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A 67-yr-old woman with a working diagnosis of osteoporosis was seen for low-back pain. Her medical history revealed a recent kyphoplasty procedure for an L2-compression fracture. Limited low-back motions with bilateral paravertebral muscle guarding were noted on physical examination. Radiologic evaluations of lumbar vertebrae and bone mineral density measurements using dual-energy x-ray absorptiometry were performed (Figs. 1 and 2). The initial L1–L4 t score was thought to be consistent with osteopenia (−1.92); however, further analysis revealed that the L2 score (+2.48) had, in effect, skewed the results (Table 1). When the value pertaining to the L2 vertebra was neglected, the mean value of t scores were recalculated using L1, L3, and L4 values as −3.12 (osteoporotic).

The authors report this case for two reasons. First, considering the mounting frequency of kyphoplasty operations, we imply that dual-energy x-ray absorptiometry measurements may yield incorrect results in such patients. Accordingly, clinicians should diligently evaluate such patients’ bone mineral density measurements in light of their medical history. Secondly, a better estimation of L1–L4 t score can easily be done with a simple correction by omitting the value of the involved vertebra.

REFERENCE
Poststroke and Brain Injury Rehabilitation Treatment Strategies


In the June, July, and August issues of the Journal, we introduced the first three parts of a four-issue special series focused on innovative, physiologic treatments for stroke and traumatic brain injury. These disorders are leading causes of adult disability in the United States, accounting for tremendous personal, social, and financial costs for survivors, caregivers, and society. In the June issue, Hillis has provided an up-to-date review on how physiologic treatments may optimize poststroke aphasia recovery. Choi et al. and Buxbaum et al. have presented data in the July issue relevant to poststroke spatial neglect treatment. The August issue has focused on pharmaceutical treatment of acquired adynamic speech and disordered consciousness.

In this issue, we consider how rehabilitative strategies can be refined and developed further. In rehabilitation science, it is absolutely critical that we move from basic discovery—new, potentially promising neurorehabilitation interventions—toward large-scale, systematic clinical studies and beyond, to their optimal application. Even within our own field, intermediate-stage studies are criticized because they do not use randomized controlled or meta-analytic methodology. However, phase III research planning is neither appropriate nor desirable when a treatment hypothesis is being refined, and its feasibility and optimal setting are being explored.

This issue presents two papers on combined treatment strategies for poststroke hemiparesis, an area emerging from observational reports into systematic group studies. Malcolm et al. added repetitive transcranial magnetic stimulation to a modified protocol for constraint-induced therapy. Although constraint-induced therapy seems to have resulted in motor improvement, adjuvant repetitive transcranial magnetic stimulation induced changes in motor excitability in treated patients without an associated, clinically evident treatment effect. Their results suggest that the relationship between physiologic parameters and functional improvement needs clarification, as do optimal parameters for designing constraint-induced therapy to produce functional gains across individuals. Levy et al. examined a combination of botulinum toxin A injections, evidence-based exercise therapy, and constraint-induced movement therapy in hemiparetic patients with spasticity, and motor function insufficient for constraint-induced movement therapy candidacy by standard criteria. Motor ability improved with toxin and exercise therapy, but in the four patients who became eligible, gains made with subsequent constraint-induced movement therapy unfortunately receded as spasticity returned. A larger-scale investigation of constraint-induced movement therapy in stroke
survivors with very low motor functional ability, after administering botulinum toxin A/exercise treatment, may now be indicated.

We are grateful for the opportunity to bring Journal readers the four-issue special series on brain injury rehabilitation. We hope these articles stimulate a continuing dialogue in the rehabilitation science community and aid in developing more studies to complete and strengthen our translational continuum.

REFERENCES

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DISCLOSURES:
Presented in part at the 41st Annual Meeting of the Association of Academic Physiatrists Meeting in Tucson, Arizona, February 2005. This research was supported by N3042C “Effect of BTX-A Plus Evidence-Based Behavioral Therapy on Motor Recovery” VA Rehabilitation and Research Development Service.

Botulinum Toxin A, Evidence-Based Exercise Therapy, and Constraint-Induced Movement Therapy for Upper-Limb Hemiparesis Attributable to Stroke
A Preliminary Study

ABSTRACT

OBJECTIVE: To determine whether the combination of botulinum toxin A (BTX-A) treatment for the upper limb and a 4-wk course of exercise therapy could improve motor function sufficiently to allow those with poststroke hemiparesis and spasticity to achieve the minimal motor criteria (MMC) to be enrolled in constraint-induced movement therapy (CIMT), and to determine the feasibility of enrolling participants into CIMT if they meet MMC after treatment with a combination of BTX-A plus exercise therapy.

DESIGN: Twelve individuals received BTX-A and exercise therapy for 1 hr/day, three times per week, for 4 wks. Those who met MMC were enrolled in 2 wks of CIMT, and the rest received a home exercise program. Outcome measures included the Ashworth Scale, Wolf Motor Function Test (WMFT), the Motor Activity Log (MAL), the Box and Blocks Test (BBT), and the upper-extremity subtest of the Fugl–Meyer Assessment of Motor Function (FM-UE).

RESULTS: Ashworth Scale scores declined from a mean score of 2.0–1.2 (P = 0.01). Four of 12 subjects were able to achieve MMC (P = 0.026). CIMT participants improved in the BBT, the MAL, and the WMFT compared with their own baseline. Gains achieved during CIMT receded by week 24 as spasticity returned.

CONCLUSION: BTX-A plus exercise therapy shows potential to improve function for those with severe hand paresis and spasticity after stroke. Those who meet MMC may initially realize further modest gains through CIMT. However, gains are likely to recede as spasticity returns. Adding medications or modifying the therapy protocol to include activities such as functional neuromuscular stimulation or robotic training may yield a more potent effect.
Stroke is the third-leading cause of death in the Western world, trailing only heart disease and cancer. Nearly 700,000 new strokes occur in the United States annually.1 Approximately 60–80% survive stroke. In the United States, there are about 1.7 million survivors with disabilities, costing society over $7 billion/yr.2 Hemiparesis is the most common deficit after stroke, affecting >80% of subjects acutely and >40% chronically.3 Rehabilitation techniques have been more successful in restoring function in the lower limb than in the upper limb.4 Unfortunately, upper-limb function is more important for independent living and self-esteem.5,6 The time course of upper-limb recovery has been placed at 11 wks after stroke, after which “further recovery of upper extremity function should not be expected.”7 Fortunately, the pessimism regarding recovery of upper-limb function has been convincingly challenged by a number of emerging behavioral therapies, including neuromuscular electrical stimulation, robot-aided sensory motor stimulation, real-time auditory feedback, and repetitive bilateral arm training with rhythmic auditory cuing.8–12 Constraint-induced movement therapy (CIMT) has attracted great attention because of its demonstrated efficacy, its sound physiologic principles, and evidence attesting that it stimulates cortical plasticity.13–22 However, to benefit from CIMT, eligible patients must meet a “minimum motor criterion” of 10 degrees of volitional extension of the wrist, 10 degrees of volitional abduction of the thumb, and 10 degrees volitional extension of two other digits in 3 mins.14–17 It has been estimated that 25% of stroke survivors can meet the minimal motor criteria. Unfortunately, this leaves a large number of affected individuals ineligible for CIMT. We have observed that many with stroke who are unable to meet the minimum motor criteria also exhibit spasticity in the upper limb.

Despite clinicians’ great familiarity with spasticity as a possible consequence after stroke, there is a paucity of information regarding its prevalence and its clinical significance. Limitations include reliance on clinical scales such as the Modified Ashworth Scale (MAS), lack of measurement of cocontraction, and reliance on global functional measurements that may lack the sensitivity to detect more subtle impairments. Watkins et al.23 applied the MAS and the Tone Assessment Scale to 106 individuals who were 1 yr post stroke; they found the prevalence of spasticity to be 40%. They note that those with spasticity also had significantly lower scores on the Barthel Index and were more likely to live in institutional settings than in their own homes. Sommerfeld et al.24 used the MAS to measure spasticity in 95 individuals at 3 mos after stroke. They found spasticity in 19% of their sample. However, the incidence rose to 28% of those with hemiparesis. At 3 mos, higher upper-limb scores on the MAS were correlated with worse performance on the Birgitta Lindmark Motor Assessment Active and Rapid Movement scores and the Nine Hole Peg Test. Although these studies add to our knowledge of poststroke spasticity, the true incidence, prevalence, and significance of poststroke spasticity have yet to be established.

Since 1989, a number of studies have demonstrated botulinum toxin A (BTX-A) as a safe, effective treatment to reduce upper-limb spasticity caused by stroke or traumatic brain injury.25–28 These studies make it clear that BTX-A–induced tone reduction can result in improved upper-limb function by easing passive manipulation of the plegic or paretic limb. Although a careful reading of the literature reveals intriguing hints, the question of whether judicious use of BTX-A can facilitate the restoration of volitional control of the hand remains unanswered.29–33 Could the existence of hypertonus and cocontraction mask a latent ability to extend and control the wrist and fingers for those who have spasticity after stroke? Could a combination of BTX-A plus exercise therapy reduce tone and, thus, reveal hidden hand movement?

We postulated that for individuals with poststroke upper-limb hemiparesis and spasticity who could not perform the minimum motor criteria to qualify for CIMT:

1. Treatment with BTX-A and then 4 wks of exercise therapy would reduce tone and impairment as measured by the Ashworth and Fugl–Meyer upper- extremity scales.34–35
2. Treatment with BTX-A and then 4 wks of evidence-based exercise therapy would improve volitional control sufficiently to meet minimum motor criteria more than would be expected by chance alone.
3. The ability to volitionally extend the wrist, fingers, and thumb at baseline would identify those who would be able to meet CIMT criteria from those who could not.

We also wished to explore the feasibility of using BTX-A plus exercise therapy combined with CIMT to improve hand function after stroke. We expected that any gains achieved during CIMT would diminish in the next 18 wks as spasticity returned.

As a preliminary trial, we were aware that the relatively small enrollment would provide insufficient statistical power to adequately test hypotheses on the basis of group differences. There would...
almost certainly be an unacceptable risk of committing a type 2 error (supporting a false-null hypothesis). Nonetheless, we thought it would be valuable to gather preliminary information from which appropriate hypotheses with adequate power could be generated for future studies. Therefore, we collected data comparing performance of those who met the minimal motor criteria with those who did not on the Wolf Motor Function Test (WMFT), the Motor Activity Log (MAL), the Box and Blocks Test (BBT), and the upper-extremity subtest of the Fugl-Meyer Assessment of Motor Function (FM-UE), for descriptive purposes. These data did not undergo statistical analysis.\textsuperscript{35–39}

**METHODS**

**Participants**

Twelve subjects ( \( \geq 21 \) yrs of age) with unilateral strokes were recruited through flyers from primary care, neurology, and physical medicine and rehabilitation clinics, and from a research screening database. As inclusion criteria, all participants must have exhibited hand paresis after a unilateral stroke at least 90 days earlier and have been unable to meet minimal motor criteria for CIMT (unable to achieve 10 degrees of voluntary extension of the wrist, 10 degrees of abduction at the thumb, and 10 degrees of extension of two fingers in the affected hand, repeated three times in 1 min). Further, potential participants must have displayed hypertonus at rest ( \( \geq 2 \) on the Ashworth Scale at the wrist, fingers, or thumb) or evidence of deleterious cocontraction (e.g., finger or wrist flexion during attempted hand opening). Participants must have reached a plateau regarding hand function. Specifically, the participants must not have been experiencing improvement or decrement in active hand function. Exclusion criteria included the following: ability to meet minimal criteria for participation in CIMT; active participation in conventional therapy for upper-limb dysfunction; joint immobility in the upper limb attributable to contracture, bony deformity, or heterotropic ossification; history of clinically apparent stroke in the contralateral hemisphere, or more than minor stroke in the contralateral hemisphere on imaging studies; history of major head trauma, dementia, learning disorder, schizophrenia, or major depression before the stroke; medical instability; known allergy to BTX-A; and current receipt of BTX-A treatment. This study was approved and monitored by a university institutional review board and a subcommittee on clinical investigations. All subjects provided informed consent to participate.

**Design**

The experimental design is illustrated in Figure 1. Subjects who met eligibility criteria for CIMT at the conclusion of exercise therapy were entered into a 2-wk course of CIMT.

**Treatment**

**Botulinum Toxin**

Doses and muscles selected for BTX-A injection were individualized on the basis of a number of factors, including the patient’s weight, the amount of resistance to passive stretch, and the degree of cocontraction present when the participant attempted to extend the wrist and fingers.\textsuperscript{40}
total dose of up to 400 U of BTX-A was used. Botox brand BTX-A Purified Neurotoxin Complex, (Allergan Pharmaceuticals, Irvine, CA) was prepared by diluting lyophilized toxin with 0.9% saline to a concentration of 25 U/ml. This created a more dilute solution than is used in some clinical settings. Although this requires larger volumes, with a possibility of spread to nontargeted adjacent muscles, several reports in humans and animals support a greater effect of more diluted solutions. Location of the targeted muscle was confirmed by use of an electrically active hypodermic needle (EZstim Model ES300, Life-tech, Inc, Stafford, TX). Between 20 and 75 units of BTX-A per muscle were injected into the flexor carpi ulnaris and flexor carpi radialis; 12.5–25 units per fascicle in the flexor digitorum sublimis and flexor digitorum profundus (maximum dose: 100 units for each of these muscles); 10–30 units in the flexor pollicis longus; 25–100 units in the brachioradialis; 50–200 units in the biceps brachii; and 25–75 units in the pronator teres. The greatest volume used for a single injection of the flexor carpi radialis, flexor carpi ulnaris, or pronator teres was 1.5 ml; for the flexor digitorum sublimis and flexor digitorum profundus, the greatest volume was 1 ml per fascicle; 1.2 ml was the maximum used for the flexor pollicis longus; and 2 ml was the maximum for the brachioradialis and biceps brachii. Thus, most subjects received more than one injection in at least some of the targeted muscles.

Exercise Therapy

The application of exercise therapy after botulinum toxin treatment for the upper limb is the norm in both clinical trails of BTX-A and in clinical practice. In fact, BTX-A treatment is so often coupled with exercise therapy that the independent effects of BTX-A treatment alone, vs. those of therapy alone, vs. those generated by the combination of the two, are unknown. To complicate matters, there exists no standard regimen of exercise therapy that is widely applied after BTX-A injection of the upper limb. A postinjection therapy was created for this protocol, commencing within 1 wk of BTX-A treatment. Its intensity was 1 hr, three times per week, with a duration of 4 wks, consistent with most current U.S. reimbursement policies. The content of therapy was built around three evidence-based physiotherapeutic concepts for improving arm and hand function in stroke patients, as elucidated by Waldag and Hummelsheim: (1) multiple motor repetitions of behaviorally meaningful task practice, (2) accurate feedback, and (3) mental practice. Operationally, this translated to a progressive program of repeated motor practice built on the elements of functional grasp, reach, and release movements. As subjects gained mastery of simpler tasks, tasks with increasing complexity were introduced. For participants lacking the capacity to actively engage in task-oriented exercise, the therapists provided active-assist and passive movements. Therapists also emphasized relaxation to allow release for those who were unable to actively release despite training and BTX-A treatment. Therapists were trained to give specific feedback regarding the accuracy and speed of movements. When actual task practice was not taking place, participants were instructed to visualize restored function of their impaired upper limbs and to imagine the kinesthetic sensations that would be involved in normal movement of the impaired upper limb. All participants received instruction to continue the exercise program initiated in the clinic at home. Participants were encouraged to incorporate the paretic limb in ordinary home activities as much as possible, emphasizing wrist and finger extension.

CIMT

CIMT consisted of 6 hrs of intensive upper-limb training 5 days/wk for 2 wks, carried out by therapists who completed instruction at the University of Alabama. CIMT included massed repetition, task practice with shaping (approach of a desired motor or behavioral objective by small steps and successive approximations), and intensive timed activities. The daily interventions were designed around a menu of functional activities that incorporated variations of strength, endurance, coordination, dexterity, and range of motion. Interest inventories and role checklists were used to incorporate the participant’s unique personality traits and interests into the menu. Typical activities included tasks such as bag toss at a target, reaching and grasping selected objects used in daily life, stacking and moving checkers, turning pages, card activities, writing on and erasing on a chalk board, and preparing and eating lunch. The participants gave daily input regarding the activities they performed in the laboratory and when they returned home or to the motel. In this way, a variety of purposeful and meaningful activities were incorporated, with attention to unique limitations. Encouragement was provided continuously. Therapists sought to prevent participants from failing, by providing assistance as necessary or changing the task. If an activity was strongly disliked or seemed to be too difficult, it was eliminated from the menu for the next day. Participants were instructed to wear a restrictive mitt on the nonparetic hand during 90% of their waking hours. The mitt was removed only for safety, hygiene, or agreed-on activities, as documented in daily diaries. The tasks requiring mitt removal were then focused on during the next CIMT session.
Baseline Measures

At baseline, all participants were evaluated for the amount of volitional control present in the hemiparetic limb. Participants were seated comfortably in a chair with their forearms supported by an armrest and their wrists placed unsupported. Participants were asked to maximally extend their wrists against gravity three times in 1 min. They were then asked to extend their fingers maximally, three times in 1 min. Finally, they were asked to extend their thumbs three times in 1 min. Determination of the range of motion was made by physical and occupational therapists measuring the maximal excursion of the segment. Participants were encouraged to give their best efforts, and they were given the opportunity to warm up and to passively range their hands. Any participant whose performance came close to meeting the minimum motor criteria was examined repeatedly, to confirm a true inability to meet criteria, before being included in the study. The presence or absence of voluntary extension or abduction was recorded dichotomously as either present or absent in the wrist, thumb, and all four fingers. The segment was rated as present if the movement exceeded or was equal to active movement with gravity eliminated.

Outcome Measures

Outcome measures consisted of the Ashworth Scale, FM-UE, BBT, WMFT, and the MAL. The Ashworth was chosen as a common, easily applied method to assess hypertonus. Each participant was sat upright in a chair with the elbow flexed at approximately 90 degrees resting on an armrest, and the wrist dangling comfortably at approximately 30 degrees of flexion off the end of the armrest. To standardize the resting activity state within and between subjects, each subject was instructed to squeeze a tennis ball in the nonplegic limb for 5 secs and then to relax for 5 secs. This was repeated for a total of five times. Then, two examiners rated each participant at the elbow, wrist, fingers, and thumb, and repeated this procedure until consensus was reached. The FM-UE was chosen to measure of severity of impairment. Participants were carefully evaluated for hypertonus and cocontraction. The BBT was chosen as a simple test of the ability to grasp and release, which was the primary behavior targeted in therapy during the 4-wk period after BTX-A injection. The MAL was chosen as a measure of self-reported use of the paretic hand in daily life tasks, and the WMFT was chosen as a measure of fine and gross motor facility of the upper limb. The WMFT and MAL were not obtained before BTX-A injection because these subjects had so little function of the paretic upper limb at baseline.

Statistics

Results were tested using repeated-measures analysis of variance. The figures presented do not reflect correction for multiple comparisons.

RESULTS

The average age of the 12 participants was 56.2 (SD = 15), and the average time since the stroke was 46.8 mos (SD = 26). The participants presented with a variety of strokes in a variety of locations; doses of BTX-A applied ranged from 287.5 to 400 units (Table 1).

Relationship Between BTX-A Treatment and 4 wks of Exercise Therapy and Resting Tone and Impairment

Mean Ashworth scores at baseline were: elbow 1.75, wrist 1.91, fingers, 2.58, thumb 1.67. At 4 wks, mean Ashworth scores declined to elbow 1.08, wrist 1.00, fingers 1.58, thumb 1.08. A mean Ashworth value for all four joints (wrist, elbow, thumb, and fingers) was calculated. Comparison of baseline mean Ashworth Scale scores with that achieved after 4 wks of exercise therapy showed a significant decrease from a mean score of 2.0 to a mean score of 1.2 (P = 0.01). No significant change was seen in the FM-UE, which was 21 at baseline and 23.8 at 4 wks (Figs. 2 and 3).

Effect of BTX-A and 4 wks of Evidence-Based Exercise Therapy on Ability to Meet Minimum Motor Criteria

Spontaneous recovery of motor control of the hand is clearly a rare event in chronic stroke. Olsen47 studied recovery from stroke for 3 yrs after onset and found that best upper-limb function was achieved by 95% of patients by week 14. Parker et al.48 found that only 13% of those with upper-limb hemiparesis had a change in function between 3 and 6 mos after stroke. Wade et al.49 found improvement in just 6.3% in those with severe upper-limb impairment between the 6 and 12 mos after stroke, and this diminished thereafter. We conservatively chose the value of a 10% rate of spontaneous recovery during 4 wks to make statistical comparisons. Four of the 12 subjects were able to achieve minimal motor criteria for CIMT during the 4-wk program of BTX-A plus exercise therapy. This reached statistical significance (P = 0.026).

The predictive value of the ability of volitionally extend the fingers against gravity at baseline was used to discriminate those who would be able to meet CIMT criteria from those who could not. Of the participants who met minimum motor criteria for CIMT after BTX-A treatment plus exercise therapy, three of the four were able to extend at least three of four fingers against gravity at baseline (before BTX-A and exercise therapy). No partici-
pant with movement in at least three of four fingers failed to meet minimum motor criteria after BTX-A and 4 wks of exercise therapy. Of the participants who were initially unable to generate any movement in any of the fingers, eight of the nine failed to meet minimum motor criteria after BTX-A and exercise therapy. Therefore, movement in three of four fingers predicted the ability to reach minimal motor criteria, with a sensitivity of 75% and a specificity of 100%. The positive predictive value of this criterion was also 100%. All subjects who were able to move at least three of four fingers were also able to move the thumb and wrist. However, the one participant who was able to move his or her thumb despite having no finger or wrist movement, and the two participants who were able

### TABLE 1 Patient characteristics

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (Months)</th>
<th>After Stroke</th>
<th>BTX-A Dose (Units)</th>
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<tbody>
<tr>
<td>1</td>
<td>84</td>
<td>29</td>
<td>287.5</td>
<td>Left subcortical lacune</td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>28</td>
<td>300</td>
<td>Right-MCA infarct of parietal–occipital cortex, frontal convexity</td>
</tr>
<tr>
<td>3</td>
<td>49</td>
<td>21</td>
<td>300</td>
<td>Left opercular, frontal, temporoparietal, infarct</td>
</tr>
<tr>
<td>4</td>
<td>48</td>
<td>76</td>
<td>400</td>
<td>Left-MCA infarct of entire operculum, and fronto–parietal convexity, insula and anterior–superior temporal lobe involved</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>89</td>
<td>400</td>
<td>Left aneurism (no MRI because of clips)</td>
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<tr>
<td>6</td>
<td>75</td>
<td>57</td>
<td>400</td>
<td>Right parietal stroke, left caudate lacune</td>
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<td>7</td>
<td>51</td>
<td>71</td>
<td>350</td>
<td>Right-MCA infarct of parietal and frontal lobe and basal ganglia</td>
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<td>8</td>
<td>60</td>
<td>70</td>
<td>400</td>
<td>Right-MCA infarct of parietal, frontal, temporal, and insular areas</td>
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<tr>
<td>9</td>
<td>63</td>
<td>37</td>
<td>375</td>
<td>Right infarct of putamen and parietal lobe, insula, and fronto–parietal convexity</td>
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<td>10</td>
<td>74</td>
<td>21</td>
<td>375</td>
<td>Hemorrhage of left periventricular and striatocapsular region</td>
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<td>11</td>
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<td>9</td>
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<td>Right-MCA infarct, deep white matter, insula, and frontal lobe</td>
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<td>12</td>
<td>49</td>
<td>53</td>
<td>400</td>
<td>Right subinsular infarct</td>
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Mean (SD) 56.2 (15.0) 48.6 (26.0)

BTX-A, botulinum toxin A; MCA, middle cerebral artery.

### FIGURE 2 Summed Ashworth scores.

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to move their wrists, but neither fingers nor thumb, were unable to meet minimal motor criteria for CIMT (Table 2).

The Effect of CIMT on Volitional Control

Four participants met minimal motor criteria. One was lost to follow-up before the start of CIMT because of health reasons unrelated to the study. A second participant received CIMT for 1 wk and then withdrew from CIMT treatment. This participant found wearing a mitt at home too burdensome and embarrassing as she tried to care for her young children. However, she displayed significant improvement from baseline during the week of CIMT, and she agreed to attempt to use her paretic hand during her daily life and to continue to follow up for assessment as scheduled. For the purposes of analysis, she was grouped with the two individuals who had completed CIMT. Two subjects who did not meet MMC failed to return for follow-up beyond the sixth week of the study. Data from a third subject were not included after the fourth week because of deviation from the experimental protocol. Performance of the three participants who were enrolled in CIMT showed improvement after 2 wks of CIMT. The number of blocks moved during the BBT increased from a mean of 4.25 after 4 wks compared with a mean of eight blocks after CIMT. The differences between the mean self-report score on the MAL–Amount of Use increased from 1.12 (very rarely using the weaker arm) to 1.93 (rarely used the weaker arm). Time on the WMFT decreased from a mean time of 41.6 to 32.9 secs—a

![Figure 3](image-url)  
**FIGURE 3** Fugl-Meyer upper-extremity scores.

### TABLE 2 Presence or absence of antigravity extension/abduction at baseline

<table>
<thead>
<tr>
<th>Wrist</th>
<th>Thumb</th>
<th>Digit 2</th>
<th>Digit 3</th>
<th>Digit 4</th>
<th>Digit 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject number: Met minimal motor criteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Present</td>
<td>Present</td>
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<td>Present</td>
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<tr>
<td>6</td>
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<td>12</td>
<td>Present</td>
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<td>Present</td>
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<tr>
<td>Subject number: Did not meet minimal motor criteria</td>
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<tr>
<td>2</td>
<td>Present</td>
<td>Absent</td>
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<td>3</td>
<td>Present</td>
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</table>
21% improvement for those who participated in CIMT (Figs. 4–6).

**Duration of Treatment Effect, Return of Spasticity**

By the 24th week, spasticity had largely reasserted itself. The mean Ashworth score at the elbow was 1.44, at the wrist 1.44, for the fingers 2.55, and at the thumb 1.11. The summed Ashworth score rose to 1.68 (SD 0.37), nearing the initial pre-BTX-A baseline measurement \( (P = 0.01) \). Initial improvements in the BBT, WMFT, and MAL had all reverted by the 24th week.

**DISCUSSION**

This preliminary investigation yielded many findings of interest. However, conclusions drawn from this study must be tempered by the many limitations inherent in its design. These include a relatively small sample size, omission of functional measures at baseline such as the WMFT and the MAL, reliance on the Ashworth Scale as the only objective measure of spasticity, the fact that BTX-A was dosed individually, and the heterogeneity of the sample regarding age, comorbidities, and time since stroke. Whereas individualization of dose and heterogeneity...
of the sample may be inherent limitations to any study of BTX-A in upper-limb hemiparesis attributable to stroke, many of the other aspects of this study could have been improved. Despite these limitations, this work brings to light several important points.

The finding that 4 of 12 subjects were able to reach minimal motor criteria with the combination of BTX-A and evidence-based exercise therapy was surprising and encouraging. It suggests that potential for improvement in hand function through CIMT or other interventions may be possible, even for those with very limited residual function. The finding that the presence of even a small amount of voluntary extension in at least three fingers at baseline predicted a response to therapy is not entirely unexpected. This validates the premise underlying the minimal motor criteria, that CIMT strengthens some minimum amount of intact connection between the motor cortex and the hand. This finding is also in accordance with Fritz et al.,50 who found that finger extension as defined by the ability to actively release a mass flexion grasp predicted WMFT outcomes for individuals enrolled in CIMT. However, perhaps more interesting is the response to therapy by the participant who had no detectable volitional control in the wrist, fingers, or thumb at baseline. In fact, while attempting finger extension, only cocontraction resulting in finger flexion could be generated. Nonetheless, this participant was able to meet minimal motor criteria with the application of BTX-A and evidence-based exercise therapy. This suggests that there may be untapped potential even in those with severely impaired hand function. Factors that might have contributed include the participant’s younger age (37 yrs old compared with a mean of 57.9 yrs for the rest of the sample) and the fact that she was only 9 mos poststroke (compared with a mean of 50.18 mos for the rest of the sample).

