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Use of Neurodevelopmental Principles in the Rehabilitation of Hemorrhagic Stroke with Left Neglect: A Case Report

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Abstract

Background: Hemorrhagic strokes affect 16-33 per 100,000 individuals per year, with 25% of individuals with right-sided strokes developing symptoms of left neglect. Despite the high prevalence and potential for low functional outcomes in these populations, research to figure out the most effective physical therapy interventions for this group is severely lacking. The purpose of this case report is to demonstrate the potential for use of the neurodevelopmental treatment (NDT) in individuals with stroke and hemispatial neglect, and to encourage further research on the topic. **Case Description:** The patient was a 49-year old female who suffered from an acute right temporal and basal ganglia parenchymal hemorrhage that caused left-sided hemiplegia, left hemispatial neglect, and cognitive deficits. She presented with gait abnormalities, inattentiveness to left-sided movements, and difficulty with functional movements. **Interventions:** The primary intervention was the use of NDT techniques, progressing through movements that follow the neurodevelopmental sequence and use somatosensation and proprioception to improve functional movement. In this case, the patient performed exercises in sitting, quadruped, half-kneeling, and tall-kneeling while progressing difficulty to challenge balance and increase activation of left-sided muscles. **Outcome Measures:** The primary outcome measures used in this case were the Berg Balance Scale and the Functional Independence Measure. Through evaluation with these measures, the patient demonstrated minimal clinically important differences in both outcomes. **Discussion:** The patient's dramatic improvements in all functional movements suggests that use of NDT techniques may be beneficial in treatment of individuals post-stroke who demonstrate symptoms of hemispatial neglect. However, additional research is needed to evaluate how effective these methods are in comparison to conventional treatment in a larger population.

Background

Hemorrhagic strokes are a common and dangerous occurrence in American society. Hemorrhagic strokes account for the second-largest group of stroke incidences, behind ischemic strokes, with around 16-33 cases per 100,000 individuals per year. With a national population of around 326 million people, approximately 81,500 individuals develop hemorrhagic strokes in the United States per year. Research shows that non-traumatic intracerebral hemorrhage (ICH) causes 8-15% of first-occurrence strokes.[2] Major risk factors for developing an ICH are hypertension, age, and Asian or African-American ethnicity. Of individuals who develop an ICH, 35-52% will not survive past 30 days, with one-half of those perishing in the first 2 days post-stroke. Only 12-39% percent of patients are able to achieve functional independence within the first 6 months. These numbers show a relatively high prevalence but poor prognosis for patients. Initial treatment is typically medical in nature and requires excellent care to halt the bleed and decrease intracranial pressure to prevent further damage to brain tissue. However, once the patient's medical status has stabilized, physical therapy can have a profound effect on the patient's progress toward independence to perform functional abilities and regain quality of life. It is still unclear what this therapy should look like in order to have the greatest positive effects for the patient.

Approximately 25% of right-sided strokes lead to some version of left neglect.[2] Left neglect, or hemispatial neglect, can manifest differently in every patient. Most often, symptoms are able to subside by 3 months post-stroke, with very few people having lasting symptoms of this manner. In general, hemispatial neglect is the inability of a person to attend to or notice external or internal stimuli on one side of the body, usually contralateral to the side of the brain lesion.[5] This can include symptoms such as not noticing objects placed to the left side of the visual field, decreased arousal, dysesthesias, difficulty with proprioception in the limbs on one side of the body, or even refusing to believe that one's limbs are their own. Left neglect occurs more frequently than right neglect, but each is possible. This disparity may be attributed to two potential reasons. It is possible that the left and right hemispheres have differences in their abilities for spatial coding. It is thought that the right hemisphere has ability to code for both sides, while the left hemisphere is only able to represent the right side spatially. This means that there is overlap for coding the right side of the body or environment, and damage to the left hemisphere can be compensated for by the right hemisphere.[5] However, there is no backup for the spatial organization of the left side, so if certain areas of the right hemisphere are damaged, symptoms of left neglect will likely occur.

