stroke are provided in Table 2. While there was considerable variability across the sample in all measures collected (see ranges), overall the sample can be characterized as individuals with mild to moderate motor and functional deficits post stroke. Aphasia and neglect ranged from absent to severe, and cognitive deficits were generally mild across the sample.

Our first hypothesis was that AROM measurements from the initial therapy evaluation would predict UE motor function 3 months later. Pearson product moment correlation coefficients indicated that shoulder flexion and wrist extension AROM measurements were moderately correlated with UE motor function 3 months post stroke (Table 3). A linear regression model, including both shoulder and wrist initial AROM, explained 28% of the variance in UE motor function three months post stroke ($F = 8.712$, $p = 0.001$).

Our second hypothesis was that non-motor covariates would not influence the predictive relationship between initial AROM and UE motor function 3 months later. Correlation coefficients quantifying the relationship between UE motor function and aphasia, neglect, and cognitive deficit were low (Table 3). Only neglect ($r = -0.26$) exceeded our threshold for entry into the regression model and was stepwise entered into the model after AROM. This covariate did not significantly contribute to UE variance when stepwise entered and was excluded from the final model.

DISCUSSION

We found that AROM measurements of the shoulder and wrist taken at the initial therapy evaluation in the acute hospital were weak predictors of UE motor function three months later, predicting only 28% of the variance in UE scores. Contrary to our first hypothesis, the prognostic information provided by AROM measures within a few days after stroke was substantially less than the prognostic information provided at three weeks after stroke (71%; Beebe & Lang, 2009a). In support of our second hypothesis, we found that the presence of aphasia, neglect and cognitive deficits, did not influence the predictive ability of initial AROM on UE motor function three months later.

The difference between the explained variance an average of two days after stroke and three weeks after stroke, as in our previous work (see Introduction), most likely involves two key prognostic factors, 1) initial severity of stroke, and 2) rate of change of severity or rate of

UE motor recovery (Kwakkel, Kollen, & Lindeman, 2004; Teasell, Foley, Salter, & Jutai, 2008). The 2-day AROM measures used in this study reflect the initial severity of motor deficits post stroke, but not the rate of change of severity because it is too early to see much change over time. In contrast, measurement at the 3 week time point would reflect some combination of the initial motor deficit and the recovery that would occur by then. When viewed from this perspective, the current data plus our previous data match the general consensus that functional motor recovery post stroke can be reasonably predicted by 3-4 weeks after stroke (Duncan, Lai, & Keighley, 2000; Jorgensen et al., 1995; Kwakkel, et al., 2004; Kwakkel, et al., 2003; Loewen & Anderson, 1990; Olsen, 1990). Three week measurements, but not two day measurements, therefore can provide specific information about motor capacity for functional UE activities such as dressing, bathing and feeding, that will be achievable late after stroke. Measurements 2 days after stroke however, are insufficient in providing the depth of information about 3-month UE motor function to make judgments about functional activities achievable later.

The weak predictive relationship found here contrasts with a recently published report that used similar measures and time points to ours (Nijland, van Wegen, Harmeling-van der Wel, & Kwakkel, 2010). Using logistic regression, they found a very high probability (0.98) of regaining dexterity, as defined by an ARAT score of ≥ 10 , when shoulder abduction and finger extension were present at the initial assessment after stroke. Their independent variables (presence of shoulder and finger movement) are conceptually similar to ours (amount of shoulder and wrist movement) in that each variable is an index of the severity of paresis post stroke. Differences in results are probably not explained by the specific independent variable selected, since the severity of paresis is strongly correlated across UE segments post stroke (Beebe & Lang, 2008, 2009a; Lang & Beebe, 2007). Instead, the difference in results may be explained by the logistic regression and dichotomization of the dependent variable. Defining return of dexterity as an ARAT score between 10 and 57 (maximum score on this measure) represents a wide range of UE functional capabilities. Persons scoring at the low end of this range, 10 or slightly above, would have little functional use of the UE. This would be observed as an inability to elevate the arm, an inability to perform tip to tip pinch, and moderate assistance required from the unaffected arm for functional gross grasp. Persons at the higher end of this range, 40 or above, would demonstrate independence with ADLs and likely require only a little additional time for fine motor activities. Dividing the dependent variable into two broad categories (scores of < 10 and ≥ 10 on the ARAT) unfortunately does not provide sufficient information about eventual activity achievement to guide clinical decisions about intervention choice, goal setting, and client and caregiver education.

