The Brain Recovery Core: Building a System of Organized Stroke Rehabilitation and Outcomes Assessment Across the Continuum of Care

Catherine E. Lang, PT, PhD, Marghuretta D. Bland, DPT, MSCI, Lisa Tabor Connor, PhD, Robert Fucetola, PhD, Michelle Whitson, PT, MHS, MA, MBA, Jeff Edmiaston, MS, CCC-SLP, Clayton Karr, MSOT, OTR/L, Audra Sturmoski, MSPT, Jack Baty, MS, and Maurizio Corbetta, MD

This Special Interest article describes a multidisciplinary, interinstitutional effort to build an organized system of stroke rehabilitation and outcomes measurement across the continuum of care. This system is focused on a cohort of patients who are admitted with the diagnosis of stroke to our acute facility, are discharged to inpatient and/or outpatient rehabilitation at our free-standing facility, and are then discharged to the community. This article first briefly explains the justification, goals, and purpose of the Brain Recovery Core system. The next sections describe its development and implementation, with details on the aspects related to physical therapy. The article concludes with an assessment of how the Brain Recovery Core system has changed and improved delivery of rehabilitation services. It is hoped that the contents of this article will be useful in initiating discussions and potentially facilitating similar efforts among other centers.

Key words: *measurement, outcome, stroke, rehabilitation*

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THE NEED FOR AN ORGANIZED SYSTEM OF STROKE CARE

Stroke is a major health problem in the United States and around the world.[1,2] Rehabilitation has the potential to save many people from disability after stroke.[3,4] While organized delivery of stroke care often exists *within* institutions[5-8] that provide care at various stages of the rehabilitation process, it does not often exist *across* institutions, as patients move from one institution to another and then to home. Rehabilitation outcomes assessments direct critical decisions at many points along the continuum of care. Decisions such as admittance to inpatient rehabilitation, length of stay/services, and the selection of specific interventions are all dependent upon results of these assessments. Results from assessments are also a critical component of communication with patients, caregivers, other health care providers, and third-party payers.

Despite persistent calls for consistency, validity, and standardization,[5,9,10] assessment tools vary across and within institutions and therapy assessment results are not routinely transmitted to later points of service. The lack of consistency and continuity results in barriers to efficient and effective care delivery such as difficulty communicating results within a facility, lack of awareness of assessment done at previous facilities, and the inability to determine individual progress due to use of different assessment tools. Given that initial severity of impairments and the rate of change of those impairments are key prognostic indicators after stroke,[11-17] making clinical decisions without the full complement of assessment data is problematic and inefficient.

GOAL AND PURPOSE OF THE ORGANIZED SYSTEM

The Brain Recovery Core (BRC) team is a multidisciplinary, interinstitutional partnership between a university medical school including the departments of physical therapy, occupational therapy, neurology, biostatistics, and psychiatry (Washington University School of Medicine), an acute care hospital (Barnes Jewish Hospital), and a rehabilitation center (the Rehabilitation Institute of Saint Louis). Detailed information on the acute and rehabilitation care facilities is given in Table 1. The major goal of the BRC system is *to build and sustain* a system of organized stroke rehabilitation across the continuum of care, from the acute stroke service to return to home and community life. Our efforts are focused on the large cohort of people who are admitted with stroke to our acute facility, are sent to inpatient and/or outpatient rehabilitation at our free-standing facility, and are then discharged to the community. The purpose of the system is to support the clinical services and the research team by providing: (1) individual patient data across the continuum of care to make better prognostic clinical decisions, (2) population data on outcomes within and across services, disciplines, and individual therapists, (3) a common

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The authors declare no conflict of interest.
Correspondence: Catherine Lang; E-mail: langc@wustl.edu

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Table 1. Brain Recovery Core Acute and Rehabilitation Care Facilities

		Rehabilitation Center[b]	
	Acute Care Hospital[a]	Inpatient Rehabilitation	Outpatient Rehabilitation
Facility information	1228-bed acute, teaching hospital (Joint Commission[c] Seal of Approval; Joint Commission[c] Primary Stroke Center)	96-bed free-standing facility providing inpatient and outpatient rehabilitation services (Joint Commission Accredited)[c]	
General focus of care	Medical treatment of stroke and any resulting complications	Achieve independence in mobility and ADL	Maximize functional potential; Return to previous life roles as able
Numbers of therapists providing rehabilitation services to people with stroke on each service			
PTs and PTAs	1 Primary stroke >30 secondary/float	6 full-time >10 float/per-diem	6 full-time 1 part-time >10 float/per-diem
OTs and COTAs	1 Primary stroke >20 secondary/float	6 full-time >10 float/per-diem	5 full-time 2 part-time >10 float/per-diem
SLPs and SLPAs	1 Primary stroke 4 secondary/float	6 full-time >6 float/per-diem	4 full-time >6 float/per-diem

[a]Barnes Jewish Hospital, the flag-ship hospital of Barnes Jewish Christian Healthcare, a large not-for-profit health care company in the Midwestern United States.
[b]Rehabilitation Institute of Saint Louis, jointly owned by Barnes Jewish Christian Healthcare and HealthSouth Corporation; managed by HealthSouth Corporation, a large for-profit health care company in the United States.
[c]Joint Commission is a United States agency that accredits health care institutions.
Abbreviations: ADL, activities of daily living; COTA, certified occupational therapy assistant; OT, occupational therapist; PT, physical therapist; PTA, physical therapist assistant; SLP, speech-language pathologist; SLPA, speech-language pathologist assistant.

set of measurements that lay the foundation for within and across service efforts to improve rehabilitation management, and (4) outcome data from new clinical programs or research interventions. The 2 key ingredients of this system are (1) a systematic assessment battery (covering motor, language, and cognitive domains) that builds across the continuum of care and meets the needs of each service, and (2) a database to collect, store, and search assessment, treatment, and follow-up data that it is accessible to rehabilitation clinicians, administrators, and researchers. An example of the clinical utility of the system is as follows: therapy staff often identify a specific need or desire to improve service delivery, such as creating a group exercise program to improve the mobility of their patients. With this system, we are now able to determine whether or not a new program produced the desired outcomes, for example, "did mobility improve as anticipated?" and "was it worth the effort to create a new program?"

