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Research in the Acute Rehabilitation Setting: a Bridge Too Far?

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Abstract

Purpose of Review The goal of this paper is to critically examine the challenges to clinical practice in acute neurorehabilitation settings to provide evidence-based recommendations for conducting research on neurologic recovery.

Recent Findings Recent changes in health care have dramatically challenged post-acute care by reducing the length of stay and increasing transitions in care with resulting loss of continuity of care and follow-up. These challenges hinder research and undermine progress in neurorehabilitation.

Summary Based on recent evidence, a hub and spoke model is proposed to bridge and facilitate continuity of care from acute to subacute to community settings to meet these challenges head on and facilitate research on mechanisms of functional recovery from neurologic conditions.

Keywords Brain injury · Stroke · Neurorehabilitation · Research · Post-acute care

Introduction

Neurological disorders are a leading cause of disability worldwide. The burden of disability from neurological disorders, such as stroke, traumatic brain injury, spinal cord injury, and other neurologic conditions, has increased substantially over the past 25 years because of the aging population and substantial decreases in mortality rates from stroke and communicable neurological disorders [1]. Neurorehabilitation is the only approved therapy for neurological recovery, and the decrease in the burden of stroke in high-income countries over the past 30 years is partly attributed to it [2]. The overall goal of neurorehabilitation is to restore—in so far as possible—normal neurological function [3] in physical, mental (cognitive and emotional), and social domains, consistent with the International Classification of Functioning, Disability and Health model (ICF; World Health Organization, 2001) [4]. Neurorehabilitation requires coordinated interdisciplinary rehabilitation to facilitate neurologic recovery, restore functional ability, and maintain quality of life. However, the delivery of neurorehabilitation is complicated by the wide range of disciplines involved in the care of the patients, the levels of care or settings in which it is provided, and the reimbursement fee structure set by payors such as the Centers for Medicare & Medicaid Services in the USA [5••].

For example, after a stroke, a patient typically transitions through multiple care settings in several unrelated facilities, starting in the emergency room, then in the stroke unit in the hospital, followed by care in an acute inpatient rehabilitation facility (IRF) and/or a skilled nursing facility (SNF), then home health care and finally outpatient rehabilitation [6] (Fig. 1). In the USA, acute neurorehabilitation refers to rehabilitation services that are provided in the IRF, and subacute rehabilitation services refer to services typically provided in an SNF. Upon discharge from the SNF, the patient may receive home rehabilitation by an independent home care agency, followed by outpatient rehabilitation at a facility of their choice. He or she may or may not return to see the neurorehabilitation team that treated him or her initially. As

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a result, the delivery of neurorehabilitation is highly fragmented as no single entity oversees the entire rehabilitation process of a given patient from the acute stage throughout the continuum of care. Furthermore, non-clinical factors often determine the selection of the specific post-acute facility [7•]. In addition, many individuals who require neurorehabilitation services do not receive it [8–10]. In this situation, everyone loses—the patient loses because of the lack of quality services to optimize recovery, the payors lose because of accruing disability and possible complications that lead to increased medical expenses over the long term, the medical and scientific communities lose because we cannot provide the scientific evidence to back clinical care, and society at large loses because of the inability to reintegrate survivors as productive members and the increased burden on caregivers.

A recent meta-analysis concluded that physical rehabilitation has a beneficial effect on functional recovery, motor function, balance, and gait velocity after stroke compared with no treatment or usual care, and that the effects persist beyond the intervention period [11]. The meta-analysis suggested that interventions were more effective when provided in the early post-stroke period, and at a dose of 30 to 60 min per day delivered 5 to 7 days per week. However, no one physical rehabilitation approach was more (or less) effective than any other approach. A more recent meta-analysis of studies on upper limb function conducted in the first 4 weeks following stroke concluded that modified constraint induced movement therapy and task-specific training as well as the supplementary use of EMG-assisted biofeedback and electrical simulation are supported by evidence for use in the acute phase post-stroke, whereas Bobath therapy is not [12]. Even stroke survivors with severe upper arm disability have been shown to achieve a clinically important change during inpatient rehabilitation [13]. In addition, a recent study of over 2000 patients recently showed that contrary to current clinical practice, older patients with stroke benefit as much from high-intensity neurorehabilitation as younger patients [14•].