The results of this study also support the concept that adjuvant therapies (in this case, the medication BTX-A plus exercise therapy, plus CIMT) may work in tandem to allow greater gains than would be expected by the application of any of the therapies individually. It seems that enrolling individuals in CIMT who are only able to meet MCC with the help of BTX-A and exercise therapy is feasible.

It may be useful to put this study in the context of the work of Brashear et al.51 Brashear et al. randomized 126 individuals with poststroke spasticity of the wrist and fingers to receive 200–240 units of BTX-A in a randomized, double-blind, placebo-controlled trial. The major outcomes included the Ashworth Scale and the Disability Assessment Scale (DAS). The DAS uses a zero- to three-point scale in which the rater assesses the amount of disability in four domains: hygiene, dressing, limb position, and pain. Zero indicates no disability, and a score of 3 indicates severe disability. Significant decreases were noted in the Ashworth scores, and significant improvement (improvement of one of the selected domains of at least one point) was noted in the DAS. This well-controlled, industry-sponsored trial provides some evidence supporting the role of BTX-A in improving passive function in selected patients, although it can be criticized for not addressing or controlling exercise therapy after injection. Although the DAS is touted as a functional scale, two of its domains—pain and limb position—though of great value to patients, are not truly functional. In contrast, the trial reported here uses more precise measures of actual hand function, and explores the potential role of BTX-A in restoring active movement.

Any enthusiasm for these findings must be set against two hard realities. First, although there was improvement in motor function, the improvement
gained was modest at best. An improvement from approximately 1 (very rarely) to 2 (rarely) on the MAL–Amount or from 41.6–32.9 secs on the WMFT falls short of most affected individuals’ ambitions. Second, even these modest gains regressed at 24 wks at the same time as spasticity was returning.

The investigators note that active functional task practice (reaching, grasping, and releasing), which is often the preferred therapeutic activity under motor learning theories, may not be practical for participants with very low levels of ability after BTX-A. For these people, alternative modes of practice may be more applicable. These may include therapies based on functional neuromuscular electrical stimulation. Second, even with our attempts at standardizing the resting state, we often witnessed significant variability in the expression of tone as measured by the Ashworth Scale. On an informal basis, we tried other methods to standardize the resting state, such as relaxation through visualization of calming environments. The results of this technique were no better than having the participants squeeze a tennis ball. The Ashworth Scale has been challenged as a reliable and reproducible test of spasticity in the poststroke hand.52,53 We have reservations regarding the precision and reproducibility of the Ashworth. Spasticity is a complex phenomenon that includes weakness, cocontraction, and exaggerated muscle stretch reflexes. Easily applied methods to quantify it are needed.

We also have noted variable response to BTX-A. Although most participants had a gradual improvement in hypertonicity during the initial 2 wks after injection, some participants demonstrated an immediate reduction in hypertonus. One participant’s tone decreased from a score of 3 of 4 on the Ashworth to flaccidity in the fingers within minutes of BTX-A injection. The response lasted for weeks, after which hypertonus gradually reasserted itself. In another case, we noted improvement in tone and volitional control during the first 2 wks of exercise therapy that was lost during the second 2 wks, never to return.

The modest successes of this investigation suggest that a combination of therapeutic and pharmacologic approaches may be warranted in the treatment of hand paresis after stroke. However, the optimal combination awaits further investigation. The preferred dose and duration of post–BTX-A exercise therapy remains undefined. Modalities such as functional neuromuscular electrical stimulation may strengthen the response. Other medications that decrease spasticity or encourage neuroplasticity may be helpful. Clearly, further research is needed to extend the benefits of emerging therapies to those most severely affected by stroke.

REFERENCES

1. 2004 Heart and Stroke Statistical Update. Dallas, American Heart Association, 2004
**ABSTRACT**


**Objective:** To test the potential adjuvant effect of repetitive transcranial magnetic stimulation (rTMS) on motor learning in a group of stroke survivors undergoing constraint-induced therapy (CIT) for upper-limb hemiparesis.

**Design:** This was a prospective randomized, double-blind, sham-controlled, parallel group study. Nineteen individuals, one or more years poststroke, were randomized to either a rTMS + CIT (n = 9) or a sham rTMS + CIT (n = 10) group and participated in the 2-wk intervention.

**Results:** Regardless of group assignment, participants demonstrated significant gains on the primary outcome measures: the Wolf Motor Function Test (WMFT) and the Motor Activity Log (MAL)—Amount of Use, and on secondary outcome measures including the Box and Block Test (BBT) and the MAL—How Well. Participants receiving rTMS failed to show differential improvement on either primary outcome measure.

**Conclusions:** Although this study provided further evidence that even relatively brief sessions of CIT can have a substantial effect, it provided no support for adjuvant use of rTMS.

**Key Words:** Stroke, Neuronal Plasticity, Transcranial Magnetic Stimulation, Rehabilitation, Hemiparesis
Since its introduction as a noninvasive method to stimulate the human brain, repetitive transcranial magnetic stimulation (rTMS) has provided a potential means to modulate cortical excitability and function. Depending on essential parameters of the stimulation frequency and number of trains of stimuli, rTMS can produce lasting up- or down-regulation of the corticospinal system. At higher frequencies (≥5 Hz) rTMS has been shown to increase excitability in the motor nervous system. The extent to which these effects persist over time may be related to the duration of stimulation. Whereas 900 stimuli delivered at 5 Hz resulted in a transient increase in corticospinal excitability lasting only a few minutes after rTMS, this same effect was extended to 30–40 min after 1800 stimuli. Some survivors of stroke may have abnormally low motor cortex excitability, a condition that may impair the relearning of functional daily skills. There is at least preliminary evidence that both skill acquisition in normal subjects and functional improvement in stroke survivors are associated with increases in cortical motor excitability. Artificially increasing cortical excitability with rTMS could facilitate motor learning and recovery after stroke. The mechanism by which high-frequency rTMS elicits sustained increases in cortical excitability is uncertain; one possibility is that by inducing coactivation of connected cortical neurons, it rapidly enhances the strength of at least some connections, a process referred to as fast Hebbian learning.

The primary motor cortex is an essential part of the neural network involved in the acquisition and mastery of motor skills. Focused, massed practice leading to learning of motor skills is associated with changes in the functional organization and excitability of the motor cortex. Learning corresponds to increases in synaptic connection strengths. The relationship between the short-lived alterations in connection strengths associated with fast Hebbian learning and the more durable alterations associated with improvement in function is unknown. The use of rapid rTMS to facilitate learning in the poststimulus period is predicated on the hypothesis that short-duration connections achieved through fast Hebbian learning facilitate the establishment of more durable connections during training conducted immediately after rTMS. Some recent studies have suggested that high- or low-frequency rTMS can enhance motor learning in healthy subjects; other studies have failed to demonstrate an effect. The evidence of a possible facilitative effect of rTMS on learning suggests that it may have value as a therapeutic adjuvant in individuals with movement deficits attributable to stroke.

Although rTMS may be capable of accelerating the development of neural connectivity underlying functional improvements, this technology cannot provide the brain with the new knowledge implicit in skill acquisition. For this reason, rTMS should be paired with an empirically supported behavioral intervention. The impact of rTMS as an adjuvant to stroke rehabilitation could easily be obscured if the therapeutic approach had only a modest effect, if it were applied to individuals with highly variable deficits, or if the approach was administered differently among therapists. Constraint-induced therapy (CIT) is an empirically supported movement therapy that addresses these concerns. By engaging the paretic arm and hand in massed practice of functional tasks, while constraining the use of the unaffected upper limb, both traditional CIT and modified versions of CIT (i.e., shorter duration of treatment sessions) increase the amount of use of the affected side. Furthermore, therapies structured like CIT are believed to reverse learned nonuse of the hemiparetic limb in the chronic stroke population. Because of its strict protocol and apparent success in remediating movement in the stroke-affected upper limb, CIT-based interventions meet the essential requirements of a "behavioral engine" to drive a study of rTMS as an adjuvant.

**METHODS**

**Subjects**

All study procedures were approved by the local institutional review boards, and all participants provided written informed consent to participate. Subjects were recruited by convenience sample from inpatient and outpatient populations at the Malcolm Randall Department of Veterans Affairs (VA) Medical Center (MRDVAMC), the Shands Hospital and Brooks Hospital systems; and through newspaper articles and advertisements and contact with stroke support groups. The study was conducted at the VA Rehabilitation Research and Development Brain Rehabilitation Research Center at the MRDVAMC. Twenty stroke survivors (eight female; mean age, 67 ± 6.8 yrs; mean time since stroke, 3.8 ± 3.3 yrs; 10 left-cerebral vascular accidents) were recruited for this study; one failed to complete it because of intercurrent health problems unrelated to the study. Inclusion criteria were:

- clinically diagnosed stroke at least 1 yr before
- at least minimal motor function in the paretic arm, as defined by Wolf et al. including 10 degrees of active finger extension and 20 degrees of active wrist extension
- magnetic resonance imaging or computed tomography performed within 2 wks of treatment
- age not less than 18 yrs

All subjects scored below 2.5 on the MAL–Amount scale at baseline. This is a typically-used
cutoff which ensures that subjects are not too high functioning to benefit from the CIT intervention. Exclusion criteria were

- use of medications that may lower seizure threshold (e.g., Metronidazole)
- history of epilepsy, brain tumor, learning disorder, mental retardation, drug or alcohol abuse, dementia, major head trauma, or major psychiatric illness
- evidence of epileptiform activity on electroencephalography obtained before beginning treatment
- history or radiographic evidence of arteriovenous malformation, intracortical hemorrhage, subarachnoid hemorrhage, or bilateral cerebrovascular disease
- history of implanted pacemaker or medication pump, metal plate in skull, or metal objects in the eye or skull
- Pregnancy

There were no restrictions related to sex, ethnicity, handedness, pain, or spasticity. Aphasia and other cognitive deficits did not preclude inclusion as long as subjects were sufficiently sentient to be able to understand the potential risks and benefits of the study, to personally provide informed consent, and to understand and cooperate with the treatment. The use of drugs that might potentially inhibit neuroplasticity (neuroleptics, α-1 noradrenergic antagonists, α-2 noradrenergic agonists, anticonvulsants, benzodiazepines, anticholinergics, and tricyclic antidepressants) constituted a relative contraindication to study entry; in general, subjects were not entered if they were on more than one of these drugs. On meeting all criteria, subjects were randomly assigned to either the rTMS (treatment, n = 9) or sham stimulation (control, n = 10) group by the neurologist who administered these interventions (WJT). Both the subject and treating therapist were blinded to group assignment.

In the sham group, six subjects had hemispheric large-vessel distribution infarcts (middle cerebral artery), and four subjects had hemispheric lacunar infarcts. In the treatment group, five subjects had hemispheric large-vessel distribution infarcts (middle cerebral artery), one had a deep hemispheric hemorrhage (i.e., nonintracortical or subarachnoid), and three had lacunar infarcts. In the sham group, two subjects were taking a benzodiazepine. In the treatment group, one subject was receiving a tricyclic antidepressant and three subjects were taking either an α-1 noradrenergic blocker or an α-2 noradrenergic agonists; one of these subjects was also taking a benzodiazepine. Further demographic data are presented in Table 1.

### Table 1: Baseline characteristics of groups

<table>
<thead>
<tr>
<th></th>
<th>rTMS (n = 9)</th>
<th>Sham rTMS (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at time of study (mean ± SD)</td>
<td>68.4 ± 8.4</td>
<td>65.7 ± 5.1</td>
</tr>
<tr>
<td>Education (mean ± SD)</td>
<td>13.4 ± 2.8</td>
<td>13.4 ± 2.4</td>
</tr>
<tr>
<td>Years since stroke (mean ± SD)</td>
<td>3.9 ± 3.1</td>
<td>3.8 ± 3.7</td>
</tr>
<tr>
<td>Females/males</td>
<td>4/5</td>
<td>4/6</td>
</tr>
<tr>
<td>Left cerebral vascular accident</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Dominant-side hemiparesis</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>WMFT, secs</td>
<td>15.5 ± 13.1</td>
<td>35.5 ± 33.9</td>
</tr>
<tr>
<td>BBT, no. of blocks</td>
<td>15.8 ± 7.9</td>
<td>15.4 ± 15.1</td>
</tr>
<tr>
<td>MAL–amount of use</td>
<td>1.1 ± 0.6</td>
<td>0.8 ± 0.6</td>
</tr>
<tr>
<td>MAL–how well</td>
<td>1.2 ± 0.7</td>
<td>0.8 ± 0.6</td>
</tr>
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</table>

WMFT, Wolf Motor Function Test; BBT, Box and Block Test; MAL, Motor Activity Log.

rTMS Procedure

All participants were seated comfortably in a chair. Surface electromyographic electrodes were placed over the first dorsal interosseous muscles and connected to a Nicolet Viking III Electromyograph. Motor evoked potential (MEP) threshold was defined as the lowest stimulus intensity eliciting MEPs >20 mV in at least 3 of 6 consecutive stimulations. We measured MEP threshold before and after each rTMS session using a 9-cm-diameter circular magnetic coil centered at the scalp vertex and connected to a Magstim 200 high-power magnetic stimulator (Magstim Ltd, UK). rTMS was then administered using a Magstim Super Rapid Magnetic Stimulator and a 7-cm-diameter figure-8 coil centered over the hand area of affected motor cortex and fixed at the optimal location for eliciting MEPs in the affected target muscle. MEP threshold was remeasured in this location using the figure-8 coil and the Super Rapid stimulator. All subjects received 2000 stimulations daily for ten consecutive weekdays. Each daily treatment of 2000 stimuli was administered as 50 trains of 40 stimuli, stimulus rate of 20 Hz, stimulus train duration of 2 secs, with an intertrain interval of 28 secs. Stimu-
lus intensity was 90% of motor threshold. In the event that MEPs could not be elicited at maximal stimulator output (two subjects randomized to the rTMS group and one subject randomized to the sham group), we referenced the location and stimulus intensity on the basis of responses obtained during stimulation of the undamaged hemisphere. When this occurred, the coil was fixed at a location over the damaged hemisphere that was homologous to the hand area of the motor cortex in the undamaged hemisphere, and the stimulus intensity was set to 90% of threshold for eliciting MEPs in the unaffected limb. All subjects received either rTMS or sham rTMS to the damaged hemisphere.

Sham rTMS (Fig. 1) was administered using a specially designed Magstim figure-eight coil (Magstim Ltd, UK). This coil generates a magnetic field that is more than 90% attenuated, but it does produce noise and vibration comparable with those of a real magnetic coil. In addition to obvious coil

![Diagram of rTMS set-up](https://example.com/diagram.png)

**FIGURE 1** Schematic of rTMS set-up. The magnetic stimulating coil was positioned over the motor cortex of the damaged hemisphere and 2000 stimuli were administered as 50 trains of 40 stimuli, stimulus rate of 20 Hz, stimulus train duration of 2 secs, with an intertrain interval of 28 secs. Passive bipolar electromyographic surface electrodes were applied over the FDI for the purpose of monitoring muscle activation during and between stimulations.
discharge noise, rTMS also is associated with transient contraction of scalp musculature during stimulus trains. We simulated this muscle contraction (and concomitant cutaneous and intramuscular neural sensory input) during sham rTMS by attaching surface electrodes underneath the magnetic coils and in contact with the scalp connected to the electromyograph. During sham rTMS, we simultaneously administered a train of 20 Hz electrical impulses to the scalp. The intensity of this stimulation (stimulus duration 0.1 msec) was adjusted to produce scalp muscle contraction discernible to the subject and a modest degree of scalp discomfort, comparable with that described by subjects receiving actual rTMS. Stimulus parameters for sham rTMS were identical to those for real rTMS (i.e., 50 trains of 40 sham stimuli administered at a rate of 20 Hz with intertrain intervals of 28 secs).

Surface electromyography from the FDI and a single electroencephalographic channel from a pair of electrodes placed over the forehead were monitored online during the 28-sec rest periods separating rTMS trains. Background electromyography remained stable during stimulation sessions, and we observed normal electroencephalographic activity.

CIT Procedure

Both rTMS- and sham-treated subjects participated in daily therapy sessions, approximating previously reported programs of CIT,19–21 for ten consecutive weekdays. We employed a modified CIT protocol consisting of both onsite training and structured home practice. Onsite training immediately followed the rTMS or sham stimulation. During these onsite sessions, participants wore a restraining mitt on the unaffected hand and were engaged in a variety of functional tasks directed at the affected upper limb. After each daily onsite CIT session, participants then performed 5 hrs of home practice of functional tasks using the affected upper limb. This structured home program was designed to ensure massed practice of upper-extremity activities as commonly performed in intensive therapies such as CIT. The treating therapist assigned home-practice tasks from a menu of commonly performed activities in the following broad areas of function: fine motor coordination, gross motor coordination, power, and endurance. This structured home program specified activities to be performed, how and for how long these were to be carried out, how to increase or decrease the difficulty level of the activity, and the number of repetitions or trials to be attempted. While at home, the participants wore the restraining mitt for 90% of their waking hours. Mitt-wearing compliance and adherence to the home practice program was monitored and ensured by use of a structured activity log, which the trainer and subject extensively reviewed on a daily basis.

Data Analysis

Outcome Measures

Our primary outcome measures were the Wolf Motor Function Test (WMFT)28 and the Motor Activity Log (MAL–Amount),29 which are commonly used to assess change in upper-extremity function after intensive treatments like CIT.19 The WMFT is an upper-extremity functional capacity test, comprising a series of 15 timed tasks that require movement at all joints. Performance on the WMFT was scored as mean performance time (in seconds) of the affected arm and hand. The MAL is a structured interview during which subjects used a six-point scale to rate how much and how well they used their hemiparetic limb to perform 30 common functional activities.19 Secondary outcome measures included the MAL–How Well and the Box and Block Test (BBT). The BBT30 was used to assess grasp, transport, and release of small objects, with performance measured as the number of blocks moved in 1 min. These outcome measures were obtained before and immediately after the rTMS-CIT intervention, and again 6 mos later. Secondary outcome measures also included determination of MEP threshold (motor threshold) before and after each rTMS session.

Statistical Analysis

All data were analyzed with SAS version 8.2 (SAS Institute, Cary, NC). For each measure, the changes at 2 wks and at 6 mos from baseline were assessed in a single analysis with the use of PROC GLM, with a group and a time effect included in the model. The group effect tested differences in improvement between the rTMS and sham rTMS groups, the time effect studied whether changes at 6 mos remained the same compared with those at 2 wks, and the intercept parameter indicated whether the scores changed from baseline. We also ran paired t tests on change in score from baseline to 2 wks and from baseline to 6 mos on each of the assessment scores to determine whether the scores improved during these two time periods.

RESULTS

rTMS and sham rTMS were associated with scalp discomfort during stimulation. However, the stimulation procedures were well tolerated, and none of the subjects asked to withdraw their participation. There were no discernible adverse effects of rTMS beyond scalp discomfort. The baseline characteristics of both groups are presented in Table 1. Notably, the rTMS group tended to perform better on all four outcome measures at base-
Primary Outcome Measures

Wolf Motor Function Test

The results of the analysis of treatment effect are detailed in Table 2 and Figure 2. The mean of the WMFT scores for rTMS group was 20.0 points lower than the sham group at the baseline ($P = 0.09$). The group by time interaction was not significant; this implies that the two groups remained marginally different at 2 wks and 6 mos and that rTMS group did not improve more than the sham group. The overall WMFT scores decreased by 7.3 secs from baseline to 2 wks after ($P = 0.01, d = 1.5$), but the difference disappeared at 6 mos. When comparing differences between the groups, the rTMS group decreased 0.85 secs less at 2 wks ($P = 0.84, d = 0.06$), and 0.21 secs less at 6 mos than did the sham group ($P = 0.89, d = 0.04$).

MAL–Amount

There was no significant difference between the two groups for the MAL–Amount at the baseline ($P = 0.54$). However, there were marginally significant differences between the groups in change over time. Compared with the baseline, the sham group increased 1.3 points at 2 wks ($P < 0.01, d = 3.28$) and increased 1.1 points at 6 mos ($P < 0.01, d = 3.43, B = 1.0$). The change in the rTMS group was 0.7 points greater at 2 wks ($P = 0.08, d = 0.57$) and 0.1 points greater at 6 mos ($P = 0.78, d = 0.09$).

Secondary Outcome Measures

MAL–How Well

There was no significant difference between the two groups for the MAL–How Well at baseline ($P = 0.33$). The group by time interaction was not found to be significant, indicating there was not a significant difference in score improvement between the treatment groups. However, both groups significantly improved over time. When comparing differences between the groups, the rTMS group increased 0.31 points more at 2 wks ($P = 0.31, d = 0.32$), and 0.02 points less at 6 mos than the sham group ($P = 0.94, d = 0.03$); neither was significant.

Box and Block Test

There was no significant difference between the two groups for the Box and Block test at baseline ($P = 0.95$). However, there were significant differences between the groups in change over time. When comparing differences between the groups, the rTMS group mean change was 3.6 points greater at 2 wks ($P = 0.10, d = 0.54, B = 0.30$), and 6.9 points greater at 6 mos ($P < 0.01, d = 1.39, B = 0.90$).

Motor Threshold

There was no significant difference in motor threshold between the two groups at baseline ($P = 0.96$). There was, however, a significant between-group difference for change in motor threshold from pre- to post-CIT ($F = 12.5, P = 0.003, F = 0.95, B = 1.0$), with the rTMS group demonstrating a larger reduction in this measure after the intervention ($t = 5.4, P = 0.002, d = 1.71, B = 0.94$).

DISCUSSION

Our study failed to demonstrate a significant effect of rTMS as an adjuvant to CIT. Furthermore, whereas CIT led to significant improvements in WMFT times at 2 wks, this improvement was not sustained at 6 mos. Significant improvements in MAL–Amount at 2 wks were sustained at 6 mos, suggesting that even though CIT did not induce a sustained improvement in motor performance, it did induce a sustained improvement in the predisposition to use the affected arm in daily life; that is, it did have a sustained effect on learned nonuse. The significantly greater variance in MAL–Amount change scores in the rTMS treated group at 2 wks ($F = 3.93, P = 0.03$) and at 6 mos ($F = 5.52, P = 0.01$) raises the possibility that there was a subgroup of subjects in this group who could be classified as rTMS responders, and that if we had means for predicting response to CIT, we could construct more powerful trials of adjuvant therapies by restricting recruitment to subjects with responder characteristics.

Possible reasons for our failure to observe an rTMS adjuvant effect include the following: (1) the transient effects in cortical networks induced by rTMS do not promote the establishment of more lasting changes through learning, as suggested by the results of our prior study18; (2) the dose or intensity of rTMS was insufficient to induce the desired effects, the locus of stimulation was incorrect, or the area of stimulation was insufficient; (3) because the effect of an adjuvant therapy is likely to be multiplicative of the effect of the behavioral therapy, if the behavioral therapy has minimal impact, one cannot expect to detect the impact of the adjuvant therapy. CIT, in the modified form given in this trial, failed to induce a lasting change in mean WMFT scores and, therefore, failed to meet the standards of a behavioral engine as defined in the introduction to this paper. It is possible that changes in motor cortex connectivity reflected in WMFT scores are more susceptible to rTMS effect than are the presumably more diffuse, largely frontal system changes involved in overcoming learned nonuse, which are likely to be reflected primarily in MAL scores; (4) there was an effect but it was small, it may have been masked by differential
<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline Mean (SD)</th>
<th>2-wk Mean (SD)</th>
<th>6-mo Mean (SD)</th>
<th>Change from Baseline to 2 wks Mean, (SD) Effect Size</th>
<th>Change from Baseline to 6 mos Mean, (SD) Effect Size</th>
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<tr>
<td>WMFT</td>
<td></td>
<td></td>
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<tr>
<td>Overall</td>
<td>26.0 (27.5)</td>
<td>18.8 (23.6)</td>
<td>23.9 (26.7)</td>
<td>−7.3 (6.9)* 1.56</td>
<td>−13 (9.8) 0.18</td>
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<td>rTMS</td>
<td>15.5 (13.1)</td>
<td>8.7 (9.1)</td>
<td>14.4 (19.5)</td>
<td>−6.8 (5.6)* 1.72</td>
<td>−12 (8.6) 0.19</td>
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<td>35.5 (33.9)</td>
<td>27.8 (29.1)</td>
<td>36.3 (31.0)</td>
<td>−7.7 (8.1)* 1.34</td>
<td>−14 (11.9) 0.18</td>
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<td>MAL–amount</td>
<td></td>
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<td>Overall</td>
<td>0.9 (0.6)</td>
<td>2.6 (1.1)</td>
<td>2.1 (1.0)</td>
<td>1.7 (0.9)* 2.51</td>
<td>1.1 (0.8)* 2.02</td>
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<td>1.1 (0.6)</td>
<td>3.1 (1.0)</td>
<td>2.3 (1.1)</td>
<td>2.0 (1.2)* 2.50</td>
<td>1.2 (1.0)* 1.66</td>
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<tr>
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<td>2.1 (1.1)</td>
<td>1.8 (1.0)</td>
<td>1.3 (0.6)* 3.20</td>
<td>1.1 (0.4)* 3.4</td>
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<td>MAL–how well</td>
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<td></td>
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<tr>
<td>Overall</td>
<td>1.0 (0.6)</td>
<td>2.5 (0.8)</td>
<td>2.1 (0.8)</td>
<td>1.4 (0.7)* 2.86</td>
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<td>1.2 (0.7)</td>
<td>2.8 (0.7)</td>
<td>2.3 (0.8)</td>
<td>1.6 (0.9)* 2.64</td>
<td>1.1 (0.6)* 2.45</td>
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<td>0.8 (0.6)</td>
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<td>2.0 (0.9)</td>
<td>1.3 (0.6)* 3.29</td>
<td>1.1 (0.4)* 4.04</td>
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<td>BBT</td>
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<tr>
<td>Overall</td>
<td>15.6 (11.9)</td>
<td>18.5 (13.2)</td>
<td>16.3 (13.3)</td>
<td>2.9 (4.6)* 0.90</td>
<td>1.6 (4.7) 0.47</td>
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<tr>
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<td>15.8 (7.9)</td>
<td>20.6 (9.6)</td>
<td>20.3 (9.9)</td>
<td>4.8 (5.3)* 1.27</td>
<td>4.6 (2.5)* 2.57</td>
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<tr>
<td>Sham</td>
<td>15.4 (15.1)</td>
<td>16.6 (16.0)</td>
<td>11.1 (16.1)</td>
<td>1.2 (3.1) 0.54</td>
<td>−2.3 (4.0) 0.81</td>
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<tr>
<td>Motor threshold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>53.3 (13.9)</td>
<td>51.8 (14.4)</td>
<td>—</td>
<td>−1.5 (2.3)* 0.95</td>
<td>—</td>
</tr>
<tr>
<td>rTMS</td>
<td>53.6 (18.3)</td>
<td>50.3 (18.5)</td>
<td>—</td>
<td>−3.3 (1.9)* 2.5</td>
<td>—</td>
</tr>
<tr>
<td>Sham</td>
<td>53.1 (10.6)</td>
<td>53.0 (11.4)</td>
<td>—</td>
<td>−0.1 (1.9) 0.13</td>
<td>—</td>
</tr>
</tbody>
</table>

* P < 0.05. WMFT, Wolf Motor Function Test; BBT, Box and Block Test; MAL, Motor Activity Log.
responses to rTMS based on lesion location, and our trial was not adequately powered to detect it; (5) a larger percentage of the subjects in the rTMS group was on potentially antineuroplastic drugs; or (6) the cerebral cortex we stimulated with rTMS was too damaged to be affected by the treatment; this seems less likely because in our observation and those of others,31–34 among subjects who qualify for CIT, the motor and premotor cortex are typically substantially spared and paresis stems predominantly from damage to the posterior periventricular white matter, where corticobulbar and corticospinal tracts pass to the brainstem and spinal cord. Although we could not elicit MEPs in two subjects in the rTMS group and in one subject in the sham group, we chose to include these individuals in our analyses because it is not a foregone conclusion that inability to obtain an MEP would predict poor response to rTMS.

