Published in final edited form as:
Anesthesiology. 2009 April ; 110(4): 788–795.

Measures of Executive Function and Depression Identify Patients at Risk for Postoperative Delirium

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Abstract

Background—Postoperative delirium is associated with increased morbidity and mortality. Pre-existing cognitive impairment and depression have been frequently cited as important risk factors for this complication. This prospective cohort study was designed to determine if individuals who perform poorly on preoperative cognitive tests and/or exhibited depressive symptoms would be at high risk for the development of postoperative delirium.

Methods—One hundred nondemented patients, 50 years and older, scheduled for major, elective noncardiac surgery completed a preoperative test battery that included measures of global cognition, executive function and symptoms of depression. Known preoperative risk factors for delirium were collected and examined with the results of the preoperative test battery to determine the independent predictors of delirium.

Results—The overall incidence of delirium was 16% and was associated with increased hospital length of stay ($p<0.05$) and an increased incidence of postoperative complications ($p<0.01$). Delirious subjects did not differ from their non-delirious cohorts with regard to their preoperative global cognitive function, preexisting medical comorbidities, age, anesthetic management or history of alcohol use. Preoperative executive scores ($p<0.001$) and depression ($p<0.001$), as measured by the Trail Making B test and Geriatric Depression Scale Short Form, respectively, were found to be independent predictors of postoperative delirium.

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Meeting: The information in this manuscript was presented as an abstract on October 20, 2008 at the American Society of Anesthesiologists Annual Meeting in Orlando, Florida.

Work Attribution: Department of Anesthesiology at Duke University Medical Center and the Durham Veterans Affairs Medical Center in Durham, NC 27705

Conclusions—Low preoperative executive scores and depressive symptoms independently predict postoperative delirium in older individuals. A rapid, simple test combination including tests of executive function and depression could improve physicians' ability to recognize patients who might benefit from a perioperative intervention strategy to prevent postoperative delirium.

Introduction

Delirium is a common and serious postoperative complication occurring in 5 to 15% of elderly patients following general anesthesia[1] and up to 64% of patients undergoing spinal anesthesia for hip fracture surgery.[2] Postoperative delirium is independently associated with increased mortality, length of hospital stay, functional disability, placement in long-term care institutions, and hospitalization costs.[3,4] It is estimated that delirium occurs in at least 20% of the 12.5 million individuals aged 65 years of age or older who are hospitalized each year and increases the cost of hospitalization by $2500 for each patient who develops this complication.[5,6] A study evaluating the total 1-year health care costs for elderly individuals who developed delirium while hospitalized estimated that the national burden of delirium on the health care system may be as high as $152 billion each year.[7]

The etiology of postoperative delirium has not been clearly elucidated because it is a heterogeneous and multifactorial disorder involving a complex interrelationship between a vulnerable patient with preoperative risk factors who is exposed to numerous precipitating factors in the perioperative period.[5,8] A recent systematic review[8] of the literature found that, while various studies have identified multiple risk factors of delirium, two previously validated prediction models[9,10] remain helpful in identifying at-risk patients. Pre-existing cognitive impairment (as measured with global mental status examinations) is the only item common to both of these predictive models and has been frequently cited as an important risk factor in numerous other studies.[8] The systemic review[8] also identified depression as a significant risk factor and more recent studies in medical[11] and surgical[12,13] patients support the view that depressed elderly patients are at high risk for developing delirium.

The elderly population is increasing at an unprecedented rate and, as a result, the number of surgical procedures in the elderly will increase dramatically in the future. The incidence of postoperative delirium will likely also increase unless strategies for preventing it can be developed. The first crucial step in delirium prevention is the identification of at-risk patients prior to surgery.

The hypothesis for this prospective cohort study was that individuals with preoperative cognitive impairment and/or depressive symptoms would be at the highest risk for the development of postoperative delirium. To investigate this hypothesis, preoperative patient risk factors for delirium were collected and patients were evaluated with neuropsychological tests prior to surgery to determine their preoperative cognitive status and level of depression. The impact of these factors was evaluated with a particular focus on identifying those cognitive measures most predictive of postoperative delirium. A companion study by Smith and colleagues[14] in this issue of *Anesthesiology* also evaluates the relationship between executive function, depression and delirium.