On the other hand, studies that have shown that for individuals with mild-moderate stroke, neurological recovery at 6 months can be predicted by motor impairment scores obtained at 72 h post-stroke, suggesting that neurological recovery is driven by injury-dependent spontaneous repair and recovery mechanisms rather than rehabilitation [15–18]. Furthermore, six out of eight large clinical trials in rehabilitation conducted in the past decade showed no differences in outcome between the experimental intervention and standard neurorehabilitation [19]. How does one reconcile these starkly different conclusions?

A major challenge is that the key ingredients of neurological rehabilitation, their timing and dose, and the mechanisms by which they enhance recovery are still unclear [20–22]. The heterogeneity of standard neurorehabilitation, including the variety of care settings in which it is delivered, makes it very difficult to study the impact of rehabilitation on true neurological recovery. Furthermore, many of the studies conducted in acute rehabilitation have been small, showed significant

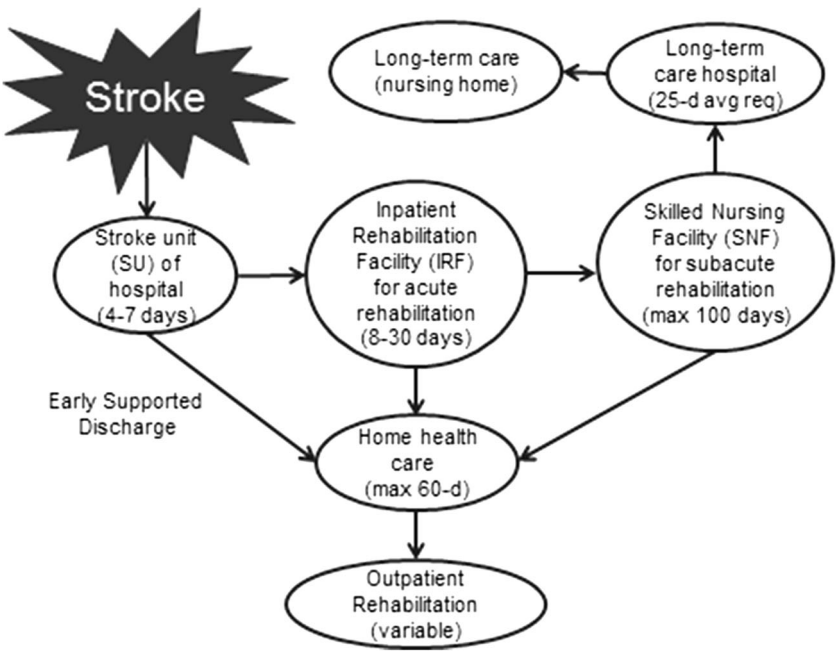

Fig. 1 Levels of care for stroke rehabilitation in the USA. Modified from Miller et al. [6]. Copyright © 2010, American Heart Association, Inc.

biases, and longer-term outcomes were not available [12]. Nevertheless, there is an expanding range of new rehabilitation technologies available and in development, thanks in part to a National Institutes of Health initiative [23]. These technologies are not necessarily superior to conventional delivery methods [24–27]; however, they have the potential to make rehabilitation more accessible across care settings. With the rising trends in neurological disability across the globe, the onus is on us to create the infrastructure to perform appropriately controlled scientific studies to demonstrate what works, when to give it, and why and how it works. This requires that we observe and measure the process of recovery across its many dimensions, over the entire time course starting from the initial injury all the way through to the point of maximum possible recovery, and/or across the lifespan of the disability. How can we achieve this?

Learning from the Past

In Twitchell's classic 1951 article, "The restoration of motor function following hemiplegia in man" [28], 121 patients with hemiplegia were followed, of whom 25 were followed for at least 9 months, "from the time of admission to the hospital to a point where a comparatively stable condition was reached." Detailed observations of these patients led to the conclusion that despite the heterogeneity in clinical presentation, there was "a remarkable uniformity in the steps of recovery" across different patients. This uniformity in the steps of recovery eventually led to the articulation of the stages of recovery by Brunnstrom [29] and to the development of a measure of motor impairment by Fugl-Meyer, the Fugl-Meyer Scale [30]. The Fugl-Meyer Scale is still considered a gold-standard measure of motor impairment that has stood the test of time. Twitchell reports that in 96 patients who were observed over a shorter time-period "postural abnormalities were not seen in all," but that "some postural abnormalities would have been detected were it possible to follow these patients for a longer time." Nevertheless, Twitchell made inferences from the 25 individuals that he observed over a long period of time to the generalized idea of "steps of recovery". Twitchell's landmark study underscores the need for careful observation and reasoning by induction and deduction *over the course of neurologic recovery*. Only such observation and reasoning will lead to the generation of hypotheses that can be tested through careful experimentation [31].

