

Comparison of Psychologic and Cognitive Functions after General or Regional Anesthesia

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The behavior of 105 patients randomly assigned to receive either general or regional anesthesia and who underwent one of three types of surgery (hysterectomy, prostatectomy, or joint replacement) was assessed before, immediately after, and 3 mo after surgery. Psychologic status was assessed by the Sickness Impact Profile, the SCL-90-R, and a Metamemory Questionnaire. Cognitive functioning was measured by a battery of ten psychomotor, memory, and skilled performance tasks. Physical health was scored by the ASA classification of physical status, a health index, postoperative complications ratings, and a self-rated measure of the patient's health. There were cognitive differences across surgery groups due to age and gender variability among the patients; however, the type of anesthesia produced no difference in behavior. Both the physical and mental health indices showed improvement from the preoperative to the postoperative periods. General anesthesia appears to pose no risk to mental function and recovery beyond that associated with regional anesthesia and surgery. (Key words: Anesthetic technique: general; regional. Brain: cognition; memory; psychomotor function. Postoperative period.)

AFTER A MAJOR surgical operation many patients complain of mental and psychologic changes including tiredness, lack of concentration, difficulty with learning and recall, and deterioration in verbal capabilities.^{1,2} For example, Bedford³ described 18 cases of gross dementia occurring after anesthesia and surgery in elderly patients and several cases that showed lesser degrees of dementia. Blundell⁴ studied 86 elderly patients who had surgery. Patients suffered deterioration of their mental functions, particularly their memory and cognitive abilities, which continued to a significant extent for several weeks at least. Seventeen patients suffered confusional states; five of these were confused longer than 7 days and in three patients the confusion lasted for 6 wk or more. Hole *et al.*⁵ studied 31 patients who had general anesthesia for total hip arthroplasty (THA); seven showed significant postoperative mental changes. Five of those affected still had

mental changes that reduced the quality of their lives several months later. Romm *et al.*⁶ interviewed patients after mastectomy, almost all of whom suffered considerable depression and other psychopathology.

A study of patients who had THA⁵ showed that none of the 29 patients who received regional anesthesia but seven of the 31 patients who received general anesthesia had significant postoperative mental changes. However, two studies^{7,8} showed similar mental performance postoperatively in two groups of patients having surgery performed during either local or general anesthesia. At least two of these studies used nonblinded investigators and employed nonstandardized and relatively insensitive assessment procedures. The small number of patients studied also makes it difficult to draw strong conclusions.

The present report is a prospective study of 105 patients randomly assigned to receive either general or regional anesthesia while undergoing one of three types of surgery: THA or total knee arthroplasty (TKA), vaginal hysterectomy, and transurethral prostatectomy. Physical and mental health measures were obtained before, immediately after, and 3 mo after surgery. The first and third mental measurements were done in the patients' homes to obtain assessments within their daily life surroundings and away from the intimidating and potentially disruptive hospital environment.^{9,10} The major focus of the study was on comparing within-subject change in perceived and actual mental abilities after surgery and either general or regional anesthesia.

Methods

PATIENT RECRUITMENT

The study was approved by the Institutional Review Board of the University of Iowa. Over approximately a 1-yr period (March 1986, to April 1987) the names and addresses of patients scheduled to undergo THA, TKA, transurethral prostatectomy, or vaginal hysterectomy at the University of Iowa Hospital and the Veterans Administration Hospital were obtained. Patients living within roughly 200 mi of Iowa City were sent a letter describing the study, followed a few days later by a telephone call soliciting their participation. The geographical restriction of the residence of patients allowed the research assistant to travel to the patient's home, conduct a testing session, and return in most instances within the same day. Patients

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were also initially excluded if they had surgery within the preceding 3 mo or suffered from conditions that would materially interfere with testing. The latter included dementia, severe hearing and/or visual impairment, inability to understand and speak English, and fewer than 6 yr of schooling.

PROCEDURE

After agreeing to participate patients were visited in their homes 1–2 wk before their scheduled hospital admission (mean, 10.2 days). The study was explained in detail once again, informed consent was obtained, demographic data were recorded, and the cognitive tasks and questionnaires were administered. One to seven days after their surgery (mean, 88 h) while the patients were still hospitalized, they were tested once again. Finally, approximately 3 mo after their surgery (mean, 90.5 days) patients were revisited at home and all the tasks and questionnaires were readministered. Testing was done by the research assistant who was only involved with this part of the study and did not know the anesthetic and medical management of the patients.

