Deficits of hand coordination and laterality of carotid endarterectomy

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OBJECT Neurocognitive performance is used to assess multiple cognitive domains, including motor coordination, before and after carotid endarterectomy (CEA). Although gross motor strength is impaired with ischemia of large cortical areas or of the internal capsule, the authors hypothesize that patients undergoing CEA demonstrate significant motor deficits of hand coordination contralateral to the operative side, which is more clearly manifest in the nondominant hand than in the dominant hand with ischemia of smaller cortical areas.

METHODS The neurocognitive performance of 374 patients was evaluated with a battery of neuropsychometric tests. Both asymptomatic and symptomatic patients undergoing CEA were included. The authors evaluated the patients’ dominant and nondominant hand performance on the Grooved Pegboard test, a test of hand coordination, to demonstrate their functional laterality. Neurocognitive dysfunction was evaluated as the difference in performance before and after CEA according to group-rate and event-rate analyses. The z scores were generated for all tests using a reference group of patients who were having simple spine surgery. Dominant and nondominant motor coordination functions were evaluated as raw scores and as calculated z scores.

RESULTS According to event-rate analysis, significantly more patients undergoing CEA of the opposite carotid artery demonstrated nondominant than dominant hand deficits of coordination (41.2% vs 26.4%, respectively, p = 0.02). Similarly, according to group-rate analysis, in patients undergoing CEA of the opposite carotid artery, raw difference scores from the Grooved Pegboard test reflected greater nondominant than dominant hand deficits of coordination (21.0 ± 54.4 vs 9.7 ± 37.0, respectively, p = 0.02).

CONCLUSIONS Patients undergoing CEA of the opposite carotid artery are more likely to demonstrate nondominant than dominant hand deficits of coordination because of greater dexterity in the dominant hand before surgery.

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KEY WORDS cerebrovascular disease/stroke; carotid endarterectomy; laterality; motor dysfunction; vascular disorders

Carotid endarterectomy (CEA) is a common surgical procedure performed to reduce the risk of stroke in patients who have high-grade carotid artery stenosis. The incidence of perioperative stroke is exceedingly rare. Therefore, investigators study subtler forms of neurological injury, such as cognitive dysfunction, to improve the safety of this commonly performed procedure.6,9,13,17,18,21 Cognitive dysfunction has important implications for quality of life18,27 and has been shown to predict both earlier retirement and mortality.25

Cognitive dysfunction is determined by evaluating cognitive performance with a battery of neuropsychometric tests before and after CEA to assess 4 functional domains—executive, verbal memory, visuospatial, and hand coordination. Because CEA can be performed on the left or right carotid artery, a number of studies have investigated whether the laterality of CEA plays a role in the kind of cognitive deficits a patient exhibits postoperatively.24 Thus far, researchers have focused on the laterality of deficits after CEA in the verbal,2,7,24 executive,4,5,9,13,24 and visuospatial domains.1,7,22 For example, postoperative language changes have been associated primarily with a left CEA.2,3,15,16,21,24 To the best of our knowledge, no previous studies have associated the laterality of CEA with its influence on subtle postoperative hand deficits of coordination.
Patients with intact gross motor skills may nevertheless have subtle hand deficits of coordination. The Grooved Pegboard test has been used to measure complex motor coordination and has historically been an effective tool for measuring subtle hand deficits of coordination in patients after CEA.2,12,13,18 Fine hand coordination is an important outcome to evaluate, because it has significant implications for quality of life.2,6,18 A previous study assessed fine hand motor functioning in a cohort of HIV-positive patients. These researchers demonstrated that subtle hand deficits detected by the Grooved Pegboard test were validated by the patients’ subjective experience and their reports of motor dysfunction in their hands.27 Again, although these findings may not indicate gross motor abnormalities, it seems that patients can recognize subtle changes in hand functioning and coordination.

The etiology of hand deficits of coordination after CEA remains somewhat unclear, but the deficits may result from reduced cerebral blood flow during cross-clamping of the carotid artery19 or microemboli after the clamp is released from the carotid artery.23,26 As the dominant hand has extensive practice in both gross and fine motor skills, we reason that the nondominant hand may be used as a more sensitive tool for demonstrating postoperative hand deficits of coordination because it is less practiced in these skills.