Another explanation is that the right hemisphere is more involved in vigilance and attention. Spatial bias is partially due to the inability to attend to one side of the body or one side of the external environment, suggesting damage to this network. Overall, sensorimotor spatial neglect can be caused by damage to the dorsal frontoparietal cortex and sensorimotor areas. There may also be involvement of the basal ganglia with the motor aspects of neglect, or involvement of the temporoparietal junction with the integration of sensory modality information.[5] However, the expansive cortical and subcortical networking surrounding the duties of attention and spatial representations suggest that damage to any of the associated areas could potentially lead to symptoms of hemispatial neglect.

The knowledge of proper physical therapy treatment for individuals post-stroke is still lacking consistent research, especially with specific cases of left-sided neglect. Interventions such as visual tracking, mirror therapy, and mental imagery may play a role in effective rehabilitation. However, in an inpatient rehabilitation hospital where the occupational therapists, speech-language pathologists, and neurofeedback experts handle these approaches, it does not leave many researched interventions for physical therapy to utilize. The Bobath method, or neurodevelopmental treatment (NDT), aims to optimize motor programs to improve motor function, and prevent the use of compensatory patterns.[13] The Bobath method has been redefined recently to include the principles of the body as a multi-joint kinetic chain where posture and sensation are critical in both perception and the resultant motor output. The focus of this treatment is on quality of movement and coordination of muscle activation patterns, all while keeping a strong postural core.[12] Because this patient had symptoms of left neglect, it seemed that these principles would be most useful to retrain the somatosensory and motor pathway to

normalize her movement patterns. Utilizing the neurodevelopmental sequence with activities is valid as a treatment to retrain the brain to handle normal and functional movement patterns; however, it is not currently an evidence-based approach for rehabilitation of hemorrhagic stroke with left-sided neglect. The purpose of this case report is to demonstrate the potential for use of the neurodevelopmental treatment (NDT) in individuals with stroke and hemispatial neglect, and to encourage further research on the topic.

Case Description

The patient was a 49-year old female who presented to an inpatient rehabilitation facility following an acute right temporal and basal ganglia parenchymal hemorrhage that occurred while on vacation with her family. Initial trials of inpatient rehabilitation physical therapy were unsuccessful due to the patient's severe lethargy, altered mental status, and persistent headache. After a few days, symptoms increased and the patient was transferred to the neurology unit for further evaluation. CT scans showed an increase in cerebral midline shift. This was treated medically with the addition of intravenous dexamethasone to decrease cerebral edema, and discontinuation of Lovenox being used for DVT prophylaxis. These interventions were able to stabilize the patient and she returned to the rehabilitation unit shortly. She remained on the rehabilitation unit for an additional two weeks, when she was discharged home with family support from her husband and teenage son. Her past medical history included hypertension and some emotional lability during the past year, both exacerbated by her high-stress job.

The major complications throughout treatment were cognition and affect. During her hospital course, the patient went through various Rancho Los Amigos levels, ranging from level III at admission to behavior consistent with level VIII/IX at discharge. Initially, she was extremely lethargic, perseverative, had a flat affect, and did not participate in conversation. She then moved to episodes of high levels of agitation, where she had to be escorted from various therapy areas due to her outbursts. She became physically combative and threw objects at a physician when given bad news. By the end of treatment, she was a very pleasant lady who participated in and initiated conversation with the staff members she trusted, and adhered to all exercises during physical therapy sessions. She was concurrently receiving occupational therapy and speech therapy, until she had an outburst and then refused all speech therapy services. She was a striking case to encounter due to the emotional, cultural, and psychological comorbidities that complicated her care. Despite all that was stacked against her, she was able to make remarkable progress with the time and therapeutic interventions.

At the start of treatment, this patient presented with multiple components affecting her treatment, including moderate mobility deficits, left hemispatial neglect, cultural differences, and difficulties with attention, emotional lability, and direction-following. Initial physical therapy evaluation after re-entry onto the inpatient rehabilitation unit was still difficult to perform. The patient was not oriented to person or time, and she had a flat affect. True manual muscle tests and goniometry were not feasible to perform due to the cognition difficulties. Overall, the patient demonstrated active and passive range of motion within normal limits, except for impaired left upper and lower extremity active range of motion. She was able to move her left upper extremity against gravity and was able to generate power when cued, but movements were slow, inconsistent, and not automatic. When attempting to isolate specific muscle contractions, she was able to perform ankle pumps and quad sets on her right leg, but was unable to have more than occasional trace reactions with either movement on her left side after various verbal and tactile cues. Since she had the strength to ambulate, this impairment was neuromuscular in nature. She presented as globally hypotonic. Left-sided coordination was impaired, as tested via the finger to nose test, trace square test, toe taps, and heel to shin test.