PERIOPERATIVE MANAGEMENT

Patients were assigned to receive either general or regional anesthesia in order of recruitment to the study according to a previously arranged randomized block design. The schedule maintained equal numbers of general and regional anesthesia within each block of eight subjects. Separate randomization schedules were used for the University and Veterans Administration patients and for male and female patients in the group undergoing joint replacement surgery to maintain proportional contribution to each anesthesia condition. Patients having a contraindication to one method of anesthesia or the other were dropped from the study and were replaced on the schedule.

The patients in the general anesthesia group ($n = 53$) received mostly diazepam (mean dose, 14.7 mg) orally as premedication. Anesthesia was induced with thiopental and maintained with nitrous oxide in oxygen and isoflurane (65% of cases), enflurane (26% of cases), or halothane (9% of cases). Adjuvants such as fentanyl and muscle relaxants were occasionally administered, particularly before tracheal intubation. The patients in the regional anesthesia group consisted of 38 subjects who received a subarachnoid block and 14 subjects who received epidural anesthesia. Most of the patients received premedication similar to that of the other group. The subarachnoid block was performed through a lumbar puncture, usually at L3–4 space, and in most cases tetracaine (Pontocaine) was injected in a hyperbaric solution of 5% dextrose. The epidural block was achieved by inserting a lumbar epidural

catheter and injecting mostly 0.5% bupivacaine (Marcaine) with 1:200,000 epinephrine. Patients usually breathed oxygen-enriched air through nasal prongs. In 54% of cases midazolam (mean dose 3 mg) and/or fentanyl (mean dose, 0.04 mg) were administered during surgery. Crystalloids were used for iv infusion. Blood loss of $\geq 15\%$ of estimated blood volume was replaced with packed cells. Postoperative care was administered according to the usual routine in the recovery room then afterwards in the ward.

ASSESSMENT OF PSYCHOLOGIC HEALTH

Three self-rated scales of psychologic function were administered during the home visits before and 3 mo after surgery and a mental status questionnaire was administered during the early postoperative visit.

Sickness impact profile (SIP). The SIP¹¹ is a behaviorally based measure of health status with 136 items that fall into two major categories: physical function (ambulation, mobility, and body care and movement) and psychosocial function (social interaction, alertness behavior, emotional behavior, and communication), plus five independent categories (sleep and rest, eating, work, home management, and recreation and pastimes).

SCL-90-R. Psychologic functioning was assessed by the SCL-90-R,^{††} which is a 90-item self-report symptom inventory designed to reflect the psychologic symptom patterns of psychiatric and medical patients.

Metamemory questionnaire. The Metamemory Questionnaire¹² asks for ratings of recent and persistent memory failures and the subject's means of coping with memory problems.

Mental status questionnaire. A brief set of 15 simple questions¹³ were asked by the research assistant to exclude delirium, disorientation, or dementia in the early postoperative phase.

Assessment of cognitive changes. A variety of tasks, adapted from laboratory investigations of memory, cognition, and psychomotor function were administered. A different set of stimulus materials was used in each test session, but the sets were administered to all patients in the same order.

Reaction time. Subjects were required to respond as quickly as possible by pushing a button to a series of 25 light flashes. The flashes were presented without warning over a 1–10 s interval with a mean interstimulus interval of 5 s. The mean reaction time was calculated over the last 20 trials.

Tapping. Subjects moved a stylus between two metal contact plates as rapidly as possible for two 30-s trials with a 30-s interpolated rest period. Each touch incremented

†† Derogatis LR: SCL-90-R: Administration scoring and procedures manual I. Baltimore: Clinical Psychometrics Research, 1977.

a counter to provide a record of performance. The mean of the two trials was used as the performance measure.

Symbol cancellation. Subjects were presented with a page of random letters. Each row started with two target letters followed by a string of 60 random letters. Subjects were instructed to cross out as many of the target letters within the rows as quickly and as accurately as possible over a 2-min period. The number of targets detected and the proportion of possible targets detected (number detected minus errors) were used as dependent variables.

