Human Simulation Under Anosognosia and Neglect in Stroke Patients

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ABSTRACT

A number of patients developing anosognosia and neglect after stroke can benefit from specific physician supervised rehabilitation programs. Assessment of these patients provides data on initial, intermediate and final affectation of such deficits in the upper limbs. We have developed a virtual environment of parametric human arm and hand with 29 degrees of freedom (DOF) to simulate these three phases.

Simulation of functional recovery of stroke patients affected by anosognosia and neglect is crucial for physicians to aid their assessment. The objective of the present paper is to describe a newly devised environment to simulate the initial, intermediate and final affectation of upper limb deficit in stroke patients with anosognosia and neglect. After a time lapse from the initial assessment and on rehabilitation therapy, we perform a new assessment. With the parameters from the two assessments we are then able to simulate the functional recovery of patients within the same time period.

Keywords: stroke, neglect, anosognosia, rehabilitation, virtual physiology simulation.
INTRODUCTION

Stroke or cerebrovascular accident is a brain infarction caused by ischemia or hemorrhage. It is the second cause of death and the first cause of severe disability among adults in developed countries, cause great burden on and resource consumption of healthcare services. It has been estimated that a third of those suffering and surviving stroke will die within the ensuing year of the event, another third will remain dependent on others for care, and another third will fare to good recovery (Garrison, 1993). Treatment improving functional outcomes can significantly reduce severity of sequelae as well as the financial burden of this illness on the individual, the family and society overall. Rehabilitation therapy aimed to reduce post-stroke disability and handicap is recognized as a corner stone of multidisciplinary stroke care (Kalra, 2007).

The mechanisms underlying recovery are may, even if mostly not yet understood, include (i.) resolution of oedema with volume reduction of non-functioning brain area, (ii.) reduction of impairment, and (iii.) acquisition of adaptive techniques to overcome impairment. Emergency medical attention and early active rehabilitation therapy are paramount toward good functional recovery (Catalonia official Clinical Practice Guidelines for stroke GPC, 2007).

Although about half of overall recovery from disability occurs over the course of the first month, it can continue up to 6 months post stroke. After this time frame the occasional patient will show significant improvement, this being the exception and rarely expected. This is well established for activities of daily living (ADL) and applies to all other features, such as aphasia, arm function, neglect and walking (Garrison, 1993).

Many studies have found single impairments to be associated with more severe disability at 6 months, including hemianopia, severe sensory loss, complete motor loss, loss of trunk balance, loss of consciousness, urinary incontinence, neglect and confusion (Wade, 1993). Hemiplegia is a common effect of stroke, which may have significant impact on upper limb function. Neglect is a common behavioural disorder in stroke patients (Plummer, 1993). Stone et al. (1993) defined anosognosia as denial or lack of awareness of a hemiparesis. Patients with neglect, compared with those without neglect, have more motor impairment, sensory dysfunction, visual extinction, basic (non-lateralized) attention deficit, and anosognosia (Tham, 2000).

Unilateral neglect (UN) is characterized by an inability to report on or respond to other individuals or objects presented at the contralateral side in space to the brain lesion. If such failure to respond can be accounted for neither by sensory nor by motor deficit, it is not considered to be neglect (Vahlberg, 2008). UN can be described in terms of the modality in which the behaviour is elicited (sensory, motor, or representational) or by the distribution of the abnormal behaviour (personal or spatial) (Tham, 2000 and Plummer, 2003).
Patients may have one type of neglect or a combination of neglect behaviours. Because UN has a wide variety of clinical presentations, there is not a single test that can reach a comprehensive diagnosis of neglect-like behaviour. Some authors have recommended using a test battery which includes measures of assessment for all types of neglect.