FROM CONCEPTUAL IDEA TO IMPLEMENTING THE BRAIN RECOVERY CORE SYSTEM

The idea of the BRC system first arose in 2008 within a group of rehabilitation researchers and then with representatives from the clinical facilities. It took nearly 14 months to complete the process of agreeing to create the system, determining the specifics of how it would operate, obtaining pilot funds, hiring a coordinator to run the project, and starting implementation efforts. Three important features of the team and environment facilitated the development of this project. First, there were already numerous research and clinical contacts between the partners. Second, there was a 10-year history of consenting and tracking patients into a clinical stroke registry at the acute stroke facility. Third, the researchers had access to and secured commitments from the administrative officials at each facility. The positive history of interactions between partners and, perhaps more importantly, the support from administrative officials[18-20] were critical in implementing the BRC system.

BUILDING A STANDARDIZED ASSESSMENT BATTERY

The first component of the BRC system is an assessment battery, covering motor, language, and cognitive domains, which builds across the continuum of care and meets the needs of each service. Here we provide details on the motor portions of the battery that are the responsibility of physical therapy. Criteria for selection of measurement tools were that the tools must have published reliability, validity, and responsiveness (preferably in people with stroke) and the tools must meet the clinical needs and constraints of each service. While the first criterion is a necessity for collecting uniform patient information,[9,21] the second criterion was essential for convincing therapists to routinely use the battery.

The 3 physical therapy services and the specific needs and constraints that the assessment battery had to address are shown in Table 2. These needs and constraints were determined from discussions with therapists, administrators, and BRC team members. Because our goal was to use the battery across the points of care, the needs and constraints of one service had to be balanced with those of the other services. Consequently, we had to select tools that could consistently be used across services and still provide sufficient information for clinical decision-making and outcome measurement within each service. The population of people served by our facilities spans the range from life-threatening strokes causing severe disability to very mild strokes causing no disability. Thus, we had to select tests that could measure the full range of impairments and disability. Systemwide rules for test administration are used to avoid problems associated with performing assessments in a nonstandardized manner. Rules for the Berg Balance Scale are described later as an example:

Table 2. Specific Needs and Constraints of Each Physical Therapy Service

Point of Care	Specific Needs and Constraints
Acute care hospital	Main role of service is to provide evaluations that inform discharge planning; many patients are seen only 1 time for the evaluation; median length of stay for persons with stroke is 3 days. Time available per evaluation is approximately 30 minutes. Patients are evaluated in hospital rooms, not in a therapy gymnasium. Any required testing equipment must be easily portable room-to-room. Measurement tools needed to assess a broad range of severity; severe and moderate motor deficits are readily apparent to all members of the health care team; more mild deficits that are not readily apparent and need to be detected at initial evaluation to obtain needed referrals upon discharge.
Inpatient rehabilitation	Main role of service is to provide treatments that will result in independence with mobility and ADL; patients are seen 2 times/day; average length of stay for a person with stroke is 16 days. Physical therapy plan of care with goals must be in place within 24 to 48 hours. Time available per evaluation is approximately 60 minutes. Patients are evaluated in both hospital rooms and in the therapy gymnasium. The FIM is a required assessment at admission and discharge; physical therapists complete the transfers, locomotion, and stairs items. Measurement tools must be appropriate to measure changes at both the lower functional status seen at admission and the higher functional status often seen at discharge.
Outpatient rehabilitation	Main role of service is to provide treatments that will improve mobility and function, with the hope of resuming prestroke activities as much as possible. Time available per evaluation is approximately 45 minutes. Patients are evaluated in a therapy gymnasium. Measurement tools needed to assess mild to severe deficits with a focus on activity- and participation-level outcomes and not on impairment-level outcomes.

Abbreviation: FIM, Functional Independence Measure.

If a person receives a 0 on the first 5 items, the rest of the items are not administered and are assigned scores of 0. Brain Recovery Core data indicate that the scale is readily capturing changes at the low end (eg, moving from a 0 to a 10). On the upper end, preliminary BRC data indicate that 5% and 8% of persons on the inpatient and outpatient services, respectively, achieve top scores (defined as a score of 55 or 56). If a person achieves a score of 55 or 56, then the treating therapist can either chose a different way to assess higher-level or job-specific balance (eg, walking on ladders for a roofer) or can choose not to evaluate balance further (ie, no additional balance needs).

Lastly, selection of specific measurement tools was informed by the idea that health care changes are easier to accept and make when the change is not too different from current practice.[22,23] Thus, when given a choice, we selected measurement tools that were already in use on one or more services.