Card sorting. Each subject was given two decks of 52 playing cards and a shallow box with a partition in the center. Subjects were instructed to sort the cards into two piles according to a specified rule (hearts and clubs to one side, spades and diamonds to the other). The number of cards correctly sorted in 1 min was the subject's score.

Backward digit span. In a single trial subjects heard a sequence of numbers presented at the rate of one digit per second and were required to repeat the digits in reverse order. The digits were chosen randomly with the constraint that the same digit did not appear consecutively. Two sequences at each length from 2 to 12 digits were presented until the subject failed two sequences. The mean number of digits correctly recalled in order over the two longest sequences was the primary measure of performance.

Immediate free recall. A 24-word list was presented at the rate of one word every 2 s. Subjects were allowed 2 min to recall aloud as many of the presented words as possible in any order immediately after presentation of the last word. The words were selected from lists used and described in previous studies.‡‡

Delayed free recall. After a 15-min interval filled with other tasks subjects were required to recall again as many of the words as they could remember from the same list used in the immediate free recall task.

Delayed recognition. Immediately after the delayed recall test subjects were presented with a sheet containing the original 24 words they heard before and an equal number of new words drawn from the same source and were asked to rate their confidence on a 6-point scale of how certain they were that each word was or was not presented.

Paired-associate learning. As a test of acquisition of new associations, subjects received four alternating study-test trials of eight item pairs. The stimulus item in each pair was a nonsense word and the response item was a two-digit number. The pairs and the stimuli were presented on flash cards for 3 s. The subject was required to respond to each test trial, guessing if necessary. Performance was scored both in terms of the number of correct associations

(i.e., number correctly paired with nonsense word) and the number of correct responses regardless of pairing.

Addition. Subjects were presented with a sheet of single-digit numbers and required to add as many successive pairs as possible in 1 min, and to write the sum to the right of the column. Performance was scored in terms of the number of problems completed and the number of errors.

Stroop color-word interference task. Subjects were timed as they named or read colors in three separate lists. List 1 consisted of columns of the words red, green, and blue, typed in black print. List 2 consisted of columns of XXXX typed in blue, green, and red print. List 3 consisted of the words red, green, and blue, typed in print of conflicting colors. A subject's score for each list was the number of colors named in 45 s.

Digit-symbol substitution test. A code of nine matched digits and symbols was presented at the top of the test sheet. Subjects were required to record the symbol below a digit to match the code. The number of correct items completed in 90 s was the score.

Assessment of physical health. The following scales were used.

ASA classification of physical status. This 5-point classification¹⁴ was used to index the patient's physical condition. It is currently the best index of operative risk and predictor of overall surgical mortality.¹⁵

Health index. Data on the severity of disease of the body's organ systems (respiratory, cardiovascular, nervous, renal, digestive, endocrine/metabolic, and muscle/skin/bone) were obtained both preoperatively and postoperatively. The physiologic and functional integrities of each organ system were classified into three grades: (1) no impairment, (2) some impairment, and (3) severe impairment. The values were summed to generate the Health Index score. Specific criteria were developed for each organ scale and were tested on 1598 patients in a previous epidemiologic survey (in preparation).

Other health information, e.g., anesthetic and surgical histories, and postoperative complications, was abstracted on a standardized form from the patient's chart. To enhance reliability of assessments, only the two investigators who rated patients in the previous study and developed an identical rating method were involved in this aspect of the present study.

Patient's self-rated health. The patient was asked to rate his or her health using a simple ascending 5-point scale (poor, fair, good, very good, excellent).

STATISTICAL ANALYSES

Because of the large number of potential dependent variables, statistical analysis was conducted by first using multivariate analysis of variance (MANOVA) procedures

‡‡ Mewaldt SP, Hinrichs JV, Ghoneim MM: Diazepam and memory: Support for a duplex model of memory. *Memory and Cognition* 11: 557-564, 1983.

