The Early Recovery of Cognitive Function After Total-Hip Replacement Under Hypotensive Epidural Anesthesia

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Background and Objectives: Recovery of cognitive function immediately after major surgery has not been previously reported, partly because of residual drug effects and pain.

Methods: Changes in cognitive function were assessed using the Stroop Color and Word Test (SCWT), which was performed preoperatively, and 1 and 2 hours after total-hip replacement performed under hypotensive epidural anesthesia. In this case series, patients were sedated with propofol alone and had a lumbar plexus block performed at the end of surgery.

Results: The SCWT was completed in 52 of 55 patients at either 1 or 2 hours after surgery. A significant reduction in cognitive function was noted 1 hour after surgery but a return toward baseline occured 2 hours after surgery. Age older than 70 years adversely affected recovery of cognitive function, but neither the preoperative diagnosis of hypertension nor the degree or duration of intraoperative hypotension (mean arterial pressure less than 45 mmHg) influenced cognitive function.

Conclusion: The Stroop Color and Word Test can be used to assess change in cognitive function immediately after surgery. Total-hip replacement performed under regional anesthesia with propofol sedation enables recovery of cognitive function (as assessed by SCWT) 2 hours after surgery. *Reg Anesth Pain Med 2005;30:123-127.*

Key Words: Epidural anesthesia, Cognitive function, Hypotensive anesthesia, Total hip, Propofol, Lumbar plexus block.

Cognitive function declines in the first week after major surgery and returns toward normal several months later, even though a small subset of patients exhibit "signs of persistent cognitive impairment."[1-3] The causes of the decline in cognitive function in the first week after surgery are presumed to be multifaceted and to include intraoperative anesthetic effects and the metabolic response to injury, as well as opioids and sedative agents administered after surgery. A repeat of cognitive function tests immediately after surgery could be helpful in defining whether anesthetic factors per se are important.

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This preliminary case series serves 2 purposes. First, it assesses whether the Stroop Color and Word Test (SCWT) can be used in the clinical setting to assess change in cognitive function in the immediate anesthetic period. This series was performed as a pilot study to assess the utility of the SCWT in the perioperative clinical setting as a measure of subtle changes in cognitive function that result from different anesthetic techniques (e.g., with or without the use of a lumbar plexus block after total-hip replacement). Second, we chose to assess cognitive function after a major surgical procedure—total-hip replacement (THR)—performed under hypotensive epidural anesthesia (HEA) with propofol sedation alone. Patients were pain free after they had received an epidural anesthetic plus lumbar plexus block (LPB). Thus, several of the variables (pain, opioid effects, residual sedation, and nausea) that would adversely affect cognition after major surgery were reduced through a regional anesthetic technique that utilized a short-acting sedative (propofol) and no opioids.

Methods

After Institutional Review Board approval, patients undergoing THR performed under HEA by 2 surgeons were studied. Patients who were color-blind or who could not read English were excluded. (N.E.S. performed all anesthetics, and S.G. and G.F. performed the SCWT.)

Anesthetic management was standardized. All patients were monitored by electrocardiography and pulse oximetry. Arterial pressure and central venous pressure (CVP) were monitored via radial artery and internal jugular catheters, respectively. Pressures were recorded on a Spacelabs monitor (Redmond, WA). Sedation was achieved by administration of intravenous propofol via infusion pump (Baxter, Deerfield, IL), and the total dose was recorded. No other sedatives or opioids were administered during surgery. Patients breathed spontaneously on nasal oxygen administered at 3 to 4 L/min throughout surgery. Patients were placed in the lateral decubitus position, and then HEA was induced by injection of 20 to 30 mL of 0.75% bupivacaine at the L_1-L_2 or T_{12}-L_1 interspaces and infusion of epinephrine via the CVP catheter at 1 to 6 μg/mL to maintain mean arterial pressure (MAP) at 40 to 50 mmHg. Lactated Ringer's solution was administered to maintain CVP and replace blood loss. At the end of surgery, the epinephrine infusion was slowly discontinued, and MAP was increased to 65 mmHg (approximately 100 mmHg systolic), with an infusion of ephedrine. LPB was then performed at L_3-L_4 with the aid of a nerve stimulator set at 2 mA. A 10-cm Braun 21-gauge Simplex needle was used to inject 30 mL of 0.5% bupivacaine. The duration of MAP of 50 mmHg or lower and 45 mmHg or lower was recorded from stored data. The lowest MAP was also measured. Two to 3 hours after surgery, an epidural infusion of 0.06% bupivacaine with 10 μg/mL of hydromorphone was administered at 2 mL/h, with a patient-controlled epidural analgesia bolus of 4 mL, 4 times per hour. This analgesia was discontinued 36 hours later and oral opioids administered.