The physical therapy battery, the rationale for each tool, and the points of service where it is used are outlined in Table 3.[12,14,24-56] Some tools are used for diagnostic decisions (ie, what are the main impairments contributing to limited mobility?), some are used for evaluating outcomes, and some are used for both these purposes. How the tools are used determines when they were administered (eg admission only vs admission and discharge or monthly). The selected battery is a reasonable, but not perfect solution to the needs, constraints, and challenges discussed earlier. The battery is the minimal requirement for all patients admitted with stroke on each service. It is intended to provide sufficient information for clinical decision-making on the majority of patients seen on each service. Therapists may administer additional tools for individual patients as appropriate (eg, ataxia rating scale for persons with cerebellar stroke). As sufficient data are collected, the battery is assessed from clinical and statistical perspectives and revised accordingly.

IMPLEMENTING AND MONITORING THE STANDARDIZED BATTERY

The battery was implemented first on the acute service, followed by the inpatient, and then the outpatient services. From health care change literature, a multifaceted implementation approach was selected.[18,20,23,57-61] Components of the multifaceted approach included (1) clear administrative and supervisory support, (2) a clinical "champion" on each service, (3) distribution of educational materials about the battery that included each tool, the rationale for selecting it, how to administer it, and where to record scores, (4) educational and interactive meetings with staff, and (5) feedback to staff and administration. For each service, the BRC coordinator and a team member with content expertise first met with the lead therapist and a supervisor to discuss the details of the battery, service-specific needs, and the implementation process. The lead therapist served as the champion of the project—the person who would advocate for using the battery and would answer specific questions about how to administer the tools. This first meeting was used to review educational materials to be provided to staff, plan the implementation time points for that service, determine equipment needs, and problem-solve potential barriers to implementation.

The second step was to have educational, interactive meetings with therapy staff. Meetings were used to orient staff to the BRC system and goals, disseminate and discuss educational materials, and answer questions. After the staff meeting, a 2- to 3-month trial period began. During the trial period, staff participated in in-services to learn to use unfamiliar assessment tools and to problem-solve process issues. Common process-related issues were insufficient forms or equipment, lack of knowledge regarding where forms or equipment were kept, and how to include forms as part of the medical record. Therapists identified barriers to implementation and generated feasible solutions. The BRC coordinator shared solutions from one service with other services. For example, staff on all 3 physical therapy services independently identified the lack

Table 3. Brain Recovery Core Assessment Battery for Physical Therapists

Measure [ICF level] Administration Time	Rationale for Inclusion	Points Administered		
		Acute	Inpatient Rehabilitation	Outpatient Rehabilitation
Active range of motion (AROM): shoulder flexion, wrist extension, knee extension[14,24-29] [Body function—UE and LE motion] ~3 min	A quick goniometric measure of ability to voluntarily activate limb muscles. AROM may be best at capturing and quantifying activation deficits at the lower end of the spectrum, which is particularly important at early time points post stroke. For the upper extremity, the ability to move segments against gravity is a strong predictor of UE function, even at different time points post stroke. Because the ability to move segments is similarly affected across the upper extremity, then measuring 2 segments (vs all segments) is sufficient. Relationships between lower extremity AROM and gait are somewhat weaker. Knee extension was selected because relationships between impairments and gait have been evaluated most often with this movement. Note that fractionated movement is not specifically tested in this evaluation. This is because the ability to fractionate movement is strongly related to the ability to move in people with stroke, particularly early after stroke. Thus, there is no need to assess both.	Ad	Ad[a]	
Motricity Index (MI)[26,27,30-32] [Body function—UE and LE strength] ~5 min	The MI quantifies strength through manual muscle testing on key, representative muscles groups, 3 for the UEs and 3 for the LEs. Like AROM, it is an indirect measure of the ability to volitionally activate limb muscles. Strength measures may be better able to capture deficits at the higher end of the spectrum, that is, can the muscles be actively sufficiently to produce force against externally imposed loads. The MI provides scores quantifying the overall strength impairments for the UE and the LE. The MI is used to quantify motor impairments post stroke in clinical practice and in research around the world.	Ad	Ad,[a] Dc[a]	Ad[a]
Modified Ashworth Scale: Plantarflexors[33,34] [Body function—tone] ~2 min	This is the most common clinical measure used to assess tone. Assessment at only the ankle plantarflexors was chosen because information gained from this segment is reasonably representative of tone across the LE and provides sufficient information for clinical decision making. Note that tone is not assessed at the acute hospital because: (1) hypotonia is typically seen early after stroke and this scale does not quantify hypotonia; and (2) information on tone does not influence clinical decision-making at this early evaluation point.		Ad	Ad
Light touch sensation: Dorsum of Foot[12,35-40] [Body function—somatosensation] ~2 min	Assessment of somatosensation is important in determining prognosis following stroke and for patient education. Light touch is the somatosensory modality most often tested. Because stroke typically affects multiple somatosensory modalities, diminished sensation on this item also conveys information about diminished sensation in other modalities. Assessment at only the bottom of the foot was chosen because information from this location is important for safe mobility.	Ad	Ad	Ad
FIM items: transfers, locomotion, stairs,[41] for review see[42] [Activity—mobility] 5-10 min	The FIM is the gold standard measure for rehabilitation outcomes. It was designed as a measure to assess functional level and need for assistance with basic activities of daily living. Using the FIM is a requirement for maintaining accreditation at inpatient rehabilitation facilities in the United States. Note that FIM items quantify performance only up to the level of independence.	Ad[b]	Ad, Dc	Ad (per patient report)
Berg Balance Scale[43-46] [Activity—balance, risk of falls] ~10 min	This is the most common clinical measure of balance across a variety of patient populations. It quantifies 2 aspects of balance: the ability to maintain upright posture and the ability to make appropriate adjustments for voluntary movement. Data on predicting fall risk from Berg scores are available. Likewise, estimates of minimal detectable change have been published. Operational rules were put in place to shorten testing (see text).	Ad	Ad, Dc	Ad, Mo
10-Meter Walk Speed[c42,47-51] [Activity—walking ability] 3-5 min	Walking speed is the most common measure of walking performance across a variety of patient populations. It allows quantification of walking ability above the threshold of independent ambulation. Published normative and threshold values are available. Walking speed is also the most common outcome measure for gait in clinical rehabilitation trials.	Ad	Ad, Dc	Ad, Mo
Timed Up and Go[c42,52,53] [Activity—functional mobility] 3-5 min	This is a common functional mobility measure used for a variety of patient populations. It is useful for quantifying deficits in transfers and functional mobility as patients achieve scores of 4 or greater on the FIM. Published normative values are available.		Dc	Ad, Mo
6-Minute Walk Test[c42,48-50,54-56] [Activity—walking endurance] ~10 min	This is the most common measure of walking endurance across a variety of patient populations. Early after stroke, walking speed and 6MWT are well correlated (people walk slowly and not very far), but later they become more dissociated. Published distances needed for community ambulation are available.		Dc	Ad, Mo