TABLE 1. Patient Demographics by Type of Anesthesia

Item	General	Regional
Sex: male/female	35/18	35/17
Age (yr)	60.1 ± 2.3	61.9 ± 1.8
Education (yr)	12.0 ± 0.4	11.6 ± 0.4
Tobacco use (cigarettes/day)	4.68 ± 1.69	3.85 ± 1.32
Alcohol use (oz/wk)	1.31 ± 0.46	0.83 ± 0.27
Number of prior surgeries	3.00 ± 0.22	2.56 ± 0.19
Self-rated health (1-5)	2.91 ± 0.15	3.08 ± 0.13
Health index (7-21)	9.60 ± 0.22	9.50 ± 0.19
ASA Physical Status	2.00 ± 0.09	2.16 ± 0.10

Values are given as mean ± SE. All *P* values are NS.

on sets of related variables (e.g., physical health, memory, psychomotor performance) and then reporting individual variables of interest. Follow-up tests were conducted when warranted by multivariate results with ANOVA and *t* tests. All reported correlations are Pearson product-moment correlations. An alpha level of 0.01 was used to indicate statistical significance, but a variable achieving a 0.05 level of significance was also noted when it was particularly relevant.

Results

PATIENT CHARACTERISTICS

A total of 105 patients completed the study and received random assignment of anesthesia. Fifty-one patients had THA or TKA, 34 patients had transurethral prostatectomy, and 20 patients had vaginal hysterectomy. The patients' characteristics are reported in table 1. As shown, random assignment led to approximately equivalent characteristics within each anesthesia group. Some general characteristics of the sample are worth noting. The sub-

jects ranged in age from 25 to 86 years of age with a mean age of about 61 years. Two-thirds of the subjects were males and three-fourths were married and living with their spouses. The subjects were generally well educated, both the mean and modal education level indicating completion of high school. Approximately one-third of the subjects lived in rural settings and two-thirds resided in small towns or cities. Consistent with the demographic characteristics of the state of Iowa, 98% were white. Subjective health ratings before surgery ranged from good to very good for most of the individuals, but one-half of the subjects felt their activity level was restricted by their disease. Self-reported alcohol and tobacco usage was low; 82% of the subjects reported not smoking and 65% said they consumed no alcohol.

An additional nine patients were studied but were excluded because they did not follow the original randomized assignment: three patients were scheduled for regional but wanted general anesthesia; two patients were scheduled for general but wanted regional anesthesia; three patients' regional anesthesia was not completely effective and general anesthesia was substituted and one patient was scheduled for regional anesthesia, but the procedure was abandoned when it was found that the patient was started on anticoagulant therapy. Two patients refused to participate in the study after the first visit. Three patients were excluded after the second visit: two had other surgeries during the three months observation period, and one moved to a distant state. Patients who dropped out of the study or who became ineligible were divided equally between general and regional anesthesia.

In addition to the patients who dropped out of the study and those who became ineligible, 42 patients were contacted but refused to participate from the beginning. A comparison of the health and demographic characteristics of these groups and those of our main sample showed no significant differences.

PREOPERATIVE MEASURES

The primary goal of the analyses reported in this section was to detect any differences between groups assigned to general and regional anesthesia before treatment was administered.

Physical health. Subjects in the two anesthesia conditions and three surgery groups were compared preoperatively on three physical health measures: the ASA classification, the health index, and the patient's self-rated health. None of the three ratings differed by anesthesia group ($P > 0.15$). The three preoperative health measures were significantly correlated. The highest correlation was between the ASA classification and the health index, $r = .62$. The correlations of self-rated health with the health index

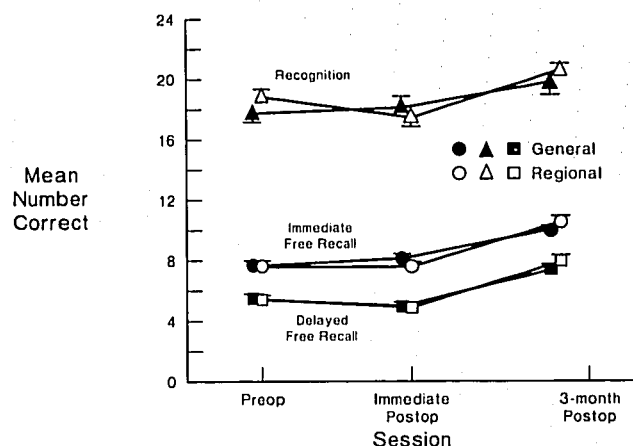


FIG. 1. Mean ± SE of the number of words recalled in the immediate free recall, delayed free recall, and recognition tasks. There were three testing sessions.