Anosognosia is the lack of awareness of a specific deficit in sensory, perceptual, motor, affective, or cognitive functioning due to brain injury (Babinski, 1914). Previous studies have shown broad variation in the incidence of anosognosia for hemiparesis ranging from 17% to 28% (Stone, 1993 and Appelros, 2006). Cutting found anosognosia in 58% of patients with right hemisphere lesions compared with 14% of patients with left hemisphere lesions. Bisiach and colleagues described a frequency of 33% for moderate or severe anosognosia in patients with right hemisphere lesions. Anosognosia is most commonly reported in association with left hemiplegia and left hemispatial neglect. Anosognosia is also more frequent after right than left hemisphere brain lesions, and may be compounded by disability deriving from the neglect status itself.

MATERIALS AND METHODS

We included four patients who had developed acute stroke within the previous
20 days, with left or right sided hemiparesis or hemiplegia with initial anosognosia and neglect. Inclusion criteria for these patients were: (i.) over eighteen years of age, (ii.) collaborative patients, good cognitive status, and (iii.) functional motor deficit associated with anosognosia and neglect. Patients who were not alert, uncooperative, or had severe aphasia were excluded only if their communication abilities precluded completing even a simple interview. The patients gave informed consent for their participation in the study, which was carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. The demographic data of patients included were collected.

We used the Oxfordshire Community Stroke Project (OCSP) for clinical classification of the stroke:

- Total anterior Circulation Infarction (TACI)
- Partial Anterior Circulation Infarction (PACI)
- Lacunar Infarction (LACI)

Stroke lesions were documented by magnetic resonance imaging or computed tomography and the severity of stroke was assessed using the National Institutes of Health Stroke Scale (NIHSS).

The Ashworth’s scale was used to assess the degree of spasticity, which was scored as 0 for no spasticity to 5 for severe spasticity with joint stiffness.

The motor control for the upper limbs was assessed by the Brünnstrom scale, which has six levels of motor control: 1 for no movement to 6 for normal movement.

The Fugl-Meyer scale was used as a system for assessing motor function, balance, some sensory details, and joint dysfunction in hemiplegic patients. Five levels of motor impairment were identified according to Fugl-Meyer. Severe scores were <50; marked scores were 50 to 84; moderate scores were 85 to 95; slight scores were 96 to 99; and normal motor function score reached 100.

The presences of neglect was assessed with the Bells test (Gauthier 1989). Anosognosia for hemiplegia was assessed using the anosognosia scale suggested by Bisiach:

- Grade 0 (no anosognosia): the disorder is spontaneously reported or mentioned by the patient following a general question about their complaints;
- Grade 1: the disorder is reported only following a specific question about the strength of the patient’s limbs;
- Grade 2: the disorder is acknowledged only after demonstrations through routine techniques of neurological examination;
- Grade 3: no acknowledgement of the disorder can be obtained.

However, the degree of independence and assistance needed during activities of the patients’ daily living was measured with ADL scales: Barthel’s Index (BI) (Mahoney 1965) and the Functional Independence Measure (FIM). The FIM is an ordinal scale composed of 18 items with 7 levels ranging from 1 (total dependence) to 7 (total independence) and can be broken down into a 13-item motor subscale and a 5-item cognitive subscale. The scoring ranges for are 13 to 91 for the motor and 5
to 35 for cognitive subscale. Total score is 126.

Disability was evaluated with the modified Rankin scale. This is a 6 grade scale, ranging from 0 (independence) to 5 (severe disability).

We also measured the deficits of angles, lengths and range of motion for arm and hand affected.

All of these tests were administered 20 days prior to, at admission and also at two months of stroke. After two months into the rehabilitation program under physician supervision, we took a second measure of the above deficits. These two measures were implemented in a virtual environment with 29 DOF.

