A Comparative Study on the Presence of the Asymmetrical Tonic Neck Reflex in Adult Hemiplegia
(postural adaptation, postural reflexes, reflex integration)

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In this study, the intensity of the asymmetrical tonic neck reflex (ATNR) was measured in post-cerebrovascular accident (CVA) adults with hemiplegia and in neurologically intact adults to determine if the reflex exaggerated following CVA. Fourteen subjects with right and left hemiplegia were matched to neurologically intact subjects by age and sex and tested for the ATNR. Intensity of the reflex was measured using electromyography (EMG) biofeedback. The results indicate that no difference exists between the two groups in intensity of the reflex. The method of rotation used to elicit the reflex did significantly affect the strength of the muscle response. A possible explanation for observation of the reflex in the hemiplegic individual's movement and its significance in neuromuscular re-education programs is discussed.

It is known and accepted that a cerebrovascular accident (CVA) can disrupt normal sensorimotor integration within the nervous system, resulting in the widespread release of primitive postural reflexes, including the tonic neck reflexes (1, 2). However, the effect these reflexes have on the movement of the post-CVA patient and the potential for recovery of normal function is less clearly understood.

Literature Review
Two major theorists in the area of neuromuscular re-education, Signe Brunnstrom and Berta Bobath, disagree on whether these reflexes, particularly the asymmetrical tonic neck reflex (ATNR), exert a positive or negative influence on the patient's recovery of normal motor control. Brunnstrom maintains that the ATNR and the other primitive reflex and movement patterns observed following CVA represent an evolution in reverse of motor control within the brain (2). She advocates the deliberate use of the ATNR in exercise and activity to re-establish normal patterns of control. Her position is supported by studies that demonstrate that the ATNR can be used to reinforce voluntary elbow extension in hemiplegic individuals (3, 4). In contrast, Bobath maintains that the exaggeration and persistence of the ATNR prevents the integration of higher level righting and equilibrium reactions (1). According to Bobath, use of the ATNR to reinforce movement strengthens primitive stereotyped movement patterns, decreasing the potential for development of selective movement.

The presence of the ATNR in both neurologically intact adults and adults with hemiplegia is well documented in the literature (5-11). According to Fukuda (5), the ATNR is automatically incorporated into normal movement patterns to reinforce the pattern and enhance equilibrium. Evidence of the ATNR's influence can be observed in many athletic postures.

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including the volley in tennis and the lunge position in fencing (5). Hellebrandt, Houtz, Partridge, and Walters (7) demonstrated that normal subjects unconsciously use the reflex to increase upper-arm strength during resisted movement. Other investigators have been able to measure the reflex in normal subjects using a variety of methods including electromyography and cinematography (6, 8, 10, 11).

Walshe (12) reported that the tonic neck reflexes were always exaggerated to some degree in cases of spastic residual hemiplegia. He observed a relationship between the exaggerated neck reflexes and spasticity, finding that the intensity and distribution of spasticity in the limbs changed in accordance with the reflex's action. A similar effect was reported by Twitchell (13). Walshe also observed that passive or unresisted active rotation of the head was generally not sufficient to elicit the ATNR. He concluded that voluntary forceful rotation of the head was necessary to elicit the reflex, and several repetitions may be required before the ATNR's influence on the limbs was observed. Similar observations on the need to provide reinforcement with head rotation to elicit the ATNR are reported in the literature (2, 3, 12, 13).

Brain (14), in a study of the influence of the ATNR on the posture of hemiplegic patients, found that body position affected the strength of the reflex. He reported that the powerful bias of the tonic labyrinthine reflex (TLR) toward extension in supine may prevent elicitation of the ATNR in this position. The tendency of the ATNR to be influenced by the TLR in supine positions is documented elsewhere in the literature (9, 12, 13). In addition, Brain found that the phenomenon of homolateral synkinesia may influence elicitation of the reflex in a seated position by predisposing the arm toward an increase in flexor tone.

Other researchers also have documented the exaggerated presence of the tonic neck reflexes following CVA and brain injury (9, 14-16). The majority of this research was completed in the early 1900s. The reports consist primarily of loosely controlled case studies completed by a single physician on one or more hemiplegic individuals. Presence of the reflex was determined by observation of movement in the limb and palpation of changes in muscle tone. Few references are made to control procedures or other aspects of experimental design. Conclusions regarding exaggeration of the reflexes and their relationship to spasticity appear to have been formulated largely on the basis of inherent logic, rather than on the presence of quantifiable data. No studies have been found in which there was direct comparison of the ATNR in normal and hemiplegic populations using an experimental design.