[a] UE portions are done by occupational therapy on the inpatient and outpatient rehabilitation services.
[b] Stairs not routinely evaluated at the acute hospital, only done with higher-level patients per PT's judgment.
[c] If the patient cannot walk without physical assistance from another person, this test is omitted and scored as "unable."
Abbreviations: Ad, admission; Dc, discharge; Mo, monthly; LE, lower extremity; ICF, International Classification of Function; UE, upper extremity.

of a consistent, reliably measured space as a barrier to completing the 10-Meter Walk Test. The acute hospital arranged to have wall tiles changed to a contrasting color at the beginning and end of a 10-meter distance as a permanent solution. This solution was shared with the inpatient and outpatient services and similar changes were made there. The BRC coordinator also observed and provided feedback to staff performing assessments.

The trial period ended when the lead therapist indicated the staff was familiar with battery administration and using battery scores for clinical decision-making. Another meeting was held with therapy staff to answer final questions, communicate additional details, and move from the trial period to live implementation. Live implementation meant that all therapists on the service were expected to use the BRC battery for evaluations of all patients with stroke admitted to that service.

Our target is to consistently achieve 90% or more completion rates on each service. Several steps are followed to monitor and improve compliance. First, the BRC coordinator observes assessments on each service monthly to ensure correct administration and provide feedback to therapists. Second, review of rehabilitation records is done monthly to quantify compliance. Monitoring and providing specific feedback are important aspects of successful health care implementation strategies.[20,60-63] Compliance data are provided to supervisors, who then share data with staff. The review of records helped identify staff who had not been educated about the BRC battery, such as per-diem therapists. Administrators now include education about the BRC project and the battery into orientation for new hires and the annual competencies for all therapists.

BUILDING AND IMPLEMENTING A PROCESS TO CAPTURE LONGER-TERM OUTCOMES AFTER STROKE

The BRC team is interested in understanding the longer-term outcomes of people with stroke who receive services at our institutions. There is a lack of routine clinical procedures for assessing functional outcomes later in the stroke rehabilitation process or after rehabilitation services have ended, particularly in the United States. Many institutions, including ours, use follow-up mail surveys to measure the quality of care received (eg, professionalism of staff, patient satisfaction), but the survey questions are distinctly different from outcome assessment. In the absence of real data on how well patients are coping in the context of their own lives, our health care institutions have no way of knowing if the stroke rehabilitation services they are delivering are sufficient and/or effective.

To capture longer-term outcomes at the end of the continuum of stroke rehabilitation care, we developed a process for 6- and 12-month telephone or e-mail follow-up contact. We chose to measure functional outcomes at specific time points after stroke instead of at individualized time points, such as at the end of therapy services. The reason for this was that variability in the need for services, treatment interventions, length of stay, and third-party reimbursements make comparisons using individualized time points only minimally useful.[64] The 6-month time point was chosen because neurological recovery poststroke has reached a plateau and physical function is typically stable by this time.[11,64,65] The 12-month time point was chosen because cognitive and language function and participation in social roles may take up to 1 year to stabilize after stroke.[66-69]

Follow-up contact via telephone and e-mail were selected as economical methods to obtain the data. In-person assessments were rejected because of the associated costs. We could not rely solely on e-mail-based methods because approximately one-half of our patient population does not have access and/or experience with computers. Telephone follow-up contacts are being completed in 20 to 25 minutes per call by staff trained on-the-job. For those patients providing e-mail addresses, e-mails are distributed and responses are returned via our secure database (see later). Three assessment tools and 2 multilevel questions are being administered (Table 4).

COLLECTING, MANAGING, AND SHARING REHABILITATION DATA

The second component of the BRC system is a database to collect, store, and search assessment, treatment, and follow-up data that it is accessible to rehabilitation clinicians, administrators, and researchers. Because data would be accessible across facilities and to researchers, approval of institutional review board (IRB) was required. The approval of IRB and a systematic verbal informed consent process have been in place for 10 years at the acute facility, where the informed consent process is managed by the stroke team nurse coordinators. The approval of IRB and a systematic informed consent process had to be established at the inpatient and outpatient rehabilitation facility. Approval had to be provided by 3 separate committees; this took approximately 7 months. Case managers were chosen to handle the consenting process on the inpatient and outpatient rehabilitation services because of their educational background. The same general process, described earlier, was used to implement and monitor the consent process. Our target is to consent 90% or more of all individuals with stroke admitted to acute hospital, and the inpatient and outpatient rehabilitation services.