Although our CIT intervention failed to induce a persistent change in mean WMFT score for either of the treatment groups (Table 2), it did achieve substantial gains at 2 wks and was associated with long-lasting gains in several subjects. Therefore, these subjects had the opportunity to experience an adjuvant effect from rTMS. Our WFMT and MAL–How Well results were comparable with those reported in traditional CIT programs.19,35 The MAL–Amount scores and effect sizes reported here were lower than findings from traditional CIT programs but were similar to results of a modified CIT protocol of lesser daily training time.23 The optimal duration of CIT and method of delivery (i.e., on-site training vs. a combined on-site, home practice program) has yet to be established. Clearly, studies like ours could be improved if we had data on reliable predictors of response to CIT.

CONCLUSION

We found a significant decrease in motor threshold for subjects receiving rTMS, with no significant changes noted in those receiving sham treatment. These data provide evidence that rTMS produced a change in the excitability of the motor system. This change, however, did not translate into a clinically evident effect, which raises questions about the rela-
rTMS as Adjunct to Constraint-Induced Therapy

September 2007

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CME Objectives:

Objectives: On completion of this article, the reader should be able to (1) discuss the time course of muscle strength recovery after Guillain-Barré syndrome, and (2) describe the temporal relationship between strength recovery and functional improvement.

Level: Advanced.

Accreditation: The Association of Academic Physiatrists is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians. The Association of Academic Physiatrists designates this continuing medical education activity for a maximum of 1.5 credits in Category 1 of the Physician’s Recognition Award of the American Medical Association. Each physician should claim only those credits that he or she actually spent in the education activity.

Disclosures: Disclosure statements have been obtained regarding the authors’ relationships with financial supporters of this activity. There are no apparent conflicts of interest related to the context of participation of the authors of this article.

ABSTRACT


Objective: To assess the recovery in muscle strength and functional capacities in subjects with Guillain-Barré syndrome (GBS) for 18 months after onset.

Design: Six GBS patients were treated and transferred to our rehabilitation center within the first week of recovery.

Results: Isometric and isokinetic strength increased significantly during the first 6 months ($P < 0.01$). Between 6 and 18 months, muscle strength increased less rapidly ($P < 0.05$). We showed a significant negative correlation between plateau period duration and knee extensors, elbow flexors muscles strength recovery ($\rho = -0.82; P = 0.05$). At 6 months, manual muscle testing and functional independence motor total scores were close to normal levels. At 18 months, all patients satisfied the criteria for a full recovery. However, they felt difficulties after prolonged exercise.

Conclusions: Until 18 months of recovery, dynamometric measures still showed significant strength improvement. This underscores the need for a minimal 24 months of clinical follow-up with an individualized rehabilitation management program.

Key Words: Muscle, Disability, Rehabilitation, Acute Immune Polyneuropathy
Guillain-Barré syndrome (GBS) is the most common form of acute acquired immune mediated peripheral neuropathy, with a general annual incidence between 1 and 3 per 100,000.1,2 Primarily characterized by rapidly evolving symmetrical limb weakness, the degree of severity ranges from minimal weakness in the lower legs to total paralysis of the muscles of all limbs and of the trunk, often associated with sensory disturbances and variable autonomic dysfunctions to respiratory insufficiency.3 The onset of symptoms can either be acute or subacute, and it reaches a plateau with a progressive installation until the maximal point of features called the nadir. After a plateau phase of 2–4 wks, recovery begins with gradual resolution of the paralysis that lasts 1–2 yrs.4 Approximately 7–15% of patients have permanent neurologic sequelae, which may lead to limitations in their physical activities and social functioning.5-7

Because muscle weakness is the major clinical manifestation during the acute phase of GBS and at long-term follow-up, periodic and objective measurements of muscle strength are necessary to monitor disease progression and response to therapy.8,9 Measuring the evolution of muscle strength is of critical importance in (1) defining physical capability, (2) determining the natural course of GBS, (3) establishing a prognosis, and (4) determining the proper timing of treatment. In this context, the manual muscle testing (MMT) and the Hughes functional scale are usually the main tools used to evaluate clinical status and observe long-term recovery in GBS patients.10 Most papers about GBS motor recovery have been single-case reports,6,11,12 retrospective studies,13-16 and fewer prospective studies.8,17,18

The clinical course in GBS is rather variable, particularly the duration of motor recovery. So, attempts have been made to identify prognosis factors in this neuropathy. These include age of patient, speed of progression, respiratory muscle paralysis, the presence and the type of antecedent disorder, selected electrophysiological features, duration of maximal symptoms and recovery, and observance of therapeutic consensus.16,19,20 The degree of motor deficit at maximum paralysis and the duration of the plateau phase have been identified as the main functional prognosis indicators in GBS.15,21 Although recovery of strength is frequently reported in the GBS population,3,22 no study to date has objectively and prospectively evaluated muscle strength recovery or motor performance with isokinetic methods in patients with GBS.

Therefore, the main purpose of this study was to accurately assess the recovery of muscle strength in patients with GBS, using skeletal muscle tension measurements for the first 18 mos after onset. A secondary purpose of this study was to determine parameters of motor recovery linked to prognosis in GBS.

METHODS

Subjects

We included seven adult patients with a diagnosis of GBS according to Asbury's criteria.22 They had been hospitalized in a neurological unit and were admitted to an adult rehabilitation center within the first week of the recovery stage, from January 2002 to July 2003. Each patient received an adapted and individualized rehabilitation program according to his or her clinical presentation. The inpatient rehabilitation program was usually completed within the first 3–4 wks of recovery in the physical medicine and rehabilitation department. Patients who exhibited significant progress returned home and completed outpatient rehabilitation in 4–10 wks with a home exercise program. Patients received an average of two to three weekly sessions of physical therapy based on muscular reinforcement and active mobilizations.

Selection criteria of our study included the ability to perform active flexion–extension at the knee, elbow, wrist, and ankle and full abduction–adduction of the shoulder against gravity (grade 3 of MMT), and the ability to undergo reliable initial
assessment. In addition, initial patients’ disabilities had to be equal to or below the fourth score of the Hughes functional scale.10 Patients were excluded if (a) any clinical cardiovascular or pulmonary abnormalities were noted during the initial testing, (b) if they had a history of other comorbidities that might influence their performance on functional tests (e.g., other non-GBS polyneuropathies, diabetes mellitus, malignancy, etc.), or (c) if they were unable to participate in physiotherapy. Withdrawal criteria were inability to perform one for three consecutive sessions of evaluation, persisting and disabling adverse events such as severe muscle cramps, or weakness interfering with assessment.

At baseline (R0), each GBS patient was matched with a healthy control subject (untrained volunteer selected from hospital workers with similar sex, age, and weight). All subjects gave informed consent before enrollment.

**Procedures**

For each patient and at each visit, assessments included muscle strength measurements (MMT and dynamometric tests) and functional evaluation (FIM measure), performed within 7 days of admission to the inpatient rehabilitation program (mean 4 ± 2 days; range 1–6 days) (R0) and subsequently after 6 mos (R6), 12 mos (R12), and 18 mos (R18) of follow-up. All measurements were taken on the same day of the week, at the same time of the day, and by the same observer for each patient. Patients were blinded to early results.

**Measures**

**Muscle Strength Measurements**

Two parameters were measured. First, using MMT, muscle strength was graded according to the scale developed by the Medical Research Council. Second, isometric and isokinetic muscle strength were evaluated, respectively, by maximal voluntary isometric contraction (MVIC) and maximum isokinetic strength. As suggested by previous studies,23 serial isokinetic strength assessment is a validated, reliable, sensitive method to detect meaningful clinical changes for the measurement of muscular performance over time in subjects with GBS or other neuromuscular disorders.

The muscle groups tested included knee and ankle extensors and flexors, ankle dorsiflexors and plantar flexors, and shoulder abductors and adductors, as described in an earlier publication.24 Each patient was evaluated on the dominant side. Isometric and isokinetic strength were measured using the Cybex 6000 (Cybex 6000 Isokinetic dynamometer, Lumex Inc., New York, NY) isokinetic dynamometer. The dynamometer was calibrated according to the manufacturer’s recommendations, and we followed the recommendations for optimal reproducibility. For each set of measurements, the subject was encouraged verbally to work as hard and as fast as possible. Measurements started with the isokinetic test protocol, which included an initial warm-up of five to ten reciprocal extension/flexion repetitions at 120 degrees/sec, followed by a 1-min rest period. During testing, three maximal contractions at each velocity were recorded for data analysis (see below). A rest period of 1 min was allowed between two sets of contractions, and the highest torque generated during these trials was considered the peak torque (PT). After a 1-min resting period, isometric warm-up was followed with two submaximal isometric efforts before data collection. Two 5-sec MVICs were performed, with a 1-min rest period between efforts, followed by a reciprocal maximal effort. The occurrence of pain during the test was rated on an 11-point visual analog scale.

**Knee Test**

The subject was comfortably seated on the chair. The hip flexion angle was held at 90 degrees. Stabilization straps were positioned across the subject’s chest, pelvis, and ipsilateral thigh. The lever-arm shin pad was placed just proximal to the malleoli. The subject performed three consecutive flexion–extension movements at velocities of 30, 60, 120, and 180 degrees/sec. Isometric knee flexion–extension strength was measured at 30 and 60 degrees of knee flexion.

**Elbow Test**

The subject lay supine on the upper-body exercise table and was restrained with straps at the level of the pelvis. The arm was positioned at 45 degrees of abduction. The elbow-joint axis was aligned with the axis of the dynamometer lever arm. The subject grasped the handle on the lever arm with the forearm supinated and performed three maximal concentric contractions at three angular velocities: 60, 120, and 180 degrees/sec. Subjects began the contractions with the elbow fully extended, and they were instructed to continue exerting maximal effort throughout the full range of movement. Isometric elbow flexion–extension strength was recorded with the elbow fixed at 90 degrees of flexion.

**Shoulder Test**

The subject was seated on the upper-body exercise table with the stabilization straps positioned across the thorax and pelvis. The subject performed three consecutive abduction–adduction movements at three angular velocities: 60, 120, and 180 degrees/sec. Isometric shoulder abduction–adduc-
Ankle Test

The subject was tested in a supine position on the upper-body exercise table. The trunk, pelvis, and thigh were stabilized by straps. The knee was stabilized at 90 degrees of flexion. The foot was placed on a foot support and stabilized by straps. One end on the platform was shaped to hold the heel in a fixed position, with the foot rigidly strapped and the toes clamped. The subject performed three consecutive flexion–extension movements at angular limb velocities of 60, 120, and 180 degrees/second. The isometric strength of ankle dorsal and plantar flexors was tested in neutral ankle position.

Functional Evaluation

Functional ability was measured using the FIM instrument, which is a valid and reliable measure of functional ability. The FIM instrument consists of 18 items that assess the degree of dependency in six areas: self-care activities, sphincter control, mobility, locomotion, communication, and social cognition. The motor subscale of the FIM instrument comprises the first 13 items, and scores range from 7 to 91. FIM motor change scores were calculated on the basis of the difference between admission to inpatient rehabilitation and discharge, and between the initial assessment and 6-, 12-, and 18-mo follow-up. We did not monitor the cognitive subscale of the FIM instrument because it is inappropriate for persons with GBS.

Statistical Analysis

All data were analyzed with the Stat View software (Abacas Concepts, Inc, Berkeley, CA, 1992), and the level of statistical significant was set at $P < 0.05$. Descriptive values were expressed as mean ± SD. Muscle strength was normalized to body weight. Longitudinal analyses to measure changes through the fourth testing were performed using one-way repeated-measures ANOVA (time effect). A Scheffé post hoc test was used to determine where the differences occurred.

At $R_0$, differences in mean muscle strength between patients and matched control subjects were examined by means of the Mann–Whitney $U$ test. Control subjects were only examined at baseline, and these values were used for comparisons with patient performance at $R_0$, $R_{12}$, and $R_{18}$.

The Spearman rank–correlation test was used to assess relationships between acute and plateau stage duration and muscle strength torques. We calculated the correlation coefficients between duration of plateau or acute stage and the strength-recovery slope of PT values. The recovery slope was adopted from a nonlinear model for two response parameters: PT and evaluation time. The form of the model used was $y = \alpha \ln x + \beta$. The $\alpha$ parameter corresponds to the slope of the curve. The $\beta$ parameter represents the constant value of the curve. The x-axis represents the time of evaluation ($R_0$ to $R_{18}$), and the y-axis represents the PT (N·m·kg$^{-1}$).

RESULTS

Participants

Initially, seven patients (four women and three men) were included. However, one female patient dropped out during the first phase of the program because she lived too far from the rehabilitation center. Thus, six patients with a mean age at GBS onset of 48.0 ± 15.2 yrs (range 19–59 yrs) were observed for 18 mos. Anthropometric and clinical features of patients and controls are presented in Table 1.

At the time of admission, motor assessment revealed weakness of the lower extremities in all patients, especially for ankle dorsiflexion and knee extension. Patients were unable to walk without assistance (third or fourth score of the Hughes functional scale). Five of them also had weakness of the upper limbs, especially decreased hand grip.

Autonomic dysfunction was recorded in three cases; it predominantly affected the cardiovascular system (cardiac arrhythmias, palpitations, or unstable blood-pressure fluctuations). Respiratory symptoms were present in one patient, who had to be admitted to the intensive care unit.

The electrophysiological data in all patients were primary demyelinating polyneuropathy, according to Asbury’s criteria. Needle examination showed no or few abnormalities as positive sharp waves and fibrillation at rest. For all patients, complete blood count, sedimentation rate, blood thyroid markers, serum immunoglobulin profile, and renal and liver function tests were normal.

All patients received initial treatment with intravenous immunoglobulin (IVIg) therapy alone (one course of IVIg in the acute phase, 0.4 g/kg daily for five consecutive days), except patient 5, who had six plasma exchanges in 2 wks, followed by a 5-day course of IVIg.

During the screening examination, no subject reported excessive soreness or fatigue. Pain was not believed to be a limiting factor, because all subjects indicated none or mild as their level of perceived pain during testing.

At baseline, the average MMT total score on the six patients (MMT total score = the sum of MMT scores of all the evaluated muscular groups for each patient; maximum = 40) was $32.2 \pm 3.1$. 


All patients were discharged home with a home exercise program within 2–6 wks, as their strength rapidly improved. All patients were working before hospitalization. Of these, five resumed their previous employment at a mean of 8 wks after discharge, and one could not return to work.

During the next 6 mos, MMT reached 38.5 ± 1.5, which is close to a normal level. Similarly, the relative total FIM motor score significantly improved between R0 and R6 (68.9 ± 10.8% to 98.7 ± 2.1%) and remained maximal at subsequent follow-ups.

At 6 mos, all patients were ambulatory, five of them without any aids (first score of the Hughes functional scale) and one with an ankle–foot orthosis (second score of the Hughes functional scale). No severe cardiovascular or respiratory problems were observed. However, all patients still experienced residual symptoms from GBS, particularly tingling in the fingers and toes.

Within 12–18 mos, residual distal motor deficits of the lower and upper limbs were still observed. The Hughes functional scale remained unchanged compared with the preceding score. In addition, all patients reported subsequent fatigability during sustaining effort.

**Strength Measurements**

**Patients vs. Controls**

Results of isometric (0 degrees/sec) and isokinetic (120 degrees/sec) testing showed the most significant differences between patient and control groups. At baseline, average isometric strength values in the knee, elbow, shoulder, and ankle muscle groups for GBS subjects were, respectively, 45, 56, 46, and 68% less than the values for healthy controls. Deficits were even more pronounced during isokinetic assessments at high angular velocities (i.e., 120 and 180 degrees/sec). Isokinetic assessments showed statistically significant patient-control differences more consistently than did isometric assessment at R12 and R18 (still using baseline control values). Isokinetic testing at 120 and 180 degrees/sec was sensitive enough to detect further improvement in all muscle groups beyond 12 mos (data not shown).

**Evolution of Muscle Strength Within Patients**

The mean percent changes in strength measurements between each contiguous assessment from R0 to R18 are displayed in Figure 1.

For each muscle group, the general trend of strength recovery was stereotypical. Both isokinetic and isometric testing were sufficiently sensitive to detect an improvement up to the 18-mo assessment. However, our results show a steeper rate of muscle strength recovery in the first 6-mo
FIGURE 1  Mean changes from baseline for maximum voluntary isometric strength and isokinetic strength at 120 degrees/sec. Knee extensors/flexors (A), elbow extensors/flexors (B), shoulder abductors/adductors (C), and ankle dorsal/plantar flexors (D). Changes in strength are expressed in percentage of initial strength, R0 (100%). For each subject, we calculated the change at follow-up of recovery, after 6 mos (R6), 12 mos (R12), and 18 mos (R18), relative to that subject’s baseline measurement (R0). C, control. Error bars represent ±SD percentage of initial value. *P < 0.05, †P < 0.05 for differences in mean between each assessment, respectively, at 0 and 120 degrees/sec.
period. From R6 to R18, the increase in strength continued at a lower rate. Isokinetic assessments consistently showed markedly greater improvement than did isometric tests.

**Relationship Between Isokinetic Muscle Strength Recovery and Acute or Plateau Phase Duration**

There was a strong negative correlation between the duration of both acute and plateau phases and the recovery slope for elbow flexor, knee extensor, and ankle plantar flexor isokinetic and MVIC strength (Table 2).

**DISCUSSION**

The results of this dynamometric prospective study of muscle strength recovery during 18 mos in treated GBS show a kinetic of strength recovery consistent with data from functional retrospective studies and MMT-based prospective and/or retrospective studies.7,8,15,19,20 The classical rapid increase in muscle strength in the first 6 mos of the recovery was confirmed, but we also observed continued, gradual, significant progress beyond 12 mos. Percent increases were statistically significant for all muscle groups, in isometric and isokinetic mode, at all angular velocities (particularly at 120 degrees/sec).

To our knowledge, no other published studies have investigated longitudinal dynamometric changes through the course of the recovery period from GBS; hence, comparing these findings against previous work is not possible. However, isokinetic muscle evaluation seems more sensitive than both routine MMT evaluation and functional assessments (e.g., Hughes grading scale and FIM measure), which improved between R6 and R3 and reached a ceiling thereafter. Assessment of functional outcomes in GBS often has been performed using a single scale, with an emphasis on walking ability.10 So, this significant increase of dynamometric strength beyond 12 mos of recovery is an objective measurement in the natural history of the GBS. At 18 mos, the mean maximal strength in GBS patients ranged between 91 and 95% of paired controls’ strength, for all studied muscle groups and all dynamometric evaluations. This should lead clinicians to consider a long-term follow-up of GBS patients and to suggest rehabilitation management beyond 1 yr. Moreover, Milner-Brown26 report that when the muscles are used regularly to generate large but submaximal forces, synchronization of motor units increases. Consequently, more intense long-term outpatient rehabilitation may enhance recovery.

All the patients of our series were demyelinating, but there were two phases of recovery. This kinetic of recovery—rapid, then slow (observed during 18 mos)—questions the relationship between electrophysiological signs (axonal and/or myelinic) and pathophysiological process described in the literature.13,14,27 The second phase of recovery could also correspond to the first signs of the muscular exercise rehabilitation.26

Similar to the retrospective studies of functional recovery by Raphael et al.15 and De Jager et al.,21 we have shown a significant negative correlation between muscle force recovery slope and

**TABLE 2 Correlation between strength recovery (slope) and acute or plateau time (days)**

<table>
<thead>
<tr>
<th>Articulation</th>
<th>Muscle Group</th>
<th>Velocity, deg·s⁻¹</th>
<th>Acute</th>
<th>Plateau</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>rho</td>
<td>P</td>
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<tr>
<td>Knee</td>
<td>Extensors</td>
<td>0</td>
<td>-0.77</td>
<td>0.08</td>
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<tr>
<td></td>
<td></td>
<td>120</td>
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<td>0.05</td>
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<tr>
<td></td>
<td>Flexors</td>
<td>0</td>
<td>-0.08</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.64</td>
<td>0.15</td>
</tr>
<tr>
<td>Elbow</td>
<td>Extensors</td>
<td>0</td>
<td>-0.24</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.25</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Flexors</td>
<td>0</td>
<td>-0.72</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.96</td>
<td>0.006</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Abductors</td>
<td>0</td>
<td>-0.27</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.81</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Adductors</td>
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<td>-0.27</td>
<td>0.54</td>
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<tr>
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<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.68</td>
<td>0.12</td>
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<tr>
<td></td>
<td>PF</td>
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<td>-0.02</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td>-0.78</td>
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Rho Spearman $r$ correlation coefficient; level of significance for $P$ value was set at 0.05.
FD, dorsal flexors; PF, plantar flexors; boldface, significant differences.
plateau stage duration. Furthermore, we observed a second predictive factor, the acute stage duration, which also was significantly correlated with the muscle force–recovery rate. Nevertheless, the severity of motor deficits did not correlate with recovery, corroborating findings reported by Chio et al., who reviewed several factors that seemed related to a worse recovery, including age, the presence and type of antecedent disorder, disability at admission and nadir, and selected electrophysiological features.

After 18 mos, despite a full clinical motor recovery, four of our six patients continued to feel persistent sensory deficits, particularly numbness and tingling dysesthesias in the extremities. Other prospective studies of unselected GBS patients have reported these phenomena at 1–2 yrs after onset. In a cross-sectional study, Bernsen et al. found that 69% of GBS patients reported dysesthesias during 3 yrs. In addition, a subsequent fatigability during prolonged exercise that requires muscular endurance was reported by GBS patients. Rees et al. and Forsberg et al., respectively, have shown that 18% and 21% of patients were unable to run 10 m, 1 or 2 yrs after onset. Merkies et al. found that 80% of patients with residual signs of GBS at 3–6 yrs after onset experienced fatigue. Dornonville de la Cour et al. suggest that persistent fatigue could be caused by a permanent loss of axons. However, neuromuscular fatigue assessment needs to be documented by adapted procedures (see Feasson et al. for review).

There are some limitations in our study. First, our case series may not be truly representative of the entire spectrum of treated GBS patients. The small size of patient number is explained by the prospective and monocentric design of this study and by the fact that some GBS patients were directly discharged home from the department of neurology. Second, other impairments also should be considered in future studies as contributors to disability; fatigability and psychosocial outcomes, which may lead to functional deficit, have been suggested as important events in these patients.

**CONCLUSIONS**

In the present study, muscle strength recovery occurred primarily during the 6 mos after onset, and strength continued to improve at a slower rate beyond this time point. This underscores the need for a minimum of 24 mos of follow-up with personalized strength assessment to adapt an appropriate individualized rehabilitation-management program. Elsewhere, persistent dysesthesias and fatigue were still reported by all patients at 18 mos. Therefore, evaluations of GBS-related impairment also could include investigations about fatigue and psychological status.

Because prognosis seems to be strongly related to a longer duration of the acute and plateau stages, early diagnosis and early choice of physical therapy are essential to optimize the potential for recovery.

**ACKNOWLEDGMENTS**

We wish to thank Dr Béthoux F, MD, PhD, for his helpful review of the manuscript.

**REFERENCES**


Lesion Characteristics, NIH Stroke Scale, and Functional Recovery After Stroke

ABSTRACT


Objective: We examined the relationships between the National Institute of Health Stroke Scale (NIHSS) and physical, cognitive, and social participation outcomes across subpopulations of stroke survivors on the basis of cortical involvement and lesion lateralization.

Design: Families in Recovery from Stroke Trial participants were classified with respect to lesion lateralization (n = 274) and cortical involvement (n = 158). NIHSS scores (average 13 days after stroke) were used to predict Physical Performance Test times (PPT), limitations in activities of daily living (Augmented Barthel Index (ABI)), Instrumental Activities of Daily Living (IADL), cognitive function, depressive symptoms (Center for Epidemiologic Studies Depression scale [CES-D]), and productive, recreational, self-care, and social role activities 3 and 6 mos later. We compared the relationship between NIHSS and each outcome in stroke subgroups classified by lesion lateralization and cortical involvement.

Results: NIHSS predicted physical performance, activities of daily living, and IADL independence. The association between NIHSS and both PPT and IADLs was less steep for patients with cortical lesions than for patients with exclusively subcortical lesions. NIHSS predicted physical performance, activities of daily living, or IADLs similarly for right- and left-hemisphere strokes, but hemisphere modified the association between NIHSS and CES-D and cognitive measures.

Conclusions: The NIHSS may predict outcomes in subpopulations of stroke survivors with subcortical lesions better than in patients with cortical involvement. NIHSS predicted CES-D in patients with right-sided lesions but not in those with left-sided lesions. In contrast, NIHSS had little association with cognitive outcomes among patients without left-side involvement.

Key Words: Stroke, NIH Stroke Scale, Imaging, Functional Outcomes
Reliable prediction of recovery in stroke survivors is of great importance to patients, clinicians, and researchers. The National Institute of Health Stroke Scale (NIHSS) is among the most frequently used tools for such predictions, and its value in predicting mortality and independence in basic and instrumental activities of daily living has been demonstrated repeatedly. It is not well understood, however, whether the NIHSS operates similarly in all stroke populations. For example, prior research indicates that large right-sided lesions correspond to lower NIHSS scores than do similarly large, left-sided lesions. It is not known whether this differential compromises the value of NIHSS scores for predicting outcomes in patients with right-hemisphere lesions. The value of lesion volume in predicting stroke outcome over and above NIHSS score is also controversial, with a recent report suggesting that the relations may differ for patient populations with a large number of severe cortical strokes.

Current models of disability emphasize the dynamic relationships among pathology, physical impairment in bodily functions, activity capacity, and meaningful participation within an individual’s environmental context. Although comprehensive stroke-impact assessments often include information on cognitive and psychosocial functioning as well as motor and physical performance, most research on outcome prediction focuses more narrowly on physical impairments, activities of daily living (ADL) independence, or broad outcome measures such as the Rankin scale. Some studies have found that stroke severity predicts physical function but that it may be more weakly associated with cognitive and psychosocial functioning. Impairment and disability measures are associated with level of handicap several months after stroke, but we have limited understanding of the relation between NIHSS scores at stroke onset and long-term outcomes (at 6 mos or 1 yr later) across domains.

In this paper, we compare the relationship between NIHSS score and functional outcome for patients stratified by lesion lateralization (left, right, bilateral) and cortical involvement (cortical vs. exclusively subcortical) in a cohort from the Families in Recovery from Stroke Trial (FIRST). FIRST included unusually comprehensive assessments of recovery in multiple domains, including physical functioning, ADL, and instrumental ADL disability, cognitive impairment, depressive symptoms, social role functioning, and productive, recreational, and self-care activities. Neuroimaging assessments of lesion location and lateralization are also available for this cohort. Thus, this data set provides an opportunity to examine the performance of NIHSS in predicting an array of outcomes relevant to patients’ quality of life and to assess whether the predictive value of the NIHSS is modified by lesion characteristics.