Since neurological recovery takes place over long periods of time extending from weeks to months and years, *careful observation over the long-term*, starting as early as possible is essential. The reason for starting the observations immediately post-stroke or post-injury is that it can enable an understanding of the contributions of stroke or injury characteristics, early treatment [32], medical co-morbidities (e.g., diabetes [33]), infections [34], sleep dysfunction [35–37], biomarkers [38], neuroprotective [39–41], and neuro-reparative processes [42] to fully understand the biological and therapeutic mechanisms of neurological recovery. Many severely disabling and critical care conditions also require a seamless and interconnected continuum of patient care from the acute phase to the end of the rehabilitation phase [43]. The acute setting is thus well-suited to starting the observations that will lead to critical insights over the long term.

The observations must include qualitative assessment and quantitative measurement of rehabilitation needs and interventions in medical, physical, mental, and social domains. This will enable the interactions across these domains to be studied. For example, it has been shown that high-intensity exercise can lead to brain states conducive to neurological recovery [4, 44], but the extent to which it contributes to short- and long-term neurological recovery is not known. Although there is modest evidence that pharmacologic agents such as amphetamine-like agents, serotonin reuptake inhibitors, and levodopa improve motor outcomes, many of the clinical trials are underpowered, and more comprehensive knowledge about the efficacy, long-term effects, and safety of these drugs is required [45]. Hence, it is important to include information about dose, intensity, duration, and timing of both pharmacologic interventions and therapy [46]. A recent study demonstrated that progressive practice (where task difficulty is increased across practice sessions) promotes both motor learning and repeated increases in corticospinal excitability across multiple days [47••]. This study provided an extremely short-term intervention over 4 consecutive days that led to measurable physiologic changes. If such a short-term trial were embedded in a longer-term prospective observational study, one may be able to determine how changes in corticospinal excitability eventually relate to changes in impairment and functionally relevant neurological recovery.

Outcomes must include physiologic assessments as well as assessments of impairment and function consistent with the International Classification of Functioning, Disability and Health model (ICF: World Health Organization [WHO], 2001) [4] to provide insight into recovery mechanisms and their impact on function and participation. Furthermore, infrastructure that enables nested short-term interventions embedded in longer-term observational studies can assist the scientific community in answering important questions. Such an infrastructure for a care continuum requires coordination not just across multiple neurorehabilitation settings but also across disciples such as neurology, neurosurgery, physical medicine, and rehabilitation (including physical, occupational, speech, and recreational therapy and neuropsychology), internal medicine, geriatrics, and population health as practitioners in all these fields contribute to the care of individuals with neurologic conditions. To create such

infrastructure, we first need to understand the major challenges of the current system, so we can overcome them.

Current Challenges

Current challenges in establishing a continuum for clinical care and research include the lack of clinical care pathways, brevity of the acute rehabilitation stay, multiple transitions across facilities with no overseer, and loss of follow-up of patients. Improved coordination of care can increase efficiency and quality of care, improve outcome, and reduce costs. To this end, clinical pathways began to be developed during the acute hospital phase post-stroke, which resulted in a significant reduction in length of stay, cost of care, and complications while improving the quality of care [48, 49]; these clinical pathways adopted by stroke units are now standard of care [50]. However, it has been more challenging to develop appropriate clinical pathways for rehabilitation (see [51] for review). Although integrated care pathways (ICP) have been developed, randomized controlled trials showed that conventional multidisciplinary care on a stroke rehabilitation unit led to faster functional recovery and greater improvement in quality of life outcomes than ICP management [52]. The lack of benefit of the care pathways has been attributed to greater attention to social functioning, higher function, and caregiver needs during rehabilitation with conventional multidisciplinary rehabilitation [53]. These studies underscore the complexity of rehabilitation services and the need to develop comprehensive clinical care pathways that address not only medical needs but also physical, mental, and social needs.