Materials and Methods

Subject Enrollment

After approval by the Institutional Review Board, 100 consecutive patients undergoing major noncardiac (general, thoracic, urologic, vascular or orthopedic) surgery at the Duke University and the Durham Veterans Affairs (VA) Medical Centers gave their written informed consent and were enrolled in this study between November 2007 and May 2008. Inclusion criteria

included adult patients who were aged 50 years or older and scheduled to be admitted to the hospital for a minimum of 2 days after surgery. Additional inclusion criteria were surgery scheduled under general anesthesia, fluency in English, ability to read, and the absence of serious hearing or vision loss that would preclude neuropsychological testing. We excluded patients who were scheduled to undergo cardiac, carotid, or neurosurgical procedures, those unwilling or incapable to give informed consent, and those not returning to the institution for follow-up visits. Patients could not be included twice, even if they had an unrelated second procedure. Patients were approached either during their preoperative screening appointment or the day before their surgery in their hospital room.

Preoperative Evaluation and Perioperative Management

The preoperative evaluation was performed within 14 days of surgery. Information about the patients' demographic status, medical and psychiatric history was obtained during the preoperative anesthesia visit. The Charlson comorbidity score[15], a weighted index that includes both the number and seriousness of comorbid medical conditions, was computed for all patients at hospital admission. The anesthesia provider performing the preoperative anesthesia assessment rated each patient's presurgical comorbidity with the American Society of Anesthesiologists physical status score.[16] All surgery was performed with general anesthesia, and there were no restrictions on the type of anesthesia or postoperative analgesia.

Neurocognitive and Delirium Assessments

A brief battery of neuropsychological tests was administered within 14 days of surgery. The neuropsychological assessment was performed in a quiet, private room with only the patient and a qualified member of the research team present. Each examiner was trained on psychometric test administration and relevant interview techniques by the neuropsychologist (DKA) involved in the protocol. All measures were administered and scored prior to the surgical procedure in a standardized manner to minimize differences between test administrators. Project investigators trained in neuropsychological assessment completed all data interpretation.

Patients were given the neuropsychological tests in the following order during their preoperative visit:

1. The Confusion Assessment Method (CAM)[17] The CAM is a screening instrument for delirium consisting of 4 clinical criteria: 1.) acute onset and fluctuating course, 2.) inattention, 3.) disorganized thinking, and 4.) altered level of consciousness. For a person to be considered delirious, both the first and second criteria have to be present and either the third or fourth criterion. The CAM has a high interobserver reliability (kappa = 0.8 to 1.0), a sensitivity of 94 to 100%, and a specificity of 90 to 95%.
2. Modified Mini-Mental State (3MS)[18] This extended measure of general cognition that was developed to overcome shortcomings of the traditional Mini-Mental State Exam (MMSE) score, specifically its ceiling effects and narrow range of possible scores.[19] The 3MS has additional items providing enhanced measures of global cognitive function and can result in a maximum total score of 100 points.
3. Trail Making Test[20] This is an executive measure of sequencing and cognitive flexibility.
    a. Trails A requires the subject to rapidly sequence a straightforward series.
    b. Trails B is a more difficult cognitive flexibility task requiring the subject to follow a sequential pattern while shifting cognitive sets and reflects executive functioning, although other cognitive abilities such as

psychomotor speed and visual scanning are necessary for successful completion of the task.[21] The scoring for this test is the time in seconds required for completion the test. The test is discontinued at 300 seconds if the subject is not able to complete it in that period of time.[22]

4. Digit Symbol Substitution subtest[23] of the Wechsler Adult Intelligence Scale-III. This executive processing speed task requires rapid sequencing of digits and symbols. Specifically, the subject is given a key grid of numbers and matching symbols, with a test grid with numbers and empty boxes. The subject fills in as many of the empty boxes with the symbol that corresponds to the printed numbers in 120 seconds. The score is the number of correct number-symbol matches.

5. Symbol Search subtest of the Wechsler Adult Intelligence Scale-III[23]. This subtest is another measure of executive processing speed involving rapid target identification. In this subtest, each item contains two target abstract line drawings. Subjects must rapidly scan a corresponding series of five line drawings and make a judgment as to whether either of the original targets is repeated among the five. The score is the number correct within the given time of 120 seconds.