**METHODS**

**Subjects**

Details of the FIRST study design are provided elsewhere. Patients aged ≥45 yrs with ischemic or nontraumatic hemorrhagic stroke were screened for eligibility by study nurses at eight acute care hospitals and rehabilitation facilities in the Boston area. The Boston Aphasia Severity Rating Scale (BASRS), a short, standardized subscale of the larger Boston Diagnostic Aphasia Exam, was used to characterize level of aphasic disability on a scale of 1–5. Patients were excluded if they were globally aphasic or had limited comprehension and expressive aphasia (BASRS of 0 or 1), extremely socially isolated, residing in a nursing home before stroke or discharged to a nursing home, cognitively impaired before stroke by medical record, living outside the study area, only mildly impaired (NIH Stroke Severity Index <3, corresponding to [a] no impairments in swallowing, feeding, dressing, toileting, walking, or communication, and [b] either a score of 0 on the NIHSS or no decrement in any ADL attributable to the current event), or too severely impaired (NIH Stroke Severity Index >8, corresponding to impaired consciousness such that the patient was difficult to arouse, was stuporous or comatose, or
had impaired comprehension of words or concepts used in everyday conversation because of severe receptive aphasia.\textsuperscript{18} Of 486 patients screened with eligible stroke, 311 provided informed consent, and 291 of these were randomized.

**Imaging Review**

We requested copies of subjects’ baseline cerebral imaging studies from acute care hospitals. An independent neurologist (K.L.F.), blinded to functional outcomes, performed qualitative neuroimaging review. Qualifying lesions identified from imaging were characterized as belonging to one of the following groups: (A) exclusively subcortical, (B) exclusively cortical, or (C) both subcortical and cortical. For the analyses presented here, we combined patients in groups B and C because of the small number (n = 18) of lesions classified as exclusively cortical. For lobar lesions, lesion size was also assessed as <1/2 lobe vs. ≥1/2 lobe. Brain imaging studies allowing classification with respect to cortical contribution were retrieved for 212 (73\%) subjects. We excluded 54 scans (27\%) with insufficient evidence of a qualifying stroke (i.e., no evident lesion or qualifying stroke was hemorrhagic), leaving 158 subjects for these analyses, of which 62\% were conducted with MRI and the remainder with CT scans. An independent neurologist repeated the reviews for a subsample of ischemic strokes (n = 7); correspondence between the two raters was perfect for the lesion location, size, and lateralization categories used in the analyses presented here.

Lesion lateralization was defined on the basis of all available imaging and clinical data. Lateralization was categorized as left, right, or bilateral; if two separate lesions were evident that affected opposite hemispheres, the patient was classified as having a bilateral lesion. Lateralization, from clinical or imaging records, was available for 274 patients.

**Measures**

The NIHSS was developed in the context of several large multicenter clinical trials as a structured method of conducting a neurologic exam that could be standardized and repeated across studies and centers.\textsuperscript{19} The NIHSS has been found to be moderately reliable, is known to be related to stroke volume assessed radiologically (reviewed by Kasner\textsuperscript{1}), and is highly correlated with other stroke scales and functional outcome measures.\textsuperscript{1,20} The NIHSS was recorded at the baseline poststroke interview (an average of 13 days after stroke). Nurse/assessors received video-based training and were subsequently certified using methods developed in the Trial of ORG 10,172 in Acute Stroke Treatment (TOAST), which has been shown to improve reliability and validity.\textsuperscript{21}

Outcome measures included the Physical Performance Test (PPT), the Augmented Barthel Index (ABI), Instrumental Activities of Daily Living (IADL), the Mini-Mental Status Exam (MMSE), a cognitive battery, the Center for Epidemiologic Studies of Depression scale (CES-D), and profile of social role activities, recreational activities, self-care activities, and productive activities. All outcomes except the cognitive battery were assessed at 3 and 6 mos after intake interview by trained examiners. The cognitive battery was only assessed at the 6-mo follow-up.

The PPT was based on timed performance of five tasks: writing a sentence, simulated eating, simulated dressing, turning in a circle, and walking 20 feet. Performance on each of the five tests was ranked from 1 (worst) to 5 (best) according to whether the participant completed the test and the amount of time required to complete the test. The ranks for the five tests are summed for the final PPT score.

Our ADL measure expands on the conventional Barthel Index (BI) of independence in ten ADLs. The BI is a standard measure of stroke outcome used in many epidemiologic studies; it has been found to have generally favorable measurement properties.\textsuperscript{22,23} Our augmented measure addresses ability to accomplish tasks using assistive equipment ("Do you require the use of any special equipment?"). It is less vulnerable to ceiling bias than the conventional index, and it is more responsive to patient adaptations. Seven IADLs (using the telephone, traveling out of walking distance, shopping, preparing meals, housework, taking medicine, and handling money) were measured with the Older Americans Resource Survey instrument. Total score was based on the sum of score on each task, ranked as completely unable to do (0), achievable with some help (1), or achievable without help (2).

The CES-D is a 20-item measure of depressive symptoms often used in stroke research. In previous epidemiologic studies assessing poststroke depression, the CES-D has been found to be a reliable, sensitive scale, with few false-positives.\textsuperscript{24}

The MMSE has a possible range of 0–30.\textsuperscript{25} Up to five missing items were considered errors; respondents who refused or skipped more than five items were considered missing the MMSE. The cognitive battery included the Wechsler Digit Span Forward (revised to assess attention), Boston Diagnostic Aphasia Examination Repetition and Comprehension, Immediate Word Recall, Delayed Word Recall, One-Minute Animal Naming Test, and combined score on Trails A and B. The summary cognitive measure averaged z-scores for each instrument (see\textsuperscript{26} for background on the neuropsychological measures). This combined measure was correlated by 0.70 with the MMSE score at the 6-mo assessment.

The enacted function profile assesses the past week’s or month’s frequency of performing 20 pos-
sible activities in four domains: productive activities (housework, providing care, volunteering, paid work, yard work, home maintenance), social role performance (contact with friends, hobby activities, visited at home, out to lunch, been to church, been to a club), recreational activities (reading, going out with friends, or indoor or outdoor recreation), and self-care activities (walking, light exercise, had hair styled, driven a car, or been shopping). Any subscale missing half of the items was considered missing. Each subscale was created by summing the frequency estimated per month for each component item and scaled as a percentage of the maximum possible score for the subscale. The questionnaire was developed from work on productive activities,

previously have been shown to predict mortality and cognitive function.27

The interaction between lesion side and size was statistically significant ($P = 0.03$), suggesting that lesion volume has a larger effect on NIHSS in left-sided strokes than in right-sided strokes. Because of the potential association between imaging modality (CT vs. MRI) and lesion characteristics, we repeated the above analyses adjusting for imaging type, and results were unchanged.

RESULTS

NIHSS was assessed an average of 12.6 days (standard deviation = 6.8) after stroke onset for all randomized patients. The final sample varied slightly for each outcome: there were 272 respondents to the PPT, ABI, IADL, CES-D, and each activity measure, 264 MMSE respondents, and 238 respondents to the cognitive battery. Baseline characteristics and average outcome measures for the sample are presented in Table 1.

Although the NIHSS is an ordinal scale, the correlation coefficients between NIHSS and each outcome using Spearman (based on ranks) and Pearson (appropriate for continuous variables) estimates were very similar, suggesting that treating NIHSS as a continuous variable introduces little bias in this sample. The most extreme discrepancies between the Spearman and Pearson correlations were for CES-D (0.12 vs. 0.15, respectively) and productive activities (−0.29 vs. −0.25). For the ABI, the correlations were identical (−0.40).

Association of Lesion Characteristics and Baseline NIHSS

Patients with cortical strokes had worse baseline NIHSS on average than patients with exclusively subcortical lesions ($P < 0.01$). Right-sided lesions were associated with worse NIHSS scores than either left or bilateral lesions ($P = 0.05$). The distributions of NIHSS by cortical involvement and lesion lateralization are compared in Figure 1. Consistent with prior research,

the relationship between lesion size and NIHSS score differed for right- and left-hemisphere strokes. Patients with small, right-sided lobar lesions (affecting less than half the lobe) had lower average NIHSS scores compared with patients with larger lobar lesions, but this relationship was not significant ($\beta = −2.0, P = 0.16$). For patients with left-hemisphere strokes, small lesions were associated with substantially better NIHSS scores ($\beta = −5.8, P < 0.01$) compared with patients with large lesions. The interaction between lesion side and size was statistically significant ($P = 0.03$), suggesting that lesion volume has a larger effect on NIHSS in left-sided strokes than in right-sided strokes. Because of the potential association between imaging modality (CT vs. MRI) and lesion characteristics, we repeated the above analyses adjusting for imaging type, and results were unchanged.
Association of NIHSS and Functional Outcomes

In the sample as a whole, baseline NIHSS was significantly associated with the three physical function outcomes (PPT, ABI, IADL), MMSE, and self-care, productive, and recreational activities. No associations were found between NIHSS and the CES-D, the cognitive battery, or social role performance (Table 2).

Higher NIHSS scores were associated with worse PPT for both cortical (β = −0.51) and noncortical (β = −0.99) strokes, but the association between NIHSS and PPT was considerably stronger in those with subcortical lesions (P = 0.02 for interaction). Similarly, the regression coefficient for NIHSS predicting IADL was twice as large for noncortical (β = −0.38) strokes as for cortical (β = −0.16) strokes (P = 0.05 for interaction). For other outcomes, there was no clear evidence of effect modification (Table 2).

The association between NIHSS scores and outcomes was similar for right- and left-sided lesions with respect to most outcomes, but there was evidence that the effect of NIHSS on the CES-D and for cognitive outcomes varied by lateralization (Table 3). Higher NIHSS scores predicted worse depression scores for patients with right-hemisphere lesions but not for left-hemisphere patients (P = 0.04 for interaction).

Higher NIHSS scores predicted worse MMSE scores for left-sided lesions but not for patients with right-sided lesions, but this interaction was not statistically significant (P = 0.12). For patients with bilateral lesions, there was also evidence that higher NIHSS scores predicted worse MMSE scores; furthermore, this association was stronger than for right-sided lesions (P = 0.04 for interaction). This discrepancy was more pronounced for the MMSE than for the cognitive battery, perhaps reflecting the greater contribution of language to the MMSE.

DISCUSSION

Key Findings

Our results provide evidence that the NIHSS is a valuable predictor of functional recovery across a range of outcomes, including productive activities. The NIHSS was not associated with our summary cognitive battery and had only a modest association with the MMSE in the overall sample; however, higher scores were predictive of worse MMSE scores in patients with left-sided or bilateral lesions. We believe this may be the result of insults to the language-production regions in left-sided lesions. The association between NIHSS and physical performance and IADL measures seemed to be weaker among patients with cortical strokes compared with patients with exclusively subcortical lesions.

Compared with our ability to predict physical recovery, the predictive power of the NIHSS for cognitive function, depressive symptoms, and enacted function was much more limited. Some research suggests that poststroke depression is more likely to occur in patients with a right-sided lesion,
but results are mixed (see review by Hackett and Anderson). If so, this may partially explain why higher scores are not associated with CES-D in patients with left-hemisphere strokes despite a strong NIHSS-CES-D relationship for right-hemisphere strokes. However, other studies find that hemispheric location is unrelated to risk of depression.

**Interpretation of Results in Light of Prior Research**

Our results are consistent with numerous prior studies demonstrating the predictive power of NIHSS for motor impairments, ADL, and IADL disability. We extend these results by examining the value of NIHSS in subpopulations defined by lesion characteristics in predicting several other functional outcomes. Outcomes such as productive activities and social role involvement pose measurement difficulties, but they have tremendous relevance to patients. The activities measures we use are unusual in that they assess what individuals have done rather than their level of satisfaction in an area or their perceived ability to do something. Such questions on enacted function may ameliorate bias attributable to differential reporting or psychological accommodations (coping) to disability. Our activities profile may thus provide more meaningful assessments of stroke recovery than typical questions about satisfaction or theoretical capacity in similar domains.

NIHSS may not be as valuable a prognostic indicator for cortical strokes as for subcortical strokes, because cortical lesions can be more heterogeneous with respect to size and distribution. For example, cortical strokes might be multifocal, attributable to small distal emboli, or part of a large
infarct affecting both cortical and subcortical structures. Because the potential for recovery and magnitude of benefit from rehabilitation may vary across these lesion characteristics, the contribution of NIHSS in predicting outcome may vary similarly.

Prior research indicates that right-hemisphere lesion volumes have a smaller effect on NIHSS scores than do left-hemisphere lesion volumes. For example, Woo et al.\(^3\) found that for a given NIHSS score, the median volume of right-hemisphere strokes is consistently larger than the median volume of left-hemisphere strokes. Lyden and colleagues\(^31\) conducted factor analysis and found two factors underlying the NIHSS, corresponding to right- and left-hemisphere function. These results left an important question unanswered: is the NIHSS of less value for predicting outcome among patients affected by right-hemisphere lesions? In our research, we found no evidence that NIHSS predicted PPT, ADL, or IADL outcomes differently for right- vs. left-hemisphere lesions. Our results suggest that NIHSS does not predict depression scores among left-hemisphere or bilateral lesions, although it is a strong predictor of depression among right-hemisphere strokes.

### Study Limitations

The associations presented are relevant for understanding predictors of outcomes among stroke survivors, and they shed light on the relation between lesion characteristics and stroke recovery. NIHSS was assessed up to 29 days after stroke onset, and thus the value of NIHSS in this sample may differ from samples when NIHSS is consistently assessed in the acute phase. Some prior evidence suggests that NIHSS at 7 days after admission is a better predictor of BI outcome than is NIHSS at admission.\(^32\) However, the relationships between NIHSS and outcomes were not very sensitive to the delay between stroke onset and NIHSS assessment. For example, contrasting coefficients in analyses restricted to the 43 patients for whom NIHSS was assessed within 4 days of stroke onset to coefficients from the remaining patients among whom NIHSS was first assessed five or more days after stroke onset, the coefficients were very similar: −0.69 vs. −0.57 for PPT, −2.27 vs. −2.92 for ABI, and −0.22 vs. −0.25 for IADLs. This suggests that the results presented here would likely generalize to NIHSS assessments taken with shorter delays in the acute phase.

Because the trial criteria excluded the mildest and most severe strokes, we cannot generalize to the entire range of NIHSS scores. Data from the FIRST study included patients with moderately severe strokes, which is the group of greatest interest for many rehabilitation and clinical decisions. Patients excluded from the sample because of mild strokes (NIH Stroke Severity Index <3) have a very low risk of poor outcome and would not generally be candidates for rehabilitation therapy. Patients excluded because of overly severe strokes are very difficult to study, and they have a high mortality risk. Nonetheless, the results might differ in a population sample or in a sample drawn with different selection criteria. This is especially a concern if the exclusion criteria may have induced an artificial relationship between lateralization and

### TABLE 2 NIHSS and functional outcomes of FIRST participants, stratified by cortical location

<table>
<thead>
<tr>
<th>Enrolled Sample</th>
<th>Cortical</th>
<th>Noncortical</th>
<th>Interaction</th>
<th>P Value*</th>
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</thead>
<tbody>
<tr>
<td>β</td>
<td>95% CI</td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
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<tr>
<td>PPT</td>
<td>−0.58 (−0.72, −0.44)</td>
<td>−0.51 (−0.81, −0.21)</td>
<td>−0.99 (−1.29, −0.70)</td>
<td>0.02</td>
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<tr>
<td>Augmented BI</td>
<td>−2.73 (−3.47, −2.00)</td>
<td>−3.13 (−4.87, −1.39)</td>
<td>−3.99 (−5.73, −2.25)</td>
<td>0.39</td>
</tr>
<tr>
<td>IADL</td>
<td>−0.24 (−0.32, −0.16)</td>
<td>−0.16 (−0.32, −0.01)</td>
<td>−0.38 (−0.53, −0.22)</td>
<td>0.05</td>
</tr>
<tr>
<td>CES-D</td>
<td>0.27 (−0.04, 0.57)</td>
<td>0.43 (−0.18, 1.03)</td>
<td>0.53 (−0.08, 1.13)</td>
<td>0.80</td>
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<td>MMSE</td>
<td>−0.10 (−0.20, 0.00)</td>
<td>−0.19 (−0.40, 0.03)</td>
<td>−0.14 (−0.35, 0.07)</td>
<td>0.72</td>
</tr>
<tr>
<td>Cognitive battery</td>
<td>−0.02 (−0.04, 0.00)</td>
<td>−0.03 (−0.08, 0.02)</td>
<td>−0.02 (−0.07, 0.03)</td>
<td>0.90</td>
</tr>
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</table>

Activities

<table>
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<th>Self-care</th>
<th>Social role</th>
<th>Productive</th>
<th>Recreational</th>
</tr>
</thead>
<tbody>
<tr>
<td>−0.88 (−1.69, −0.08)</td>
<td>−1.06 (−3.21, 1.09)</td>
<td>−1.40 (−3.55, 0.76)</td>
<td>0.80</td>
</tr>
<tr>
<td>−0.82 (−0.75, 0.32)</td>
<td>−0.83 (−2.01, 0.35)</td>
<td>−0.65 (−1.83, 0.53)</td>
<td>0.82</td>
</tr>
<tr>
<td>−1.32 (−1.74, −0.90)</td>
<td>−2.13 (−3.16, −1.10)</td>
<td>−1.15 (−2.19, −0.12)</td>
<td>0.17</td>
</tr>
<tr>
<td>−0.77 (−1.25, −0.29)</td>
<td>−1.18 (−2.38, 0.02)</td>
<td>−0.43 (−1.62, 0.77)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Outcomes were measured at 3 or 6 mos after stroke. All models include adjustment for an indicator of 3- or 6-mo assessment wave. The confidence intervals reflect standard errors adjusted for the correlations between repeated measures on the same patient.

*Tests the null hypothesis that the coefficient for NIHSS predicting this outcome is the same for cortical vs. noncortical strokes.

PPT, Physical Performance Test; BI, Barthel Index; IADL, Instrumental Activities of Daily Living; CES-D, Centers for the Epidemiologic Study of Depression; MMSE, Mini-Mental Status Exam.
TABLE 3 NIHSS and functional outcomes of FIRST participants, stratified by lesion lateralization

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Interaction P Value</th>
<th>95% CI</th>
<th>Interaction P Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPT</td>
<td>0.06 (-0.60, 0.40)</td>
<td>0.03 (-0.63, 0.22)</td>
<td>0.02 (-0.67, 0.25)</td>
<td>0.04 (-0.68, 0.28)</td>
</tr>
<tr>
<td>Augmented BI</td>
<td>0.83 (-0.89, 0.90)</td>
<td>0.50 (-0.35, -0.65)</td>
<td>0.93 (-0.51, -0.32)</td>
<td>0.04 (-0.63, -0.53)</td>
</tr>
<tr>
<td>IADL</td>
<td>0.45 (-0.36, 0.21)</td>
<td>0.11 (-0.32, -0.02)</td>
<td>0.22 (-0.08, 0.00)</td>
<td>0.03 (-0.69, 0.69)</td>
</tr>
<tr>
<td>Cognitive Battery</td>
<td>0.79 (-1.08, 0.50)</td>
<td>0.02 (-0.00, 0.012)</td>
<td>0.26 (-0.04, 0.00)</td>
<td>0.03 (-0.06, 0.05)</td>
</tr>
<tr>
<td>Activities</td>
<td>0.39 (-0.76, 0.04)</td>
<td>0.12 (-0.29, 0.00)</td>
<td>0.93 (-0.16, 0.00)</td>
<td>0.03 (-0.68, 0.68)</td>
</tr>
<tr>
<td>Social role</td>
<td>0.24 (-0.29, 0.00)</td>
<td>0.31 (-0.47, -0.08)</td>
<td>0.48 (-0.22, 0.73)</td>
<td>0.06 (-0.47, 0.58)</td>
</tr>
<tr>
<td>Productive</td>
<td>0.79 (-2.22, 0.35)</td>
<td>1.00 (-1.47, -1.00)</td>
<td>1.86 (1.82, 0.36)</td>
<td>0.78 (-0.48, 0.78)</td>
</tr>
</tbody>
</table>

Outcomes were measured at 3 or 6 mos after stroke. All models include adjustment for an indicator of 3- or 6-mo assessment wave. The confidence intervals reflect standard errors adjusted for the correlations between repeated measures on the same patient.

NIHSS. Another possible limitation is the different imaging modalities used in the sample, which may have led to inconsistent classifications of lesion size; however, adjusting for the imaging modality did not affect results. Missing data for patients without outcome assessments at either 3 or 6 mos may also introduce bias; our approach depends on the assumption that data are missing at random.33 Our results focus on prediction and should not be given a causal interpretation. As with any observational study, the results should be interpreted cautiously, especially in light of the multiple hypothesis tests we present. We did not explicitly adjust for multiple comparisons, because in a small study such adjustment would potentially obscure meaningful differences in outcomes and, ultimately, fail to advance the research as much as possible.

CONCLUSION

Despite these limitations, this research expands our understanding of baseline stroke-severity measures and poststroke functional outcomes in domains beyond ADL and IADL disability. Although NIHSS is a simple, powerful predictor of stroke outcome, it should not be used alone for prognostication. This study demonstrates that lesion location and lateralization modify the impact of the NIHSS score on a range of outcomes. Individuals who are fully recovered with respect to ADL independence may still endure tremendous burden from their stroke because of cognitive losses, depressive symptoms, and restricted social, recreational, or productive activities. Conversely, patients with continuing ADL or IADL limitations may ultimately fare well if they have good cognitive function and psychosocial integration. Current understanding of the relations among physical impairment, disability, and participation in meaningful life contexts emphasizes the possibility of nonlinear, multidirectional relationships. Incorporating an understanding of these broader domains of recovery and outcome is crucial to improving stroke care and rehabilitation. Importantly, our results indicate that one of the most widely used predictive scales, the NIHSS, operates differently in domains beyond ADL and IADL disability. Although NIHSS is a simple, powerful predictor of stroke outcome, it should not be used alone for prognosis. As with any observational study, the results should be interpreted cautiously, especially in light of the multiple hypothesis tests we present. We did not explicitly adjust for multiple comparisons, because in a small study such adjustment would potentially obscure meaningful differences in outcomes and, ultimately, fail to advance the research as much as possible.

REFERENCES


10. Celik C, Aksel J, Karaoglan B: Comparison of the Orpington Prognostic Scale (OPS) and the National Institutes of Health Stroke Scale (NIHSS) for the prediction of the functional status of patients with stroke. *Disabil Rehabil* 2006;28:609–12


Urinary Tract Infection and Bacteriuria in Stroke Patients
Frequencies, Pathogen Microorganisms, and Risk Factors

ABSTRACT

Objective: To investigate the frequencies, pathogen microorganisms involved, and possible risk factors of urinary tract infections, asymptomatic bacteriuria, and significant bacteriuria in subacute and chronic stroke patients.

Design: The frequencies were determined and compared for subgroups with respect to age, gender, level of education, type of lesion, side of lesion, bladder-emptying method, postvoid residual urine, ambulation-level class, and Brunnstrom recovery stage class of upper and lower extremities in 110 consecutive stroke patients.

Results: Frequencies were 27.3, 11.8, and 39.1% for urinary tract infections, asymptomatic bacteriuria, and significant bacteriuria, respectively. Bladder-emptying method ($P < 0.05$), presence of postvoid residual urine $>50$ ml ($P < 0.04$), and Brunnstrom recovery stage class of upper extremity ($P < 0.02$) were significant factors for the frequency of urinary tract infections. Bladder-emptying method, ambulation-level class, Brunnstrom recovery stage class of upper and lower extremities ($P < 0.01$), presence of postvoid residual urine $>50$ ml ($P < 0.02$), gender, and level of education ($P < 0.05$) were significant factors for the frequency of significant bacteriuria.

Conclusions: Early treatment of urinary dysfunction for elimination of indwelling catheter use and high postvoid residue, early physical rehabilitation for better ambulation and hand function, patient education about prevention, and close monitoring of patients with unmodifiable risk factors may decrease the frequency of urinary tract infections and significant bacteriuria in stroke patients.

Key Words: Stroke, Urinary Infection, Bacteriuria, Microorganisms
Impairment of lower–urinary tract function is observed in many stroke patients, and related urinary symptoms are associated with disability and have negative effects on patients’ lives. A higher rate of urinary tract infections (UTI) has been reported in stroke patients with lower–urinary tract dysfunction, and UTI is one of the most common medical complications in hospitalized stroke patients. The frequency of UTI has been reported as 11–24% for inpatient stroke individuals and as 22–23% during follow-up (6–30 mos). Although UTI is not reported as one of the common causes of death in stroke patients in the short term, morbidity from UTI, related delay in rehabilitation and recovery, and negative influence of urinary symptoms on daily life are important. Furthermore, the effects of UTI on long-term mortality are not clear in this patient group. Despite the high frequency of the problem, no specific study has focused on the details of UTI in stroke.

The aim of this study was to investigate the frequencies, pathogen microorganisms involved, and possible risk factors of UTI and asymptomatic bacteriuria in stroke patients. We suggested that determination of the frequencies of UTI and asymptomatic bacteriuria might concentrate attention on this problem, that determination of the risk factors might be helpful in developing strategies for prevention, and that documentation of frequent pathogen microorganisms isolated in stroke individuals would be helpful in appropriate, effective treatment of UTI in this patient group.

METHODS

During a period of 8 mos, between July 2004 and February 2005, we prospectively studied 110 consecutive stroke patients without history of administration of antibacterial therapy in the previous month. They were 49 male and 61 female patients. Mean age was 62.6 ± 12.0 yrs (range: 27–90, median: 64). All patients were admitted to our hospital for rehabilitation and were evaluated for UTI within 72 hrs of admission. The mean interval between the cerebrovascular accident and the evaluation for UTI was 188 ± 285 days (range: 30–1800, median: 90). Bladder-emptying method and urinary symptoms, including urgency, frequency, dysuria, and suprapubic tenderness, were questioned and recorded. General physical and neurological examinations were carried out. Body temperature was monitored by using an axillary thermometer. Ambulation level was evaluated by using Massachusetts General Hospital Functional Ambulation Classification, which includes six classes (0–5) and allows use of any type of mechanical assistance device or ambulation aid. Recovery stage of the patients was determined using Brunnstrom hemiplegia classification, which has six stages and is an evaluation procedure used for recovering stroke patients to determine their level of recovery by testing muscle tone and voluntary control. The diagnosis of hemorrhagic or ischemic stroke and determination of the lesion side was made by a neurologist in all patients and was confirmed on computed tomography scan or magnetic resonance imaging of the brain. Patients underwent laboratory investigations, which consisted of routine blood analysis, complete blood count, erythrocyte sedimentation rate, C-reactive protein, urinalysis, abdominal USG, and urine culture. Midstream urine samples during voiding were collected to make diagnosis of UTI in the spontaneously voiding group. In patients with indwelling catheters, the old catheter was removed and the samples were collected from a new catheter. Voided volume after the patient reported strong desire to void, and postvoid residual volume, were measured in spontaneously voiding patients, and the patients with postvoid residuals higher than 50 ml were recorded. Presence of symptomatic UTI or asymptomatic bacteriuria were determined according to the U.S. Centers for Disease Control and Prevention criteria.

Criteria for Symptomatic Urinary Tract Infections

Symptoms in Patients >12 mos of Age
(1) fever (>38°C), (2) urgency, (3) frequency, (4) dysuria, (5) suprapubic tenderness

Criteria 1
age >12 mos AND
at least one symptom for age >12 mos AND
urine culture with ≥100,000 colonies per milliliter, with no more than two species of organisms

Criteria 2
age >12 mos AND
at least two symptoms for age >12 mos AND
at least one of the following:
dipstick test positive for leukocyte esterase and/or nitrate
Pyuria (either ≥10 WBC per milliliter, or ≥3 WBC per high-powered field of unspun urine organisms seen on gram stain of unspun urine two urine cultures with repeated isolations of the same uropathogen (gram negative bacteria; *Staphylococcus saprophyticus*) with ≥100 colonies per milliliter in nonvoided specimen urine culture with ≤100,000 colonies per milliliter of urine of single uropathogen in patient being treated with appropriate antimicrobial therapy physician’s diagnosis physician institutes appropriate antimicrobial therapy

SPSS version 9.0 was used for data analysis. The data were expressed as mean and standard deviation, as median, or as frequencies as appropriate. The frequencies of symptomatic UTI, asymptomatic bacteriuria, and significant bacteriuria (≥10^5 CFU/ml) were compared by χ² test for subgroups with respect to age (≥65 or <65 yrs), gender (male or female), level of education, type of lesion (ischemic or hemorrhagic), side of lesion (right or left), bladder-emptying method (spontaneous or indwelling catheter), presence of postvoid residual urine >50 ml, ambulation-level class (=2 or >2), and Brunnstrom recovery stage class of upper and lower extremities (stages 1–2, 3–4, or 5–6). Holm’s sequential Bonferroni method for control of type I error for all pairwise comparisons was carried out for level of education and Brunnstrom recovery stage class of upper and lower extremities.