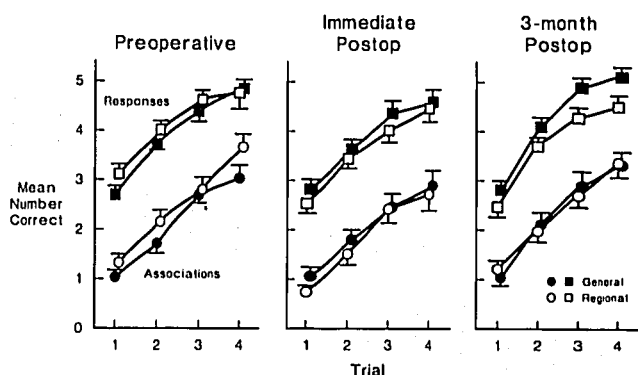


FIG. 2. Mean \pm SE of the number of words recalled in the paired-associate learning task. Patients received four trials at each of the three testing sessions. Performance was scored both in terms of the number of correct associations and the number of correct responses regardless of pairing.

and ASA classification were markedly lower, $r = .27$ and $r = .31$, respectively.

Memory and cognitive tasks. Eleven tasks were compared across the three surgery groups and the two anesthesia conditions with a MANOVA analysis. There were no differences between anesthesia groups either overall or for individual tasks (all $P > 0.05$) (figs. 1, 2, and 3, table 2). There were also no differences in performance between regional and general anesthesia subgroups across all surgery groups and tasks. These results, therefore, show that the anesthesia groups were well matched in terms of performance on the cognitive tasks before the operations. Not shown are several significant differences in performance that occurred between surgery groups. These differences are to be expected because of the differences in patient characteristics associated with the three surgery groups, particularly age and sex. For comparison of general and regional anesthesia, however, the most important result is that none of the surgery group differences interacted significantly with anesthesia condition either before or after surgery. Consequently, surgery group differences are not reported in subsequent analyses.

Metamemory. A similar MANOVA was conducted on nine metamemory scales corresponding to the nine sets

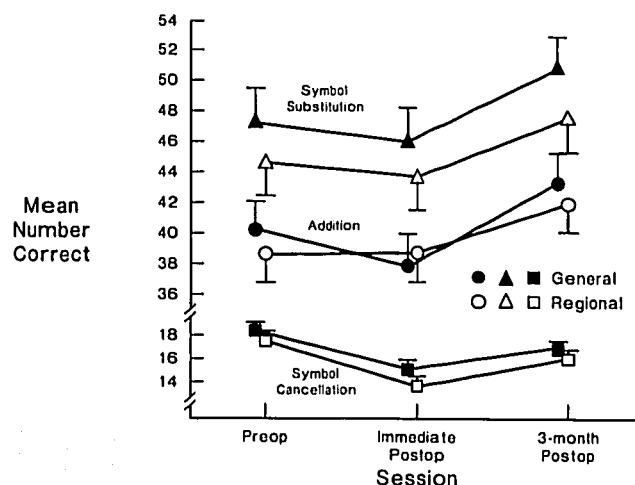


FIG. 3. Mean \pm SE of the number of correct: targets detected in the symbol cancellation task, problems completed in the addition task, and items completed in the digit-symbol substitution task. Testing was done in three sessions.

of questions about memory problems and concerns. Anesthesia type, surgery, or interaction did not produce significant differences either overall or on any subscale. The overall mean rating was 4.83 ± 0.12 (SE) in the general anesthesia group and 4.63 ± 0.10 in the regional group.

Psychologic health. Both the SCL-90-R and the SIP detected marginally significant differences ($P < 0.05$) between the two anesthesia groups before surgery, suggesting that the subjects assigned to the regional anesthesia condition began the study slightly more distressed than patients in the general anesthesia condition (table 3). On the SIP the differences between anesthesia groups existed only on the psychologic dimension, $P < 0.02$.