Sensation was also impaired on this left upper and lower extremities, with light touch, sharp/dull, and proprioception tests showing impaired perception. During all of these tests, she demonstrated inattention and lack of awareness of the left extremities. The patient was able to sit edge of bed without upper extremity support, but did not demonstrate protective and righting reactions to the right side. She was severely limited in skills of functional mobility as well. She was able to transfer from the bed to- and

from- a wheelchair with moderate assistance for navigation and physical assistance, with use of a rolling walker. She was able to navigate 4 stairs, with bilateral railings and minimal contact assistance from the physical therapist. She required total assistance for ambulation, with a two-person assist. Because of her left neglect, she required verbal and tactile cues for left lower extremity advancement and moderate physical assistance to steer her rolling walker. She ambulated with a steppage gait, or excessive hip flexion, to clear her feet bilaterally, and would verbalize, “left, right” as she was stepping and repeat any cues the physical therapists would give her. Her left foot supinated during swing phase and at heel contact, but was normalized during stance. She had severe difficulty using a walker due to steering difficulties, inattention to left-sided obstacles around which to steer, and inability to keep her left hand gripped around the handle. Confounding factors included severe patient lethargy, disorientation, and a language barrier, as Mandarin was her primary language.

Interventions

Initially, the main focus of rehabilitation was gait training. Task-specific training has been shown to be effective in patients who are post-stroke. Because this patient’s gait was impaired, it was important to specifically practice ambulation. Studies have shown the importance of high dosage of repetitions for increased functional gains in individuals after stroke.[3] The patient was in inpatient rehabilitation, so a high dosage of therapeutic intervention was possible. Gait was initiated with a rolling walker and moderate assistance of two individuals for steering the walker, verbal cues for limb placement, and the necessity of a wheelchair follow due to her decreased endurance. Due to her symptoms of left neglect, she would often drop her left hand off the walker handle and forget to advance her left lower extremity. Verbal and tactile cues were used to remind the patient of these.

Once the patient became steadier on her feet, she progressed from using a walker to pushing a tray table. Because of the increased weight and resistance of moving the tray table compared to the walker, it was hypothesized that this would increase afferent input to her upper extremities and trunk, and therefore increase reflexive activation of her left abdominal muscles and left upper extremity muscles. When the physical therapist held the patient’s left hand on the table to prevent slippage, she was able to maintain control and push the table in front of her. Gait was normalized through repeated trials and challenged with decreased use of assistive devices. Endurance was decreased during the first part of the hospital stay, so she used the Nu-Step machine in conjunction with true gait training. The purpose of this was not only to increase muscular and cardiovascular endurance, but also to practice the reciprocal limb motions used in gait and other functional activities that she enjoyed, such as swimming. By discharge, she was able to ambulate community distances without the use of an assistive device and without loss of balance, even on uneven surfaces. The task-specific practice may have contributed to the improvement. Additionally, Mikołajewska shows that NDT interventions can normalize gait velocity in 70% of cases, cadence in 65% of cases, and stride length in 83.3% of cases, based on standardized norms from anthropometric data.[8] Therefore, the NDT-based interventions discussed below may have also played a role in improving her gait.

After gait training was initiated, the primary goal of the therapeutic interventions used was to promote use of left-sided muscles and core stabilizers. The principles of the Neurodevelopmental theory, best used in children and adults with neurologic insult, purport that individuals best progress through a certain order of postures to reach normal function. These postures include: prone, rolling, sitting, quadruped, tall kneeling, half kneeling, and standing. The benefit of using these positions for exercise is the forced weight bearing through different parts of the kinetic chain and forced activation of the core musculature for balance.

The first of these positions the physical therapist used specifically for exercises was short sitting on the edge of the mat. However, the patient was required to be in the prone position or to roll in order to get into these other positions, so she was still able to train these transitional skills. With her right hand in her lap, the patient was tasked to reach her left hand to “high-five” the physical therapist. This required core control for dynamic sitting balance, as well as use of the left shoulder and arm musculature to reach out and position her hand correctly to match up with the therapist’s hand.