Bladder-emptying method categories were determined as spontaneous or indwelling catheter because the method of bladder emptying was spontaneous in 95 patients (41 male and 54 female) and indwelling catheter in 14 (seven male and seven female). There was only one patient with condom urinal; this patient was included in the spontaneous group because he was able to urinate spontaneously, using this external collector system because of incontinence episodes. Ambulation level and Brunnstrom recovery stage classes were determined to form comparable groups for statistical analysis. In this process, sequential stages and classes with similar clinical characteristics were put together (patients with functional ambulation class =2 need physical assistance of another person for ambulation, whereas patients >2 are physically independent in ambulation; patients at Brunnstrom recovery stages 1–2 do not or minimally have voluntary movement in the involved extremity and the extremity is dysfunctional, patients at stages 3–4 have some voluntary movement and minimal function in the involved extremity, and for patients at stages 5–6, isolated movements are possible and the extremity can be used functionally). A logistic regression model was used to determine predictive factors for UTI, asymptomatic bacteriuria, and significant bacteriuria. In logistic regression analysis, the nine parameters (age, gender, level of education, type of lesion, side of lesion, bladder-emptying method, ambulation-level class, and Brunnstrom recovery stage class of upper and lower extremities) were included in the model. The parameter presence of post void residual urine >50 ml was excluded because it was not determined in patients with indwelling catheters.

**RESULTS**

There were symptomatic UTIs in 30 (27.3%), asymptomatic bacteriuria in 11 (11.8%), and significant bacteriuria in 43 (39.1%) of the 110 stroke patients. In all 30 patients who were diagnosed as UTI, the diagnosis was based on U.S. Centers for Disease Control and Prevention criteria 1. Five of the 30 patients were diagnosed with UTI because of fever >38°C and urine culture with ≥100,000 colonies per milliliter; in the remaining 25 patients, the diagnosis was based on the other symptoms besides urine culture with ≥100,000 colonies per milliliter. The results of the comparisons of the subgroups with respect to demographic and clinical parameters for the frequencies of symptomatic UTI, asymptomatic bacteriuria, and significant bacteriuria are presented in Tables 1, 2, and 3, respectively.

There were statistically significant differences between stroke subgroups with respect to bladder-emptying method (P < 0.05), presence of postvoid residual urine >50 ml (P < 0.04), and Brunnstrom recovery stage class of upper extremity (P < 0.02) for the frequency of symptomatic UTI. In Holm’s sequential Bonferroni method for control of type I error for all pairwise comparisons, there was a statistically significant difference between Brunnstrom recovery stage class of upper extremity 1 (stages 1–2) and 2 (stages 3–4) for the frequency of symptomatic UTI (P = 0.011; required P value = 0.0167) but not between 1 and 3 (P = 0.039; required P value = 0.025) or 2 and 3 (stages 5–6; P = 0.643; required P value = 0.05). Age (≥65 yrs), female gender, low level of education, functional ambulation class (=2), and Brunnstrom recovery stage class of lower extremity (stages 1–2) are potential factors that may affect the frequency of symptomatic UTI; higher frequencies were observed in these subgroups, but P values did not reach statistical significance. The frequency of asymptomatic bacteriuria was different in stroke subgroups with respect to bladder-emptying method (P < 0.04) and functional ambulation class (P < 0.03). Higher frequencies of asymptomatic bacteriuria were determined in female patients and in the patients with postvoid residual urine, but these were not statistically significant. The frequency of significant bacteriuria was different in stroke subgroups with respect to bladder-emptying method, functional ambulation class, Brunnstrom recovery stage class of upper and lower extremities (P < 0.01), presence of postvoid
TABLE 1 Comparison of the stroke subgroups with respect to demographic and clinic parameters for the frequencies of symptomatic urinary tract infection

<table>
<thead>
<tr>
<th>Factor</th>
<th>Frequency</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;65 yrs</td>
<td>11/56 (19.6%)</td>
<td>0.067</td>
</tr>
<tr>
<td>≥65 yrs</td>
<td>19/54 (35.2%)</td>
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</tr>
<tr>
<td>Gender, male/female</td>
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</tr>
<tr>
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<tr>
<td>Ungraduated</td>
<td>18/46 (39.1%)</td>
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<tr>
<td>Primary school</td>
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<tr>
<td>Secondary/high school or university</td>
<td>3/20 (15.0%)</td>
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</tr>
<tr>
<td>Type of lesion</td>
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<tr>
<td>Ischemic</td>
<td>22/82 (26.8%)</td>
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<tr>
<td>Side of lesion</td>
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</tr>
<tr>
<td>Right</td>
<td>6/29 (20.7%)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>24/81 (29.6%)</td>
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<td>Bladder-emptying method</td>
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<tr>
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<td>Indwelling catheter</td>
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</tr>
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<td>Residual urine &gt;50 ml</td>
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<tr>
<td>Present</td>
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<tr>
<td>Functional ambulation class</td>
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<tr>
<td>≤2</td>
<td>20/61 (32.8%)</td>
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<tr>
<td>&gt;2</td>
<td>10/49 (20.4%)</td>
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<tr>
<td>Brunnstrom stage class of upper extremity</td>
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<td>1–2</td>
<td>23/59 (39.0%)</td>
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</tr>
<tr>
<td>3–4</td>
<td>3/26 (11.5%)</td>
<td></td>
</tr>
<tr>
<td>5–6</td>
<td>4/25 (16.0%)</td>
<td></td>
</tr>
<tr>
<td>Brunnstrom stage class of lower extremity</td>
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<td>0.055</td>
</tr>
<tr>
<td>1–2</td>
<td>16/39 (41.0%)</td>
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</tr>
<tr>
<td>3–4</td>
<td>9/44 (20.5%)</td>
<td></td>
</tr>
<tr>
<td>5–6</td>
<td>5/27 (18.5%)</td>
<td></td>
</tr>
</tbody>
</table>

residual urine >50 ml (P < 0.02), gender, and level of education (P < 0.05). In Holm’s sequential Bonferroni method for control of type I error for all pairwise comparisons, the frequency of significant bacteriuria was different in the lowest and highest education-level groups (P = 0.015; required P value = 0.0167) but not between the lowest and middle (P = 0.084; required P value = 0.025) or the middle and highest (P = 0.253; required P value = 0.05) education-level groups. There were significant differences between Brunnstrom recovery stage class of upper extremity 1 and 2 for the frequency of significant bacteriuria (P = 0.003; required P value = 0.0167), between 1 and 3 (P = 0.011; required P value = 0.025), but not between 2 and 3 (P = 0.679; required P value = 0.05). There were significant differences between Brunnstrom recovery stage class of lower extremity 1 and 3 for the frequency of significant bacteriuria (P = 0.003; required P value = 0.0167), between 1 and 2 (P = 0.013; required P value = 0.025), but not between 2 and 3 (P = 0.383; required P value = 0.05).

In logistic regression analysis, no statistically significant result was obtained for UTI, but bladder-emptying method, with a regression coefficient of 1.22, P value of 0.078, and odds ratio of 3.41 (0.87–13.36 [95% CI]), was close to significance level. There was no statistically significant result for asymptomatic bacteriuria, but bladder-emptying method was a predictive factor for significant bacteriuria, with a regression coefficient of 2.12, P value of 0.01, and odds ratio of 8.39 (1.66–42.31 [95% CI]).

Mean sedimentation rate values were 23.44 ± 13.14 and 37.20 ± 25.23 mm/hr (P < 0.001), mean CRP values were 0.78 ± 1.29 and 2.53 ± 3.37 mg/dl (P < 0.001), and mean WBC values were 7556 ± 1997 × 10⁹/mm³ and 7147 ± 2130 × 10⁹/mm³ (P = 0.349) for stroke patients without and with UTI, respectively.

In abdominal ultrasounds, we found hydroureteronephrosis in one (with UTI) and urolithiasis in four (one bladder [with UTI], three kidney [one with UTI]) stroke patients. Prostatic enlargement was present in 17 of the 49 male patients, and three of them had UTI.

The isolated microorganisms and their frequencies in all stroke patients, in patients who voided spontaneously, and in patients with indwelling catheter.
eters are shown in Table 4. Although it is common to find multiple organisms with indwelling catheters, there were no patients with two or more organisms in the study population, possibly because of the small number of patients with indwelling catheters.

**DISCUSSION**

The frequency of symptomatic UTI in our study (27.3%) was slightly higher than the results of the previous studies12–14 (11–24%), but higher percentages up to 28% during the acute hospitalization period and up to 30% during the follow-up period (6–18 mos) have been reported in different centers.13 Furthermore, the range of frequencies from reviewed previous prospective studies has been reported as 11–28% in the study of Langhorne et al.13 The low education level of our study population and the mild female gender preponderance may have contributed to this slightly higher UTI frequency. The different criteria used for the diagnosis of UTI in different studies may be another possible source of the variation in UTI frequency among stroke patients. Whatever the underlying factors, this is a frequency high enough to show the need to concentrate attention on UTI in stroke patients.

According to our results, bladder-emptying method, presence of postvoid residual urine >50 ml, and Brunnstrom recovery stage class of upper extremity are significant factors for the frequency of symptomatic UTI in stroke individuals. Higher UTI frequency was observed in patients with indwelling catheter (50%) than in spontaneously voiding patients (24%), but the frequency was still high in the spontaneously voiding group. Also, higher frequencies of asymptomatic and significant bacteriuria were observed in the indwelling catheter group. Biofilm formation on indwelling catheters, which conveys a survival advantage to the microorganisms, is well known in catheter-associated infections. This biofilm consists of adherent microorganisms, their extracellular products, and host components deposited on the catheter, and it protects the causative microorganisms from host defenses and antimicrobial therapy. It also can

<table>
<thead>
<tr>
<th>Factor</th>
<th>Frequencies</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
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</tr>
<tr>
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<td>8/56 (14.3%)</td>
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</tr>
<tr>
<td>≥65 yrs</td>
<td>5/54 (9.3%)</td>
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</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<tr>
<td>Male</td>
<td>3/49 (6.1%)</td>
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<tr>
<td>Female</td>
<td>10/61 (16.4%)</td>
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<td>Level of education</td>
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<td>Primary school</td>
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<tr>
<td>Type of lesion</td>
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<td>Ischemic</td>
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<tr>
<td>Right</td>
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</tr>
<tr>
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<td>Bladder-emptying method</td>
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<td>Spontaneous</td>
<td>9/96 (9.4%)</td>
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<td>Indwelling catheter</td>
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<tr>
<td>Residual urine &gt;50 ml</td>
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</tr>
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<td>Absent</td>
<td>6/77 (7.8%)</td>
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<td>Present</td>
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<tr>
<td>Functional ambulation class</td>
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<tr>
<td>≤2</td>
<td>11/61 (18.8%)</td>
<td>0.024</td>
</tr>
<tr>
<td>&gt;2</td>
<td>2/49 (4.1%)</td>
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<tr>
<td>Brunnstrom stage class of upper extremity</td>
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</tr>
<tr>
<td>1–2</td>
<td>9/59 (15.3%)</td>
<td>0.486</td>
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<td>3–4</td>
<td>2/26 (7.7%)</td>
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<td>5–6</td>
<td>2/25 (8.0%)</td>
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<tr>
<td>Brunnstrom stage class of lower extremity</td>
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<td></td>
</tr>
<tr>
<td>1–2</td>
<td>7/39 (17.9%)</td>
<td>0.210</td>
</tr>
<tr>
<td>3–4</td>
<td>5/44 (11.4%)</td>
<td></td>
</tr>
<tr>
<td>5–6</td>
<td>1/27 (3.7%)</td>
<td></td>
</tr>
</tbody>
</table>

| Table 2: Comparison of the stroke subgroups with respect to demographic and clinic parameters for the frequencies of asymptomatic bacteriuria |
|-----------------|-----------------|--------|
| Factor          | Frequencies     | \( P \) |
| Age             |                 |        |
| <65             | 8/56 (14.3%)    |        |
| ≥65 yrs         | 5/54 (9.3%)     |        |
| Gender          |                 |        |
| Male            | 3/49 (6.1%)     |        |
| Female          | 10/61 (16.4%)   |        |
| Level of education |             |        |
| Ungraduated     | 6/46 (13.0%)    |        |
| Primary school  | 6/44 (13.6%)    |        |
| Secondary/high school or university | 1/20 (5.0%) |        |
| Type of lesion  |                 |        |
| Hemorrhagic     | 3/28 (10.7%)    |        |
| Ischemic        | 10/82 (12.2%)   |        |
| Side of lesion  |                 |        |
| Right           | 4/29 (13.8%)    |        |
| Left            | 9/81 (11.1%)    |        |
| Bladder-emptying method |         |        |
| Spontaneous     | 9/96 (9.4%)     |        |
| Indwelling catheter | 4/14 (28.6%) |        |
| Residual urine >50 ml |          |        |
| Absent          | 6/77 (7.8%)     |        |
| Present         | 3/19 (15.8%)    |        |
| Functional ambulation class |          |        |
| ≤2              | 11/61 (18.8%)   |        |
| >2              | 2/49 (4.1%)     |        |
| Brunnstrom stage class of upper extremity |          |        |
| 1–2             | 9/59 (15.3%)    |        |
| 3–4             | 2/26 (7.7%)     |        |
| 5–6             | 2/25 (8.0%)     |        |
| Brunnstrom stage class of lower extremity |          |        |
| 1–2             | 7/39 (17.9%)    |        |
| 3–4             | 5/44 (11.4%)    |        |
| 5–6             | 1/27 (3.7%)     |        |
serve as a nidus for reinfection. Prolonged catheterization (<6 days) and backflow of urine from a collection bag and drainage tube to the urinary system, resulting from improper positioning, can increase UTI frequency in catheterized patients. Extra mortality attributable to urinary catheter–associated UTI in intensive care units has been reported to be 10.5%. In the specific review of the literature for stroke patients, having a urinary catheter seemed to be a significant factor for elevated body temperature. Insertion of the catheter using an aseptic technique, correct positioning of the drainage tube and collection bag (the tube should remain below the bladder but above the bag), maintenance of closed drainage, removing the indwelling catheter as soon as it is no longer needed (early evaluation and rehabilitation of bladder, achieving spontaneous voiding, or starting condom drainage or intermittent catheterization) are known to be effective strategies for preventing catheter-associated UTI.

In our study, significantly higher symptomatic UTI frequency was observed in patients with upper-extremity Brunnstrom recovery stage class 1 (stages 1–2). Similar high frequency was present for lower-extremity Brunnstrom recovery stage class 1, but the P value did not reach statistical significance, although it was close. Both upper- and lower-extremity Brunnstrom recovery stage class were significant factors for the frequency of significant bacteriuria. Because the patients at Brunnstrom recovery stages 1–2 do not or minimally have voluntary movement in the involved extremity, and because the extremity is dysfunctional, inability in activities of urination and hygiene attributable to upper-extremity involvement and absence of ambulation and prolonged bed rest attributable to lower-extremity involvement may be possible explanations for the higher UTI frequency. Although we could not find any report about the association between UTI and Brunnstrom recovery stage, association between UTI and poor NIHSS (National Institute of Health Stroke Scale) and Barthel index scores have been reported. NIHSS is an acute assessment scale consisting of 11 categories evaluating motor, sensory, and cognitive functions, and the Barthel index is an outcome scale with 10 items.

### TABLE 3 Comparison of the stroke subgroups with respect to demographic and clinic parameters for the frequencies of significant bacteriuria (≥10^5 CFU/ml)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Frequencies</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>&lt;65</td>
<td>19/56 (33.9%)</td>
<td>0.258</td>
</tr>
<tr>
<td>≥65 yrs</td>
<td>24/54 (44.4%)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
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</tr>
<tr>
<td>Male</td>
<td>13/49 (26.5%)</td>
<td>0.016</td>
</tr>
<tr>
<td>Female</td>
<td>30/61 (49.2%)</td>
<td></td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ungraduated</td>
<td>24/46 (52.2%)</td>
<td>0.033</td>
</tr>
<tr>
<td>Primary school</td>
<td>15/44 (34.1%)</td>
<td></td>
</tr>
<tr>
<td>Secondary/high school or university</td>
<td>4/20 (20.0%)</td>
<td></td>
</tr>
<tr>
<td>Type of lesion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemorrhagic</td>
<td>11/28 (39.3%)</td>
<td>0.834</td>
</tr>
<tr>
<td>Ischemic</td>
<td>32/82 (39.0%)</td>
<td></td>
</tr>
<tr>
<td>Side of lesion</td>
<td></td>
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</tr>
<tr>
<td>Right</td>
<td>10/29 (34.5%)</td>
<td>0.553</td>
</tr>
<tr>
<td>Left</td>
<td>33/81 (40.7%)</td>
<td></td>
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<tr>
<td>Bladder-emptying method</td>
<td></td>
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</tr>
<tr>
<td>Spontaneous</td>
<td>32/96 (33.3%)</td>
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</tr>
<tr>
<td>Indwelling catheter</td>
<td>11/14 (78.6%)</td>
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<tr>
<td>Residual urine &gt;50 ml</td>
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</tr>
<tr>
<td>Absent</td>
<td>21/77 (27.3%)</td>
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</tr>
<tr>
<td>Present</td>
<td>11/19 (57.9%)</td>
<td></td>
</tr>
<tr>
<td>Functional ambulation class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤2</td>
<td>31/61 (50.8%)</td>
<td>0.005</td>
</tr>
<tr>
<td>&gt;2</td>
<td>12/49 (24.5%)</td>
<td></td>
</tr>
<tr>
<td>Brunnstrom stage class of upper extremity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>32/59 (54.2%)</td>
<td>0.002</td>
</tr>
<tr>
<td>3–4</td>
<td>5/26 (19.2%)</td>
<td></td>
</tr>
<tr>
<td>5–6</td>
<td>6/25 (24.0%)</td>
<td></td>
</tr>
<tr>
<td>Brunnstrom stage class of lower extremity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>23/39 (59.0%)</td>
<td>0.005</td>
</tr>
<tr>
<td>3–4</td>
<td>14/44 (31.8%)</td>
<td></td>
</tr>
<tr>
<td>5–6</td>
<td>6/27 (22.2%)</td>
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for evaluation of self-care activities, bladder–bowel function, and mobility. Another possible explanation is the recovery of bladder and lower–urinary tract function parallel to the progression of Brunnstrom stages. Because the change in Brunnstrom recovery stage cannot be modified easily with rehabilitative efforts and is a matter of time in general, close monitoring of the patients with stages 1 and 2 for UTI seems reasonable.21,24

Significantly higher frequencies of symptomatic UTI and significant bacteriuria were observed in stroke patients with postvoid residual urine. A higher rate of UTI previously has been reported in stroke patients with postvoid residual urine.1,7,4 Continuous presence of residual urine in the bladder, attributable to incomplete emptying, predisposes colonization of UTI pathogens.25 Treatment of bladder-emptying dysfunction with alpha-adrenergic blockers or intermittent catheterization is an appropriate approach in patients with high postvoid residual urine; this may also decrease UTI and significant bacteriuria frequencies.1,6,26

Significantly higher frequencies of bacteriuria and higher frequencies of symptomatic UTI with nearly significant P values were observed in patients with female gender and with age ≥65 yr in our study. Associations of UTI with older age and female gender in stroke patients also have been reported previously.24 Short urethra and higher frequency of incontinence make entrance of uropathogens to the urinary system easier in female patients. Decreased immune function and increased urinary system comorbidities (benign prostatic hyperplasia, pelvic relaxation, etc.) may play a role in the higher UTI frequency in older stroke patients. Because age and gender are not modifiable factors, close monitoring of female and old stroke patients for UTI and administration of prophylactic antibacterial drugs when needed would be a judicious strategy.24

Low education level also was a significant factor for significant bacteriuria: an approximately twofold-higher UTI rate was observed in the lowest education level compared with other education levels in our patient population. Education of the patients, especially the ones in the lowest education level for prevention of UTI and general hygiene in the short term, and increasing the public education level in the long term, may decrease the negative effect of this parameter on UTI frequency.

Finally, in our study, functional ambulation class ≤2 was associated with significantly higher asymptomatic and significant bacteriuria rates. UTI frequency was also high in this group, although it was not statistically significant. We could not find any previous report about the association between UTI or bacteriuria and functional ambulation class, but, as mentioned above, associations between UTI and poor NIHSS and Barthel index scores have been reported.24 Eliminating the negative effects of bed dependency through better functional ambulation might be the underlying mechanism. Early, intensive rehabilitation of patients and use of appropriate orthoses and walking aids for achieving better functional ambulation may also help lower frequencies of asymptomatic and significant bacteriuria and UTI in stroke patients.

The most common isolated microorganism was *Escherichia coli* in all stroke patients, in patients who voided spontaneously, and in patients with indwelling catheters in our study. *Pseudomonas aeruginosa* was isolated in 36.4% of the patients with indwelling catheters but in none of the spontaneously voiding ones. *E. coli* is known to cause the majority of uncomplicated UTIs, and *P. aeruginosa* is relatively more common in patients with catheter-associated UTI, although *E. coli* is still the most common pathogen.21,22,25,27 *P. aeruginosa* has been well documented to form dense biofilms surrounded by glyco-calyx material.25 Hence, in this context, it seems reasonable to use agents that provide a broad spectrum of antimicrobial activity covering most expected pathogens, including *P. aeruginosa*, in the empirical treatment of UTI in stroke patients with indwelling catheters, until the urine culture results are obtained.

**CONCLUSION**

According to our study results, the frequency of UTI is high in stroke patients, and it is necessary to concentrate attention on this problem. Bladder-emptying method, presence of postvoid residual urine >50 ml, and Brunnstrom recovery stage class of the upper extremity are significant factors for the frequency of UTI, whereas bladder-emptying method, postvoid residual urine >50 ml, ambulation-level class, Brunnstrom recovery stage class of upper and lower extremities, gender, and level of education are significant factors for the frequency of significant bacteriuria.

We believe that early treatment of lower–urinary tract dysfunction by medical and rehabilitative approaches for elimination of indwelling catheter use and high postvoid residue, early physical rehabilitation for better ambulation and hand function, patient education about UTI prevention, close monitoring of patients with unmodifiable risk factors for UTI (older age, female gender, Brunnstrom stages 1 and 2), and appropriate early treatment of UTI may decrease the frequency and morbidity of UTI in stroke patients. Further studies with larger sample sizes may lead to better management of this frequent problem.

**REFERENCES**


September 2007 Urinary Tract Infection in Stroke 741

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CME Self Assessment Exam Questions

CME Article Number 2: L. El Mhandi, et al.

1. At initial assessment, muscle strength deficits were most pronounced with:
   A. Isometric testing.
   B. Isokinetic testing.
   C. Manual muscle testing.
   D. None of the above.

2. At the 12-month follow-up, statistically significant improvements were seen in which outcome measure?
   A. FIM scores.
   B. Strength via isokinetic testing.
   C. Hughes scores.
   D. Strength via manual muscle testing.

3. In this study, patients displayed the most change in FIM scores during:
   A. The first 6 months after the onset of Guillain-Barre syndrome (GBS).
   B. 6–12 months after the onset of GBS.
   C. 12–18 months after the onset of GBS.
   D. 18–24 months after the onset of GBS.

4. For patients at 12–18 months of follow-up, which of the following was true?
   A. Residual lower-limb motor deficits resolved.
   B. Residual upper-limb motor deficits resolved.
   C. All symptoms of fatigue resolved.
   D. The Hughes Functional Scale remained unchanged.

5. Muscle strength in patients at 6–18 months after the onset of GBS was noted to:
   A. Increase at the same rate as in the first 6 months.
   B. Increase at a slower rate than in the first 6 months.
   C. Plateau compared with the first 6 months.
   D. Worsen compared with the first 6 months.

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1. Read the Designated CME Articles in this issue.
2. Read the following CME Self-Assessment Exam Questions.
3. Photocopy and complete the CME Self-Assessment Exam Answering Sheet and CME Evaluation.
4. Send the completed Answering Sheet and Evaluation to:
   Bradley R. Johns, Managing Editor, CME Department-AAP, American Journal of Physical Medicine & Rehabilitation, 7240 Fishback Hill Lane, Indianapolis, IN 46278
**CME Article Number 3: M.M. Glymour, et al.**

1. According to the results of this study, which of the following statements best describes the value of the National Institute of Health Stroke Scale (NIHSS) score?
   A. The NIHSS is a consistent indicator of lesion volume in stroke survivors.
   B. The NIHSS is a valuable predictor of a range of post-stroke functional outcomes.
   C. The NIHSS predicts all outcomes similarly for stroke survivors, regardless of lesion lateralization.
   D. The NIHSS predicts all outcomes similarly for stroke survivors with subcortical and cortical lesions.

2. Which of the following functional stroke outcomes was *not* significantly predicted by the NIHSS score?
   A. Physical performance of tasks.
   B. Self-reported independence in activities of daily living (ADLs) and instrumental activities of daily living (IADLs).
   C. Social role activities.
   D. Productive activities.

3. Which of the following functional stroke outcomes had a strong association with the NIHSS score when cortical lesions were compared with subcortical lesions?
   A. Physical performance of tasks (PPT).
   B. Depressive symptoms (Center for Epidemiologic Studies Depression [CES-D] scale).
   C. The Mini-Mental Status Exam (MMSE) score.
   D. Self-care activities.

4. Which of the following functional stroke outcomes had a strong association with the NIHSS score when left-hemisphere lesions were compared with right-hemisphere lesions?
   A. Physical performance of tasks.
   B. Self-reported independence in IADLs.
   C. Depressive symptoms (CES-D).
   D. Recreational activities.

5. Compared with NIHSS scores assessed five or more days after stroke onset, NIHSS scores assessed within 4 days of stroke onset were:
   A. Consistently more strongly predictive of the functional outcomes of PPT, ADLs, and IADLs measured at 3 and 6 months.
   B. Consistently less strongly predictive of the functional outcomes of PPT, ADLs, and IADLs measured at 3 and 6 months.
   C. Similar in their relationship with the functional outcomes of PPT, ADLs, and IADLs measured at 3 and 6 months.
   D. Displayed no relationship with the functional outcomes of PPT, ADLs, and IADLs measured at 3 and 6 months.

---

**CME Article Number 4: M. Ersoz, et al.**

1. In this study, what was the approximate symptomatic urinary tract infection frequency in stroke patients?
   A. 4%.
   B. 10%.
   C. 27%.
   D. 35%.

2. According to the findings in this study, which of the following is *not* a significant risk factor for urinary tract infection in stroke patients?
   A. High post-void residual urine.
   B. Ischemic cerebrovascular accident etiology.
   C. Chronic indwelling urethral catheter use for bladder emptying.
   D. Lower Brunnstrom recovery stage of the upper limb.

3. According to the findings of this study, which of the following is a risk factor for significant bacteriuria in stroke patients?
   A. Male gender.
   B. Lower-limb Brunnstrom recovery stage 3.
   C. Functional ambulation class 2.
   D. High education level.

4. Which of the following is *not* an effective strategy for the prevention of catheter-associated urinary tract infections?
   A. Catheter insertion using an aseptic technique.
   B. Allowing the system to be open at night.
   C. Proper positioning of the drainage tube and bag.
   D. Removing the indwelling catheter as soon as possible.