The high cost of hospital care has led to financial incentives to reduce the length of hospital stay, including the length of stay in acute inpatient rehabilitation units (IRF) [6]. However, reducing the length of stay during early neurorehabilitation distracts the focus from long-term neurologic recovery to short-term compensation that may detract from the process of recovery [54]. This is particularly so because neuroreparative mechanisms are active in the immediate post-injury period; using this valuable time to teach compensatory strategies rather than facilitate neurological recovery may actually limit eventual recovery. In fact, a 1-day increase in rehabilitation hospitalization correlated with 19% decreased odds of acute care readmission, and one unit increase in functional ability (on the discharge FIM) correlated with 13% decreased odds of acute care readmission, regardless of the administration of t-PA in a cohort of stroke patients [55]. The extremely limited length of stay in the acute rehabilitation unit is a major barrier in the collection of data on mediators of recovery (for example actigraphy to measure sleep dysfunction [37] and any kind of rehabilitation intervention that requires repetitive training (personal observation). Hence, most studies on recovery are conducted in the subacute and chronic phases when patients are discharged home; however, the timing of the interventions may impact the extent of recovery, as spontaneous recovery mechanisms may no longer be active [56].

A natural consequence of the impetus to reduce length of hospital stay is to transition patients for post-acute care to other facilities along the continuum. However, transitioning of care from acute inpatient settings to in- and outpatient rehabilitation or long-term care environments has consistently been identified as an obstacle to quality stroke rehabilitation [57]. From the patient and caregiver's perspective, "pushing" patients out of acute care hospitals leaves them to navigate post-acute care arrangements by themselves [58], and they feel abandoned by the health care system. A consensus conference on the state-of-the-science for post-acute rehabilitation that took place over a decade ago underscored the need for well-designed collaborative research on the active ingredients of the rehabilitation process that produce the best outcomes [59]. This goal remains elusive however.

Is There a Path Ahead?

One possible solution to overcome the limitation of reduced length of stay on repetitive training is to initiate and train patients and caregivers on training techniques using video and/or portable technology in the acute care setting, which can then transition along with the patient to other care settings. If one can incorporate measurement and evaluation with the training, one can then assess recovery over time agnostic of the care setting. Telemedicine and telerehabilitation can also be used to monitor progress and adjust the intervention(s) across care settings. Such transitions will however require improved systems of care.

Cameron et al. have proposed that stroke systems of care can be optimized at multiple levels (i.e., at society, system, and/or individual levels) to enhance transitions across care environments [58]. Societal level initiatives occur at the federal or state level and include financial incentives and funding for a broad cause; system level changes refer to partnerships or agreements within a health care system to coordinate resources such as in following clinical care pathways, where as individual level changes focus on one individual at a time such as improved case management, patient navigators, and self-management. Most importantly, the system of care should build bridges across the levels of care and the various disciplines involved. Given the available evidence on recovery processes [60], a hub and spoke model of care integration and organization is proposed (Fig. 2).

The first step in neurological recovery is the optimization of neurological state, which is necessary for later functional recovery. This requires attention to the biological processes that mediate recovery, reflected in the levels of biomarkers

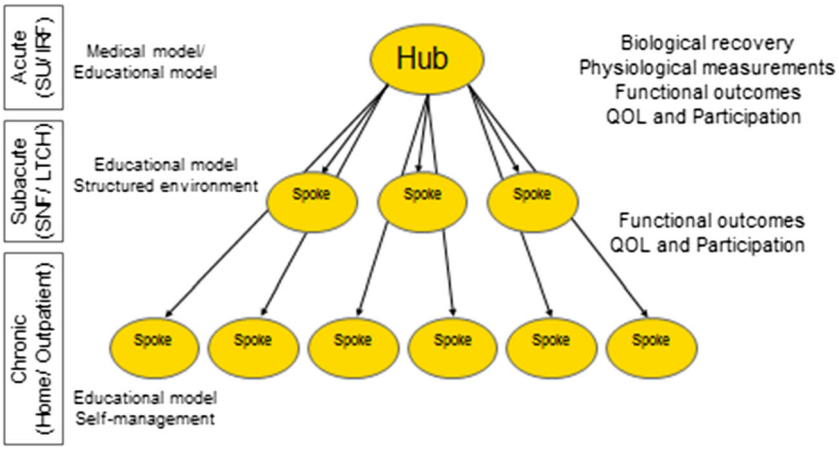

Fig. 2 A hub and spoke model of integrated care across the levels of care for practice and research in neurorehabilitation. SU, stroke unit; IRF, inpatient rehabilitation facility; SNF, skilled nursing facility; LTCH, long-term care hospital