Paralleling the development of the consent process was the construction of a database to collect and store patient information. Data are collected and managed using REDCap (Research Electronic Data Capture) hosted by Washington University.[70] REDCap is a secure, Web-based application designed to support large projects, providing an intuitive interface for validated data entry, audit trails for tracking data manipulation and export procedures, automated export procedures for seamless data downloads to common statistical packages, and procedures for importing data from external sources. The database allows for both data transfer from the electronic medical records at the acute hospital and manual data entry from the paper medical record at the other services. In addition, REDCap has a survey feature, which is used to collect 6- and 12-month follow-up information via e-mail or via manual entry during telephone calls with the patients.

The final step in building the database is providing access to collected data to our BRC constituents. This is achieved via a password-protected, BRC Web page with data queries for the

Table 4. Assessment Tools and Questions Used for the 6- and 12-Month Follow-Ups

Assessment Tool/Question	Information and Rationale for Inclusion
Stroke Impact Scale (SIS)[64,72-79]	This was chosen as our main assessment tool because it measures stroke-specific outcomes in multiple domains. Developed with input from patients with stroke and their caregivers, the SIS is a 59-item, patient-based, self-report scale measuring outcomes across 8 domains: Strength, Hand Function, Mobility, Activities of Daily Living, Memory, Communication, Emotion, and Participation. Items from the first 4 domains can be summed to create a Physical Function score while scores on other domains are represented separately. Floor and ceiling effects are minimal compared to other common tests (eg, Functional Independence Measure, Barthel Index, SF-36). Using this single tool (vs multiple tools for multiple domains) reduces the testing burden. Finally, the SIS can be used via interview, telephone, or mail, and answers can be provided by proxy if needed.
Modified Rankin Scale[64,80-83]	This scale, used here as a secondary outcome assessment, is a single-item tool for determining overall disability. A rating of 0-5 is used, with 0 indicating no symptoms and 5 indicating severe disability. It provides a gross indicator of global outcome and is somewhat insensitive to change. Because of its ease of use, low testing burden (< 2 min), and commonality of use in stroke clinical trials, it was included as a secondary measure.
Reintegration to normal living[84,85]	This is a quality of life measure capturing how a person is able to resume normal life activities after an incapacitating illness or injury. It quantifies a person's satisfaction with basic self-care, in-home mobility, leisure activities, travel, and productive pursuits. It was included in the follow-ups to capture an individual's satisfaction with the outcome vs their perception of outcomes themselves (as captured by the SIS).
Return to work questions	This is a multilevel set of questions asking if the person has returned to work after stroke. Available answers and follow-up questions capture information related to: not previously working, working in the same vs different job, working for the same employer vs different employer, paid vs voluntary work, part-time vs full-time, etc.
Return to driving question	This is a question asking if the person has returned to driving. Available answers capture information related to: return to driving, and driving prior to stroke. Driving is significantly associated with community integration after stroke.[86]

3 main groups of constituents. Through this system clinicians can access stored data from individual patients, administrators and therapy supervisors, the BRC coordinator can access data related to compliance and outcomes (such as completion rates), and researchers can access de-identified rehabilitation data to conduct retrospective analyses.

2010 COMPLIANCE AND BENEFITS TO DATE

The efforts of the BRC team, therapy staff, and administrators have resulted in a system of organized stroke rehabilitation across the continuum of care. Physical therapy compliance rates for April to December 2010 are shown in Figure 1A. Compliance fluctuates and therapists report the greatest difficulty with administering discharge (inpatient) and monthly (outpatient) assessments. In general, these compliance rates are better than those reported for other health care change efforts (mean compliance with 143 clinical recommendations = 54%).[71] We note that intra- and interrater reliability of individual battery tools are not being evaluated as part of this project. While this may be considered a flaw of the project, our intent was to take evidence from the literature (ie, selection of tools already shown to be reliable) and implement a system to use them in routine clinical practice. The percentage of patients consented to have their data stored in the database, from April to December 2010 are shown in Figure 1B. As discussed

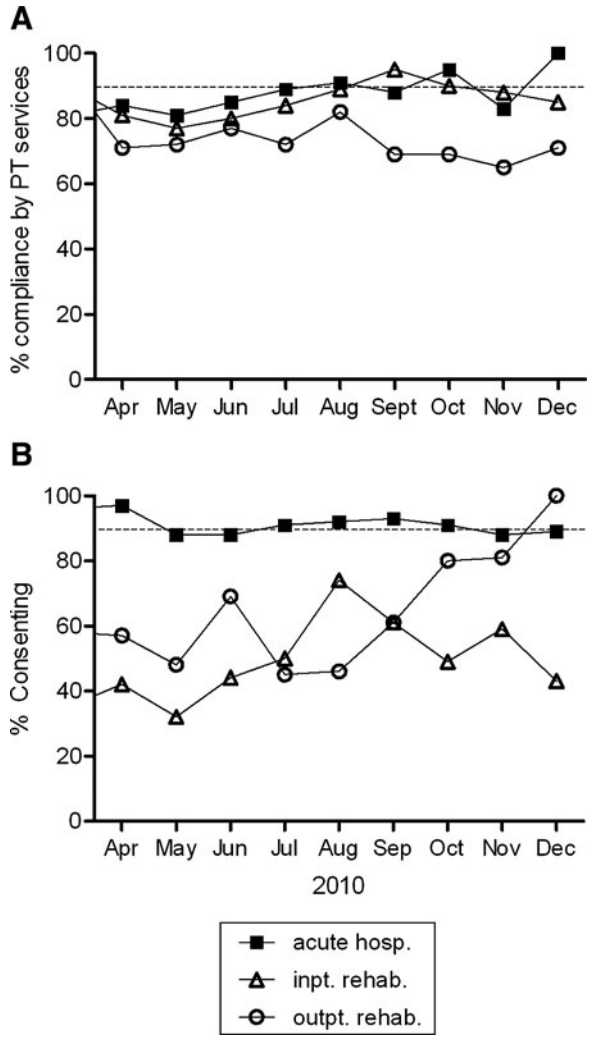

Figure 1. A: Compliance with the required physical therapy (PT) battery on all 3 services. B: Percent of patients consenting to have their rehabilitation and demographic information stored in the Brain Recovery Core database. Note that the acute hospital consent process has been in place for 10 years, while the inpatient and outpatient rehabilitation consent processes started in March 2010. The dashed horizontal lines indicate the desired 90% target rates.