We hypothesize that patients undergoing CEA may demonstrate more nondominant hand deficits of coordination when the hemisphere controlling the nondominant hand is affected during CEA. Given the implications of even subtle changes in motor functioning on quality of life, it is reasonable to investigate whether the laterality of CEA is significantly associated with fine hand deficits of coordination after surgery.

Methods

Patients, Anesthesia, and Surgery

Three hundred seventy-four patients were scheduled for elective CEA at Columbia University Medical Center in New York, New York, between 1995 and 2012. This was a single-center observational study, and participants were recruited after their written informed consent was obtained for this institutional review board–approved study. Data from these patients have been analyzed in other studies for purposes unrelated to this study.11–13 Eligible participants were English speakers and had no Axis I psychiatric disorders. Both asymptomatic and symptomatic patients undergoing CEA were included. This study was registered with the ClinicalTrials.gov database (http://clinicaltrials.gov), and its registration no. is NCT00597883.

Hand Motor Function of Coordination

Neurocognitive performance was evaluated with a battery of neuropsychometric tests. These tests assess a variety of cognitive domains; in addition to hand function of coordination, we evaluated verbal memory, visuospatial organization, and executive action, as described previously.13

Both dominant and nondominant hand functions of coordination were assessed using the Grooved Pegboard test,18 which is a timed fine hand task that requires the patient to manipulate 25 notched pegs to place them into 25 slots on a pegboard as quickly as they can in a standardized way. The notched pegs need to be manipulated with the fingers to find the orientation that matches the slots on the pegboard, similar to fitting a key into a lock. Patients are instructed to use their left hand to place pegs beginning at the right-most corner of the board and continue leftward until all 25 slots are filled. Likewise, patients are then instructed to use their right hand to place pegs beginning at the left-most corner of the board and continue rightward until all 25 slots are filled. This test was completed for the dominant and nondominant hands in all 374 patients before and after CEA.

CEA Relative to Handedness

Dominant and nondominant handedness was established on the basis of which hand the patient used to write. We termed the procedure “CEA/dominant hand” if a right-handed patient was having a left CEA or a left-handed patient was having a right CEA; similarly, we termed the procedure “CEA/nondominant hand” if a right-handed patient was having a right CEA or a left-handed patient was having a left CEA. We expected CEA/nondominant hand to affect nondominant hand coordination more so than CEA/dominant hand to affect dominant hand coordination.

Statistical Analyses

Statistical analysis was performed using JMP 10 software (SAS Institute Inc.). For univariate analyses, the Student t-test, Wilcoxon rank-sum test, Fisher’s exact test, Pearson’s chi-square test, and simple logistic regression were used where appropriate. A p value ≤ 0.05 was considered significant.

Neurocognitive performance was evaluated as previously described. Similar to previous studies,9,10,13,20 z scores were generated for all of the neurocognitive tests on the basis of a surgical reference group’s performance to account for practice effect, trauma of surgery, general anesthesia, and the overnight hospital stay experience. The mean difference score of the surgical reference group was subtracted from the difference score for the patient undergoing CEA and then divided by the standard deviation (SD) of the surgical reference group to generate z scores. Therefore, performance was evaluated in units of SD of the surgical reference group’s change in performance. A significant change in cognitive performance was defined as ≥ 1.5 SD change in performance compared with that of a reference group of patients having simple spine surgery.13 The performance for all cognitive domains was analyzed by both group- and event-rate analyses.

Performance on the Grooved Pegboard test was scored in seconds using a stopwatch. Scores for the dominant and nondominant hands were collected the morning before surgery (baseline) and 24 hours after surgery. For fine hand performance of coordination, the Grooved Pegboard test was evaluated as follows. First, by group-rate analysis, we compared the average raw score differences before and after CEA for dominant and nondominant hand
performance based on CEA/dominant hand versus CEA/nondominant hand. We evaluated the average raw scores and the average raw score differences. Raw score differences represent the average change in Grooved Pegboard test performance, in seconds, from the preoperative to the postoperative period. Secondly, using event-rate analysis, we used a stringent cutoff value of 1.5 SD as a threshold to designate hand motor deficit. We determined whether significantly more patients had nondominant than dominant hand deficits as a function of whether the patient had a CEA/dominant hand versus CEA/nondominant hand procedure.