RESULTS

Four patients were studied. One man with left hemiplegia, two women with left hemiplegia and another woman with right hemiplegia. Mean age was 67.75 years. Clinical classification by the OCSP is described in Table 1.1. Demographic data and clinical variables of these patients are given in Tables 1.1 and 1.2. Table 1.2 presents profiles of the neglect test and anosognosia at the first assessment and two months later. Table 1.3 presents the profiles of the functional capacities with BI and FIM at the first and second assessments. The table shows that cognitive and motor FIM scores of the second evaluation were higher than those of the first evaluation. BI also showed an improvement in the second assessment. Table 1.3 also describes patient disability evaluated with the Rankin scale. At admission, disability was severe in all of the patients. After rehabilitation, the disability was still severe.

Table 1.1 Demographic data and clinical variables of patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Aetiology</th>
<th>Side of lesion</th>
<th>OCSP</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Man</td>
<td>78</td>
<td>Ischemic</td>
<td>Left</td>
<td>PACI</td>
<td>TBG*</td>
</tr>
<tr>
<td>2</td>
<td>Woman</td>
<td>38</td>
<td>Ischemic</td>
<td>Left</td>
<td>PACI</td>
<td>TPC*</td>
</tr>
<tr>
<td>3</td>
<td>Woman</td>
<td>82</td>
<td>Ischemic</td>
<td>Right</td>
<td>PACI</td>
<td>Protuberance*</td>
</tr>
<tr>
<td>4</td>
<td>Woman</td>
<td>73</td>
<td>Ischemic</td>
<td>Left</td>
<td>PACI</td>
<td>FPC</td>
</tr>
</tbody>
</table>

TBG = Temporary basal ganglia
TPC = Temporal parietal cortex
FPC = front-parietal cortex
Table 1.2 Clinical variables at the first and second assessment for each patient

<table>
<thead>
<tr>
<th>Patient</th>
<th>NIHSS</th>
<th>Ashworth</th>
<th>Fugl-Meyer</th>
<th>Brunnstrom</th>
<th>Anosognosia</th>
<th>Neglect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17/13</td>
<td>1/2</td>
<td>0/8</td>
<td>1/2</td>
<td>3/2</td>
<td>yes/yes</td>
</tr>
<tr>
<td>2</td>
<td>13/2</td>
<td>1/1</td>
<td>8/65</td>
<td>1/6</td>
<td>3/0</td>
<td>yes/yes</td>
</tr>
<tr>
<td>3</td>
<td>11/7</td>
<td>1/2</td>
<td>0/21</td>
<td>1/4</td>
<td>1/0</td>
<td>yes/yes</td>
</tr>
<tr>
<td>4</td>
<td>21/13</td>
<td>1/1</td>
<td>0/8</td>
<td>1/2</td>
<td>3/2</td>
<td>yes/yes</td>
</tr>
</tbody>
</table>

Table 1.3 Profiles of the functional capacities with BI and FIM at the first and second assessment and disability evaluated with the Rankin scale.

<table>
<thead>
<tr>
<th>Patient</th>
<th>IB</th>
<th>FIM</th>
<th>Rankin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10/24</td>
<td>30/39</td>
<td>5/4</td>
</tr>
<tr>
<td>2</td>
<td>31/94</td>
<td>57/122</td>
<td>5/2</td>
</tr>
<tr>
<td>3</td>
<td>11/45</td>
<td>58/75</td>
<td>5/4</td>
</tr>
<tr>
<td>4</td>
<td>0/24</td>
<td>30/39</td>
<td>5/4</td>
</tr>
</tbody>
</table>

FIGURE 1.2 Left hand of Patient #1 at first and second evaluations.
FIGURE 1.3 Hands of Patient #3. Left at first evaluation and right at second evaluation two months into rehabilitation.

FIGURE 1.4 Hands of Patient #4. Left at first evaluation and right at second evaluation two months into rehabilitation.

It is noted that Patient #2 was not shown here because the limb was a normally functional hand.

**HUMAN SIMULATION UNDER ANOSOOGNOSIA AND NEGLECT**

Once the patients were assessed with the scales mentioned above, simulation was implemented in a virtual environment. With two virtual human models, one woman and one man, we implemented the range of motion from the functional capabilities for the positions between the first evaluation and second evaluation.