Part of the disagreement in the literature on the use or avoidance of the tonic neck reflexes to enhance normal movement results from the absence of research indicating whether a quantifiable difference actually exists in intensity of the ATNR between hemiplegic and neurologically intact individuals. Both Brunnstrom and Bobath are able to cite references in the literature to support their viewpoints. Brunnstrom cites what is known about the reflexes' action in normal adults. Bobath refers to the work of Walshe and others indicating that the ATNR is exaggerated following brain injury and related to spasticity. The clinician is caught in the middle.

The purpose of this study was to attempt to provide preliminary answers to basic questions regarding the presence and nature of the ATNR in post-CVA adult hemiplegia. The investigator sought answers to three questions:

1. Do adults with post-CVA hemiplegia demonstrate a significantly increased ATNR when compared with neurologically intact adults of comparable age and sex?

2. Does the method of eliciting the reflex, active rotation of the head versus active head rotation with reinforcement, influence the intensity of the reflex response?

3. Does the position in which the subject is tested, supine versus seated, influence the intensity of the reflex?

Answering these questions would add new perspective to the old argument on use and reinforcement of the ATNR in neuromuscular re-education programs.

Method
Subjects. The study sample consisted of 14 subjects with hemiplegia and 14 control subjects with no known neurological deficits. The two groups were matched on sex and to within six months of one another on age. There were nine males and five females in each group. Their ages ranged from 48 to 70 years, with a mean age of 64.9 years.

The hemiplegic sample was selected randomly from the outpatient population of the Rehabilitation Institute in Kansas City, Missouri. Each subject exhibited some degree of upper extremity
motor paralysis and spasticity due to CVA. In each case except one, the CVA was of a thrombotic origin. The exception was an aneurysm that hemorrhaged during surgery. Ten subjects exhibited right hemiplegia and four exhibited left hemiplegia. None of the subjects displayed bilateral paralysis and spasticity due to CVA. In each case except one, the CVA was of a thrombotic aneurysm that hemorrhaged during surgery. Six of the subjects with right hemiplegia were diagnosed as aphasic, four with expressive aphasia only, and two with mild receptive as well as expressive aphasia. All of the subjects were able to follow the test instructions. None of the subjects were on medication that altered muscle tone when the testing was done.

The length of time elapsed since onset of the CVA ranged from 3 to 22 months, with a mean time span of 12.3 months.

The control group was selected from the community on the basis of availability. The subjects were screened for evidence of neurological insult or disease through the use of a detailed questionnaire.

Procedure. A Cyborg electromyographic (EMG) biofeedback unit, model P303, interfaced with a Cyborg Q700 data accumulator was used to measure the intensity of the ATNR. Electromyographic biofeedback was selected to measure the reflex because of its ability to measure changes in muscle activity, objectively and accurately, as verified by Basmajian (17, 18) and others (6, 10, 19, 20).

Disposable external electrodes were used to monitor the changes in muscle response. Two active electrodes were placed 2 cm (.08 in) apart over the center of the muscle belly of the biceps brachii and triceps brachii muscles. The reference electrode was centered between the two recording electrodes on the muscle belly. Careful skin preparation was completed prior to application of the electrodes to ensure adequate contact with the skin.

Muscle responses were recorded in the involved upper extremity of the hemiplegic subjects. Control subjects were matched for side of placement with their hemiplegic counterparts. The lower extremity was not tested. Prior to beginning the evaluation, a baseline level of muscle activity was established by obtaining an average of EMG action potentials over a 60-second period.

The ATNR was elicited by rotation of the head to the right and left sides. Two methods of rotation were used: (a) active head rotation and (b) active head rotation accompanied simultaneously by forceful squeezing of a hard rubber pad in the normal hand. Head rotation was repeated two times to each side using the two methods, for a total of four times to each side. The subject was instructed to hold the test position 10 seconds while the reflex response was averaged and then return to a neutral head position. During rotation of the head away from the involved extremity, muscle activity in the biceps brachii was recorded. During rotation toward the involved extremity, activity in the triceps brachii was recorded. A rest period of 60 seconds was provided between each rotation to allow the muscle activity to return to baseline.

Each subject was tested in two positions: (a) supine on a padded bench and (b) seated in a straight-backed chair. The order of the test positions was assigned randomly prior to the experiment. The data were collected and analyzed by a single researcher. All subjects were evaluated in the same test environment with variables such as temperature, noise, and lighting controlled.