POSTOPERATIVE MEASURES

Physical health. Analysis of the change in mean rating of the health index over time revealed a significant improvement (from 9.54 to 8.90) with no effect of anesthesia, $F < 1$. Frequency of postoperative complications

TABLE 2. Performance by Type of Anesthesia and Test Session for Some Memory, Cognition, and Psychomotor Tasks

Task	Session 1		Session 2		Session 3	
	General	Regional	General	Regional	General	Regional
Digit span	3.86 \pm 0.24	3.70 \pm 0.13	3.55 \pm 0.15	3.54 \pm 0.14	3.67 \pm 0.16	3.75 \pm 0.14
Stroop task	34.9 \pm 1.7	32.2 \pm 1.3	31.4 \pm 1.8	33.2 \pm 1.7	35.5 \pm 1.9	32.5 \pm 1.3
Tapping	81.0 \pm 3.2	77.7 \pm 3.0	81.2 \pm 3.4	82.7 \pm 3.7	92.6 \pm 4.0	91.0 \pm 3.2
Card sorting	61.9 \pm 2.9	61.3 \pm 2.2	60.8 \pm 3.3	57.6 \pm 2.8	64.0 \pm 3.0	63.1 \pm 2.7
Reaction time	0.353 \pm 0.011	0.365 \pm 0.018	0.351 \pm 0.011	0.336 \pm 0.008	0.336 \pm 0.011	0.343 \pm 0.011

Values are given as mean \pm SE.

TABLE 3. Psychologic Health Scores by Type of Anesthesia and Session

Task	Session 1		Session 2		Session 3	
	General	Regional	General	Regional	General	Regional
SCL-90 total	51.83 ± 1.17	56.42 ± 1.76	51.56 ± 1.59	54.90 ± 1.64	48.60 ± 1.64	53.48 ± 1.75
SIP						
Physical	11.51 ± 1.30	12.70 ± 1.35	—	—	10.10 ± 1.34	9.91 ± 1.24
Psychologic	6.93 ± 1.08	11.20 ± 1.61	—	—	5.00 ± 0.92	7.36 ± 1.18
Total	9.56 ± 0.99	12.37 ± 1.32	—	—	7.81 ± 1.01	8.82 ± 1.06

Values are given as mean ± SE.

did not vary significantly among anesthesia and surgery groups with only 18 minor and one life-threatening complication reported. Minor complications were evenly divided between general and regional anesthesia groups.

Memory and Cognitive Tasks. Means and SE for the individual tasks of each session are reported in figures 1, 2, and 3 and table 2. All the analyses showed the same general pattern: no significant effect of anesthesia, no interaction with surgery group or session, little or no change from session 1 to session 2 (some modest decreases in some tasks), and a general improvement in session 3 (with the exception of the symbol cancellation task).

Paired-associate learning was analyzed separately because it contains an additional factor of change over trials and because it can be measured in two different ways. The most rigorous scoring method requires subjects to produce the correct response to the test stimulus with which it was paired during presentation trials; this is called associative scoring. A more lenient method gives credit for producing any response item in the list to a presented stimulus; this is called response scoring. As shown in figure 2, the effects of trial were significant for both measures, but all interactions were nonsignificant. Most of the change in performance was the improvement from session 2 to session 3, although follow-up tests did show a marginally significant ($P < 0.05$) decrease from the preoperative period (first panel of fig. 2) to the immediate postoperative period (middle panel of the fig. 2).

TABLE 4. Number of Patients with SCL-90-R
T-Scores ≥ 70 by Session

Symptom Dimension	Preoperative	Immediate Postoperative	Three-month Postoperative
Somatization	11	6	7
Obsessive-compulsive	9	7	6
Interpersonal sensitivity	3	3	4
Depression	11	9	11
Anxiety	4	7	4
Hostility	2	3	1
Phobic anxiety	4	5	2
Paranoid ideation	1	0	2
Psychoticism	6	4	6
Total	10	7	9

Metamemory. The analysis compared the nine subscales before and 3 mo after surgery over the two anesthesia groups. There were no significant effects for anesthesia, time of administration, or their interaction. The overall means were 4.75 ± 0.11 for the general anesthesia group and 4.58 ± 0.11 for the regional group.

The correlation between overall metamemory ratings at session 1 and session 3 was .665, suggesting consistent replies at the two times separated by 3 mo. One exception was one item rating memory in terms of the "kinds of problems that you have" (1 = major problems, 7 = no problems), exhibiting a marked increase in the number of individuals (from 7 to 17 cases) reporting some problems (scale values of 1-3) from the first to the third session.