Results

Patient Characteristics

Patient characteristics are presented in Table 1. Of the entire cohort, 92.5% (n = 346) were right handed, and 7.5% (n = 28) were left handed; 52.7% underwent right CEA, and 47.3% underwent left CEA. The procedure for these patients was referred to as CEA/dominant hand (n = 181), because the CEA would have affected their dominant hand. Those having CEA that would have affected the nondominant hand were referred to as having CEA/nondominant hand (n = 193). Patient characteristics were similar between those patients having a CEA that would have affected the dominant hand versus the nondominant hand. The one exception was that patients undergoing CEA/dominant hand had a significantly higher incidence of diabetes mellitus (22.1% vs 14.0%, p = 0.04).

Performance According to Laterality of CEA

Average baseline and postoperative Grooved Pegboard scores, and their average raw score differences (postoperative minus preoperative scores), are presented according to whether the surgery would have affected the dominant or nondominant hand (Table 2). By group-rate analysis, the differences in the raw scores before and after surgery were greater in the nondominant hand in the CEA/nondominant hand group (21.0 ± 54.4 vs 9.7 ± 37.0, respectively, p = 0.02) (Table 2). By event-rate analysis for the sum of all 4 cognitive domains, 27.5% (53 of 193) of the patients having CEA/nondominant hand exhibited cognitive dysfunction 24 hours after surgery, as defined previously, versus 23.2% (42 of 181) of patients having CEA/dominant hand surgery displaying such dysfunction (p = 0.34) (Table 3). In addition, there were no significant differences according to laterality of the CEA in the individual domains: visuospatial (p = 0.84), verbal (p = 0.68), executive (p = 0.06), and hand coordination (p = 0.07) (Table 3). By event-rate analysis, 18.7% (n = 70) of all patients had fine hand motor deficits of coordination 24 hours after the surgery (data not shown). However, if one examines coordination deficits by dominant and nondominant hand deficits, performance in the dominant hand remained independent of the laterality of the CEA (37.4% vs 36.2%, respectively, p = 0.85) (Fig. 1). However, performance in the nondominant hand was affected after the CEA/nondominant procedure more than after the CEA/dominant hand procedure (41.2% vs 26.4%, respectively, p = 0.04) (Fig. 1). No differences in hand coordination were found in our reference group (patients having simple spine surgery) on the basis of the Grooved Pegboard scores from before and after surgery in dominant versus nondominant hand performance (–4.3 ± 14.6 vs –8.3 ± 15.5, respectively, p = 0.47).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Patients (n = 374)</th>
<th>CEA/Nondominant Hand (n = 193)</th>
<th>CEA/Dominant Hand (n = 181)</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right handed</td>
<td>92.5 (346)</td>
<td>52.3</td>
<td>47.7</td>
<td>0.34</td>
</tr>
<tr>
<td>Left handed</td>
<td>7.5 (28)</td>
<td>42.9</td>
<td>57.1</td>
<td>0.34</td>
</tr>
<tr>
<td>Age &gt;75 yrs</td>
<td>27.5</td>
<td>30.1</td>
<td>24.9</td>
<td>0.26</td>
</tr>
<tr>
<td>Male sex</td>
<td>67.4</td>
<td>70.0</td>
<td>64.6</td>
<td>0.27</td>
</tr>
<tr>
<td>Education in yrs</td>
<td>14.8 ± 3.4</td>
<td>14.9 ± 3.1</td>
<td>14.6 ± 3.7</td>
<td>0.41</td>
</tr>
<tr>
<td>BMI in kg/m²</td>
<td>26.9 ± 4.2</td>
<td>26.7 ± 4.1</td>
<td>27.0 ± 4.3</td>
<td>0.42</td>
</tr>
<tr>
<td>History of smoking</td>
<td>66.3</td>
<td>64.3</td>
<td>68.5</td>
<td>0.38</td>
</tr>
<tr>
<td>Aspirin use</td>
<td>83.7</td>
<td>85.0</td>
<td>82.3</td>
<td>0.49</td>
</tr>
<tr>
<td>Statin use</td>
<td>58.0</td>
<td>58.6</td>
<td>57.5</td>
<td>0.83</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>17.9</td>
<td>14.0</td>
<td>22.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Hypertension</td>
<td>56.4</td>
<td>59.1</td>
<td>53.6</td>
<td>0.29</td>
</tr>
<tr>
<td>PVD</td>
<td>28.5</td>
<td>29.7</td>
<td>27.1</td>
<td>0.58</td>
</tr>
<tr>
<td>Previous MI</td>
<td>23.5</td>
<td>24.9</td>
<td>22.1</td>
<td>0.53</td>
</tr>
<tr>
<td>Previous CABG</td>
<td>8.8</td>
<td>7.8</td>
<td>9.9</td>
<td>0.46</td>
</tr>
<tr>
<td>Symptomatic status</td>
<td>38.5</td>
<td>37.3</td>
<td>39.8</td>
<td>0.62</td>
</tr>
<tr>
<td>Cross-clamp duration in mins</td>
<td>42.8 ± 16.6</td>
<td>43.5 ± 17.7</td>
<td>42.1 ± 15.3</td>
<td>0.43</td>
</tr>
</tbody>
</table>