Next, she performed the same exercise in quadruped, with her back forming a table-top position. When reaching with her left arm in this position, it required her to go through greater ranges of shoulder flexion. However, this exercise was most beneficial for her to reach with her right arm and hold herself up with the left. Certainly, this exercise required high levels of muscle activation, particularly in the scapular stabilizers and abdominal muscles to maintain balance. However, the weight-bearing through the left arm and having joint compression through the left shoulder could be beneficial for retraining the somatosensory input of the affected joints and providing some neuromotor input. The patient performed well with this activity, although at times she would say “uh-oh” and seem to think she was collapsing at the left arm, when she was in fact holding herself up. At these times, the physical therapist gave the patient tactile cues at the elbow or shoulder to show the patient that she was maintaining the correct joint positions. Once she was able to perform this exercise with ease, it was advanced to a contralateral arm/leg raise for increased core control requirements. Although she was initially not able to lift her left leg as high as her right leg, she was able to maintain balance throughout, and improved her form with cueing.

The next progression from this was tall kneeling exercises paired with PNF shoulder diagonals. She would be in the tall kneeling position and pull a resistance band from the upper hand corner of one side of her body to the opposite diagonal. Again, this required use of core musculature, such as her internal and external obliques, as well as use of upper extremity muscles to move the resistance band. She also had more of her body weight going through her knees compared to the quadruped position, again forcing her to comprehend the proprioceptive and somatosensory input from her legs in order to maintain balance. She noted that her left knee “felt weird” when she was in this position, because it felt numb to her. However, she was able to perform this exercise and maintain her balance.

Next, she performed the same exercise in the half kneeling position with a narrow base of support. This position required increased core control for balance due to the decreased size of the base of support. As expected, she exhibited slightly decreased balance when kneeling on her left leg compared to her right. She progressed well with this activity and with practice, was able to maintain this position with external perturbations provided on her upper extremities, lower extremities, and trunk. She was also able to perform the same PNF diagonals as with the tall kneeling. The exercise was progressed with kneeling on foam pad and then a disc balance cushion, in order to decrease somatosensory input and challenge balance, forcing the patient to use increased proprioceptive information and motor output to stabilize herself.

She was able to progress to standing balance exercises. Resistance tubing was utilized to provide resistance with walking in all four directions. This external resistance activates different muscles based on the direction of the resistance and the direction of movement. While she initially had difficulty with eccentrically resisting the pull from the tubing, especially coming back from sidestepping to the right, she was eventually able to perform the activity. During these therapy sessions, she progressed through neurodevelopmental sequence as stated above.

Alternative treatment ideas that are used in rehabilitation of hemispatial neglect include robot-assisted upper limb training, visual scanning training, prism adaptation, constraint-induced movement therapy, and eye patching. Choi, et. al compared the use of upper limb rehabilitation robot therapy to traditional treatments, like visual scanning training and range of motion exercises. With this therapy, patients would sit with the robot and screen on their left side, forcing them to attend to tasks on this side of their body, and they would perform games that would take the patient through passive and active exercises of each joint in the upper extremity. At the end of a 3 week-trial consisting of 30-minute sessions 5 days per week, both groups of individuals with left hemispatial neglect stroke had statistically improved scores in the Motor-Free Visual Perception Test 3rd edition, line bisection test, star cancellation test, Albert’s test, Catherine Bergego scale, Mini-Mental State Examination, and the Modified Barthel Index.[4] While it is difficult to separate out the improvements due to spontaneous recover and those due to the therapeutic interventions, use of robot-assisted upper limb training may be as effective as the conventional treatments.