6. Geriatric Depression Score Short Form (GDS-SF)[24] The GDS-SF is a questionnaire that screens for the presence and degree of depression in adults. The GDS-SF consists of 15 questions and has been shown to have a robust correlation with the Beck Depression Inventory and to be a valid screening tool for depression in the preoperative setting.[25]

7. Numerical rating scale for pain:[26] 0 indicates no pain and 10 indicates the worst imaginable pain.

Patients were visited for the first 3 days after surgery or until discharge, whichever came first, and the CAM was administered to determine if the patient was experiencing delirium. Each patient was interviewed by the same trained research assistant prior to surgery and during the postoperative visits. We defined the occurrence of delirium as the patient meeting the CAM criteria for delirium on any of the postoperative assessments. If a patient was positive for delirium, a second member of the research team was consulted to verify the diagnosis. The second evaluator agreed with the diagnosis of delirium in all of the cases.

Postoperative Outcomes

We evaluated length of hospitalization, lowest postoperative hemoglobin, 30 day morbidity as defined by the National Surgical Quality Improvement Program outcomes,[27] and 90 day mortality as secondary outcomes in the study. The National Surgical Quality Improvement Program was originally developed by the Department of Veteran Affairs to provide reliable risk adjustment, morbidity, and mortality information to compare outcomes in VA medical centers to those reported nationwide. The categories used to classify outcomes in the National Surgical Quality Improvement Program database are: 1.) Wound - occurrences which include superficial or deep incisional surgical site infections, and wound disruptions; 2.) Urinary tract - occurrences which include renal insufficiency, acute renal failure, and urinary tract infections; 3.) Respiratory -occurrences which include pneumonia, unplanned intubation, pulmonary embolism, and prolonged mechanical ventilation (>48 hours); 4.) Central nervous system occurrences which include stroke, coma longer than 24 hours, and peripheral nerve injury; 5.) Cardiac - occurrences which include cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction; and 6.) Other - occurrences which include postoperative bleeding requiring transfusion, graft/prosthesis/flap failure, deep vein thrombosis/thrombophlebitis, systemic sepsis, organ/space surgical site infection, and *Clostridium difficile* colitis.

Assessment of Descriptive Characteristics and Covariates

The potential preoperative covariates that were included in the analysis were age, education, alcohol use, American Society of Anesthesiologists physical status, Charlson comorbidity index, pain score, depression, general cognition score as measured by the 3 MS, and scores on the Digit Symbol, Symbol Search, and Trails B tests. All of these covariates were collected during the preoperative anesthesia visit.

Statistical Analysis

Sample Size Calculation

Due to a scarcity of previous studies examining this relationship in noncardiac samples, sample size calculation was difficult. Based on previous literature indicating that delirium is prevalent in approximately 10-15% of elderly patients, we estimated that recruiting approximately 110 participants would allow for a 5 to 10% dropout rate and provide us with adequate statistical power to conduct preliminary analyses into the predictive ability of both neurocognitive and depression variables.

Data Analysis—The primary outcome of concern for this analysis was the occurrence of delirium during the first 3 days of the postoperative period. Patients were stratified into two groups by presence of delirium. Bivariate analyses of the preoperative covariates that were expected to be associated with postoperative delirium were examined using two-sample t tests for continuous data and Pearson's chi-square tests for categorical data. All preoperative covariates that were significant in the bivariate analysis (p value ≤ 0.05) were included in a multivariate logistic regression model to determine the independent predictors of delirium.

As a secondary exploratory analysis, we examined the relationship between executive function, depression, and delirium using published cut-off scores. This provides a preliminary risk stratification illustration for clinicians to consider as an example of how at-risk individuals might be identified preoperatively. We used published normative data for the Trails B and GDS-SF, the two cognitive tests that were significant in the model, to determine accepted cutoff scores for executive dysfunction and depression. The cutoff score for the Trails B was determined from an epidemiological study of 526 older adults.[21] In this sample, normal elders had a Trails B time of 81.5 ± 36.1 seconds and the cutoff score was greater than 154 seconds (2 SD above the mean). The cutoff scores for the GDS-SF was 5 or greater. A score of 5 or greater on the GDS-SF has been shown to have a 91% sensitivity for diagnosing depression in older adults.[28]

Finally, post-surgical outcomes were examined comparing individuals with and without postoperative delirium. Postoperative outcomes were evaluated using two-sample t tests and Pearson's chi-square tests as appropriate. We used JMP software version 7.0 (SAS Institute Inc., Cary, NC) for all analyses.