5. In our study, which bacteria were isolated more frequently in stroke patients with indwelling catheters than in patients without catheters?
   A. *Pseudomonas aeruginosa*.
   B. *Klebsiella pneumoniae*.
   C. *Proteus mirabilis*.
   D. *Staphylococcus aureus*. 
The answers to any essay questions must be typed or computer printed on a separate piece of paper and attached to this page.

After finishing this exam:
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Journal Issue Month and Year ________________________
Volume Number ______ Issue Number _______________
CME Article Number _________________________________
CME Article Author’s Name __________________________

Circle the appropriate answers.

1. A  B  C  D
2. A  B  C  D
3. A  B  C  D
4. A  B  C  D
5. A  B  C  D
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<td>CME Article Author’s Name</td>
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<th>Poor</th>
<th>Satisfactory</th>
<th>Outstanding</th>
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<td>1</td>
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| Did reading this article prepare you to achieve its stated objectives? | 1 | 2 | 3 |

| Is reading this article likely to enhance your professional effectiveness? | 1 | 2 | 3 |

| Was the article format conducive to learning? | 1 | 2 | 3 |

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The Effect of Providing Power Mobility on Body Weight Change

ABSTRACT


Objective: To investigate whether the provision of power mobility would have an effect on body weight in adults who were first-time qualifiers for power mobility.

Design: This was a retrospective observational study of consecutive subjects, who served as their own controls. The medical records of 468 subjects who were approved for power mobility during a 17-mo period were reviewed. Three weight groups (12 mos before, at, and 12 mos after the power mobility evaluation) were evaluated with repeated-measures analysis of variance (ANOVA). The weight changes on subjects in different age groups (45–54, 55–64, 65–74, and >74), in geriatric vs. nongeriatric groups, and in different body mass index (BMI) groups were analyzed.

Results: Eighty-nine subjects met the inclusion criteria. They were obese (49.4%), and most of them were geriatric (64%). Congestive heart failure (30.34%) and chronic obstructive pulmonary disease (22.47%) were the two main presenting diagnoses. The repeated-measures ANOVA showed no significant weight change in the three studied weight groups. Similar results were seen in the age and BMI subgroups.

Conclusions: There was no statistically significant weight change in adults who were first-time qualifiers and who used power mobility for 1 yr.

Key Words: Wheelchairs, Weight Gain, Weight Loss, Immobilization
Assistive mobility devices, including manual and power wheelchairs and scooters, are used to increase mobility, increase participation in community and social life, and improve quality of life for patients with mobility impairments. However, the use of these assistive devices has grown at a much higher rate than the growth of the aging population, and also at a higher rate than the general population.\(^1\) Since the first commercial power wheelchair was introduced in 1956 and the first power scooter in 1968, the use of power wheelchairs and scooters has been rising. According to a report from the United States General Accounting Office (GAO) in 2004, Medicare spending for power wheelchairs rose 450% from 1999 through 2003 (more than $1 billion in 2003), whereas overall Medicare spending rose by only about 11% for the same period.\(^2\)

Along with the increasing use of assistive devices and growing aging population, the United States population is also experiencing increased rates of obesity.\(^3\) Overweight is defined as having a body mass index (BMI, weight in kilograms divided by height in meters squared) equal to or greater than 25 kg/m\(^2\) but less than 30 kg/m\(^2\), and obese is defined as having a BMI equal to or greater than 30 kg/m\(^2\). According to the United States Department of Health and Human Services Centers for Disease Control and Prevention, between 1988 and 1994, 56% of adults between the ages of 20 and 74 were overweight or obese, and 23.3% were obese. By 1999–2002, 65.2% of adults between the ages of 20 and 74 were overweight or obese, and 31.1% were obese.\(^4\) According to projections from a report by Trust for America’s Health, by 2008, 73% of American adults could be overweight or obese, with a 39% obesity rate.\(^5\) The National Institutes of Health (NIH) and Centers for Disease Control (CDC) reports obesity has been implicated in exacerbating a multitude of physical problems, including more than 35 major diseases such as cardiac, respiratory, gastrointestinal, and musculoskeletal diseases.\(^6\) Along with excessive intake of calories, a lack of exercise has been identified as a contributing cause of obesity.\(^7\)

Because the primary goal of prescribing power mobility is to increase functional and community mobility of patients, the question arises as to whether providing these devices might contribute to weight gain by decreasing already minimal physical activity levels. We have found that healthcare providers are, in fact, frequently concerned about weight gain and decreasing function in their patients as a result of power mobility prescription. A review of the literature shows that there have been no studies on the association of power mobility prescription with weight change in new power mobility device users as a whole or in different age and BMI groups. In this study, we retrospectively evaluated weight change in subjects who received power mobility devices for the first time.

**METHODS**

This was a retrospective observational study of consecutive subjects with a self-matched design.

**Subjects**

This study was performed at a local Veterans Affairs (VA) medical facility. All the research subjects were adults, and most of them were male.

We selected research subjects approved for power mobility devices from August 2003 through December 2004 (17 mos) in the medical center. Previously established approval criteria for power mobility include (1) inability to ambulate attributable to severe chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), neurological disorders, or similar conditions, (2) inability to propel a manual wheelchair attributable to any medical condition, (3) the condition was permanent, and (4) no contraindications for driving a power mobility device such as seizure activity in less than 6 mos before referral, severe visual deficits, severe cognitive impairment, or severe behavioral problems. We excluded those whose medical condition might significantly affect body weight such as cancer diagnoses other than skin cancer, amyotrophic lateral sclerosis, stroke, Paget disease, Parkinson disease, end-stage liver disease, previous liver transplant, amputation during study period, or weight loss surgery. We also excluded subjects who were already in possession of a power mobility device when referred for a power mobility assessment. We required three weight readings: 12 mos before, at, and 12 mos after the power mobility evaluation (labeled as reading groups W1, W3, and W5, accordingly). When no weight reading was available at the targeted reading time, weight readings were considered valid if a weight was taken within two months before or after the due date. Subjects who did not have the three weight readings were excluded from the study. Most of the subjects received power mobility (either a scooter or a power wheelchair) within 2 mos of the evaluation. The electronic medical records of 468 subjects were reviewed. Eighty-nine subjects met the criteria for this study, and their data were collected.

**Minimal Sample Size**

To calculate the minimal sample size, we selected the level of significance \( \alpha = 0.01 \), and the desired value of power was 0.99; therefore, \( \beta \), the complement of power, was 0.01. On the basis of preliminary research, we assumed that the weight differences before and after power mobility pre-
scription will range from a minimum of 0 kg to a maximum of 22.7 kg (50 lbs). The standard deviation of the response variable in the study population was \( \sigma = 22.7/6 = 3.78 \) kg. After consulting with other physiatrists within our physical medicine and rehabilitation department, we determined that a weight change of 4.54 kg (10 lbs) in 12 mos would be significant; therefore, we used 4.54 kg as the absolute effect size. The units of standard deviation were \( \Delta = 4.54/3.78 = 1.20 \). The study was a double-sided test; therefore, the minimal qualified sample size needed was 21 subjects. We had 89 qualified study subjects—more than the minimal number needed.

**Hypotheses**

Our primary hypothesis was that the provision of power mobility would have no effect on weight change for adults who were first-time qualifiers for power mobility. This meant that the mean weight among the three weight readings 12 mos before, at, and after the power mobility evaluation (labeled as \( \mu_1, \mu_2, \mu_5 \) for reading groups W1, W3, and W5) would not differ significantly (Ho: \( \mu_1 = \mu_3 = \mu_5 \)).

Our secondary hypothesis was that provision of power mobility would have no effect on weight change for adult first-time power mobility qualifiers in age subgroups and BMI subgroups.

**Institutional Review Board Review**

The study was reviewed and approved by the institutional review board overseeing human subject research at the medical center where the study was conducted. We used an electronic medical record system for our retrospective study. The system is protected by a unique, secure password. We had a master log to record the first letter of the subjects’ last name and the last five digits of the subjects’ social security number, along with the date of the appointment for the powered mobility device assessment. Each subject was assigned a neutral sequential code that would prevent identifying the subjects’ identity. That information was kept in a locked cabinet. We used a data sheet that had the assigned code with age, sex, referring diagnosis, height, and three weight readings. The data are stored in a password-protected computer system.

**Data Analysis**

To see whether there was a significant change in a subject’s weight after prescription of power mobility, we first looked at overall weight change for all subjects. We then looked at weight changes on the basis of age and BMI classification to determine whether there were age groups or weight groups that might be more susceptible to weight change, even if there was no overall risk of weight gain. Weight changes according to diagnostic classification were not included in the study because most subjects already had multiple medical conditions that overlapped.

We divided all weight readings into three weight groups (W1, W3, and W5) according to the time points. A repeated-measures ANOVA was performed by SPSS (Chicago, IL) to evaluate differences between these groups. We then evaluated the weight changes on subjects in four different age groups (45–54, 55–64, 65–74, and ≥75 yrs old). After that, we compared the weight changes between the geriatric group (≥65 yrs old) vs. nongeriatric group (<65 yrs old). Finally, we analyzed weight changes among groups with different body mass index classifications (normal, overweight, and obese).

To test the justification of using ANOVA, we analyzed the normality of the data in each weight group and did not see any serious departure from normality. The homogeneity of variance was tested by Levene’s test and led to the result that the assumption holds well. In each univariate approach of the repeated-measures ANOVA tests, Mauchly’s test of sphericity led to a P value of less than 0.001, so the assumption of sphericity did not hold. Therefore, the P value in the repeated-measures ANOVA test had to be adjusted. In our analysis, we used the Huynh–Feldt correction. The multivariate Wilk test was used as a secondary approach to test statistical significance. Therefore, Huynh–Feldt adjusted within-subject P value and multivariate Wilk P value were calculated for statistical significance.

**RESULTS**

During our data-collection process, the main reasons for subjects being excluded from this study were lack of required readings, death during study period, and cancer diagnoses other than skin cancer.

**Characteristics of Subjects, BMI, and Diagnoses**

A majority of the qualified research subjects were male (M:F = 29:1). The subjects’ age range at the time of power mobility evaluation was 45–86 yrs old, with a mean of 69.06 yrs. The population consisted of mostly geriatric subjects (64.0%). The remaining 36.0% of the subjects were between the ages of 45 and 65. None were under the age of 45.

Subjects’ weight at the time of power mobility evaluation ranged from 49.94 to 166.62 kg, with a mean of 98.26 kg. The height of the subjects ranged from 157.48 to 195.58 cm, with a mean of 178.47 cm. The BMI at the time of power mobility evaluation ranged from 49.94 to 166.62 kg, with a mean of 178.47 cm. The BMI at the time of power mobility evaluation was also calculated; the lowest was...
16.64 kg/m², the highest was 55.87 kg/m², and the mean was 30.76 kg/m². According to the BMI standard, 49.4% of our subjects were obese, 31.5% of our subjects were overweight, and 18.0% were normal. Only one subject (1.1%) was underweight.

CHF (30.34%) and COPD (22.47%) were the two main presenting diagnoses for the prescription of power mobility, followed by degenerative joint disease (10.11%), peripheral neuropathy (6.74%), coronary artery disease (5.62%), and rheumatoid arthritis (3.37%) (Table 1). The definition of presenting diagnosis is the primary diagnosis the referring provider used on the power mobility referral consult. Most subjects had multiple medical conditions, so a subject with a primary diagnosis of CHF might have a secondary diagnosis of COPD and/or degenerative joint disease.

### Table 1: Presenting diagnosis category

<table>
<thead>
<tr>
<th>Presenting Diagnosis</th>
<th>Frequency</th>
<th>Rate, %</th>
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<tbody>
<tr>
<td>CHF</td>
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<td>30.34</td>
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<td>COPD</td>
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<td>22.47</td>
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<tr>
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<td>CAD</td>
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<td>5.62</td>
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<tr>
<td>RA</td>
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<td>Renal failure</td>
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<tr>
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</tr>
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<td>Ankylosing spondyloitis</td>
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<td>Cervical stenosis</td>
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<tr>
<td>Cervical spinal disease</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Cardiomyopathy</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Chronic ischemic heart disease</td>
<td>1</td>
<td>1.12</td>
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<tr>
<td>Chronic arthritis</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Deformity of limb</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Lower-back pain</td>
<td>1</td>
<td>1.12</td>
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<td>Diabetes mellitus</td>
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<tr>
<td>Asbestos</td>
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<tr>
<td>Asthma</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>SLE</td>
<td>1</td>
<td>1.12</td>
</tr>
</tbody>
</table>

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DJD, degenerative joint disease; CAD, coronary artery disease; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus.

### Table 2: Overall weight measurement for all subjects

<table>
<thead>
<tr>
<th>Weight Interval</th>
<th>Count</th>
<th>Mean μ, (kg)</th>
<th>Standard Deviation</th>
<th>Standard Error of Mean</th>
<th>Minimum, (kg)</th>
<th>Maximum, (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1 group</td>
<td>89</td>
<td>97.15</td>
<td>23.19</td>
<td>2.46</td>
<td>50.85</td>
<td>171.61</td>
</tr>
<tr>
<td>W3 group</td>
<td>89</td>
<td>98.26</td>
<td>24.64</td>
<td>2.61</td>
<td>49.94</td>
<td>176.61</td>
</tr>
<tr>
<td>W5 group</td>
<td>89</td>
<td>97.91</td>
<td>25.52</td>
<td>2.71</td>
<td>49.94</td>
<td>184.78</td>
</tr>
</tbody>
</table>

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DJD, degenerative joint disease; CAD, coronary artery disease; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus.
The multivariate Wilk $P$ value was 0.070. Therefore, there were no significant differences among the three weight readings between geriatric subjects and nongeriatric subjects.

From analyzing each interval weight mean between both groups, there was no significant interaction between geriatric group and nongeriatric group ($P$ values were 0.322 and 0.128).

**Comparison of W1, W3, and W5 Weight Change in Different BMI Groups**

Our final subgroup analysis looked at the significances in weight change among different BMI groups. The one subject that was underweight (group 1) was not included in the statistical analysis of BMI weight group changes (Table 5). Changes were small and not statistically significant. In the repeated-measures ANOVA test, the Huynh–Feldt adjusted within-subject $P$ value was 0.653, and the multivariate Wilk $P$ value was 0.490. Therefore, there were no significant weight-reading differences among the three readings of the different BMI groups.

From analyzing each interval weight mean among BMI groups, there was no significant interaction among the BMI groups ($P$ values were 0.358 and 0.09).

Out of the 89 subjects we studied, compared with BMI at the time of power mobility evaluation, nine subjects moved to lower BMI class (weight loss), and two subjects moved to higher BMI class (weight gain) 1 yr later. The rest (78 subjects) did not change BMI class.

**DISCUSSION**

Our data show that there is no statistically significant weight change 1 yr after the subjects were provided with power mobility.

Our study population consisted of mostly geriatric subjects (64.0%); 39.3% were 75 yrs and older. The remaining 36.0% of the subjects were

| TABLE 3 Weight readings in different age groups |
|---------------------------|-----------------|-----------------|-----------------|
| Age Group  | Count | Mean Weight at W1, kg | Mean Weight at W3, kg | Mean Weight at W5, kg |
|---------------------------|-----------------|-----------------|-----------------|
| 1 (45–54) | 9 | 86.87 | 88.93 | 91.25 |
| 2 (55–64) | 23 | 105.49 | 108.11 | 104.66 |
| 3 (65–74) | 22 | 104.96 | 105.14 | 106.77 |
| 4 (≥75) | 35 | 89.4 | 89.87 | 89.61 |

**FIGURE 1** Box and whisker plot using the data from W1, W3, and W5 to show mean weight and weight distribution.
between the ages of 45 and 65. None were under the age of 45. This age distribution differs from data reported by LaPlante from data collected in the National Health Interview Survey (NHIS) in 1994 in which users of power mobility devices were more likely to be nonelderly. According to LaPlante, out of 1.7 million adults using wheeled mobility devices, 142,000 used power scooters and 155,000 used power wheelchairs. Of these power scooter users, 45.1% were elderly; 30% of the power wheelchair users were elderly. One possible reason for the discrepancy between our study and NHIS might be related to different prescribing criteria for power mobility. Another possible explanation is a smaller sample size and a shorter cross-section of time that we used in this study.

The population of 75 yrs and older, which in our study was most likely to have been prescribed a power mobility device, grew almost three times as quickly as the total population according to the CDC, from 4 to 17 million. Population growth among older age groups is anticipated, according to this study, to continue to grow more than twice as rapidly as the total population. The body weights of both geriatric and nongeriatric population are increasing, and more people are becoming overweight or obese. The potential effect of power mobility use, including weight gain, becomes more significant as the population continues to age. Given the power of this study, we can state there were no differences in weight among all age groups, including geriatric vs. nongeriatric users, and none for any BMI group except the youngest, for whom statistical power was less because of smaller sample size. Even for that group, the magnitude of any change is small and in the opposite direction.

On the basis of BMI calculation, our subjects were more obese than the general population according to the data collected from the National Health and Nutrition Examination Survey (NHANES) in 1999–2000. In that study, in males ages 40 yrs and older (i.e., the group comparable with our studied subjects), about 31% were obese and about 44% were overweight. Our data support the contention that obese people tend to be more disabled and need more power mobility devices. In our study, the mean weight measured 1 yr after prescription to obese subjects actually decreased, as did the weight of normal BMI subjects who received power wheelchairs or scooters. The mean weight gain of overweight subjects was less than 0.5 kg (not statistically significant). Therefore, addition of power mobility had no effect on their BMI class overall. Our data lend support to the contention that obese people tend to be more disabled and affected by medical conditions and more likely to qualify for power mobility use.

In our study, CHF (30.34) and COPD (22.47%) were the two main presenting diagnoses (Table 3). This was consistent in both geriatric and nongeriatric subgroup. These subjects also had multiple medical comorbidities that were often as severe as the presenting diagnosis for which the subject was initially referred. These additional comorbidities were often used to support the decision regarding qualification for power mobility. The most prevalent conditions in 1994 cited by Kaye et al. as causing mobility limitations among wheeled mobility device users were arthritis (13%), stoke (11%), and multiple sclerosis (5%). These data, however, refer to use of all mobility devices, including manual wheelchairs, rather than just power wheelchairs and scooters. Because Kaye et

<table>
<thead>
<tr>
<th>BMI Group</th>
<th>Count</th>
<th>Mean Weight at W1, kg</th>
<th>Mean Weight at W3, kg</th>
<th>Mean Weight at W5, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (&lt;18.5 kg/m²)</td>
<td>1</td>
<td>Not tested</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>2 (18.5–24.9 kg/m²)</td>
<td>16</td>
<td>69.09</td>
<td>69.63</td>
<td>69.18</td>
</tr>
<tr>
<td>3 (25.0–29.9 kg/m²)</td>
<td>28</td>
<td>88.98</td>
<td>87.96</td>
<td>88.37</td>
</tr>
<tr>
<td>4 (≥30.0 kg/m²)</td>
<td>44</td>
<td>113.41</td>
<td>116.16</td>
<td>115.33</td>
</tr>
</tbody>
</table>
Yang et al.\textsuperscript{10} did not separate the main diagnosis of power mobility users from nonpower mobility users, we cannot compare the significance of the diagnosis difference between our study and the study by Kaye et al. Kaye et al.\textsuperscript{10} further point out that in the 18–64 age group, multiple sclerosis, paraplegia, and cerebrovascular disease are the leading conditions, and in the elderly population (age 65 and older), osteoarthritis and cerebrovascular disease are the leading causes of wheelchair or scooter use. In our study, we did not see differences in the presenting diagnosis between geriatric and nongeriatric subjects. This is because power mobility devices are prescribed in our facility for people who have significant problems with ambulation and problems with the ability to propel manual wheelchairs. Most people who meet these criteria are those with severe CHF, severe COPD, or severe arthritis, regardless of whether they are geriatric or not. Stroke subjects were excluded from our study. Stroke would be ranked the fourth-leading referral diagnosis if it had not been excluded in our study.

Previous studies have shown that despite the growth of the population using wheeled mobility devices, there is no evidence that mobility impairments have increased in the general population.\textsuperscript{2} The increased use of wheeled mobility devices is probably due to improved design, increased societal acceptance, and increased home and community accessibility for wheeled mobility devices. It may also be related to marketing efforts of commercial companies. Moos\textsuperscript{13} cites a statistic that Medicare claims for power wheelchairs soared from $289 million in 1999 to $1.2 billion in 2003, and that in Houston, TX alone, Medicare paid for more than 31,000 power wheelchairs in 2002 compared with 3000 in 2001. There is a need to have a more clear-cut way of deciding eligibility. In our study, we did not see any significant increases in the number of approved power mobility devices during the 17-mo study period; this might be attributable to our standard protocol for power mobility approval, which remained unchanged during the study period.

Our data showed no statistically significant weight change 1 yr after the subjects in our study were provided with power mobility. Our initial hypothesis that the provision of power mobility would have no effect on weight change for adults who qualified for power mobility was confirmed. We believed this would be the case because objective information had to support the patient and provider claims that there was limited physical capacity for community mobility, on a permanent and not a temporary basis. By issuing power mobility to subjects that met those objectives and well defined criteria, only subjects who were already inactive and unable to ambulate or propel a manual wheelchair either within their homes or the community received power mobility. Therefore, this was unlikely to adversely affect their preexisting functional status. Hopefully, their home and community mobility improved and they decreased their overall level of handicap rather than decreasing their overall level of activity.

During our data-collection process, we found that a significant number of subjects died less than 1 yr after their motorized mobility evaluation. They were excluded from this study because of the lack of last weight readings. For this special population who have terminal illness, using a power mobility device loaner program might be a more economically sound decision.

Limitations

One limitation of the study was the weakness inherent in a retrospective study; that is, we could not guarantee that all subjects had the standard care for their medical conditions such as CHF and COPD.

Another limitation of our study was lack of female subjects (only three subjects), which is a limitation observed in most VA medical centers. Another limitation was the number of qualified younger subjects we studied. We need more younger subjects to be more certain on the outcomes. We were unable to address the issues for children, adolescents, or young adults, and whether things could be different at all for older adult women vs. men. We need more diverse subjects if we want to compare the age distribution and diagnosis differences between our study and other bigger studies such as the NIHS.

We cannot comment on the effect of providing power mobility on weight change when power mobility is inappropriately prescribed to groups who do not meet this study’s criteria. Further research to address this question is recommended.

Body weight change evaluates only one aspect of a person’s health status. Other measures such as skinfold thickness, resting heart rate, aerobic capacity, functional status, and quality of life could also be used as health/fitness indicators. Therefore, the effect of power mobility devices on other health/fitness measures may have been missed in our study.

A multisite study to look into the age, BMI, presenting diagnosis distribution of power mobility users, and the effect on physical, functional, and quality of life of the power mobility users, as well as the financial effects on society, is recommended.
CONCLUSIONS

The provision of power mobility does not cause weight change in adult patients who were qualified for power mobility. When based on sound objective criteria, a healthcare provider’s decision to prescribe power mobility should not be affected by the concerns of weight gain with power mobility use.

ACKNOWLEDGMENTS

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The Impact of Diabetes Mellitus on Stroke Acute Rehabilitation Outcomes

ABSTRACT

Objective: To examine the impact of diabetes mellitus (DM) on functional outcomes after acute rehabilitation for cerebrovascular accident (CVA).

Design: A retrospective research design was used to analyze outcomes in patients with a primary diagnosis of unilateral stroke (n = 367) admitted to an urban, acute rehabilitation center in the Southeastern United States.

Results: Multivariable hierarchical regression revealed that DM did not contribute statistically significant variance to stroke acute rehabilitation prediction models. Rehabilitation admission functioning scores, rehabilitation length of stay, age, and stroke type were significant predictors of poststroke rehabilitation motor outcomes ($r^2 = 0.603$) and cognitive outcomes ($r^2 = 0.712$). Diabetes also had no significant impact on acute stroke rehabilitation lengths of stay or rehabilitation discharge setting.

Conclusions: Diabetes does not seem to significantly impact short-term acute rehabilitation outcomes after stroke. Persons with diabetes who suffer a stroke seem to benefit and improve during their acute rehabilitation stay at levels equivalent to peers who are not diagnosed with diabetes. Future research should examine the impact of diabetes subtypes and undiagnosed diabetes on short- and long-term outcomes.

Key Words: Diabetes Mellitus, Cerebrovascular Accident, Stroke, Rehabilitation, Outcome
Cerebrovascular accident (CVA) or stroke is the leading cause of adult disability and the third-leading cause of death in the United States. An estimated 550,000–750,000 strokes occur each year, causing 150,000 deaths and leaving many survivors with long-term neurological impairment. Healthcare expenses and lost productivity costs from stroke are estimated at $49 billion annually. Because stroke has a significant impact on functional capacity, persons who suffer a stroke are typically provided acute multidisciplinary rehabilitation services to facilitate recovery. Given the apparent multifactorial nature of stroke sequelae and recovery, research attention has turned toward identifying factors that improve or impede acute rehabilitation functional outcomes. One medical condition often believed to negatively impact functional outcome after stroke is diabetes mellitus (DM).

DM is a spectrum of disorders characterized by the body’s inability to metabolize glucose. DM is the most common endocrine disorder in the United States and diabetes-related end-organ pathology such as peripheral neuropathy and nephropathy is growing in epidemic proportions. Epidemiology studies indicate that there are approximately 8 million diabetic persons in the United States. DM is also associated with a two- to fourfold increase in cardiovascular deaths, 40% of all new renal-failure cases, and peripheral neuropathy, which is now the leading cause of nontraumatic amputation in the United States.

Because DM has been identified as a risk factor for stroke, cardiovascular disease, renal disease and peripheral neuropathy, clinicians and researchers have expressed concern that DM may also negatively impact recovery and functional outcome after stroke. Although no mechanisms have been empirically identified, researchers hypothesize that the unfavorable effects of DM on brain cells could impede natural recovery after stroke. Increased incidences of comorbidities such as hypertension and cardiac disease, prestroke disability, and peripheral motor impairments secondary to DM might also negatively impact stroke rehabilitation and outcomes.

Most contemporary studies examining the influence of DM on stroke outcomes have been conducted in non-U.S. samples. A Danish study (n = 1135) found that DM significantly impacted mortality rates but did not affect stroke rehabilitation discharge outcomes. Functional recovery in the Denmark study was significantly slower for persons with diabetes than their nondiabetic peers. A multicountry, European clinical trial (n = 4537) revealed that persons with stroke and DM had higher rates of disability compared with persons with stroke and no history of diabetes at 3 mos after stroke. Conversely, a UK study (n = 530) determined that diabetes did not predict functional independence at 6 mos poststroke. Likewise, a German stroke study (n = 1079) found that diabetes was not predictive of survival or complete functional recovery at 100 days after stroke onset. A Polish study (n = 4062) failed to reveal an impact of diabetes on poor functional outcome, defined as either death or severe disability. Finally, data from a small sample in India (n = 72) found that a premorbid diagnosis of DM did not affect functional outcome at 3 mos after stroke.

Stroke outcome models have been studied for some time, and several factors have been consistently linked to outcomes. Stroke severity and initial neurological deficit have been shown to be strongly associated with recovery. Other factors such as age, prestroke disability, and medical comorbidities also seem to significantly impact outcomes and rates of recovery. Etiology is a predictor of outcome; hemorrhagic stroke has been associated with higher mortality rates than embolic or thrombotic stroke, but survivors of hemorrhagic stroke admitted to acute rehabilitation programs typically make greater functional gains.

The primary objective of this study is to identify the impact of DM on stroke rehabilitation functional outcomes. The unique features of this study include an analysis of data from a large urban, American sample, the separate analyses of motor and cognitive functional outcomes after stroke, and an examination of discharge disposition as a primary indicator of disability. The three specific objectives of this study are to

1. describe and compare the characteristics of poststroke patients with and without DM;
2. examine whether DM is a significant predictor in models of poststroke acute rehabilitation functional outcomes; and
3. identify whether patients with DM are more likely than patients without DM to be discharged from stroke rehabilitation to an institutional setting.