These conventional therapies include visual tracking tasks. Kerkhoff, et. al compared smooth pursuit eye movement therapy with traditional visual scanning therapy. In this study, those in the smooth pursuit group would have to follow moving objects traveling to the left in their visual fields. Those in the visual scanning group would have to scan their visual field in a leftward direction to find a static object, so they were essentially making the same overall eye movements as the other group. However, the smooth pursuit group has significant improvements after five one-hour sessions, and had lasting changes, while the visual scanning group did not change significantly. A newer and somewhat controversial approach to spatial neglect therapy is prism adaptation.[9] In this rehabilitation, patients wear prism goggles that shift their visual field approximately 10 degrees to the right. With initial reaching trials to a target, they reach to the right side of the target. However, after repeated reaching trials, patients adapt their behavior and the error decreases. When the prisms are removed, the patient reaches inaccurately, this time to the left, producing the compensatory after-effect. While patients were always shooting too far to the right with reaching tasks prior, this would mean they could reach midline now. One criticism of this was the lack of expansion, or ability for this to lead to improvements in functional tasks. However, positive effects have been seen in tasks such as wheelchair driving, visuo-verbal tasks, oculomotor patterns, imagery tasks, spatial judgment, and detection of tactile stimulation. However, there have been few to no studies looking at the effects on activities of daily living, so more research needs to be performed on this intervention as well.

Constraint-induced movement therapy (CIT) has been used often in rehabilitation for individuals with hemispatial neglect and those with traditional hemiplegia due to stroke. Constraint-induced movement therapy includes the forced use of the affected extremity, while restricting use of the unaffected extremity, decreasing the chance for relying on compensatory patterns of the unaffected extremity. Eye patching is the comparable technique to force attention and use to the left side by blocking input from the right visual field into the unaffected left hemisphere of the brain. In a study by Wu, et. al, the combination treatment of CIT with eye patching (EP), as well as constraint-induced therapy alone, both produced statistically improved scores on the Catherine Bergego Scale compared to the control treatment of stretching, weightbearing, strengthening, and practicing functional tasks.[14] Additionally, either the CIT+ EP or CIT alone groups reported improved left fixation points on visual tracking trends, decreased right trunk lean, and shortened reaction time. It is possible that forcing use of the affected limbs and visual fields may improve outcome after stroke.

Many possible interventions exist for patients who are post-stroke, specifically those exhibiting signs of left neglect. However, due to this patient's presentation and environment, some of these options were not feasible. First of all, the rehabilitation hospital where her treatment occurred had limited resources and did not have access to the tools necessary for robot-assisted movement, visual tracking goggles or associated computer software, prism glasses or computer software. Additionally, it was important to stay within the scope of practice of a physical therapist, so performing the eye tracking therapies would not have been relevant for those therapies. Finally, the patient was initially very impulsive and resistant to many therapeutic interventions. Due to her cognitive deficits, it would not have been possible to ensure that she was abiding by the CIT protocol outside of therapies. As the study by Wu, et. al required at least six hours a day of wearing a mitt on the unaffected hand, it was not feasible to think she would remember the instructions or adhere to the plan. The one to two hours per day of physical therapy would likely not have been a high enough dose of constraint to be effective. Due to the limitations of resources and patient cognition, it seemed more realistic to perform interventions such as NDT-based therapies that can be performed in treatment sessions only, and that focused on the areas of expertise of physical therapy, rather than other specialties.

Outcome Measures

Standardized outcome measures that are successfully used with individuals after stroke include the Berg Balance Scale and Functional Independence Measures (FIM) scores. FIM scores are commonly used in inpatient rehabilitation hospitals as an indication of an individual's disability and level of assistance required. It includes 18 items, but only 13 are motor tasks that are related to physical

therapy. This is an approved assessment tool in the stroke population, with one study showing an average intake motor score of 43.8, which improved to 55.9 with standard occupational, physical, and speech therapy by the time of discharge.[11] The proven minimal clinically important difference (MCID) for improvement in this population is 17 points for the motor subscore.[1] The Berg Balance Scale is another assessment for static and dynamic balance tasks approved for use in the stroke population. The minimal detectable change in these acute stroke patients during their inpatient rehabilitation stay is 6.9 points.[10] A score at or below a 45/56 designates an increased fall risk in the stroke population.[6]

Initial outcome measures include a FIM score of 1, or total assistance for walking, due to the necessity of 2 individuals for moderate assistance on the patient's gait belt and walker, as well as a wheelchair follow. She received a FIM of 3, or moderate assistance for transfers, meaning she performed 50-75% of the task. She received a 2 on stairs, because she required use of bilateral rails, minimal physical assistance, and could only complete 4/12 stairs. At the hospital where her rehabilitation occurred, those were the only 3 FIM measures scored by physical therapists, the rest were used by occupational therapy. Her first Berg score, completed several weeks after her initial assessment, was a 39/56, and required 2 sessions to complete the test, due to argumentative behavior and decreased ability to stay on task. Because of this score, she was deemed to be at increased risk for falls.