The SCWT was administered preoperatively on the day of surgery, 1 and 2 hours after surgery, and on the first and second postoperative days when possible. The first part of the SCWT involves asking each subject to read a list of the words "red," "green," and "blue" presented in black and white as fast as possible in 45 seconds (word test). The second part involves identifying the same 3 colors in a similar list to the word test, but with Xs taking the places of letters so as to form the shape and size of names but not actually spell anything ("XXXX") (color test). In the third and final section of the test, the subject must identify the color of the ink that the word ("red," "green," or "blue") is printed in, while the word actually spells a different color. Red would be printed in yellow, for instance, and yellow is the correct answer (color/word test). All 3 of the raw scores were corrected for age and education. The test required 5 to 10 minutes to complete and was administered according to the guidelines defined by Golden and Freshwater.[4] This test was chosen because it could be completed in less than 10 minutes with a patient confined to bed.

Changes in each test were compared with the preoperative value by use of paired *t*-tests. Independent *t*-tests were run between those with and without hypertension. Analysis of variance with hypertension as the between-groups factor and age and the baseline value as covariates were run. The change in score was the dependent variable. The difference between the preoperative values and those recorded 2 hours postoperative were derived for each subject to assess the relationship between any changes in cognition and the dose of propofol or the lowest MAP by use of linear correlation; α was set at 0.05.

Results

Sixty-one patients were approached, and 55 were enrolled. Six patients did not complete the test: 1 patient, age 82 years with marked dementia (who scored a 5 on the preoperative color/word test), felt unable to continue the study after surgery; a second patient refused out of frustration; a third patient was unable to continue because of chest pains and difficulty breathing; and 3 patients refused with no reason given. No patients were unable to perform the test because of nausea. The patient demographics are shown in Table 1. The mean age was 65 years (range: 21 to 86; SD = 12.8).

Fifty-five patients enrolled and 47 completed the test 1 hour after surgery, whereas 49 completed the test 2 hours after surgery. Fifty-two of 55 patients completed the test at either 1 or 2 hours after sur-

Table 1. Demographics for the 55 Patients Enrolled in the Study

Age (yr)	65 ± 12.8 (21-86)*
Height (cm)	168.8 ± 11.2 (142-188)
Weight (kg)	78.1 ± 19.6 (43-131)
Male	30
Female	25
Attended high school	53
Attended college	32
Attended graduate school	6
Clinical depression	2
History of hypertension	34
History of coronary artery disease	2
Carotid occlusive disease	1

*Mean ± SD (range).

Table 2. Average *t* Scores and *P* Values for Each Data Collection Timepoint for General Population

	Presurgery	POH1	POH2	POD1	POD2
Word	43.7 ± 12.9	35.2 ± 12.4*	38.1 ± 12.9**	41 ± 13.8	44.9 ± 11.6
Color	39.3 ± 10.4	34.5 ± 11.7***	36.1 ± 11.7	36.6 ± 12.1	41.7 ± 10.2
Color/word	47 ± 9.6	44.7 ± 9.5	48 ± 10.7	47 ± 10.8	48 ± 10.3

NOTE. POH1 and POH2 = 1 and 2 hours after surgery, respectively. POD1 and POD2 = 1 and 2 days after surgery, respectively.
*$P < .0001$; **$P < .001$; ***$P < .0005$; compared with presurgery values.

gery. On postoperative day 1, 45 patients completed the test, and 30 completed the test on the second day after surgery. Causes for not completing the test in the first 2 hours after surgery included chest pain ($n = 2$), shivering ($n = 2$), somnolence ($n = 2$), and nonspecific causes ($n = 5$).

The mean scores for each timepoint for word, color, and color/word are shown in Table 2. Difference between the preoperative and each postoperative score was analyzed. A significant decline in word and color score was noted 1 hour after surgery ($P < .001$; $P < .0005$, respectively) (Table 2). One hour later (2 hours after surgery) word score had increased significantly ($P < .005$) from the previous hour but remained unchanged at 24 and 48 hours after surgery.