earlier, the consent process was required because of need for separate facilities to access private health information. Multiple efforts are being pursued to increase the percentage of people who agree to have their information stored, because this type of system is most valuable with maximum inclusion.

A brief summary of benefits realized thus far include the following: (1) provision of ongoing evidence-based education on evaluation and outcome measurement for stroke rehabilitation to therapy staff, (2) a "common language" of objective assessment results with which therapists are now engaging in discussion about exactly how they are making clinical decisions, (3) a perceived reduction in the time to complete assessments, and (4) improvement of numerous service delivery processes (eg, regular availability of assessment kits, consistency in reevaluations across staff). Continued efforts are needed to improve the BRC system, sustain it over time, and adapt it to meet the needs of the constituents.

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REFERENCES

1. Kelly-Hayes M, Robertson JT, Broderick JP, et al. The American Heart Association stroke outcome classification. *Stroke*. 1998;29:1274-1280.
2. Lloyd-Jones D, Adams R, Carnethon M, et al. Heart disease and stroke statistics–2009 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation*. 2009;119:e21-181.
3. Donnan GA, Davis SM, Levi CR. Strategies to improve outcomes after acute stroke. *Med J Aust*. 2003;178:309-310.
4. Gilligan AK, Thrift AG, Sturm JW, Dewey HM, Macdonell RA, Donnan GA. Stroke units, tissue plasminogen activator, aspirin and neuroprotection: Which stroke intervention could provide the greatest community benefit? *Cerebrovasc Dis*. 2005;20:239-244.
5. Duncan PW, Zorowitz R, Bates B, et al. Management of adult stroke rehabilitation care: a clinical practice guideline. *Stroke*. 2005;36: e100-e143.
6. Teasell R, Foley N, Salter K, Boghal S, Jutai J, Speechley M. *Evidence-Based Review of Stroke Rehabilitation*. London, Ontario, Canada: University of Western Ontario; 2008.
7. Langhorne P, Williams BO, Gilchrist W, Howie K. Do stroke units save lives? *Lancet*. 1993;342:395-398.
8. Govan L, Weir CJ, Langhorne P; for the Stroke Unit Trialists' Collaboration. *Organized inpatient (stroke unit) care for stroke*. *Cochrane Database Systc Rev*. 2007;4.
9. Duncan PW, Lai SM, van Culin V, Huang L, Clausen D, Wallace D. Development of a comprehensive assessment toolbox for stroke. *Clin Geriatr Med*. 1999;15:885-915.
10. Gresham GE, Duncan PW, Stason WB, et al. Post-stroke rehabilitation. *Clinical Practice Guideline No. 16*. Rockville, MD: US Department of Health and Human Services. Public Health Service, Agency for Health Care Policy and Research. AHCPR Publication No. 95-0662. May 1995.
11. Jorgensen HS, Nakayama H, Raaschou HO, Vive-Larsen J, Stoier M, Olsen TS. Outcome and time course of recovery in stroke. Part II: time course of recovery. The Copenhagen stroke study. *Arch Phys Med Rehabil*. 1995;76:406-412.
12. Patel AT, Duncan PW, Lai SM, Studenski S. The relation between impairments and functional outcomes poststroke. *Arch Phys Med Rehabil*. 2000;81:1357-1363.
13. Jorgensen HS, Nakayama H, Raaschou HO, Vive-Larsen J, Stoier M, Olsen TS. Outcome and time course of recovery in stroke. Part I: outcome. The Copenhagen stroke study. *Arch Phys Med Rehabil*. 1995;76:399-405.
14. Beebe JA, Lang CE. Active range of motion predicts upper extremity function 3 months after stroke. *Stroke*. 2009;40(5):1772-1779.
15. Shelton FN, Reding MJ. Effect of lesion location on upper limb motor recovery after stroke. *Stroke*. 2001;32:107-112.
16. Olsen TS. Arm and leg paresis as outcome predictors in stroke rehabilitation. *Stroke*. 1990;21:247-251.