that reflect these processes [61••, 62]. The consequence of such optimization will be reflected in physiological measurements of the processes rather than the outcomes alone. For example, sensorimotor impairments can be easily measured by muscle activation patterns and range of motion using wearable sensors even remotely, compared with using the Fugl-Meyer Scale. Functional measures such as the ability to reach and grasp and gait speed could also be reliably and easily measured using wearable sensors. These measures can be obtained in the acute phase prior to transitioning out of the stroke unit in the acute care hospital, and at the beginning and end of the acute rehabilitation stay at the IRF. The acute phase which typically occurs in a hospital setting within the medical model of interdisciplinary care is particularly convenient to obtain outcome measures encompassing all processes that are expected to change over the course of recovery. Hence, it is the ideal hub to facilitate, measure, and monitor recovery. At this stage, focusing on optimizing neurological recovery rather than teaching compensatory strategies that may detract from recovery would best serve the patient.

Socially oriented features of disability such as quality of life related to physical health, psychological health, community integration, and participation often respond to neurorehabilitation at much later time points, once the neurological state has been optimized [63]. In fact, this requires a shift in the approach to neurorehabilitation from a medical model to an educational model, where rehabilitation is initially provided in a structured environment and gradually transitions to less-structured environments, with the goal of increased independence and self-management of disability [64]. The subacute rehabilitation phase is well-suited for learning new skills in physical, mental, and social domains, while also adapting to residual disability. However, medical needs often persist, requiring supervision by the medical team from the hub. In an ideal integrated system of care, the team from the hub would continue to be involved with multiple subacute rehabilitation units or spokes through mutually beneficial partnerships. This would provide the infrastructure to ensure continued quality rehabilitation, as well as measurement and monitoring of recovery. Partnerships that establish communication across all the stakeholders will ensure the success of integrated care [65]. The goal of subacute rehabilitation and/or the long-term care hospital would be to ensure that patients are prepared to self-manage their disability in the community.

Once at home and in the community, a patient needs to feel empowered to participate in his or her own recovery. Self-management programs for people with stroke include specific education about the stroke and likely effects, as well as skills training to encourage people to take an active part in their rehabilitation and recovery. Such skills training can include problem-solving, goal-setting, decision-making, and coping skills that have been shown to improve quality of life and self-efficacy [66••]. Home health agencies and outpatient facilities including disability gyms and community rehabilitation programs can facilitate self-management of physical disability. The key questions in the chronic stage are to understand what activity-dependent repair and recovery processes are ongoing and can be facilitated. Hence, it remains important for hubs to partner with spokes in the community and continue to facilitate, measure, and monitor recovery. This is likely to be more challenging than creating partnerships with other outpatient facilities; however, it would be critical for truly integrated care.

Hubs in acute care settings should be versatile in managing patients at all levels of care. Self-management in acute stroke settings is feasible and can lead to increased independence in self-care [67]. Interactive arts programs can be provided both in the acute stage [68] as well as in the community [69]. One dose of rehabilitation at a specific time is not likely to meet all needs. Regular reassessment is required in order to identify whether an individual will benefit from rehabilitation at a particular time [70]. If at any time over the course of recovery, function declines, inpatient interval rehabilitation programs (IRP) can achieve specific functional goals even in the chronic stage [71]. Whether the mechanisms of recovery are similar or different can only be determined by comparing the process of recovery in the two phases using similar outcome measurements.

Acute phase hubs led by primary care providers have been shown to be effective in overcoming fragmented post-stroke care in areas where access to specialty neurorehabilitation is limited or lacking [72].

Conclusion

The current system of post-acute care for neurorehabilitation is so highly fragmented that it precludes systematic high-quality observation and measurement of the recovery processes across its various stages. As a result, we lose the opportunity to gain insights into the mechanisms of recovery. As new technologies such as wearable sensors and telemonitoring systems are developed, new opportunities arise for bridging care across the continuum. Any complacency in the scientific community about the lack of benefit of neurorehabilitation reflects our own inability to figure out the answers, rather than a lack of capacity for neurological recovery with neurorehabilitation.

Compliance with Ethical Standards

Conflict of Interest Preeti Raghavan reports conflict from Mirrored Motion Works, Inc., other and from Movease, Inc., outside the submitted work. In addition, Preeti Raghavan has patents on Rehabilitative training devices for use by stroke patients issued, a patent on Game-Based Sensorimotor Rehabilitator pending, and a patent on Use of Hyaluronidase for Treatment of Muscle Stiffness pending.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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