The effect of age on the change in cognitive function was assessed by a comparison of change in patients age 69 years or less with those age 70 years or more (Table 3). In patients age 69 years or less, a significant decline in word and color occurred at 1 hour but no difference occurred in color/word. By 2 hours no difference was seen in word or color, but an improvement occurred in the color/word score ($P < .05$). Scores were unchanged after the day of surgery. Those 70 years of age or older exhibited a decline in color and word score that persisted by the first day after surgery (Table 3). The mean scores of patients with hypertension ($n = 34$) were not significantly different from patients with no hypertension.

The difference between the preoperative measurement and the measurement taken 2 hours after surgery was calculated for each assessment (word, color, and color/word) in each patient. These values were not related to the dose of propofol, the duration of MAP less than 51 mmHg (32 to 177 minutes), the duration of MAP less than 46 mmHg (7 to 120 minutes) (Fig 1), or the lowest MAP (33 to 44 mmHg) (Fig 2). Furthermore, no relationship existed between the duration of surgery and changes in SCWT ($R^2 = 0.041$).

Discussion

This study demonstrates that the SCWT can be utilized in the perioperative setting to assess changes in cognitive function. Each value declined 1 hour after surgery but had normalized 1 hour thereafter, which reflected a return of cognitive function (as assessed by the SCWT) in those patients who were pain free and who had not received opioids. The test was easy to perform with patients lying in bed, took no longer than 10 minutes to complete, and was found suitable in elderly patients. In 52 of 55 patients, at least 1 measurement was recorded in the first 2 hours after surgery. An earlier version of the SCWT had been a useful predictor of cognitive changes after surgery in prior studies.[3,5]

Under regional anesthesia (epidural anesthesia plus LPB) and after administration of a propofol infusion without opioids or other sedative agents, patients under the age of 70 years exhibited return of cognitive function 2 hours after THR. In fact, the performance on the most complex of the 3 sections of the test (the color/word section) improved statistically over the presurgical score. This improvement possibly reflects a practice effect and also at-

Table 3. Average *t* Scores and *P* Values for Each Data Collection Timepoint for Subgroups

		Presurgery	POH1	POH2	POD1	POD2
Age ≥ 70 ($n = 23$)	Word	40.9 ± 11.7	30.3 ± 11.6*	32.3 ± 10**	34.7 ± 10.8***	37.3 ± 8.3
	Color	37.2 ± 10.9	28.7 ± 11.3****	30.5 ± 10.4****	31.6 ± 10.7***	37.1 ± 6.9
	Color/word	46.4 ± 9	40.4 ± 7.8****	43.3 ± 7.5	42.9 ± 7.7	44.1 ± 6.9
Age ≤ 69 ($n = 29$)	Word	46 ± 13.8	39.1 ± 11.7*	43.2 ± 13.2	47 ± 13.7	49.4 ± 11.1
	Color	41 ± 9.7	39.1 ± 10***	41 ± 10.5	41.4 ± 11.6	44.4 ± 10.6
	Color/word	47.5 ± 10.2	48.2 ± 9.3	52.2 ± 11.4***	50.9 ± 11.9	50.7 ± 9

NOTE. POH1 and POH2 = 1 and 2 hours after surgery, respectively. POD1 and POD2 = 1 and 2 days after surgery, respectively.
*$P < .005$; **$P < .0005$; ***$P < .05$; ****$P < .01$; compared with presurgery values.

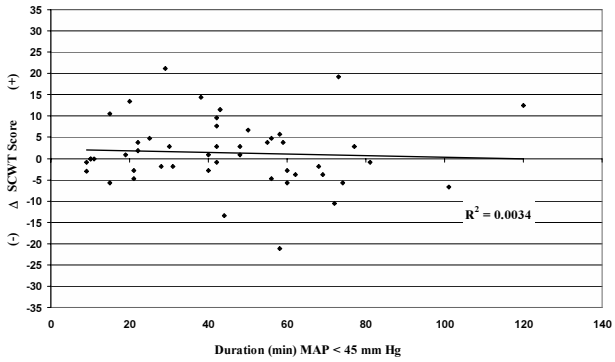

Fig 1. Change in Stroop Color/Word Test score (ΔSCWT score) for each patient vs. duration mean arterial pressure (MAP) less than 45 minutes.

tests to the mental clarity noted so soon after major surgery with this anesthetic technique.