17. Twitchell TE. The restoration of motor function following hemiplegia in man. *Brain*. 1951;74:443-480.
18. Wang A, Wolf M, Carlyle R, Wilkerson J, Porterfield D, Reaves J. The north carolina experience with the diabetes health disparities collaboratives. *Jt Comm J Qual Saf*. 2004;30:396-404.
19. Anderson RJ, Amarasingham R, Pickens SS. The quest for quality: perspectives from the safety net. *Front Health Serv Manage*. 2007;23:15-28.
20. Forthman MT, Wooster LD, Hill WC, Homa-Lowry JM, DesHarnais SI. Insights into successful change management: empirically supported techniques for improving medical practice patterns. *Am J Med Qual*. 2003;18:181-189.
21. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient-based outcome measures for use in clinical trials. *Health Technol Assess*. 1998;2:i-iv, 1-74.
22. Brown RW. Why is quality assurance so difficult? A review of issues in quality assurance over the last decade. *Intern Med J*. 2002;32:331-337.
23. Weinert CR, Mann HJ. The science of implementation: changing the practice of critical care. *Curr Opin Crit Care*. 2008;14:460-465.
24. Beebe JA, Lang CE. Absence of a proximal to distal gradient of motor deficits in the upper extremity early after stroke. *Clin Neurophysiol*. 2008;119:2074-2085.
25. Lang CE, Beebe JA. Relating movement control at 9 upper extremity segments to loss of hand function in people with chronic hemiparesis. *Neurorehabil Neural Repair*. 2007;21:279-291.
26. Hislop HJ, Montgomery J. *Daniel's and Worthingham's Muscle Testing*. Philadelphia, PA: Saunders; 2002.
27. Andrews AW, Bohannon RW. Short-term recovery of limb muscle strength after acute stroke. *Arch Phys Med Rehabil*. 2003;84:125-130.
28. Bohannon RW, Andrews AW. Relationships between impairments in strength of limb muscle actions following stroke. *Percept Mot Skills*. 1998;87:1327-1330.
29. Bohannon RW. Muscle strength and muscle training after stroke. *J Rehabil Med*. 2007;39:14-20.
30. Collin C, Wade D. Assessing motor impairment after stroke: a pilot reliability study. *J Neurol Neurosurg Psychiatry*. 1990;53:576-579.
31. Masiero S, Avesani R, Armani M, Verena P, Ermani M. Predictive factors for ambulation in stroke patients in the rehabilitation setting: a multivariate analysis. *Clin Neurol Neurosurg*. 2007;109:763-769.
32. Piazzini DB, Ferrara PE, Maggi L, et al. Application of "Protocollo di Minima per l'ictus" (PMIC—Minimal Protocol for Stroke) for inpatient rehabilitation setting. *Eur J Phys Rehabil Med*. 2008;44:277-281.
33. Bohannon RW, Smith MB. Interrater reliability of a Modified Ashworth Scale of muscle spasticity. *Phys Ther*. 1987;67:206-207.
34. Shumway-Cook A, Woolacott MH. *Motor Control: Translating Research Into Clinical Practice*. Philadelphia, PA: Lippincott Williams & Wilkins; 2007.
35. Sullivan JE, Hedman LD. Sensory dysfunction following stroke: incidence, significance, examination, and intervention. *Top Stroke Rehabil*. 2008;15:200-217.
36. Winward CE, Halligan PW, Wade DT. Somatosensory recovery: a longitudinal study of the first 6 months after unilateral stroke. *Disabil Rehabil*. 2007;29:293-299.
37. Winward CE, Halligan PW, Wade DT. Current practice and clinical relevance of somatosensory assessment after stroke. *Clin Rehabil*. 1999;13:48-55.
38. Reding MJ, Potes E. Rehabilitation outcome following initial unilateral hemispheric stroke. Life table analysis approach. *Stroke*. 1988;19:1354-1358.
39. Kent BE. Sensory-motor testing: the upper limb of adult patients with hemiplegia. *Phys Ther*. 1965;45:550-561.
40. Kusoffsky A, Wadell I, Nilsson BY. The relationship between sensory impairment and motor recovery in patients with hemiplegia. *Scand J Rehabil Med*. 1982;14:27-32.