At the end of treatment, she reached FIM scores of 7's, or total independence, in gait and transfers, with a 6 in stair ambulation due to use of bilateral rails. In these 3 categories alone, she improved by 14 points. When including the rest of the motor subscales scored by occupational therapy showing that she was independent in all ADLs, she easily reached the MCID of a 17-point increase. Table 1 shows the detailed FIM reports. The patient also improved on the Berg Balance Scale by increasing from 39/56 to 56/56. Not only did she reach the minimal detectable change of 6.9 points, but she also was able to go from being an increased fall risk to someone with no increased risk of falls.

Table 1. FIM scores at admission and discharge, and initial goals set. The patient met or bypassed most goals set at admission. Measures scored by physical therapy are bolded.

	Admission	Goal	Discharge
Eating	5	7	7
Grooming	5	6	7
Bathing	4	5	7
UE Dressing	2	5	7
LE Dressing	4	5	7
Toileting	1	5	7
Bladder	5	6	7
Bowel	5	6	7
Bed, Chair, W/C	**3**	**6**	**7**
Toilet Transfer	1	5	7
Tub Shower Transfer	4	5	4
Locomotion Walk	**1**	**6**	**7**
Locomotion Stair	**2**	**5**	**6**
Comprehension*	4	5	6
Expression*	3	5	5
Social Interaction*	2	5	5
Problem Solving*	2	4	4
Memory*	2	4	5
Total:	55	95	112

*Measures scored by speech therapy may not have been current or accurate due to early termination of services.

Discussion

The purpose of this case report is to demonstrate the potential for use of the NDT in individuals with stroke and hemispatial neglect, and to encourage further research on the topic. In this case, the patient was able to improve in all aspects of movement, such as gait, transfers, balance, and complex movement patterns. While it is impossible to decisively attribute those changes to the utilization of NDT interventions rather than spontaneous progress, these interventions may have helped to improve neuromuscular control and facilitate proper muscle activation and motor patterns. The fact that her FIM scores improved well beyond the average discharge score for stroke patients could show increased improvements with use of NDT exercises compared to other treatment approaches. Based on the theoretical principles supporting NDT interventions, they may be beneficial in other cases of stroke with left neglect. In cases of stroke, somatosensation and motor output are often impaired. This is especially important in cases of hemispatial neglect, where not only is light touch impaired, but also proprioception and kinesthesia impair the individual's joint sense. NDT focuses on increasing sensory input, including proprioception, somatosensation, and kinesthesia, so it allows individuals to learn to reintegrate this information and use it to affect appropriate motor responses. Thus, it is clear that NDT principles need to be studied more in-depth than the current literature stands.

A review of the literature shows that most RCTs examining NDT in post-stroke rehabilitation use NDT as the control, thus the standards for regulating these interventions were not held to the same level as the experimental groups.[12] While most of these groups did show improvements in outcomes, the specific interventions used were not standardized or explained clearly so that they can be replicated. It has been difficult to compare various rehabilitation protocols, especially when the idea behind NDT is to optimize movement patterns and improve quality of movement, yet most outcome measures are quantity-based. These research studies utilize outcome measures such as the Timed Up-and-Go, 6MWT, and Functional Independence Measure, which look at speed, distance, and assistance requirements, respectively, but do not take quality of movement into consideration.

Furthermore, because of differences in the specific areas affected and amount of damage to tissue in each post-stroke brain, it is difficult to know if the differences in how individuals respond to different treatments is based on these factors rather than the actual intervention. Further research is definitely needed to show the benefits and potential uses for NDT interventions. Research should focus on comparisons between a specific NDT protocol that is standardized, with results being measured with various outcome measures that indicate both functional improvements and improvements in movement quality, in order to truly see the effects and benefits of NDT alone.

*Verbal consent was obtained from this patient and the hospital for use of this case.

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