Results

A total of 162 patients were assessed for eligibility in the study; 39 refused to participate and 14 did not meet the inclusion criteria resulting in a total enrollment of 109 patients. One of the patients was excluded because he refused to accept standard blood transfusion management and the others were excluded because they were not returning to the institutions for follow-up medical care. Of the original 109 patients, 4 patients withdrew prior to surgery, 4 patients had their surgery cancelled, and 1 patient did not receive preoperative cognitive testing. Therefore, 100 patients were included in the study. Eighty-four patients were enrolled at the Durham VA Medical Center and 16 were enrolled at the Duke University Hospital. The baseline

characteristics of the patients and the surgical procedures are outlined in Table 1. In the majority of the cases, the patients received preoperative midazolam and anesthesia was maintained with inhalational anesthesia and air/oxygen mixtures (Table 1). The type of anesthesia was not statistically different between delirious and non-delirious patients. The mean scores for the depression scale and the neuropsychological tests at baseline are presented in Table 2.

Overall, 16 of 100 patients (16%) developed delirium during the first 3 days after surgery. The bivariate analyses of the preoperative covariates that were expected to be associated with postoperative delirium are shown in Table 3. The preoperative patient characteristics that were collected as covariates (age, education, alcohol use, body mass index, American Society of Anesthesiologists physical status, preoperative pain, Charlson comorbidity index, history of depression) and the measure of global cognition (3MS) were not significantly different in this patient sample. However, all of the preoperative measures of executive function (digit symbol, symbol search, and Trails B test) and depression (GDS-SF) were significantly different between patients with and without postoperative delirium. These variables were entered into a multivariate logistic regression model to determine which cognitive measures best independently predicted postoperative delirium. The multivariate analysis is summarized in Table 4. Of the variables considered, only preoperative depression (GDS-SF) and Trails B time scores remained significant in the multivariable logistic regression analysis.

In the current analysis of the 27 patients who scored above the cutoff for the Trails B test, 12 (44%) patients developed delirium. Twenty six patients were above the cutoff for the GDS-SF and 9(35%) developed delirium. Forty seven patients scored above the cutoff in one of these two tests but only 16 (34%) developed delirium. Of the six patients who were positive on both of these two tests, 5 (83%) developed delirium. The sensitivity analysis for these tests is shown in Table 5.

Not surprisingly, the length of hospital stay was longer in patients with delirium compared to those who did not develop delirium (7.4 ± 5.0 *vs.* 4.4 ± 3.9 days, p = 0.034). Patients with delirium had lower postoperative hemoglobin levels than non-delirious patients but this difference did not reach significance (9.0 ± 2.2 *vs* 10.2 ± 1.7, p = 0.068). Thirty day postoperative outcomes using National Surgical Quality Improvement Program criteria are included in Table 6. Patients who experienced postoperative delirium experienced more respiratory complications (p = 0.013) and also tended to have more urinary tract infections (p = 0.052). There were more postoperative complications in patients who developed delirium after surgery compared to non-delirious patients (p = 0.006). None of the patients died in the first 90 days after surgery.

Discussion

The results of this prospective cohort study confirm that low preoperative executive function and depression are significant risk factors for the development of postoperative delirium in elderly patients undergoing major non-cardiac surgery. Specifically, we found that a rapid measure of executive function (Trails B) and a simple screening tool for depression (GDS-SF) were highly predictive of postoperative delirium. Moreover, the combination of these two tests was a robust predictor of delirium in our patients having a specificity of 99% and a positive predictive value of 83% in our patient population (Table 5).