METHODS

Setting

This study was conducted at an urban, university-based, acute rehabilitation unit in the southeastern United States. Patients were admitted who met our facility’s standard inpatient rehabilitation criteria. Physiatry consultations were conducted before rehabilitation admission. Typically, at least 3 hrs of therapy were prescribed and completed daily during the rehabilitation hospital stay. Interdisciplinary services provided included physiatry and...
related medical services; nursing; physical, occupational, speech, and recreational therapies; psychological and neuropsychological assessment; and case management/social work services.

Participants
The data in this study was retrospectively retrieved from an archival clinical dataset of all patients admitted for acute rehabilitation services. Participants were included for data selection on the basis of the following criteria:

a. Primary diagnosis of a unilateral stroke
b. A minimum of 5 days of rehabilitation treatment
c. Complete data available for primary variables of study, including FIM scores and length of stay (LOS)

Only patients with clear radiographic evidence of single-hemisphere lesions were included (n = 373) to control for the effects of multiple strokes. All patients admitted to the rehabilitation unit provided informed consent for retrospective use of clinical data for research purposes. Means and standard deviations were calculated on the primary outcome measures (FIM motor total score, FIM cognitive total score, and acute rehabilitation LOS) to identify potential outliers. Six participants had rehabilitation LOS four standard deviations greater than the group mean and were removed from further analyses.

Measures
The following treatment and outcome measures were collected for analysis:

*Stroke diagnosis*: coding of rehabilitation admission diagnosis.
*Diabetes diagnosis*: based on coding of past medical history comorbidities from admission history documentation.
*LOS*: the duration of stay in acute medical care and in acute rehabilitation were calculated separately.

*FIM score*: per standard protocols, motor scores ranging from 13 to 91 and cognitive scores ranging from 5 to 35 were assigned with higher scores denoting greater levels of independence. Scores were derived at the time of rehabilitation admission and discharge. The FIM has demonstrated high levels of stability, reliability, and construct validity.29–31

*FIM change scores*: calculated on the basis of the difference between each patient’s rehabilitation discharge vs. rehabilitation admission rating.

*FIM efficiency scores*: were calculated by dividing each patient’s FIM change score by their respective LOS.

Data Collection
All patients were evaluated per standard clinical procedures with data originally recorded in the hospital medical record. Admission data collected and used in this study were demographic information including age, gender, marital status, and ethnicity; injury-related information including etiology and lateralization of the lesion; acute care discharge date; and diabetes diagnostic information. Data collected at discharge included acute rehabilitation discharge data and discharge destination. Uniform Data System–certified rehabilitation professionals rated patients on the FIM on admission to rehabilitation (within 72 hrs) and again within 24 hrs of discharge. Resident physicians and a research assistant recorded the information from the medical record into the research data file on a password-protected, internal network. Data for each patient were assigned a unique nonidentifying number to protect patient privacy in compliance with the Health Insurance Portability and Accountability Act of 1996 regulations. Quality control checks were conducted to assure the data integrity.

Data Analyses
All data analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 11.5. Descriptive statistics, including proportions, means, and standard deviations were compiled for all demographic, injury and outcome measures. Qualitative and quantitative statistical analyses were conducted to examine differences between the DM and non-DM groups on demographic and injury-related variables. To examine qualitative variable (e.g., gender, ethnicity, marital status, stroke lateralization, and stroke etiology) differences between groups, Cramer’s V was calculated to derive a product moment r value corrected for sample size and number of categories. Cramer’s V can range from 0.000–1.000 with higher values denoting more substantial group differences. To examine quantitative variable (e.g., age, length of acute medical care stay) differences between groups, one-way analysis of variance (ANOVA) procedures were conducted. When between DM group differences were identified on demographic and injury-related variables, ANOVA was conducted to identify potential demographic and injury-related covariates of stroke outcomes.

Bivariate analyses were conducted to examine the relationship between each covariate/predictor variable, all other covariate/predictor variables, and the functional outcome measures. When bivariate analyses revealed highly correlated covariate/pred-
dictor variables \( r \geq 0.70 \), one of each pair was deleted. To test for normality, descriptive statistics—means, medians, standard deviations, ranges, skewness, and kurtosis—were compiled for all continuous predictor and outcome measures. To test for linearity and homoscedasticity, bivariate scatter plots were examined.

For the two multivariable regression analyses, a hierarchical approach was used. Categorical variables were dummy coded as 0 or 1, representing the presence or absence of a particular variable. Four blocks of predictors were entered into the regression analysis in the following hierarchical order: (1) rehabilitation admission functional score, (2) rehabilitation LOS, (3) gender and/or age, and (4) injury etiology (embolic and hemorrhagic). The final block entered was DM diagnosis. For the multivariable regression models, \( R^2 \) change evaluated the proportion of variance contributed by predictor variables (each block) to each outcome measure. \( R^2 \) values range from 0 to 1, with values closer to 1 indicating a more predictive model.

Cramer’s V was calculated to determine whether there was a difference in discharge disposition between DM and non-DM patients. Given the limited number of planned comparisons and minimal potential for familywise error rates, an alpha level of \( P < 0.05 \) was deemed acceptable.

**RESULTS**

**Demographics**

The sample \((n = 367)\) was predominantly female (53%). Patients’ mean age at time of admission was 62.9 yrs (SD = 13.7; median = 64 yrs) and ranged from 20 to 96 yrs. African Americans comprised 67% of the sample; 32% were Caucasian, and 1% were of other ethnic backgrounds. With regard to marital status, 41% were married, 26% were widowed, 19% were never married, 9% were divorced, and 4% were separated.

| TABLE 1 Demographic and injury comparisons between diabetes and nondiabetes groups |
|---------------------------------|-----------------|-----------------|-----------------|------|
| **A. Qualitative Variables**    |                 |                 |                 |     |
|                                  | **Group Distributions, %** |                 |                 |     |
|                                  | **Diabetes** \((n = 114)\) | **Nondiabetes** \((n = 253)\) | **Cramer’s V** | **P** |
| Gender                          |                 |                 |                 |     |
| Female                          | 62              | 48              | 0.130           | 0.013|
| Male                            | 38              | 52              |                 |     |
| Ethnicity                       |                 |                 |                 |     |
| African American                | 71              | 64              | 0.076           | 0.547|
| Caucasian                       | 27              | 34              |                 |     |
| Other                           | 2               | 2               |                 |     |
| Marital                         |                 |                 |                 |     |
| Married                         | 47              | 39              | 0.160           | 0.052|
| Widowed                         | 28              | 26              |                 |     |
| Single                          | 11              | 23              |                 |     |
| Divorced                        | 8               | 10              |                 |     |
| Separated                       | 6               | 3               |                 |     |
| Stroke Lateralization           |                 |                 | 0.044           | 0.403|
| Left Hemisphere                 | 48              | 53              |                 |     |
| Right Hemisphere                | 52              | 47              |                 |     |
| Stroke Etiology                 |                 |                 | 0.289           | <0.001|
| Lacunar                         | 47              | 23              |                 |     |
| Thrombotic                      | 28              | 29              |                 |     |
| Hemorrhagic                     | 14              | 39              |                 |     |
| Embolic                         | 11              | 10              |                 |     |
| **B. Quantitative Variables**   |                 |                 |                 |     |
|                                  | **Group Means and SDs** |                 | **ANOVA**       |     |
|                                  | **Diabetes** \((n = 114)\) | **Nondiabetes** \((n = 253)\) | **F** | **P** |
| Age at rehab admission           | 63.7 ± 12.6     | 62.5 ± 14.2     | 0.57            | 0.452|
| Acute care length of stay, days | 9.4 ± 7.7       | 10.2 ± 8.7      | 0.59            | 0.444|

*Because of rounding, some percentages do not add up to 100%.*
Injury, treatment, and comorbidity-related data were also computed. Patients with left-hemisphere strokes comprised 52% of the total sample. With regard to stroke etiology, 31% were hemorrhagic, 30% lacunar, 29% thrombotic, and 10% embolic. The acute care LOS ranged from 1 to 56 days, with a mean of 9.9 days (SD = 8.4; median = 7 days). Patients’ acute rehabilitation LOS ranged from 5 to 68 days, with a mean of 20.0 days (SD = 7 days). Patients who had a hemorrhagic stroke etiology had better motor discharge scores and rates of motor and cognitive improvement during acute rehabilitation. Stroke etiology did not impact acute rehabilitation LOS ($F = 0.93$, $P = 0.424$) or discharge home vs. other setting (Cramer’s V = 0.062, $P = 0.705$). Because of the significant effects of hemorrhagic stroke etiology on cognition and motor outcomes, hemorrhagic stroke also was treated as one of the covariates (predictors) when examining the impact of diabetes on stroke cognitive outcomes.

Stroke etiology had profound impacts on measures of cognitive and motor functioning (see Table 2). Patients who had a hemorrhagic stroke etiology had better motor discharge scores and rates of motor and cognitive improvement during acute rehabilitation. Stroke etiology did not impact acute rehabilitation LOS ($F = 0.93$, $P = 0.424$) or discharge home vs. other setting (Cramer’s V = 0.062, $P = 0.705$). Because of the significant effects of hemorrhagic stroke etiology on cognition and motor outcomes, hemorrhagic stroke also was treated as one of the covariates (predictors) when examining the impact of diabetes on stroke functional outcomes.

**Impact of DM on Stroke Motor Outcomes**

On the basis of bivariate correlations and univariate analyses, six independent variables were identified as potential predictors of stroke motor outcomes: age, embolic etiology, hemorrhagic etiology, DM status, acute rehabilitation LOS, and FIM motor admission score. Table 3 displays the cumulative $R^2$ for each successive block entered, the $R^2$ change for each block, and statistical significance ($P$) of each block entered. The first four blocks entered (FIM motor admission, acute rehabilitation LOS, age, and hemorrhagic and embolic etiology) were each significant and contributed 60.3% in shared variance to the prediction model for acute rehabilitation stroke motor outcomes. FIM motor admission scores individually accounted for the largest variance (52.0%). Diabetes was not a significant predictor of acute rehabilita-

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**TABLE 2 Impact of stroke etiology on acute rehabilitation functional scores**

<table>
<thead>
<tr>
<th>Stroke Etiology Group Means and SDs</th>
<th>ANOVA and Tukey post hoc Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
</tr>
<tr>
<td>Hemorrhagic ($n = 114$)</td>
<td></td>
</tr>
<tr>
<td>FIM motor admission</td>
<td>37.5</td>
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<tr>
<td>FIM motor discharge</td>
<td>61.8</td>
</tr>
<tr>
<td>FIM motor efficiency</td>
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<td>17.9</td>
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<tr>
<td>FIM cognitive discharge</td>
<td>23.9</td>
</tr>
<tr>
<td>FIM cognitive efficiency</td>
<td>0.30</td>
</tr>
<tr>
<td>Lacunar ($n = 110$)</td>
<td></td>
</tr>
<tr>
<td>FIM motor admission</td>
<td>39.5</td>
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<tr>
<td>FIM motor discharge</td>
<td>57.2</td>
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<tr>
<td>FIM motor efficiency</td>
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</tr>
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<td>FIM cognitive admission</td>
<td>22.0</td>
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<td>FIM cognitive discharge</td>
<td>24.6</td>
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<tr>
<td>FIM cognitive efficiency</td>
<td>0.16</td>
</tr>
<tr>
<td>Thrombosis ($n = 105$)</td>
<td></td>
</tr>
<tr>
<td>FIM motor admission</td>
<td>38.9</td>
</tr>
<tr>
<td>FIM motor discharge</td>
<td>56.8</td>
</tr>
<tr>
<td>FIM motor efficiency</td>
<td>0.97</td>
</tr>
<tr>
<td>FIM cognitive admission</td>
<td>20.0</td>
</tr>
<tr>
<td>FIM cognitive discharge</td>
<td>23.6</td>
</tr>
<tr>
<td>FIM cognitive efficiency</td>
<td>0.19</td>
</tr>
<tr>
<td>Embolic ($n = 38$)</td>
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</tr>
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<td>35.3</td>
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<tr>
<td>FIM motor discharge</td>
<td>48.1</td>
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<tr>
<td>FIM motor efficiency</td>
<td>0.77</td>
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<tr>
<td>FIM cognitive admission</td>
<td>20.9</td>
</tr>
<tr>
<td>FIM cognitive discharge</td>
<td>23.3</td>
</tr>
<tr>
<td>FIM cognitive efficiency</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Results in boldface type are statistically significant.

FIM efficiency scores = (FIM discharge score – FIM admission score)/rehabilitation LOS.

H, hemorrhagic; L, lacunar; T, thrombosis; E, embolic.
tion stroke motor outcomes, contributing only 0.4% of the variance.

**Impact of DM on Stroke Cognitive Outcomes**

On the basis of bivariate correlations and univariate analyses, seven independent variables were identified as potential predictors of stroke motor outcomes: age, gender, embolic etiology, hemorrhagic etiology, DM status, acute rehabilitation LOS, and FIM cognitive admission score. In Table 4, the first four blocks entered (FIM cognitive admission, acute rehabilitation LOS, age and gender, and hemorrhagic and embolic etiology) were each significant and contributed 71.2% in shared variance to the prediction model for acute rehabilitation stroke cognitive outcomes. FIM cognitive admission score individually accounted for the largest variance (66.9%). Diabetes was not a significant predictor of acute rehabilitation stroke cognitive outcomes; it contributed 0.1% of model variance.

**Impact of Diabetes on Rehabilitation LOS and Discharge Home**

One-way ANOVA revealed that diabetes had no significant effect on stroke patients’ acute rehabilitation LOS. Stroke patients with and without diabetes had mean rehabilitation stays of 20.4 and 19.8 days, respectively. Cramer’s V indicated that diabetes had no significant effect on stroke patients’ discharge setting (see Table 5). Persons with stroke and diabetes were discharged home at a rate equivalent to that of persons with stroke and no diabetes.

**DISCUSSION**

Clinicians and researchers have been concerned that the presence of DM adversely impacts recovery after stroke. Thus far, most contemporary studies of DM and stroke have been conducted in Europe and these studies have not found that persons with diabetes have worse short-term functional outcomes after stroke. Unfortunately, many studies have used global outcome measures such as mortality or single item ratings of disability/severity. Only the European Clinical Trial reported a significant negative impact for diabetes on short-term functional outcomes, however, a close examination of their data raises questions about the investigator’s conclusions. For instance, the diabetes–stroke group had significantly higher rates of prestroke disability and hypertension compared with the stroke-only group. Thus, it is difficult to determine whether higher levels of disability were a result of prestroke differences or were attributable to the interaction of diabetes with stroke.

In the current study, persons with DM and stroke had functional outcomes, home discharge rates, and rehabilitation LOS that were equivalent to persons with stroke alone, which add support to findings obtained in some European trials. The importance of analyzing hemorrhagic stroke as a potential covariate in studies of diabetes and stroke outcomes cannot be underappreciated. In our study, persons with hemorrhagic stroke had

| TABLE 3 Hierarchical regression model for diabetes and stroke motor outcomes (dependent variable: discharge FIM motor score [n = 367]) |
|---|---|---|---|
| Block | Variables | Cumulative $R^2$ | $R^2$ Change | Signif. ($P$) $R^2$ Change |
| 1 | FIM motor (admission) | 0.520 | 0.520 | <0.001 |
| 2 | Rehabilitation LOS | 0.549 | 0.029 | <0.001 |
| 3 | Age | 0.580 | 0.031 | <0.001 |
| 4 | Hemorrhagic etiology/embolic etiology | 0.603 | 0.023 | <0.001 |
| 5 | Diabetes mellitus | 0.607 | 0.004 | 0.076 |

| TABLE 4 Hierarchical regression model for diabetes and stroke cognitive outcomes (dependent variable: discharge FIM cognitive score [n = 367]) |
|---|---|---|---|
| Block | Variables | Cumulative $R^2$ | $R^2$ Change | Signif. ($P$) $R^2$ Change |
| 1 | FIM cognitive (admission) | 0.669 | 0.669 | <0.001 |
| 2 | Rehabilitation LOS | 0.680 | 0.011 | <0.001 |
| 3 | Age/gender | 0.692 | 0.012 | 0.001 |
| 4 | Hemorrhagic etiology/embolic etiology | 0.712 | 0.020 | <0.001 |
| 5 | Diabetes mellitus | 0.713 | 0.001 | 0.277 |
significantly better outcomes than persons with ischemic stroke independent of a diabetes diagnosis. Consistent with other outcome studies, initial neurologic/functional deficit, age, and rehabilitation LOS were also significant predictors of motor and cognitive outcomes after stroke. Not surprisingly, the preponderance of variance in stroke motor and cognitive functional outcomes seems to be accounted for by initial neurologic functional impairment.

Most importantly, persons with diabetes who suffered a stroke significantly benefited from their acute rehabilitation. Compared with persons with stroke alone, persons with diabetes had equivalent poststroke functional recovery, equivalent rehabilitation LOS, and were just as likely to be discharged home. Consequently, clinicians should be optimistic regarding the rehabilitation potential of persons with diabetes and stroke.

Despite the encouraging outcomes observed in the current study, the effects of hyperglycemia on tissue health and healing are well documented. Thus, rehabilitation professionals should be familiar with the implications and management of DM. The presence and management of hyperglycemia during the recovery period after stroke may be more important than simply a diagnosis of DM. Because physiatrists are typically attuned to hyperglycemia during rehabilitation, it is likely that patients in this study were well managed regarding their glucose levels. Exercise has also been shown to increase endogenous levels of insulin in hypertensive subjects and may have protective effects. Persons with diabetes should be encouraged to adopt and continue exercise programs that may assist in long-term recovery from stroke while helping with glucose metabolism.

**Limitations**

Although this study benefited from having a large sample size and psychometrically valid measures of motor and cognitive outcomes, several methodological limitations should be noted. Because of the retrospective nature of the data analysis, no data were available distinguishing type I from type II diabetes or the duration of the DM diagnosis. The limitations of our database also precluded glycemic control analysis in stroke recovery, an area that needs more research. We also have no long-term follow-up data on stroke patient outcomes. Thus, there remains a possibility that a combination of DM severity and disease duration may create a tipping point in which DM has a deleterious long-term interaction effect on stroke outcomes. Additionally, our sample predominantly comprised African Americans from an urban setting, which may not generalize to all samples of persons with diabetes and stroke, though it matches other observations of stroke demographics in the Southern United States. Lastly, individuals in this database constitute persons with stroke who were appropriate referrals for inpatient rehabilitation. Thus, there is a preselection bias that precludes persons with either very mild or very severe stroke impairments from being part of the study sample.

**CONCLUSIONS**

Growing evidence suggests that diabetes has little impact on acute rehabilitation functional outcomes after stroke. Persons with diabetes who suffer a stroke seem to benefit and improve during their acute rehabilitation stay at levels equivalent to peers who are not diagnosed with diabetes. Further investigation is warranted to examine the impact of diabetes subtypes and undiagnosed diabetes on short- and long-term outcomes.

**REFERENCES**


| TABLE 5 Impact of diabetes on discharge disposition after acute stroke rehabilitation |
|-----------------------------------|-------------------|------------------|---------|
| Diabetes Diagnosis, %             | No (n = 253)      | Yes (n = 114)    | Cramer’s V | P     |
| Discharge setting                 |                   |                  | 0.011    | 0.831 |
| Institutional                     | 19                | 18               |          |       |
| Private residence                 | 81                | 82               |          |       |

_Institutional_ includes nursing homes, group living arrangements, and hospitals.
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Physical Medicine and Rehabilitation Conditions in the Astrodome Clinic After Hurricane Katrina

ABSTRACT

Objective: To report the physical medicine and rehabilitation (PMR) conditions seen in the Astrodome Clinic after Hurricane Katrina.

Design: Retrospective chart analysis from the county hospital–sponsored disaster-relief clinic in large urban city, including a study of 239 patients with 292 PMR conditions. The total number of patients seen in the Astrodome Medical Clinic was 11,245. The Astrodome database was reviewed for PMR condition diagnostic codes. A retrospective chart analysis was conducted, including date of visit, age, gender, ethnicity, and PMR diagnosis category. Descriptive statistics were obtained for the entire sample. \( \chi^2 \) or \( t \) tests were used to determine gender, age, or date-of-service predominance for the most common diagnostic categories.

Results: Mean \( \pm \) SD age was 45.7 \( \pm \) 14.3 yrs; 56% were women, 43% were men (1% unspecified), and 76% were African American. The majority (75%) of PMR conditions presented in the first week. Most frequent were swollen feet and legs (22%), leg pain and cramps (17%), headache (12%), and neck and back pain (10%). Persons with headaches were younger than those without (41.3 vs. 46.3 yrs, \( P = 0.048 \)). Persons with neck and/or back pain were older than those without those conditions (51.3 vs. 44.8 yrs, \( P = 0.004 \)). Women had more headaches (20.9%) than did men (6.7%, \( P = 0.002 \)). There were no Caucasians with leg pain/cramps, whereas 20.2% of African Americans had this condition (\( P = 0.028 \)).

Conclusions: This study documents the time of clinic presentation and most frequent types of PMR conditions of patients treated in the Astrodome Clinic after a historic hurricane. Most PMR conditions were treated by PMR personnel during the first week. Thus, future disaster planning should include PMR professionals as early responders.

Key Words: Disaster Preparedness, Physical Medicine and Rehabilitation, Hurricane, Emergency Relief
Hurricane Katrina, a category 4 hurricane, struck New Orleans on August 29, 2005. Tens of thousands of people who were stranded in the New Orleans Superdome were evacuated to the Houston Astrodome 3 days later on September 1, 2005. Many stood or sat for long hours, some in flood waters, waiting to be rescued. Approximately 27,000 persons were eventually housed and fed in the Astrodome. The effort was given the name Operation Dome Shelter by the federal government.

Creation of The Astrodome Center Medical Clinic

The Astrodome Medical Clinic was created within 12 hrs. The Harris County Health Department, under Dr. Herminia Palacio, directed the Harris County Hospital District and Baylor College of Medicine with the organization and implementation of this clinic. The Ben Taub Hospital is a level I trauma hospital that is part of the Harris County Hospital District. The Harris County Hospital District physicians and staff were expected to be first-line disaster-relief personnel in this disaster. All specialties were expected to participate. Within the next 19 days, 11,245 patients were seen in the Astrodome Clinic. Exam rooms were constructed from convention hall display-booth curtains, including a curtain in the front for privacy. The rooms were positioned in a square surrounding a central medical command center that had code-blue “crash” carts, a medication cart, and supplies. A medical leader also worked at the command center to answer volunteers’ questions and to facilitate operations. Mobile pharmacy, pathology, and radiology laboratories were available in the parking lot outside of the medical clinic. A “taxi” line of ambulances transported patients requiring inpatient admission to nearby hospitals. Identification wristbands were needed to enter the medical clinic. Security guards were positioned at entrances and exits to the medical clinic. They were also positioned with metal detectors at every entrance and exit of the Astrodome. The details of the infrastructure and implementation of this clinic can be found in Gavagan et al.1

Physical Medicine and Rehabilitation Participation and Needs in The Astrodome

The Harris County Hospital District Physical Medicine and Rehabilitation (PMR) chief and assistant chief of service were the first PMR physicians on-site for disaster relief. This was soon followed by PMR physicians from Baylor College of Medicine and affiliated hospitals, then practitioners from the surrounding area. In the first few days, efforts were focused on general disaster relief and acute medical care. This included code blues, acute dehydration, rhabdomyolysis, and illnesses related to going several days without medication. It is not appropriate in such a setting to single out and treat only patients with PMR conditions; however, with the multitude of specialties available, PMR patients were triaged to PMR when possible. It soon became apparent, after the initial influx of critical patients, that there were acute PMR issues that needed to be addressed. These included mobility devices, wound-care materials, intermittent catheter kits, and refills for baclofen and pain pumps. The full report of the authors’ eyewitness experiences is documented by Bloodworth et al.2

PMR Conditions Analysis Overview

The goal of this paper is to describe the range and frequency of PMR conditions and the dates they presented to the Astrodome Clinic. In addition, the relations of age, gender, race/ethnicity, and date of service to the four most frequent types of conditions treated are described. This information will be needed to provide adequate staffing and supplies in advance of future hurricanes, floods, or other disasters.

METHODS AND MATERIALS Participants

A retrospective analysis was performed of the medical charts of the 11,245 persons seen in the Astrodome Medical Clinic from September 1, 2005 through September 19, 2005. Each chart was reviewed and assigned diagnoses codes by the billing office of the Harris County Hospital District. Researchers in the department of family and community medicine organized these codes into general body-system categories, such as skin, respiratory, genitourinary, etc. All categories within the entire database were reviewed by the authors to identify PMR diagnoses. These were defined as PMR conditions for which general and trauma rehabilitation commonly receive consultation requests. Trauma rehabilitation is a relatively newly identified area of expertise in physiatry. The physiatrist that specializes in trauma rehabilitation is called a rehabilitation traumatologist.3 An example of certification for trauma rehabilitation service is available in the text Trauma Rehabilitation by Robinson.3 For example, leg or arm swelling is a condition for which general rehabilitation is occasionally consulted; however, it is frequently a condition for which trauma rehabilitation is consulted. This is because after trauma, there is profound swelling from the trauma itself, or a disruption of venous or lymphatic return that sometimes requires fasciotomy and skin grafts to prevent compartment syndrome. This is later followed by custom pressure garments to reduce swelling.
Procedures

Approval was obtained for chart review from the local hospital and institutional review boards. Demographic data (age, gender, and race/ethnicity) were gathered from the Astrodome database. The medical chart was then pulled for each patient, who received a medical code with a PMR condition. Each chart was reviewed by all of the physician authors to confirm the correct diagnosis. A separate database containing only PMR conditions was created. The conditions were reclassified into 16 diagnostic categories (Table 1). The data on conditions were merged with the appropriate demographic information.

Statistical Analyses

Descriptive statistics were obtained, including the means, standard deviations, and ranges for age and date of service and number and percentage for categorical variables (gender, race/ethnicity, diagnosis category). The relations of age and date of service to the four most frequent diagnostic categories were assessed with $t$ tests. $\chi^2$ tests were used to assess relations of the four most frequent diagnostic categories with gender and race (African American or Caucasian). There were too few Hispanics ($n = 7$) to include in the analyses, and those categorized as other race/ethnicity were also excluded. Because 16 analyses were conducted, some of the results indicating a significant relation may have been found by chance. However, because the purpose of this paper is descriptive rather than testing a research hypothesis, it was determined that $P$ value adjustment was not necessary, and 0.05 was set as the significance level.

RESULTS

Demographic Data

Two hundred thirty-nine patients were included in the study. The mean ± SD age was 45.7 ± 14.3 yrs. The age range was 18–88 yrs (see Figure 1 for the age-distribution curve). Age was not specified for eight (2.1%) persons. There were 56.1% women and 43.1% men in the study. For 0.8%, gender was not specified. Race/ethnicity distribution was 76.2% African American, 7.1% Caucasian, 2.9% Hispanic, 10.5% other, and 3.3% unspecified.

Date of Service

The majority (74.4%) of patient visits for PMR conditions occurred within the first 7 days of the clinic (Fig. 2). This corresponds to the fact that the majority of patients were seen in the clinic during the first week (Fig. 3). Date of service was missing for 10 (4.1%) of the 245 clinic visits.