Psychologic health. Analysis of the overall scores of the SCL-90-R showed marginal effects of anesthesia group ($P = 0.056$), significant effects of time of testing ($P < 0.001$), but no interaction of the two (table 3). On all scales patients generally exhibited little change or slight improvement from session 1 (preoperative) to session 2 (immediate postoperative), and significant gains in session 3 (3 mo postoperative). The number of severely distressed patients (T-score ≥ 70) on each scale remained about the same over test sessions (table 4).

Analysis of the total score of the SIP revealed a significant decrease in illness-related behavioral restrictions, reflecting the patients' generally improved health. The improvement occurred on both the physical and psychologic dimensions. There was no overall difference between anesthesia groups or interaction of time and anesthesia conditions. The analysis detected a marginally significant ($P < 0.05$) difference in the two anesthesia groups on the psychologic dimension subscale both before and after surgery, indicating as noted before that the patients scheduled for regional anesthesia were somewhat more impaired in their psychologic functioning. There were no interactions with time of testing.

Discussion

The available literature on prolonged postoperative mental dysfunction is sparse (apart perhaps from studies on patients after open heart surgery), flawed, and occa-

sionally contradictory. Generally, studies in this area have suffered from methodologic deficiencies, have tested only few mental functions, and/or have been based on a small number of patients.

There is the possibility that some or all of the post-surgical complaints of cognitive dysfunction do not reflect actual deficits related to surgery or anesthesia. The patient's operation could trigger a number of psychologic events, *e.g.*, mild depression or awareness of age-related changes, which could lead to subjective feelings of cognitive dysfunction not associated with impaired performance on objective cognitive tests. Consequently, the alternative hypothesis of complaint without cognitive dysfunction must be carefully examined. Past studies have rarely examined both subjective reports and objective performance together. Any attempt to account for psychologic and cognitive deficits following surgery must also take into consideration the physical health status of the patient before, during, and after surgery.¹⁶

The present study included patients who underwent one of three specific types of common surgeries that had some demographic and clinical advantages for our purpose. One of the surgeries is exclusively male, one exclusively female, and the other is almost evenly divided in frequency between the two sexes. However, the inclusion of patients from the VA Hospital who were all males in order to recruit enough numbers in the study led to a higher percentage of male patients. All operations included mostly the upper middle age and elderly patients (which allowed us to examine increasing age as a risk factor) and could be performed during either general or regional anesthesia.

For psychologic assessment we chose the SIP for its applicability to wide differences in level of functioning and type of disease, sensitivity to small changes in function, and extensive psychometric data documenting the instrument's reliability and validity.¹¹ The advantages of the SCL-90 for use in our study included its relatively pure depression scale, additional symptom scales, evidence for reliability and validity, and the presence of norms. The metamemory questionnaire permitted self-assessment of memory in a reliable and detailed way, which could be compared to actual memory performance.

Detection of changes in cognitive and intellectual functioning across the wide range of normal human abilities is a difficult, subtle task even when an individual has suffered a profound injury to the central nervous system. A major advantage of our study is the use of precomparisons and postcomparisons of performance. Assessors of cognitive deficits in most clinical situations seldom have access to premorbidity measures and must rely on normative standards. We employed a series of tasks, with special emphasis on memory because that is a central complaint of postoperative patients.^{17,18} Other reasons for the choice

of some of these tasks is their reported sensitivity² and their requirement of only simple and portable equipment.

The choice between subarachnoid and epidural blocks in the regional anesthesia group was left to the anesthesiologist responsible for the patient. The physiologic effects of both techniques are almost the same and there is no reason to expect different behavioral sequelae.¹⁹ Also, the use of one potent inhalation anesthetic or another in the general anesthesia group should not be of significance, particularly for any late effects.^{20,21} We chose the time of our last assessment to be at the end of the third postoperative month because by this time tissue healing would have occurred, usually patients in the joint replacement group can become reasonably independent, and many patients would have returned to work if they were employed before. A longer assessment time could have led to some attrition of our sample.