Results
A three-factor mixed analysis of variance (ANOVA) design with repeated measures on two factors was used to analyze the data. The repeated measures were the method of eliciting the reflex, plain versus reinforced head rotation, and the test position, supine versus seated. The data obtained on the biceps and triceps muscles were analyzed separately using this design.

The results of the analyses are shown in Tables 1 and 2. No significant difference was found between the hemiplegic and control groups in the degree of change in either the biceps or triceps muscle in response to elicitation of the ATNR. This implies that the intensity of the reflex response to testing is equal between the two groups. Claims of the presence of an exaggerated ATNR response in hemiplegia cannot be verified by these data.

The position (supine or seated) in which the subjects were tested also failed to cause a significant difference in intensity of the reflex response for either the biceps or triceps muscles. This indicates that for these subjects, test position was not an important factor in eliciting the reflex.

The method of eliciting the reflex, plain versus reinforced head rotation did cause a statistically significant difference in the response of the biceps muscle to testing. This implies that the type of head rotation used to elicit the reflex affects the intensity of the muscle response.

A Newman-Keuls post-hoc analysis of the rotation main effect for
Table 1
Three-Factor ANOVA with Repeated Factors Comparing Group, Rotation, and Position on Muscle Response of the Biceps to Elicitation of the ATNR

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sums of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1440.97</td>
<td>167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between subjects</td>
<td>1017.36</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3.33</td>
<td>1</td>
<td>3.33</td>
<td>.09</td>
</tr>
<tr>
<td>Error</td>
<td>1014.03</td>
<td>26</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Within subjects</td>
<td>423.61</td>
<td>141</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>0.38</td>
<td>1</td>
<td>0.38</td>
<td>.56</td>
</tr>
<tr>
<td>Rotation</td>
<td>9.44</td>
<td>2</td>
<td>4.72</td>
<td>5.36*</td>
</tr>
<tr>
<td>Group × rotation</td>
<td>0.03</td>
<td>2</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Group × position</td>
<td>24.18</td>
<td>1</td>
<td>24.18</td>
<td>2.11</td>
</tr>
<tr>
<td>Position × rotation</td>
<td>0.03</td>
<td>2</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Group × position × rotation</td>
<td>0.5</td>
<td>2</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td>Error₁</td>
<td>298.53</td>
<td>26</td>
<td>11.48</td>
<td></td>
</tr>
<tr>
<td>Error₂</td>
<td>45.62</td>
<td>52</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Error₃</td>
<td>39.35</td>
<td>52</td>
<td>0.76</td>
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</tbody>
</table>

* Significant at the .01 level

Table 2
Three-Factor ANOVA with Repeated Factors Comparing Group, Rotation, and Position on Muscle Response of the Triceps to Elicitation of the ATNR

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Sums of squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1525.53</td>
<td>167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between subjects</td>
<td>1260.85</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>59.1</td>
<td>1</td>
<td>59.1</td>
<td>1.28</td>
</tr>
<tr>
<td>Error</td>
<td>1201.75</td>
<td>26</td>
<td>46.22</td>
<td></td>
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<tr>
<td>Within subjects</td>
<td>264.68</td>
<td>141</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>82</td>
<td>1</td>
<td>82</td>
<td>1.12</td>
</tr>
<tr>
<td>Rotation</td>
<td>9.4</td>
<td>2</td>
<td>4.7</td>
<td>4.9</td>
</tr>
<tr>
<td>Group × rotation</td>
<td>2.3</td>
<td>2</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Group × position</td>
<td>9.88</td>
<td>1</td>
<td>9.88</td>
<td>1.49</td>
</tr>
<tr>
<td>Position × rotation</td>
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<td>2</td>
<td>0.04</td>
<td>0.1</td>
</tr>
<tr>
<td>Group × position × rotation</td>
<td>0.5</td>
<td>2</td>
<td>0.28</td>
<td>0.68</td>
</tr>
<tr>
<td>Error₁</td>
<td>172.66</td>
<td>26</td>
<td>6.64</td>
<td></td>
</tr>
<tr>
<td>Error₂</td>
<td>49.82</td>
<td>52</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Error₃</td>
<td>21.25</td>
<td>52</td>
<td>0.41</td>
<td></td>
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</tbody>
</table>

Table 3
Newman-Keuls Post-hoc Analysis Comparing Methods of Rotation on Muscle Response of the Biceps to Elicitation of the ATNR