PMR Conditions

Among the 239 patients, there were 289 PMR-related conditions. One hundred ninety-four (81.2%) had one PMR-related condition, 38 persons (16%) had two PMR conditions, six (2.5%) had three PMR conditions, and one (0.4%) had four PMR conditions. Follow-up visits for the same condition were excluded from the analyses. Six (2.4%) persons had two clinic visits for different PMR conditions. The most frequent PMR conditions were swollen feet and legs, leg pain and cramps, headache, and neck and back pain (see Fig. 4 and Table 1). The majority of the musculoskeletal arm, leg, and trunk diagnoses can be described as pains, strains, sprains, pulls, and tendonitis/fasciitis. These would be expected in harsh physical conditions. The remaining musculoskeletal problems were exacerbations of more generalized chronic conditions, such as arthritis and fibromyalgia.

Age Differences

Persons with headaches were significantly younger than those without (41.3 vs. 46.3 yrs, $P = 0.048$). Persons with neck and/or back pain were older than those without (51.3 vs. 44.8 yrs, $P = 0.004$). Women had more headaches than did men (20.9% vs. 6.7%, $P = 0.002$, forward exact). All six patients with prior stroke who presented were men. There were no Caucasians who presented with leg pain and/or cramps, whereas 20.2% of African Americans reported leg pain or cramps ($P = 0.047$). Persons with headaches presented approximately 1.5 days later than persons without headaches (6.85 vs. 5.33 days, $P = 0.010$).

DISCUSSION

Literature

There is little literature on rehabilitation issues in short-term disaster situations. Eldar4 discusses preparation of an intact hospital to receive rehabilitation patients in a war zone. That situation differed from this one for several reasons. First, this situation required the creation of a clinic in the field. Second, this was not in a war zone. Eldar’s paper describes therapy and supply staffing ratios. This applies to the situation after Hurricane Katrina, but different types of personnel and supplies were needed. As an example, there were many volunteers, but few had knowledge of transfer techniques appropriate for the disabled population.

Lim et al.5 have described the impact of a viral respiratory epidemic on the practice of medicine during the severe acute respiratory syndrome (SARS) outbreak. This also was a different type of situation—an infectious disease outbreak in an intact hospital. Although an outbreak of acute gastroenteritis from norovirus affected about 1000
<table>
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<th>Category</th>
<th>Number</th>
<th>Percentage of 239 Persons</th>
<th>Percentage of 289 Conditions</th>
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<td>Swollen feet or legs</td>
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<td>Leg pain and cramps</td>
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<td>4</td>
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<td>1.38</td>
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<td>1.26</td>
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<td>TOTAL</td>
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persons in the Astrodome, this did not affect the persons with PMR conditions. Thus, these first two articles provide little in common with the Hurricane Katrina disaster and how to prepare for one.

More recently, an executive summary assessing the impact of Hurricane Katrina on persons with disabilities was issued by the Universities of Kansas and New Mexico, funded by the National Institute on Disability and Rehabilitation Research. It identifies three significant gaps. These included (1) predisaster planning, (2) pre- and postdisaster communication and information sharing, and (3) pre- and postdisaster coordination deficiencies. This resource discusses this disaster from a national programmatic, rather than medical planning, perspective. However, it highlights the important fact that there is a need for advanced planning and good communication/coordination.

There has been much public criticism of the rescue efforts in this hurricane; however, this is an example in which the medical efforts fortunately succeeded. This can be credited to strong leadership at the state, county, and city levels. In addition, the trust earned by the Harris County Administration, chiefs of staff, and chiefs of services in their leadership abilities and motivations was essential. This was evident within the Astrodome Clinic itself, perhaps because the chiefs of services were already accustomed to working well with each other in the hospital district. Practice from prior hurricanes allowed for efficient execution of services. Computer Internet Web access in the Astrodome allowed the physician services department to quickly verify the authenticity of physician volunteers with the Texas state board. Finally, assistance from private corporations and organizations that sent mobile services from across the country, amassed legions of volunteers, and donations were critical once the frontline staff began to show signs of physical fatigue and run out of resources.

Discussion of Demographic Data

There is an expected bell-shaped age-distribution curve, despite the media preference to record the elderly and children. The fact that most of the patients were African American is consistent with most media reports. There was a fairly even distribution of men and women.

Discussion of Timing of Visits and PMR Intervention

It was interesting to note that most of the patients with PMR conditions came to the clinic in the first few days, as did most of the patients in general. Because it is often assumed that patients with PMR conditions would not have presented initially, because the rehabilitation phase comes after the acute trauma phase, PMR physicians who volunteered early did so to help with general medicine. The authors were surprised to learn that there were several PMR issues that needed to be resolved during the first few days. Issues that arose included a need for foam mattresses, mobility devices, wound-care products, intermittent catheterization kits, refill systems for baclofen and narcotic pumps, and persons trained in cot-to-wheelchair transfers. In particular, there initially were only a handful of wheelchairs available, with no other assistive devices or mobility aids, despite an abundance of wooden crutches. Families resorted to grocery carts from nearby stores to transport loved ones until volunteers mobilized in the next few days to supply and donate enough adult and pediatric mobility aids. Wound-care and intermittent catheter kits were obtained from nearby hospitals. The timing of PMR-related visits (Fig. 2) supports the need for PMR intervention early in disaster relief.

As noted by Bloodworth et al., problems arose when requests for narcotic pain medications and pain pump refills were made. Understandably, there was reluctance on the part of general practitioners to refill narcotics without prior documentation. This would include old pill bottles or medical records. However, it is also understandable that someone who had just experienced life-threatening floodwaters and had everything swept away including their personal identity cards (driver’s license and wallet) would not have such items. In addition, the medical records in Louisiana were not available because of a lack of electricity to access electronic records or destruction of paper records by flood waters. In the end, the American Academy of Pain Medicine and Substance Abuse and Mental Health Service Administration were called in at a national level for assistance. These national organizations with assistance from private pump vendors provided a patient list and made recommendations on refilling pain medication prescriptions for Katrina/Rita disaster victims. In general, the American Academy of Pain Medicine recommends
(a) believing patients when they complain of pain, 
(b) meeting the need for short-term continuation 
of opioids, and (c) increasing follow-up frequency. 
The Substance Abuse and Mental Health Service 
Administration has provided information about 
signs and symptoms of abrupt withdrawal from 
medication. The recommendations can be viewed 
at the following Internet Web sites7,8:
1. www.samhsa.gov/csatdisasterrecovery/featured 
   reports/hurricanephysicianrecommendations.pdf
2. www.samhsa.gov/csatdisasterrecovery/featured 
   reports/Abrupt%20Withdrawal.pdf

**Discussion of Type of PMR Conditions**

Most of the PMR-related visits were musculo-
skeletal in origin and related to the legs and spine. 
Patients reported that they stood or sat for several 
days (many in flood water), which could account 
for much of the leg swelling and pain. The locations 
in which they stood or sat were harsh. These 
included tree limbs, roofs, small sections of Inter-
state 10 (in which moving and changing positions 
would cause someone to fall and possibly drown in 
the surrounding flowing waters), and crowded 
transport buses. The buses were extremely crowded, 
such that it was difficult for people to be removed 
on arrival to the Astrodome. In each case that a 
deep venous thrombosis was suspected and a Doppler 
scan ordered, the scan was negative for deep 
venous thrombosis. Many of the patients also had a 
skin rash, cellulitis, or trench foot (a term from 
World Wars I and II; also known as immersion foot)
from the floodwater. The number of reported neck- and back-pain patients is not surprising, given the harsh physical conditions and the fast-moving flood waters and rescue efforts.

It is not surprising that there were few spinal cord–injured, amputee, or stroke patients who visited, proportionate to the population as a whole. Those who did visit came for common complications of those respective diagnoses, such as requests for intermittent catheterization, wound care, bowel and bladder issues, and hypertension medications.2

Age, Gender, and Race/Ethnicity Differences

It is not surprising that persons with back and neck pain were older. It is not known why women had more swollen legs than did men. The authors can only hypothesize that perhaps the women had a greater premorbid risk for varicose veins, given the general middle-aged distribution and, therefore, possible venous stasis; however, other research would be needed to prove this. It is known that women have more migraines than do men; however, only 5 of 36 patients with headache were classified as migraine. It is known that tension headaches are equally distributed between women and men. It is possible that more of the headaches were migraines but were not recorded as such in the medical record.

Limitations of Study

There are several limitations to this study. The first is that it is a retrospective study; thus, control of the variables was not possible. It would not be appropriate to do a prospective study in the middle of life-saving triage efforts. The second is that multiple specialties were called on to care for patients who did not fall into the physicians’ usual subspecialties. Thus, it is very possible that patients received more generalized, rather than specific, diagnoses (e.g., leg pain rather than tendonitis or shin splint). Third, the sheer massive number of emergent patients who needed to be triaged during the first several hours and days limited documentation efforts. This situation could account for the fact that in this PMR subsample, 2% of charts had no age recorded, 1% had no gender recorded, 3% had no ethnicity recorded, and 4% had no date of service recorded. Fourth, the coding of patients and entry into the Astrodome Clinic database could have some errors. It would be impossible to know which ones were flawed without reviewing all 11,000 charts. Efforts were made to confirm that the coding was performed correctly for the 239 patients in this sample. Fifth, comparisons based on race/ethnicity were limited by the uneven distribution among the racial/ethnic groups, and 14% were categorized as other race/ethnicity or had no race/ethnicity recorded. Lastly, future prospective research would not be appropriate, because no one would wish to recreate this disaster.

CONCLUSIONS

Hurricane Katrina and the medical response to this disaster were a historic event from which lessons can be derived. It has demonstrated that PMR physicians have an important role as early participants in medical treatment after a natural disaster. In terms of hurricane preparedness for rehabilitation healthcare providers, it implies early participation from the field of PMR. This study also pro-
vides a profile of the types of PMR conditions with which the patients might present, such as swollen or painful legs and feet, headache, and neck and back pain. This information will assist healthcare providers and administrators to anticipate the types of supplies (e.g., wound care, foam mattresses, compression hose, antibiotics, pain medications), assistive devices (walkers, wheelchairs, scooters, and not simply wooden crutches), and personnel needed to address the PMR-related health problems that arise acutely after a natural disaster such as Hurricane Katrina.

Planning for the Future

With hurricane season an annual event along the Gulf Coast states, the lessons derived from Hurricane Katrina were applied immediately at the hospital district in preparation for the next one. After a debriefing session of all the chiefs of services, a compilation of “lessons learned” was created by specialty. Personal contact information was updated for all physicians. This included whether the physician needed to evacuate and provide alternative care for their own elderly or young family members. This is especially relevant in families in which both parents are physicians and are expected to respond. Designation and contracts detailing obligations and consequence of abandonment of duties with level I (immediate) and level II (relief) responders of hospital staff were updated. Disaster-preparedness supplies were updated to include missing supplies. Private vendors were contacted for planning and for donations for the next disaster. Finally, this retrospective study was conducted for the field of PMR to determine the volume, timing, types of diagnoses, and demographics of patients. This knowledge will be applied directly to create staffing ratios, on-call schedules, and lists of amount and type of medications, equipment, and supplies that may be needed. In addition, we hope this paper will assist in the education of physiatrists and the concept of immediate need for PMR responders to acute disability issues in a disaster of any kind.

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Impairment and Disability in the Astrodome after Hurricane Katrina

Lessons Learned About the Needs of the Disabled After Large Population Movements


Key Words: Disability, Hurricane Relief, Disaster Preparedness, Medical Supplies

Hurricane Katrina and its devastation of New Orleans and the mid–Gulf Coast caused the largest interstate migration of citizens since the 1930s Dust Bowl.1 The hurricane made landfall with 125 mph winds along the Louisiana–Mississippi state line on August 29, 2005. Hurricane force winds generated by the storm were sufficient to overcome protective levees surrounding New Orleans and flooded 80% of the city.1 Citizens, unable to evacuate before the storm, used the Louisiana Superdome as a shelter, but then they became trapped by rising water.

Physiatric Observations at the Katrina Medical Clinic

Approximately 27,000 persons were evacuated from the Superdome in New Orleans to the Astrodome in Houston, TX, where the Katrina clinic treated more than 11,000 individuals between September 1 and the clinic’s closure on September 16.2 Medical care for evacuees included immediate triage on unloading from buses, on-site triage in the dormitory areas of the Astrodome, and the Katrina medical clinic in the Reliant Arena.2

Five physiatrists, including the four authors, volunteered to care for patients who were convoyed 320 miles from the Louisiana Superdome to the Houston Astrodome/Reliant Sports Complex, which opened as an emergency shelter with medical services (the Katrina clinic) 3 days after the August 29 hurricane.2 Observations at the Katrina clinic suggest that needs of the acutely and chronically disabled require more preparation. Categorization and advocacy for these needs now may improve preparedness for the special needs of disabled citizens during the next regional disaster that results in large population shifts. The observations regarding impaired mobility and impaired function from the Katrina clinic are described and discussed in the context of the existing literature, and resources to learn more about disaster management are provided.

Physiatrists treated patients in the internal medicine areas and also in the orthopedic areas of the Katrina clinic. Five physiatrists participated at either the Katrina clinic or the George R. Brown Convention Center, which became a second large emergency domiciliary and medical clinic in Houston on Septem-
Mobility and Transfers: The Need for Wheeled Mobility and Volunteer Training in Proper Transfer Techniques

Four wheelchairs, some walkers, and an abundance of crutches were immediately available to the disabled. Acute, subacute, and chronic conditions debilitated individuals and impaired mobility. In some cases, people who did not use wheelchairs before Hurricane Katrina needed assistance with mobility on leaving the transporting buses. Anecdotes about patients losing mobility devices, casts, and braces were recounted to all the authors. Incident commanders at the Astrodome immediately communicated a need for wheelchairs to local resources. More than 100 wheelchairs, many donated by manufacturers, became available in the first several days of operations at the Astrodome (G.V. Masi, personal communication, October 1, 2006). Without wheelchairs, the evacuees with lower-limb injuries would have experienced impeded access from the football field-sized dormitory to restrooms and other accommodations.

Despite instruction from trained staff, an abundance of eager volunteers did not always comply with proper transfer techniques of the disabled. Physical therapists from the Harris County Hospital District volunteered at the Astrodome dormitory but assisted evacuees in using technologies to locate family members (B. Duncan, personal communication, February 13, 2006). Cast-application technicians with backgrounds in physical therapy volunteered in the orthopedic area of the Katrina clinic.

Military-type cots, approximately 17–18 inches tall, served as dormitory bedding. Abundant Internet photographs show that standard wheelchair seats are just slightly taller than these cots. Able-bodied persons were able to transfer on and off this low surface with relative ease. However, persons with lower-limb impairment experienced difficulty and discomfort.

Sensory and Cognitive Impairments and Other Considerations in Environmental and Discharge Planning

Competency issues in the fragile elderly and separation of minor children from their parents or guardians necessitated isolated protective sections for these vulnerable populations. State agencies charged with the protection of these groups were involved, as documented by Internet photographs. A tracking system for the discharge of patients was developed after area care facilities presented themselves as relocation options for Astrodome residents without clearance through incident command.

No persons with cognitive deficits resulting from brain injury were encountered. However, persons with stroke, who had been discharged from acute care hospitals just before the storm, were examined. Most motor deficits were mild.

Special sections emerged in the Astrodome. Volunteers were observed staffing child play areas, which were distinguished by contiguous metal barriers. By Monday night, September 6, a large sign in the Astrodome announced a section for the hearing impaired, as seen in photographs on the Internet. Visual limitations and hearing impairments affected function in a foreign environment. Neurosensory-impaired persons were unable to see signs or hear announcements.

Evacuees arrived with nothing other than the clothes they wore. They had no money or ability to transact purchases or relocations. Information retrieval in New Orleans was not practicable, and phone lines to the region were largely nonoperational. Social service graduate students volunteered at the clinic for the purpose of relocation.

Medical Supplies: Specific Medical Supply Needs for the Disabled Are Physiatric Areas of Expertise

The medical treatment areas at the Astrodome initially lacked urethral catheterization supplies. Spinal cord–injured persons arrived using chronic indwelling catheters, which required changing. Clear intermittent catheters (but not Foley-type catheters) were available. Couriers traveled between the main Harris County Hospital District hospital and the Katrina clinic for catheters and a variety of other needs.

Assistance with diabetic and decubitus wound care was needed. Patients were instructed to return for daily dressing changes, as opposed to dispensing wound care supplies for independent application by the individual. One spinal cord–injured patient packed trochanteric decubiti with baby diapers while stranded in Louisiana; he was mildly febrile because of a urinary tract infection, but the stage 4 wounds were clean with healthy granulation tissue.

Industry supported the Astrodome/Reliant Complex clinic. National pharmacy retailers and radiographic equipment manufacturers donated supplies and equipment. Local vendors and manufacturers of mobility equipment supplied wheelchairs.
The Treatment of Pain and Handling of Controlled Substances

Persons requesting methadone for the treatment of opioid dependence presented immediately at the Astrodome. One of the authors, with a clinical focus in chronic pain, was asked to assist in treatment decisions regarding methadone-dependent patients. Despite the existence of a federally declared disaster, the federal prohibition against opioid prescription for narcotics dependency without special Drug Enforcement Administration registration as a narcotics treatment facility remained in effect. Legally, methadone prescription for opioid dependence could not occur at the Astrodome clinic. Psychiatrists staffing the Katrina clinic obtained and implemented a treatment protocol for symptoms of opioid withdrawal suggested by a local addictionologist using alpha-adrenergic agonists. Within 48 hrs, the psychiatric service had established referral and transportation to local methadone treatment centers.

A central command decision was made not to stock federally controlled medications, including opioids for pain, on the on-site pharmacy. Concerns existed that a pharmacy area, distinguished only by cordonso, curtains, and shelving, could not be secured against the possibility of theft. Only noncontrolled medications (i.e., tramadol, acetaminophen, and nonsteroidal antiinflammatory medications) were available to treat pain on site. Prescriptions for controlled substances were written and could be filled at local retail pharmacies cooperating with the Katrina clinic.

Medical records for evacuees were not available. Phone service to New Orleans was limited or nonexistent, and hospitals and physician offices were not reachable. Physiatrists advocated for the effective treatment of intractable or chronic pain on the basis of reasonable medical history, and they prescribed controlled medications that could be filled at local pharmacies. No patients with intrathecal pumps to treat pain or spasticity were encountered at the Katrina clinic, but three patients from the mid–Gulf Coast states with this need were encountered at or referred to other Houston facilities (A. Schwabe, personal communication, January 24, 2006; B.T. Sitzman, personal communication, September 2005).

COMMENTARY

Disaster response exceeds the selfless rescue efforts of first responders and surgical prowess in response to mass casualties. Several stages of disaster response have been described, and two stages occur before disaster ever strikes: (1) preparedness and vulnerability modification, and (2) warning and evacuation, with (3) emergency relief and rescue efforts in the immediate aftermath, and (4) rehabilitation, recovery, and reconstruction subsequently. As a field, physiatry cannot make the disabled population we serve more prepared or understand the logistics of evacuating them out of harm’s way until the needs of the disabled during disaster are described. This commentary describes observations gathered about evacuated persons at a shelter and clinic site remote from the disaster area after a specific type of natural disaster, a hurricane. Not all observations made may have applicability in other types of disaster or for a response within a disaster area. Physiatrists and rehabilitation personnel should be encouraged to describe the needs of disabled persons and persons with a variety of disorders or impairments, such as chronic pain, brain injury, and spinal cord injury, so that the needs of these persons are not overlooked in large-scale disasters.

Preparedness is the first step in managing disaster. Discussing a plan with patients in the event of an emergency is useful and has been advocated by others. In the absence of specific data about the needs of the disabled, existing preparedness strategies can be applied generally. Emergencies can be personal or nationwide, and many citizens are not prepared. U.S. Centers for Disease Control and Prevention surveys suggest that just under half of all citizens have no disaster plan or preparation, even when hurricane landfall is imminent. The inability or refusal to evacuate, especially by persons with disability, chronic illness, and depression, as well as poverty and no means of escape, has been discussed. Regardless, all persons with chronic health problems will need to articulate their needs to new healthcare providers if they evacuate from a disaster area or to first medical responders if they are trapped in a disaster area. Patients should carry a brief medical history and the written names and dosages of their medications. Patients sometimes knew medication names and doses, but physicians, including the authors, deduced unlabeled medications and dosages brought with patients, using available photographs of medications. Innumerable medications were refilled at the Katrina clinic for patients who whose medications were exhausted or contaminated.

Preparedness includes education and policies that offer the patient contingencies. Patients should know that certain medications that are associated with withdrawal phenomena should not be stopped abruptly. When disasters can be predicted, such as hurricanes, policies that allow patients to pick up early refills of medications facilitate evacuation. The authors provided early refills when Hurricane Rita caused a mass evacuation along the Texas Gulf Coast in September 2005, 3 wks after Katrina. Providing a patient with physician refer-
rals and contact information, if the patient knows the general area to which he or she will evacuate, promotes the individual’s healthcare transition.

Patients requiring special supplies should not assume that shelters and emergency clinics will have them. Whether patients “shelter in place” or evacuate, they need several days of not only food and water, as recommended by the U.S. Centers for Disease Control and Prevention,11 but they also need any required dressings and ostomy or catheter site supplies. The Katrina clinic experience suggests that supplies at shelters can be obtained but may not be available immediately.

Many resources11–15 have catalogued basic supplies needed for medical purposes and discussed the consequences of infrastructural failures so that any citizen requiring chronic medical care or any provider can prepare. Unique considerations for hospitals and research facilities have also been broached.15–20 The importance of preparedness of patients and physicians as a first step in managing disaster cannot be overstated.

Systems of warning and evacuation just before disaster probably fall outside the control of the medical community and are governmental functions. For example, at the federal level, Department of Defense assets provide medical evacuation.21 Locally, since Katrina, Gulf Coast communities have recognized the inability of some populations to evacuate in the event of a hurricane and have coordinated local mass transit assets to evacuate persons with no other mode of transportation.22 Alternative to evacuation are special-needs shelters that may exist in some communities; physicians may want to contact public health officials to inquire about transportation alternatives and location of these shelters. Often, disabled persons require equipment. Although getting an individual out of harm’s way is always a priority, the individual’s independence will be promoted in the safe area, and needs will be less burdensome at the sheltering facility if equipment can move with the disabled individual.

Immediate emergency relief and rescue efforts occur locally. Although available resources instruct citizens to be self-sufficient for 3–5 days,11 the misconception that the federal government stands by to commence instantaneous rescue operations after a disaster seems pervasive. The “process” of disaster response is a legal, cross-jurisdictional, and multijurisdictional process, and it takes time. The governor of an affected state, via official disaster declaration through regional FEMA offices, must request the assistance of the federal government.23 Additional time delays occur after major disasters are declared because assets must be mobilized and transported. The Astrodome dormitory and Katrina clinic began as local responses, using local resources and local professional and lay volunteers to aid Gulf Coast neighbors on August 31.2 The state of Texas and municipalities participating in the care of Katrina victims were not declared federal emergency areas for two more days, September 2.24 Before September 2, the local medical industries, physicians, healthcare providers and administrators, and lay volunteers were providing donated time and donated medications and supplies to care for the influx of evacuees from Louisiana. In New Orleans, firefighters and other local first responders used the New Orleans International Airport as a drop zone for rescued citizens 24 hrs after Katrina.25 Federal medical help, DMATs, first arrived at the airport August 31.25 Louisiana had been declared a major disaster area on August 29.24 For victims and volunteer responders, several days can be spent waiting for help or waiting to help.

During disaster response, skilled and lay volunteers coexist with designated incident commanders and local, state, and federal agency first responders and representatives.26–29 Volunteers are encouraged to identify, register with, and request assignments from incident command so that services can be put to optimal use.2,26,27 Volunteers from the medical professions are also directed to Internet resources from professional organizations that highlight continuance or relaxation of licensing, malpractice, Health Insurance Portability and Accountability Act, Emergency Medical Treatment and Active Labor Act, and medical practice requirements during disaster.30 The requirements for licensing and malpractice requirements for out-of-state volunteering physicians varied from state to state after Katrina. Volunteers with medical training may provide general services but, as skilled observers, may provide cogent recommendations to incident commanders to remediate and improve shelter and medical situations. Chain of command does exist, and volunteers should comply; all persons at a shelter or in a disaster area, victim, volunteer, or designated responder consume resources and stress a compromised infrastructure. Respect for the process increases the volunteer medical provider’s efficacy.

Equipment management is a complex issue. Within the disaster zone, mobility equipment, supplies, and medications may become depleted, lost, soiled, or obsolete because of environmental hazards, and supplies must match needs.2,13,14,31 Wheelchairs are not practical in flooded or rubble-cluttered areas; electric wheelchairs’ batteries require electrical charge. Rescuers will save lives but may be unable to transport mobility devices.32 At shelter sites geographically remote from the disaster area, such as the Katrina clinic, the point prevalence of wheelchair use will be higher than in the predisaster community.2,23 The clinic experience
also suggests that donations of chairs will take several days; rubberized components of wheelchairs and other supplies decay with storage,\textsuperscript{13} so strategies of stockpiling\textsuperscript{33} have limitations.

The skills of rehabilitation personnel could be used to benefit disaster victims. Physical and occupational therapy volunteers “circulating” on the dormitory floor when wheelchairs are in short supply, as well as providing a cogent survey of dormitory areas for persons with cognitive, neurosensory, transfer, and mobility disability, follows psychiatry’s proactive approach to engaging patients with needs after disaster.\textsuperscript{46} The literature has also advocated that the use of occupational therapy personnel in disaster response, to normalize victims’ activities and to facilitate resolution of the psychological trauma.\textsuperscript{34} Persons with cognitive and special sensory deficits may be at marked disadvantage in new environments and may not hear or understand instructions.\textsuperscript{5} Alternative signage and communication for persons with sensory deficits should coexist with routine communications. Protective settings and strict discharge planning should be in effect for minors without guardians and for delirious, demented, cognitively impaired, or otherwise fragile adults.\textsuperscript{2} Social service volunteers coordinating discharge, and child life specialists engaging children, may help identify problems for incident commanders. It can be anticipated in the next large regional disaster that controlled substances may not be readily available. Federal and state laws regarding the prescription of controlled substances should be considered to be in effect despite the existence of a national disaster or emergency. Physiatrists, who treat chronic pain, may be considered by incident commanders as a resource to solve controlled substance issues in general. If Internet access is available and utilities are intact, the SAMSHA Web site (www.samhsa.gov) and Drug Enforcement Administration Web sites may provide the most current information. Certain medications commonly used in physiatry, such as opioids, benzodiazepines, spasticity agents, neuroleptics, and some antidepressants (alpha- and beta-blockers), have associated withdrawal phenomena. Other specialties in which medication access is restricted, such as addiction medicine and pain medicine, have advocated their patients proactively forming an “emergency plan.”\textsuperscript{7,8,35} This plan might include patient education about the following: (1) how to taper medications associated with withdrawal phenomena; and (2) how to communicate clearly with rescuing medical personnel that the individual is taking these medications and may experience withdrawal complications if they cannot be tapered safely or be prescribed their medication. As a result of the Katrina experience, pain patients receiving opioids and other medications in our clinic are encouraged to pack a copy of the pain contract and consent form with important papers and take it with them in the event of an emergency, and they also are taught about withdrawal symptoms from various medications and how to manage medications while trying to find medical assistance. This strategy applies to patients taking medication for seizures and spasticity. This proactive approach could be applied to any patient with highly specialized medical needs.

In a large-scale emergency or disaster, the needs of disabled persons have not been fully investigated or described. Few descriptions of psychiatric response to disaster exist.\textsuperscript{41–43} Experiences resulting from Hurricane Katrina suggest that natural and unplanned environment barriers, new impairments and disabilities for previously able-bodied persons, underestimation of disability-specific supplies, durable medical equipment, and specific medications, as well as a limited response of rehabilitation personnel, may place disabled persons at additional disadvantage. Persons with rehabilitation expertise who are comfortable assuming volunteer roles should consider assisting disaster victims, because disabled persons may be among those trapped in disaster areas and eventually evacuated to safe remote geographic locations. To refine and expand recommendations, additional lessons learned about the needs of the disabled in a variety of disaster situations need to be reported to the rehabilitation community at large.

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