Depression, as measured by standardized depression scales, has been found to have a significant association with delirium across numerous studies.[8] The findings of three recent studies in elderly surgical and medical patients support the notion that preexisting depression plays an important role in the development of delirium.[11-13] The GDS-SF was used in our investigation and in two previous studies. Several of these studies demonstrated that depression

was associated with both the incidence[11,13] and duration[13] of delirium. The GDS-SF is a 15-item questionnaire that uses a yes/no format and is simple to administer and complete. This short form eases the burden on elderly and ill patients and has been validated as a screening instrument in preoperative patients.[25] The GDS-SF is especially useful in surgical populations because it eliminates the somatic items contained in other depression scales that could lead to an increased rate of false-positive depression diagnoses in physically ill populations.[25] It can be completed in approximately 5 minutes and is free for use in the public domain.

Cognitive impairment, as measured by global cognitive testing such as the MMSE, is also a well-known risk factor for delirium.[8,9,29] The 3MS, an extended version of the MMSE, was not predictive in our sample. Kalisvaart et al.[29] enrolled 603 elderly patients undergoing hip surgery (both acute fractures and elective hip surgeries) in a prospective cohort study validating a risk factor model for predicting postoperative delirium. The MMSE was an independent predictor of delirium in this study and patients who developed delirium had a significantly lower mean MMSE of 21.7 compared to 25.7 in nonaffected patients.[29] A second study by Rudolph et al.[30] also found an association between poor performance on the MMSE and an increased risk for delirium in elderly patients (mean age 75 years) undergoing coronary artery bypass graft surgery. The raw scores for MMSE were not reported in this study but the subjects had a 50% incidence of delirium suggesting that they had low preoperative MMSE scores making them high-risk for delirium. A MMSE score less than 24 (out of a possible 30) is generally considered to be the threshold for cognitive impairment.[31] We extracted the MMSE scores from the 3MS and found that the mean preoperative MMSE scores in our study were 26 for patients who developed delirium and 28 for the patients who did not have this problem. It is likely that the 3MS and the MMSE were not predictive in our study because our patients had better preoperative global cognitive function than the patients in previous studies and the MMSE was not sensitive enough to predict postoperative delirium in our cohort with relatively normal cognition. As such, the predictive ability of executive tasks as observed in this study and in our companion study[14] among relatively non-impaired samples is intriguing.

Our finding that preoperative executive functioning predicts delirium is in agreement with a study by Rudolph and colleagues.[30] This study enrolled 80 elderly subjects undergoing coronary artery bypass graft surgery. The authors defined memory and executive function composites using confirmatory factor analysis. After adjusting for preoperative risk factors, they found that poor performance on measures of executive function were independently associated with the development of delirium.[30] These studies collectively suggest that executive dysfunction may be a strong indicator of postoperative risk, even among subjects who are considered cognitively intact preoperatively. The finding that global measures of cognition did not predict delirium in either sample, despite its common clinical usage, may be due to the relative insensitivity of general screening measures for identifying very mild cerebral dysfunction,[32] particularly among highly educated subjects. In addition, executive measures may better reflect aspects of central nervous system integrity and the underlying pathophysiology related to the development of delirium.[14]

One of the limitations of this paper is that the majority of patients (91%) were male limiting the generalizability of these results to females. However, a companion paper in this journal[14] replicates our analysis in a large cohort of patients undergoing noncardiac surgery in which the majority (63%) were female and confirmed our findings in this second patient population. Together these two manuscripts strongly suggest that preoperative depressive symptoms and low executive scores may be important predictors of individuals at risk for postoperative delirium regardless of the gender of the patient. Other factors limiting the generalizability of these results is the preponderance (69%) of Caucasians in the sample and the inclusion of only major intra-abdominal, thoracic or orthopedic surgical procedures in the study. Future studies should target racially diverse populations and other types of surgical

procedures. Another potential limitation of this paper is the inclusion of four preoperative covariates in our multivariate logistic regression model, possibly overfitting the model. The general rule of thumb is that there should be 10 events per variable in the model. However, more recent studies suggest that commonly used rules of thumb regarding number of events may be overly conservative in the "analysis of casual influences of observational data."[33]

In contrast to previous publications,[8] we did not find an association between age or preoperative comorbidity (Charlson and American Society of Anesthesiologists scores) and delirium. However, our study had a relatively small sample size of 100 patients and included only individuals who were 50 years or older. It is likely that, with the limited range of scores on these variables, our study was underpowered to show differences in these variables. However, preoperative executive skills and depression status correlated with postoperative delirium suggesting that cognitive measures are much more sensitive than measures of physical status for predicting delirium.