There was no evidence of any differences in behavior between patients who received general and those who received regional anesthesia. No consistent differences were found either in the first few days after surgery or 3 mo later. (It is possible that differences between the two groups could be found in the early hours after surgery.) The failure to find differences between the two anesthesia groups raises the question of a Type II error, *i.e.*, could there be important differences between the two conditions that our measures lacked the power to detect? The assessment of the power of a test among other things depends on stipulating what is an important difference. For the sake of generality, assume that differences between general and regional anesthesia in excess of one-half standard deviation on any particular performance measure should lead to rejection of the null hypothesis. With a sample size of approximately 100, power calculations yield a value in excess of 0.99. In brief, the relatively large sample sizes employed in the present study ensured adequate statistical power to detect reasonable differences in performance caused by differences in anesthesia.²²

Other aspects of the data suggest that the lack of differences between the two anesthesia groups cannot be attributed to insensitive or unreliable tasks. The tasks easily detected small changes in behavior over sessions and between surgery groups as well as exhibiting high correlations between levels of performance and subjects' characteristics known to affect them such as age and degree of education. (Delayed free recall and digit-symbol substitution were among the most sensitive measures in terms of their ability to detect surgery and age differences; the Stroop task and backward digit span were two of the less sensitive.) It should be noted that the only report in

§§ Fish KJ, Helms K, Sarnquist FH, Tinklenberg J, Miller DC: Neuropsychological dysfunction after coronary artery surgery (abstract). *ANESTHESIOLOGY* 57:A55, 1982.

the literature⁵ that suggested a difference in mental health outcome between general and regional anesthesia used noncontrolled observations.

The overall results of the memory and cognitive tasks can be described as showing a slight decline immediately after surgery, followed by a marked improvement 3 mo later, but this pattern must be interpreted with caution. The lack of a nonsurgery, nonanesthetic control group means that observed changes cannot be unequivocally attributed to the effects of surgery and/or anesthesia. No such control was included because it would be difficult and probably unethical to test comparably sick patients whose anesthesia and surgery would be delayed for more than 3 mo after recruitment. It is interesting that Riis *et al.*⁸ showed similar results on tests of memory and attention: a significant decrease 2 days after operation, equal scores 4 days afterwards, better scores after 7 days, then further improvement at the third month. The immediate and very transient decline may be due to residual effects of anesthetic drugs, other administered medications, sleep deprivation, and/or increased oxygen consumption in patients with limited cerebral reserve.^{23,24} The improvement in mental state is probably the result of improved physical state postoperatively, improvement in function, diminished pain and discomfort, and some practice effect due to more familiarity with the psychomotor and cognitive tests as they were repeated.

Although not reported, differences between surgery groups were a prominent characteristic of cognitive performance. The differences must be interpreted with caution because the groups varied widely on factors correlated with ability such as age, education, and gender. More important than simple between-group differences, surgery group failed to interact with anesthesia condition, strongly suggesting that type of anesthesia did not differentially influence surgery groups regardless of their great discrepancy in subject characteristics. Nor did anesthesia interact with age when patients were divided into three age groups (<60, 60–69, >69 yr) and compared over anesthesia conditions. Failures to find significant interactions between anesthesia condition and either surgery group or age suggest that general and regional anesthesia have the same effect over a wide range of patient characteristics and the varieties of surgeries studied.

Postoperative delirium has been identified as a significant postoperative complication in patients undergoing total joint replacement²⁵ and in elderly patients undergoing all types of surgery.²⁶ Titchener *et al.*²⁷ found an incidence of 7.8 cases per 100 in a general surgical

population, whereas others²⁸ reported an incidence of approximately 25%. The absence of cases in our sample is encouraging because delirium can be the cause of prolonged disability, lengthened hospital stay, and even mortality.²⁹ It seems also that the incidence of reports concerning delirium have decreased in the last decade.¹⁰ Understanding the risk factors and etiologic mechanisms²⁹ and trying to eliminate or reduce them in addition to better psychologic care preoperatively and postoperatively when indicated must have contributed to this decline.

The present report is very assuring when one considers citations in the literature about the occurrence of gross dementia⁹ and deterioration of mental functions⁴ following anesthesia and surgery. Perhaps there has been an improvement in the quality of health care administered to patients in the perioperative period, and this has changed for the better the mental outcome of the majority of patients. Both the physical and psychologic health indices showed improvement from the preoperative to the postoperative periods. The present study is methodologically more complete than its predecessors, combining the results of objective performance, subjective patients' reports, and physical health correlates. In summary, we found that either method of anesthesia, general or regional, was satisfactory, with no difference in behavior, physical health, or complications between patients of the two groups.

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