BMI = body mass index; CABG = coronary artery bypass graft; MI = myocardial infarction; PVD = peripheral vascular disease.

* Values are presented as the percentage (number) of patients or mean ± SD.

† Student t-test or chi-square test between ipsilateral CEA and contralateral CEA.
Discussion

Cognitive dysfunction is an important neurological finding that is exhibited by approximately 25% of patients 24 hours after CEA. Cognitive dysfunction is more common than perioperative stroke and can be used as a platform to improve the neurological safety of CEA. Cognitive dysfunction can be detected with a battery of neuropsychometric tests that assess cognitive domains. No conclusive work has been presented to clarify whether the laterality of CEA influences subtle hand deficits of coordination. Our previous and current work demonstrate that fine hand deficits are present as early as 24 hours after CEA in approximately one-third of our population. To our knowledge, we are the first to investigate the relationship between the laterality of CEA and fine hand deficits in this population (374 patients undergoing CEA) using the well-validated Grooved Pegboard test as our main outcome measure. This test assesses both dominant and nondominant hand function of coordination.

A comparison between patients having left- or right-sided CEA revealed that there were no significant differences in the visuospatial, verbal, or executive domains based on laterality of the CEA: CEA/dominant hand versus CEA/nondominant hand. No differences were found for coordination of the dominant hand with left or right CEA. The raw score difference in performance in the nondominant hand was affected more by the CEA/nondominant hand. We found worse nondominant hand deficits of coordination, evaluated as both raw score performances and z scores. With the exception of the incidence of diabetes mellitus, the groups in this study were comparable in terms of patient characteristics. It should be noted that we found no differences between the dominant and nondominant hand performances in the surgical reference group from before and after surgery.

Fine hand deficits of coordination can lead to decreased quality of life in a number of ways. One study demonstrated a cutoff score for the Grooved Pegboard test that indicated decreased driving ability after neurological insult. As there are important implications of motor dysfunction for driving, it is reasonable to consider that many other activities of daily living are also affected by motor deficits. Again, this reinforces the fact that deficits of coordination in the fine motor skills of the hand can limit patients, although to a different extent than for patients suffering from gross motor dysfunction. In fact, patients are aware of their motor deficits.

Wilkins et al. evaluated motor dysfunction in HIV-positive patients and found that there was a significant association between self-reported fine hand motor deficits of coordination and actual motor dysfunction as measured by the Grooved Pegboard test.