Patients who developed delirium had lower scores on tests of executive function suggesting that, although they were functioning normally, they may have had less preoperative cognitive reserve. Cognitive reserve is a concept that attempts to explain why individuals with similar degrees of cerebral insult often have significant differences in the degree of cognitive symptoms. Different levels of baseline cognitive capacity between patients may explain differences in cognitive outcomes associated with traumatic brain injury,[34] cerebral infarction,[35] and the development of dementia[36,37] in the elderly. Cognitive reserve may also protect against delirium as evidenced by a study that correlated higher educational attainment with a lower risk of developing delirium.[38] Executive function may be an ideal marker of cognitive reserve as it reflects higher order complex cognition. Preoperative executive skills may be a marker of the integrity of the patient's central nervous system.

Preoperative identification of patients at risk for delirium will allow the clinician to implement behavioral or pharmacologic interventions to minimize this problem once effective intervention strategies have been identified. A recent Cochrane database review[39] examined the literature on delirium prevention. This review identified only six randomized controlled trials assessing the effectiveness of interventions to prevent delirium and concluded that "the research evidence on the effectiveness of interventions to prevent delirium is sparse." The only study that was considered to have adequate power to determine effectiveness was a trial by Marcantonio et al.[40] concluding that a proactive geriatrics consultation can significantly decrease postoperative delirium in elderly patients following hip fracture repair. A second study compared two anesthetic approaches (halothane versus epidural anesthesia)[41] while the remainder of the trials focused on a variety of pharmacological interventions including daily prophylactic haloperidol administration[42] and the use of doneprezil, an acetyl cholinesterase inhibitor used in the treatment of Alzheimer's disease.[43] The Cochrane review concluded that there was inadequate evidence available on the effectiveness of pharmacological strategies and that "future trials of delirium prevention are urgently needed."[39]

In summary, we found that preexisting executive dysfunction and symptoms of depression, as measured by the Trails B and GDS-SF respectively, were independent predictors of postoperative delirium in elderly patients. Combining the results of these screening tests improved their predictive accuracy. A measure of global cognitive ability (3MS) did not distinguish between those who developed delirium and those who did not. This suggests that less sensitive global measures of cognitive function may misidentify some patients as being low risk for postoperative delirium. The combination of a test of executive function and a depression index as an effective screening tool for patients at risk of postoperative delirium requires validation and further refinement in large patient populations. The development of a

rapid simple screening tool that identifies elderly surgical candidates at risk for delirium and appropriate intervention strategies to prevent this complication should be a research priority.

Acknowledgments

The authors thank Helen Enfiedjian, PhD, RN for her assistance in the collect National Surgical Quality Improvement Program Coordinator and the Surgical Peer Review Program Coordinator at the Durham Veterans Affairs Medical Center in Durham, NC

Funding Source: Clinical and Translational Science Award Scholarship TL1RR024126, National Institute of Health, Bethesda, MD, USA and Duke University, Durham, NC, USA

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Table 1

Preoperative Demographic Data and Characteristics of the Surgical Procedure (n = 100)

	Mean ± S.D. or %
Age (years)	64.6 ± 7.7
Gender	
Female	9%
Male	91%
Race	
Caucasian	69%
Other	31%
Educational level (years)	13.4 ± 2.7
Alcohol use	
No	56%
Yes	44%
ASA physical status	
II	22%
III	74%
IV	4%
Charlson comorbidity index	
0	12%
1 – 2	38%
3 – 4	35%
≥ 5	15%
Numeric pain score	2.1 ± 3.1
Type of surgery	
Abdominal	59%
Thoracic	8%
Orthopedic	33%
Duration of anesthesia (hours)	3.7 ± 1.2
Preoperative midazolam	
Yes	76%
No	24%
Inhalational anesthesia	97%
Total intravenous anesthesia	3%
Nitrous oxide use	
Yes	11%

	Mean ± S.D. or %
No	89%

S.D. is Standard Deviation
% is percentage
ASA is American Society of Anesthesiologists

Table 2

Preoperative Depression and Cognitive Status Data (n = 100)