<table>
<thead>
<tr>
<th></th>
<th>Midline</th>
<th>Active rotation</th>
<th>Active rotation with reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>6.72</td>
<td>6.85</td>
<td>7.78</td>
</tr>
<tr>
<td>Midline (baseline)</td>
<td>6.72</td>
<td>—</td>
<td>1.05*</td>
</tr>
<tr>
<td>Active rotation</td>
<td>6.85</td>
<td>—</td>
<td>0.92*</td>
</tr>
<tr>
<td>Active rotation with reinforcement</td>
<td>7.78</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* Significant at the .01 level

The biceps showed that head rotation with reinforcement produced a significant change in muscle response compared to baseline, whereas plain rotation did not cause a significant change. Reinforced head rotation also produced a significantly greater change in muscle response to the reflex than did plain rotation. The results of this analysis (see Table 3) indicate that reinforced head rotation is necessary to elicit the reflex response, and plain rotation will not elicit a sufficient reflex response. These findings support those of Walshe (12) and others (2, 3, 12, 13) who reported that reinforced head rotation was necessary to elicit the ATNR.

Discussion
Failure of the hemiplegic group to show a statistically significant difference in muscle response to elicitation of the ATNR indicates that no real difference exists between normal and hemiplegic subjects in intensity of the reflex.

These results contradict previously published findings on the ATNR that the reflex was significantly exaggerated in hemiplegic populations (1, 12-16). This contradiction may be partly due to differences in experimental design. Earlier research relied on subjective observations of movement and alterations in muscle tone on individual patients. In the present study, an objective measurement, EMG biofeedback, was applied to both experimental and control groups with a statistical analysis of the data. Although changes in limb position were observed during evaluation of two of the hemiplegic subjects in this study, the changes did not correspond to the ATNR. Instead both subjects displayed noticeable increases in
elbow flexion during rotation toward the hemiplegic side.

Although the results of the study indicate that the intensity of the reflex does not exaggerate with hemiplegia, therapists often observe elements of the reflex in the hemiplegic patient's movement, sometimes in a striking fashion. If the reflex does not quantitatively change in hemiplegia, why is it that its appearance and influence is more readily noticeable in the movement of the hemiplegic adult than in the neurologically intact adult? The answer may lie partly in how the reflex is incorporated into normal movement patterns during development and in the nature of movement deviations following CVA. Gilfoyle, Grady, and Moore (21) report that during normal development the tonic neck reflexes are adapted to primitive holding strategies. These strategies enable the child to develop the necessary midline stability to support posture and movement against gravity. As development proceeds, the tonic neck reflexes are integrated into righting, support, and protective reactions, eventually becoming part of the child's internal postural control (21). Integration of the reflexes occurs in a spiraling fashion; the lower level tonic neck reflexes being modified for higher level patterns of postural control by central nervous system (CNS) maturation and environmental experiences. According to Gilfoyle et al.:

"a child does not acquire totally new behaviors, rather new behaviors are higher level modifications of older, lower level reactions...the lower level reactions are integrated into the ontogenetic sequence to the extent that they may lose their original identity, but their trace effect contributes to higher level spatiotemporal adaptations" (21, p 50).

During development, when a child experiences an environmental demand that exceeds functional ability, the child meets that challenge by recalling a lower level reaction temporarily to increase stability (21). An example of this process can be observed when a child tries ice skating for the first time. To meet the new challenge of moving on ice, the child calls forth remnants of the early prone extension posture. He or she retracts, abducts, and flexes the upper extremities to increase extension of the upper trunk, at the same time abducting the lower extremities to lower the center of gravity. This process of using lower level reactions to meet environmental challenges occurs throughout life whenever the individual's motor system is stressed (21). Easton (22) refers to this process as "reflex recruitment." When CNS pathways to the complex reflex centers are overstressed by fatigue or effort and movement is required, the CNS automatically recruits simpler reflexes to produce the needed motion. According to Easton, this method provides the CNS with the most efficient way to handle motor stress and ensures that the least amount of energy is expended in meeting environmental demands.

The same strategies of reflex recruitment operant in normal children and adults would logically also be operant in hemiplegic individuals and could explain why elements of the tonic neck and other primitive reflexes can be observed in the hemiplegic individual's movement. It may be that, following hemiplegia, the ATNR itself does not intensity, but the individual's need to use the reflex to add stability to movement against gravity increases with the loss of the higher level righting and equilibrium reactions; that is, the reflex remains qualitatively unchanged in the hemiplegic individual, but its use during movement increases. As with the child on the ice skates, the hemiplegic person's nervous system, in using the ATNR, is simply providing a normal response to the stress placed on it as a result of the CVA.