41. Keith RA, Granger CV, Hamilton BB, Sherwin FS. The functional independence measure: a new tool for rehabilitation. *Adv Clin Rehabil*. 1987;1:6-18.
42. Finch E, Brooks D, Stratford PW, Mayo NE. *Physical Rehabilitation Outcome Measures*. Hamilton, ON: BC Decker Inc; 2002.
43. Berg K, Wood-Dauphinee S, Williams JI. The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. *Scand J Rehabil Med*. 1995;27:27-36.
44. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. *Can J Public Health*. 1992;83(suppl 2):S7-S11.
45. Stevenson TJ. Detecting change in patients with stroke using the Berg Balance Scale. *Aust J Physiother*. 2001;47:29-38.
46. Shumway-Cook A, Baldwin M, Polissar NL, Gruber W. Predicting the probability for falls in community-dwelling older adults. *Phys Ther*. 1997;77:812-819.
47. Salbach NM, Mayo NE, Higgins J, Ahmed S, Finch LE, Richards CL. Responsiveness and predictability of gait speed and other disability measures in acute stroke. *Arch Phys Med Rehabil*. 2001;82:1204-1212.
48. Dean CM, Richards CL, Malouin F. Walking speed over 10 metres overestimates locomotor capacity after stroke. *Clin Rehabil*. 2001;15: 415-421.
49. Dobkin BH. Short-distance walking speed and timed walking distance: redundant measures for clinical trials? *Neurology*. 2006;66: 584-586.
50. Robinett CS, Vondran MA. Functional ambulation velocity and distance requirements in rural and urban communities. A clinical report. *Phys Ther*. 1988;68:1371-1373.
51. Schmid A, Duncan PW, Studenski S, Lai SM, Richards L, Perera S, Wu SS. Improvements in speed-based gait classifications are meaningful. *Stroke*. 2007;38:2096-2100.
52. Thompson M, Medley A. Performance of community dwelling elderly on the Timed Up and Go Test. *Phys Occup Ther Geriatr*. 1995;13:17-30.
53. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39:142-148.
54. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med*. 1998;158:1384-1387.
55. Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. *Stroke*. 1998;29:1122-1128.
56. Duncan P, Richards L, Wallace D, et al. A randomized, controlled pilot study of a home-based exercise program for individuals with mild and moderate stroke. *Stroke*. 1998;29:2055-2060.
57. Prior M, Guerin M, Grimmer-Somers K. The effectiveness of clinical guideline implementation strategies—a synthesis of systematic review findings. *J Eval Clin Pract*. 2008;14:888-897.
58. Mawil Z, Stillman P, Laskowski R, et al. First do no harm: integrating patient safety and quality improvement. *J Qual Improv*. 2002;28:373-386.
59. O'Loughlin J, Renaud L, Richard L, Gomez LS, Paradis G. Correlates of the sustainability of community-based heart health promotion interventions. *Prev Med*. 1998;27:702-712.
60. Kahn JM, Fuchs BD. Identifying and implementing quality improvement measures in the intensive care unit. *Curr Opin Crit Care*. 2007;13:709-713.
61. Scott I. What are the most effective strategies for improving quality and safety of health care? *Intern Med J*. 2009;39:389-400.
62. Klassen A, Miller A, Anderson N, Shen J, Schiariti V, O'Donnell M. Performance measurement and improvement frameworks in health, education and social services systems: a systematic review. *Int J Qual Health Care*. 22:44-69.
63. Sugarman JR, Frederick PR, Frankenfield DL, Owen WF Jr, McClellan WM. Developing clinical performance measures based on the dialysis outcomes quality initiative clinical practice guidelines: process, outcomes, and implications. *Am J Kidney Dis*. 2003;42:806-812.
64. Duncan PW, Jorgensen HS, Wade DT. Outcome measures in acute stroke trials: a systematic review and some recommendations to improve practice. *Stroke*. 2000;31:1429-1438.
65. Duncan PW, Lai SM, Keighley J. Defining post-stroke recovery: Implications for design and interpretation of drug trials. *Neuropharmacology*. 2000;39:835-841.
66. Mayo NE, Wood-Dauphinee S, Ahmed S, et al. Disablement following stroke. *Disabil Rehabil*. 1999;21:258-268.
67. Ch'ng AM, French D, McLean N. Coping with the challenges of recovery from stroke: long-term perspectives of stroke support group members. *J Health Psychol*. 2008;13:1136-1146.
68. Cott CA, Wiles R, Devitt R. Continuity, transition and participation: preparing clients for life in the community post-stroke. *Disabil Rehabil*. 2007;29:1566-1574.
69. Cruice M, Worrall L, Hickson L, Murison R. Finding a focus for quality of life with aphasia: social and emotional health, and psychological well-being. *Aphasiology*. 2003;17:333-353.
70. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42:377-381.
71. Grilli R, Lomas J. Evaluating the message: the relationship between compliance rate and the subject of a practice guideline. *Med Care*. 1994;32:202-213.
72. Duncan PW, Wallace D, Studenski S, Lai SM, Johnson D. Conceptualization of a new stroke-specific outcome measure: the stroke impact scale. *Top Stroke Rehabil*. 2001;8:19-33.
73. Buck D, Jacoby A, Massey A, Ford G. Evaluation of measures used to assess quality of life after stroke. *Stroke*. 2000;31:2004-2010.
74. Williams LS, Weinberger M, Harris LE, Biller J. Measuring quality of life in a way that is meaningful to stroke patients. *Neurology*. 1999;53:1839-1843.
75. Duncan PW, Bode RK, Min Lai S, Perera S. Rasch analysis of a new stroke-specific outcome scale: the stroke impact scale. *Arch Phys Med Rehabil*. 2003;84:950-963.
76. Duncan PW, Wallace D, Lai SM, Johnson D, Embretson S, Laster LJ. The stroke impact scale version 2.0. Evaluation of reliability, validity, and sensitivity to change. *Stroke*. 1999;30:2131-2140.
77. Lai SM, Studenski S, Duncan PW, Perera S. Persisting consequences of stroke measured by the stroke impact scale. *Stroke*. 2002;33:1840-1844.
78. Duncan PW, Lai SM, Tyler D, Perera S, Reker DM, Studenski S. Evaluation of proxy responses to the stroke impact scale. *Stroke*. 2002;33:2593-2599.
79. Duncan PW, Reker DM, Horner RD, et al. Performance of a mail-administered version of a stroke-specific outcome measure, the stroke impact scale. *Clin Rehabil*. 2002;16:493-505.
80. Rankin J. Cerebral vascular accidents in patients over the age of 60. *II. Prognosis. Scott Med J.* 1957;2:200-215.
81. van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJ, van Gijn J. Interobserver agreement for the assessment of handicap in stroke patients. *Stroke*. 1988;19:604-607.
82. Granger CV, Hamilton BB, Gresham GE, Kramer AA. The stroke rehabilitation outcome study: Part II. Relative merits of the total barthel index score and a four-item subscore in predicting patient outcomes. *Arch Phys Med Rehabil*. 1989;70:100-103.
83. Wolfe CD, Taub NA, Woodrow EJ, Burney PG. Assessment of scales of disability and handicap for stroke patients. *Stroke*. 1991;22:1242-1244.
84. Wood-Dauphinee S, Williams JI. Reintegration to normal living as a proxy to quality of life. *J Chronic Dis*. 1987;40:491-502.
85. Wood-Dauphinee SL, Opzoomer MA, Williams JI, Marchand B, Spitzer WO. Assessment of global function: the reintegration to normal living index. *Arch Phys Med Rehabil*. 1988;69:583-590.
86. Finestone HM, Guo M, O'Hara P, et al. Driving and reintegration into the community in patients after stroke. *PM R*. 2010;2:497-503.