To simulate the range of motion of these positions, we used a virtual hand and arm with 29 DOF, 25 DOF were used to simulate the hand, 2 DOF for the wrist and 2 DOF for the arm. Shoulder movement was not considered in this simulation.

The virtual hand and arm to simulate the patients’ were implemented using the model presented by Peña-Pitarch and colleagues in 2005.

Once the patients were evaluated first 20 days before admission, all the angles of joints for the hand and wrist were introduced in a database, and two months after stroke was read an introduced in the database with the patient data. Both angles depicted in Table 1.4, are the maximum angles reached by the patients. Movements
of adduction/abduction (A d/Ab) for the metacarpophalangeal joint (M C P), Proximal Interphalangeal joint (PIP) and Distal Interphalangeal joint (DIP) in flexion/extension (F/E) are also shown in Table 1.4.

Table 1.4 Maximum angles at first and second evaluation two months later.

<table>
<thead>
<tr>
<th>Index angles</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP (Ab/Ad)</td>
<td>13/13</td>
<td>13/42</td>
<td>13/30</td>
<td>13/30</td>
</tr>
<tr>
<td>MCP (E/F)</td>
<td>30/30</td>
<td>30/80</td>
<td>30/60</td>
<td>60/80</td>
</tr>
<tr>
<td>PIP (E/F)</td>
<td>30/30</td>
<td>30/100</td>
<td>30/70</td>
<td>60/100</td>
</tr>
<tr>
<td>DIP (E/F)</td>
<td>10/10</td>
<td>10/90</td>
<td>10/45</td>
<td>10/70</td>
</tr>
</tbody>
</table>

Other fingers depict similar evolutions and are not showed herewith in order not to crowd the manuscript with a similar tables.

FIGURE 1.4 Simulation of an intermediate position for patients #2, #3 and #4.

DISCUSSION

This is the first study of our group testing how this approach to simulate the movements proposed may work in the clinical setting.

Tables 1.1 to 1.3 show the assessment degrees per each patient. Patient #1 at both assessments show severe stroke; the physicians did not appreciate any variation, simulation of this patient is done by setting the hand and arm in a neutral position where the angles for each joint are 0 or 30 degrees for MCP, PIP and 10
degrees for DIP (Peña-Pitarch et al. 2005).

Patient #2 was a young patient, the stroke was slight and within two months recovery for this patient was complete; simulation was similar to a normally functioning hand.

Patients #3 and #4 had similar evolutions within two months and simulation was based on reading the minimum and maximum angles reached in the first assessment and the minimum and maximum angles two months later. Bearing these parameters we devised a value interval that can be implemented in our virtual environment. Table 1.4 shows the maximum angles at the two assessments. The first assessment for Patient #3 showed, as seen on the left on Figure 1.3, the hand in a neutral position and on the right two months later. The new angles are shown in Table 1.4. Patient #4 showed in the left at the first assessment. The new angles are showed in Table 1.4.

To simulate any one of these patients in a virtual environment, we introduced the initial and final angles for the first assessment and the initial and final angles for the second assessment. These four parameters allowed us to simulate the evolution of recovery for patients and apply the same to other patients with similar assessments. This is the first time that an anticipation of what can occur one month into therapy.

CONCLUSIONS

Virtual human simulation of the arm and hand in patients affected by anosognosia and neglect after stroke supplies an new and objective tool for physicians allowing a simulated evolution of deficits in some patients. Anosognosia and neglect deficit associated with hemiplegia impair functional recovery. Relevance of this simulation for patients affected by these deficits is, upon the first physician interview, to inform on planned evolution as to the time functional recovery will take. The simulation is also relevant because the model arm and hand are implemented with parametric lengths allowing to extrapolate to other patients affected with the same deficits.

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REFERENCES