	Mean ± S.D. (range)
GDS-SF	3.1 ± 3.2 (0 – 13)
3 MS	92.5 ± 4.9 (75-99)
Digit Symbol Test (number correct)	46.5 ± 15.6 (8- 93)
Symbol Search Test (number correct)	21.1 ± 7.9 (4-36)
Trails B Time (time in seconds)	135.0 ± 75.5 (42-300)

GDS-SF is Geriatric Depression Score – Short Form
3MS is Modified Mini-Mental State

Table 3

Bivariate Analysis of the Preoperative Factors Associated with Postoperative Delirium[†]

	No Delirium (n = 84)	Delirium (n = 16)	P value
Age (years)	64.4 ± 7.2	66.3 ± 9.7	0.449
Education (years)	13.5 ± 2.6	12.8 ± 3.1	0.380
Alcohol Use n (% of group)			
No	45 (54%)	11 (69%)	0.262
Yes	39 (46%)	5 (31%)	
ASA physical status n (% of group)			
II	20 (24%)	2 (13%)	0.366
III	60 (71%)	14 (87%)	
IV	4 (5%)	0 (0%)	
BMI	29.8 ± 4.9	28.9 ± 6.7	0.623
History of depression n (% of group)			
No	52 (62%)	10 (62%)	1.000
Yes	32 (38%)	6 (38%)	
Charlson comorbidity index n (% of group)			
0	8 (10%)	4 (25%)	0.592
1 – 2	33 (39%)	5 (31%)	
3 – 4	30 (36%)	5 (31%)	
≥ 5	13 (15%)	2 (13%)	
Preoperative Pain Score	1.9 ± 3.1	2.8 ± 3.4	0.386
3 MS	92.9 ± 4.2	89.9 ± 7.2	0.124
GDS - 15	2.7 ± 2.9	5.3 ± 3.5	0.011*
Digit Symbol Test (number correct)	48.3 ± 14.9	37.1 ± 16.5	0.019*
Symbol Search Test (number correct)	22.1 ± 7.8	15.9 ± 6.1	0.002*
Trails B Time (time in seconds)	119.3 ± 63.8	217.8 ± 79.9	0.0002*

[†]All data is Mean ± SD unless otherwise indicated;

*P < 0.05

ASA is American Society of Anesthesiologists
GDS-SF is Geriatric Depression Score – Short Form
3MS is Modified Mini-Mental State
BMI is Body Mass Index

Table 4

Multivariate Analysis of Preoperative Factors Associated with Postoperative Delirium

	Per Unit Odds Ratio	95% Confidence Interval	P value
GDS - 15	1.53	1.22 – 2.05	0.0001*
Trails B Time	1.02	1.01 – 1.04	0.0007*
Digit Symbol Test	1.03	0.95 – 1.13	0.4916
Symbol Search Test	0.92	0.77 – 1.11	0.3715

GDS-SF is Geriatric Depression Score – Short Form

* P < 0.05

Table 5

Sensitivity Analyses using the Preoperative Geriatric Depression Score - SF and/or the Trails B Time to Predict Postoperative Delirium

	Sensitivity	Specificity	PPV	NPV
GDS -SF alone	56%	80%	35%	91%
Trails B Time alone	75%	82%	44%	95%
Either GDS-SF or Trails B Time	100%	63%	34%	100%
Both GDS-SF and Trails B Time	31%	99%	83%	88%

GDS-SF is the Geriatric Depression Score – Short Form
PPV is the positive predictive value
NPV is the negative predictive value

Table 6

30 Day Postoperative Outcomes in Patients with Postoperative Delirium *vs.* No Delirium

	No Delirium (n = 84)	Delirium (n = 16)	P value
Wound infections n (%)	12 (14.1%)	2 (13.3%)	1.000
Urinary tract n (%)	6 (7.1%)	4 (26.7%)	0.052
Respiratory n (%)	1 (1.2%)	3 (20.0%)	0.013*
Cardiac n (%)	3 (3.5%)	1 (6.7%)	0.248
Central nervous system n (%)	1 (1.2%	1 (6.3%)	0.296
Other n (%)	17 (20.2%)	5 (31.3%)	0.336
Number of complications n	40	16	0.006*

† mean ± standard deviation

n = number of patients

* $P < 0.05$