In contrast, the elderly patients (70 years of age and older) exhibited a slight but statistically significant decline in all tests after surgery, which persisted for the following 2 days. This decline was not related to the dose of propofol or the degree of hypotension but warrants further study. Elderly patients are known to suffer greater decline in cognitive function after surgery than do younger patients.[6]

During total-hip replacement, "fat" emboli may traverse through the pulmonary circulation and embolize to the brain.[7] The likelihood of such a complication is greater when cemented femoral components are inserted.[8] It could possibly account for the slight persistent decline in cognitive function in the patients older than 70 years. Seven of 29 patients younger than 69 years had noncemented femoral components. We noted no difference in cognitive function in these 7 patients compared with age-matched patients who received cemented femoral components. This study was designed to assess any difference in this regard.

HEA was first described in 1990.[9] The technique involves injecting a large volume of plain local anesthetic (approximately 25 mL of 0.75% bupivacaine) at a high lumbar interspace (T_{12}-L_1 to L_1-L_2) to achieve an extensive sympathetic block. A low-dose epinephrine infusion (2 to 5 μg/min) is utilized to maintain filling pressure, heart rate, and cardiac output while mean arterial pressure falls to 45 $\pm$ 5 mmHg.[9,10] The benefits of this technique include low blood loss, low rate of deep-vein thrombosis,[11] improved cement fixation,[12] and low mortality.[13,14] A series of 1,000 patients were reported in which no patients developed stroke.[15] In a subsequent randomized clinical trial, HEA had no demonstrable effect on cognitive function at 7 days or 4 months after surgery.[1] This study shows recovery of cognitive function immediately after HEA.

In this study, MAP was kept lower (40 to 45 mmHg) than in our previous studies (approximately 50 mmHg). The mean duration between 40 and 45 mmHg was 43.9 minutes (range: 7 to 120 minutes, SD = 24.6), and the mean duration below 50 mmHg was 74.8 minutes (range: 32 to 177 minutes, SD = 32.5). Despite these low blood pressures, changes in cognitive function were minimal and no cardiovascular complications occurred. Neither the duration of hypotension nor the lowest blood pressure recorded was related to changes in cognitive function. This observation has been made in prior studies.[1]

The preoperative diagnosis of hypertension did not affect cognitive function with this degree of intraoperative hypotension. HEA (45 to 55 mmHg) has previously been demonstrated to have no affect on cognitive function assessed at 1 week and 4 months after surgery. This study extends these observations by demonstrating that with HEA, changes in cognitive function are not adversely affected by MAP of 40 mmHg. As determined by multiple linear-regression analysis, age and baseline word score accounted for 38% of the variance in change in cognitive function from baseline (r = 0.38). Neither the duration of hypotension nor a preoperative diagnosis of hypertension was related to change in cognitive function.

Many tests are available to assess cognitive function perioperatively, but none have been accepted as the "gold standard." Furthermore, most entail a battery of tests that take 30 minutes or more to perform, which makes them difficult to repeat rapidly with a patient lying in bed. Rasmussen reanalyzed data from the International Study of Post-Operative Cognitive Dysfunction[3] and found that the SCWT provided similar data to the entire bat-

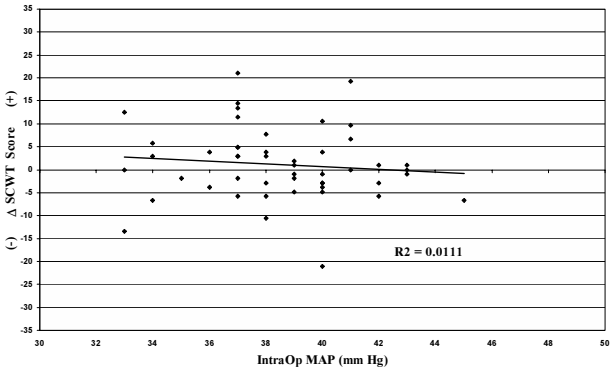

Fig 2. Change in Stroop Color/Word Test score (ΔSCWT Score) for each patient vs. lowest intraoperative mean arterial pressure (MAP) recorded.

tery of previous tests and recommended we use the SCWT because it could be performed quickly and could be used by patients lying in bed (personal communication). Although the test has been validated in a variety of settings, to our knowledge, it has not been previously used as a sole cognitive function test in the perioperative period. However, these data suggest that the SCWT is easy to use and may prove to be a useful tool.

This preliminary study demonstrates that the SCWT can be used to assess cognitive function in middle aged and elderly patients perioperatively and may be a useful tool to assess factors that affect early recovery after surgery.

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