The dominant hand may not demonstrate subtle deficits as readily as the nondominant hand, perhaps because the dominant hand is more dexterous than the nondominant hand at baseline; it is well practiced and overly trained compared with the nondominant hand. The Grooved Pegboard test is an excellent measure of fine hand function of coordination. Although it requires gross motor function-

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### Table 2. Grooved Pegboard test performance by patients with CEA affecting either the nondominant hand or the dominant hand

<table>
<thead>
<tr>
<th>Grooved Pegboard Test</th>
<th>CEA/Nondominant Hand (n = 193)</th>
<th>CEA/Dominant Hand (n = 181)</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant hand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preop</td>
<td>103.2 ± 37.3</td>
<td>111.2 ± 48.4</td>
<td>0.07</td>
</tr>
<tr>
<td>Postop</td>
<td>117.4 ± 47.1</td>
<td>123.1 ± 49.8</td>
<td>0.26</td>
</tr>
<tr>
<td>Difference score</td>
<td>14.2 ± 32.9</td>
<td>12.0 ± 34.1</td>
<td>0.51</td>
</tr>
<tr>
<td>Nondominant hand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preop</td>
<td>121.2 ± 52.9</td>
<td>126.3 ± 50.2</td>
<td>0.34</td>
</tr>
<tr>
<td>Postop</td>
<td>141.9 ± 79.3</td>
<td>135.7 ± 52.7</td>
<td>0.39</td>
</tr>
<tr>
<td>Difference score</td>
<td>21.0 ± 54.4</td>
<td>9.7 ± 37.0</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* Values are presented as the mean ± SD time in seconds.
† Student t-test or chi-square test between ipsilateral CEA and contralateral CEA.

### Table 3. Summary of dysfunction by laterality of CEA

<table>
<thead>
<tr>
<th>Dysfunction by Domain</th>
<th>Percentage (no.) of Patients</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEA/Nondominant Hand (n = 193)</td>
<td>CEA/Dominant Hand (n = 181)</td>
</tr>
<tr>
<td>Overall cognitive dysfunction</td>
<td>27.5 (53)</td>
<td>23.2 (42)</td>
</tr>
<tr>
<td>Verbal domain</td>
<td>12.4 (24)</td>
<td>11.1 (20)</td>
</tr>
<tr>
<td>Visuospatial domain</td>
<td>3.1 (6)</td>
<td>2.8 (5)</td>
</tr>
<tr>
<td>Executive domain</td>
<td>13.0 (25)</td>
<td>7.2 (13)</td>
</tr>
<tr>
<td>Hand motor coordination</td>
<td>22.3 (43)</td>
<td>14.9 (27)</td>
</tr>
</tbody>
</table>

* Student t-test or chi-square test between ipsilateral CEA and contralateral CEA.
ing to move the entire arm, the test simultaneously evaluates patients’ sensation to locate the notch on the peg and fine motor skill to manipulate the notched peg and place it into the pegboard, simulating a lock-and-key mechanism. Deficits in the nondominant hand may be more readily manifest because the nondominant hand is not as practiced as the dominant hand. 

We acknowledge the limitations of our study. This was a single-center, nonrandomized, retrospective study of 374 eligible patients undergoing CEA. One unexpected finding was that patients in the dominant hand group had a significantly higher incidence of diabetes mellitus than patients in the nondominant hand group. The association between the laterality of CEA and deficits in fine motor coordination is a finding that may be considered preoperatively.

Conclusions

Patients undergoing CEA demonstrated greater subtle deficits of hand coordination in their nondominant hand than in their dominant hand when undergoing CEA on the opposite carotid artery. The nondominant hand may be more likely to exhibit fine motor deficits than the dominant hand because it is less trained and less practiced; hence, deficits in the nondominant hand may be more readily apparent.

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References


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Conception and design: Heyer, Mergeche, Stern, Connolly. Acquisition of data: Heyer, Mallon, Mergeche, Connolly. Analysis and interpretation of data: all authors. Drafting the article: Heyer, Mallon, Mergeche, Connolly. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Heyer. Statistical analysis: all authors. Administrative/technical/material support: Heyer, Mallon, Mergeche. Study supervision: Heyer, Stern, Connolly.

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