The finding of a significant main effect for the method of rotation used to elicit the reflex, specifically the use of reinforced head rotation to elicit the reflex, lends support to this theory. In recounting his personal experience in recovering from a post-CVA left hemiplegia, Brodal (23) reported that the hemiplegic individual experiences significant stress whenever requested to use the involved limbs. According to Brodal, considerable mental and physical effort is required to produce a contraction of the paretic muscle; the greater the degree of paralysis present, the greater the effort required for movement. By requesting that the subject forcefully squeeze a hard rubber gripper while rotating his or her head, a temporary state of increased stress was artificially created in the subject's motor system. To meet that stress, the subject automatically recruited a simpler reflex to reinforce the movement required. The ATNR would logically be the reflex recruited since rotation of the head triggers the reflex.

The problem in the hemiplegic person's use of the tonic neck reflexes to enhance movement is that they are not phasic or movement reflexes. Instead, the reflexes function to distribute mus-
cible tone and fix movement at particular points within the range to provide stability (21). For the tonic neck reflexes to be effectively incorporated into movement, the nervous system must be able to superimpose movement on them and modify their action at any point in the movement pattern. According to Gilfoyle et al. (21), a damaged nervous system lacks the capacity to modify lower level reactions, leaving them available for adaptation to mature motor patterns only in their original form. Without modification, the tonic neck reflexes may become too readily available to the nervous system for the production of movement. When this occurs, the individual's ability to elicit a variety of movement patterns selectively becomes severely limited by the predominance of these primitive stereotyped reflexes. The problem is further complicated by the presence of abnormal muscle tone and sensory assimilations that reinforce these primitive patterns as the basis of movement (21).

Results

Implications for Occupational Therapy. The results of this study and those describing the function of the ATNR in normal movement suggest that observation of an exaggerated ATNR in the hemiplegic person's movement should be viewed as a normal response to nervous system distress rather than a symptom of pathology. Reorientation to thinking about the reflex in this way enables the therapist to see it in the proper perspective. Rather than dismissing the reflex as a symptom, the therapist can use it to analyze the patient's movement and determine what is needed to regain normal function.

Since the function of the ATNR is to increase postural tone and stability, observation of the reflex in the patient's movement can be interpreted as an indication of inadequate postural adaptation to a given situation. According to Gilfoyle et al. (21), three factors tend to produce stress within the motor system: gravity, the complexity of the movement required, and the requirements of the activity or skill itself. During normal development, the desire of the child to overcome these factors provides the impetus for development. However, when distress exists within the motor system, these same factors tend to elicit a dysfunctional response, which is often characterized by use of the primitive postural reflexes. Evidence of the ATNR in the adult hemiplegic's movement often is observed when one of these factors has been introduced into the treatment program. Observation of the ATNR or other primitive reflexes signals to the therapist that the selected activity is too difficult and must be modified for the patient to complete the activity in a normal fashion.

The results of this study support Brunstrom's view that the ATNR is automatically used by both normal and dysfunctional nervous systems to enhance posture and movement. However, the question of whether to encourage or discourage the patient's use of the reflex in therapy programs still lacks a definite answer. Preventing patients from using the ATNR to increase their posture and movement without providing added assistance to complete the requested task may only increase the patient's distress and produce another form of dysfunctional response. However, reinforcing the patient's use of the reflex to accomplish an activity may prevent his or her reintegrating a higher level of postural control.

The goal of therapy may not be to encourage or prevent the use of the ATNR, but to improve the patient's postural adaptation so that he or she does not rely on the reflex to make an adaptive response to the environment. It is the therapist's responsibility to determine when to permit and when to discourage the patient's use of primitive reflex strategies and to design the treatment activity accordingly. Understanding of the role the tonic neck reflexes play in normal and dysfunctional movement enables the therapist to make this decision and ensures that the therapeutic activity provided is truly therapeutic.

Further Research. The results of this study have provided some preliminary information on the nature of the ATNR in hemiplegia. However, any conclusions drawn from the study are limited by the size of the sample, the age range of the subjects, and the severity of their hemiplegia. Replication of the study results is needed before conclusive statements can be made regarding use of the reflex in neuromuscular re-education programs.

Acknowledgments

Thanks to Scott Smith, RPT, for his generous support in this project; to Shelley Tillery, OTR; and Dr. Roma Lee Taunton, whose invaluable assistance with the statistical design and analysis of the data was greatly appreciated.

This study was submitted in partial fulfillment of the requirements for a Masters of Science Degree in
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