An important limitation of the current study is that our sample was comprised of stroke survivors who could be reached for follow-up and who could return to the laboratory for the follow-up testing. Individuals with the most severe strokes were missing from the sample, as they may have died, were residents in extended care facilities, were not reachable at their listed phone numbers, and/ or were unwilling to participate. Results presented here, therefore, are most appropriately generalized to stroke survivors living in the community at three months post stroke. A second limitation was the rather insensitive measures used to index the covariates. It is possible that more sensitive tools to quantify aphasia, neglect, and cognitive deficits, such as The Boston Naming Test, Unstructured Mesulam, and Trail Making Test - B, might have identified at least minimal influences on later UE motor function. Unfortunately, initial evaluation data using these more sensitive tools (or similar ones) were not consistently available for each person serviced by the acute stroke therapists. We speculate that deficits in non-motor domains do not influence the capacity to use the UE for functional activities (as tested in the laboratory in this study), but instead might influence

actual use of the UE, or participation in the real world. This speculation requires further study with different dependent variables.

In summary, AROM measures taken at the time of initial therapy evaluation in the acute hospital were weakly predictive of later UE motor function. Further work is needed to determine the earliest and most effective time point post stroke to obtain prognostic information about functional upper extremity activities the individual with stroke will be able to achieve by the end of the rehabilitation process.

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Table 1

Subject characteristics (N = 50).

	Mean $\pm$ SD/Frequency	Range/Percent
Age (years)	59 $\pm$ 15	19 – 87
Gender	26 M, 24 F	-
UE affected	22 L, 28 R	-
Dominant UE affected	27	54%
NIHSS total	8 $\pm$ 6	2 – 31
Ischemic stroke	44	88%
Race/ethnicity	29 AA, 20 W, 1 AS	58%, 40%, 2%
Time from stroke to initial assessment (days)	2 $\pm$ 1	0 – 5
Time from stroke to follow-up assessment (days)	101 $\pm$ 13	77 – 129

UE: Upper extremity; M: Male; F: Female; L: Left; R: Right; NIHSS: National Institutes of Health Stroke Scale, range 0 – 42 with higher scores indicating greater stroke severity; AA: African-American; W: White; AS: Asian

Table 2

Initial and three month follow-up measurements.

Initial assessment: motor and non-motor impairments		
	Mean $\pm$SD	Range
AROM Shoulder flexion (degrees)	88 $\pm$ 59	0 – 140
AROM Wrist extension (degrees)	24 $\pm$ 32	-30 – 65
Motricity index	56 $\pm$ 32	0 – 100
Short Blessed	6 $\pm$ 5	0 – 22
NIHSS Aphasia	Median = 0	0 – 3
NIHSS Neglect	Median = 0	0 – 2
3 mo. assessment: UE battery scores and overall motor function score		
Grip strength (% of unaffected side)	57 $\pm$ 36	0 – 122
Nine hole peg test (pegs/sec)	1.37 $\pm$ 1	0 – 4
ARAT	42 $\pm$ 18	0 – 57
Stroke Impact Scale: Hand function	58 $\pm$ 31	0 – 100
UE motor function score *	0 $\pm$ 1	-2 – 1

AROM: Active range of motion; NIHSS: National Institutes of Health Stroke Scale; UE: Upper extremity; ARAT: Action Research Arm test, score range = 0 – 57, with higher scores indicating better performance.

* Calculated as a standardized z score for each person from the weighted, linear coefficients of the first principal component.

Table 3

Pearson correlations between initial impairments and 3 month UE motor function scores.

	Correlation coefficient
AROM Shoulder flexion	0.51 *
AROM Wrist extension	0.46 *
Short Blessed	-0.06
NIHSS Aphasia	-0.07
NIHSS Neglect	-0.26

AROM: Active range of motion; NIHSS: National Institutes of Health Stroke Scale

*
significant at $p < 0.05$ level