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A novel approach for the detection of cognitive impairment and delirium risk in older patients undergoing spine surgery

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Abstract

BACKGROUND: Postoperative delirium is a common postsurgical complication in older patients associated with high morbidity and mortality. The objective of this study was to determine whether a digital cognitive assessment and patient characteristics could identify those at-risk.

METHODS: Patients 65 years and older undergoing spine surgeries ≥3 hours were evaluated as part of a single-center prospective observational cohort study at an academic medical center, from January 1, 2019, to December 31, 2020. Of 220 patients eligible, 161 were enrolled and 152 completed the study. The primary outcome of postoperative delirium was measured by the Confusion Assessment Method for the Intensive Care Unit or the Nursing Delirium Screening Scale, administered by trained nursing staff, independent from the study protocol. Baseline cognitive impairment was identified using the tablet-based TabCAT Brain Health Assessment (TabCAT-BHA).

RESULTS: Of the 152 patients included in this study, 46% were women. The mean [SD] age was 72 [5.4] years. Baseline cognitive impairment was identified in 38% of participants, and 26% had postoperative delirium. In multivariable analysis, impaired Brain Health Assessment

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Author Contributions:

Drs. Barreto Chang and Possin had full access to all the data in the study and take responsibility for the integrity of the data and accuracy of the data analysis.

Study concept and design: Barreto Chang, Hellman, Bickler, Miller, Possin.

Acquisition of subjects and/or data: Barreto Chang, Arias, Possin.

Interpretation of data: Barreto Chang, Whitlock, Allen, Tsoy, Possin.

Drafting of manuscript: Barreto Chang, Possin, Whitlock.

Statistical analysis: Barreto Chang, Whitlock, Tsoy, Allen, Possin.

Critical revision of the manuscript for intellectual content: All authors.

Cognitive Score (BHA-CS) (OR 2.45; 95% CI, 1.05-5.67; p = 0.037), depression (OR 4.54; 95% CI, 1.73-11.89; p = 0.002), and higher surgical complexity Tier 4 (OR 5.88; 95%CI, 1.55-22.26; p = 0.009) were associated with postoperative delirium. The multivariate model was 72% accurate for predicting postoperative delirium, compared to 45% for the electronic medical record-based risk stratification model currently in use.

CONCLUSION: In this prospective cohort study of spine surgery patients, age, cognitive impairment, depression, and surgical complexity identified patients at high risk for postoperative delirium. Integration of scalable digital assessments into preoperative workflows could identify high-risk patients, automate decision support for timely interventions that can improve patient outcomes and lower hospital costs, and provide a baseline cognitive assessment to monitor for postoperative cognitive change.

Keywords

cognitive assessment; anesthesia and surgery; postoperative delirium; postoperative outcomes

INTRODUCTION

Delirium is one of the most common complications of perioperative care for older patients,[1, 2] and is associated with adverse in-hospital and long-term outcomes.[3-7] Delirium preventative interventions, including nonpharmacological and pharmacological interventions such as orientation, using glasses, hearing aids, and avoidance of certain medications, substantially reduce the risk of developing delirium, but tend to be resource-intensive, limiting their application to at-risk populations.[8-10]

Baseline cognitive impairment is a major risk factor for postoperative delirium,[11] but cognitive disorders, including mild cognitive impairment (MCI) and dementia, are substantially underdiagnosed in older surgical patients.[12-14] Therefore, cognitive assessment for older patients undergoing surgery is widely recommended.[15-17] In comparison to traditional paper-based brief cognitive assessments, digital measures may be both more accurate and practical to use in busy clinical workflows due to ease of administration and electronic medical record (EMR) integration.[18] The TabCAT (Tablet-based Cognitive Assessment Tool) Brain Health Assessment (TabCAT-BHA) efficiently measures associative memory, executive functions and speed, language generation, and visuospatial skills[18, 19] and scoring has been optimized for the detection of cognitive impairment in diverse older adults.[18-20] In a nonsurgical sample of 451 neurologically healthy controls and 399 with cognitive impairment (289 with MCI and 110 with mild dementia), the TabCAT-BHA showed 88% sensitivity at 80% specificity for detection of cognitive impairment and excellent long-term stability at 1-year follow-up (r = .89).[19] We evaluated whether preoperative performance on the TabCAT-BHA and baseline patient characteristics could identify older spine surgery patients at high risk for developing postoperative delirium, and compared it with our existing perioperative delirium risk stratification instrument AWOL-S (Age, WORLD backwards, Orientation, iLlness severity, Surgery-specific risk).[21]

METHODS

This is a substudy of a prospective observational cohort study of older spine surgery patients conducted at the University of California San Francisco from January 2019 to December 2020. The first 162 patients enrolled in the parent study were included in this analysis. The study was approved by the UCSF Committee on Human Research (IRB 18-26716), and participants provided written informed consent. Details of the study have been published elsewhere.[22] Inclusion criteria included age 65 years and older, undergoing spine surgery 3 hours or longer, and ability to understand and sign an informed consent. Exclusion criteria included inability to read, understand, or speak English. In addition, patients undergoing emergent surgery were excluded. Eligible patients were identified by reviewing surgery schedules and were recruited via phone call. Of the 161 participants who enrolled in the study, only 2 did not complete the tablet assessment, and these noncompletions were due to technical issues with an older version of the software (Figure 1). Patients enrolled in other cognitive studies during the duration of this study were excluded. The study was conducted following STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines.

Preoperative baseline cognitive testing was performed using the TabCAT-BHA.[18] This 10 minute test battery includes Favorites (associative memory), Match (executive functions and speed), Line Orientation (visuospatial), and Animal Fluency (language generation).[18] The time of administration is similar to traditional brief tests such as the MoCA. However, TabCAT-BHA can be administered by any clinical staff with minimal training, features automated scoring, and instantly generates a clinical report that can be integrated with the electronic medical record to guide care. TabCAT account request, training and licensing information can be found online.[23] Testing was performed by a trained research assistant prior to the surgery (Supplemental Figure S1). The automated and published scoring system applies regression-based normative corrections for age, education, and sex to generate z-scores for each subtest; next, weights are applied to compute a composite score, the BHA-CS, which is optimized for the detection of cognitive impairment.[19] Scores < -1.5z were considered impaired. Baseline patient characteristics, including demographics, medical history, and health behaviors, were collected before the surgery from electronic records and verified with the patient during interviews. The baseline patient characteristics collected and evaluated have been previously reported as predictors of postoperative delirium.[24] Frailty was assessed using the 5 points FRAIL (Fatigue, Resistance, Ambulation, Illness, Loss of weight) scale.[25] Surgical invasiveness was divided into 4 different tiers based on the level of complexity as follows, Tier 1: microdissection, Tier 2: lumbar laminectomy, anterior cervical procedure or minimal invasive fusion (simple laminectomy either anterior or posterior) ACDF, Tier 3: lumbar fusion, trauma, posterior cervical procedure and Tier 4: tumor, infection, deformity or combined anterior and posterior cervical procedures.[26,27] Patients were assigned American Society of Anesthesiologists (ASA) classification as previously reported.[28] Additional clinical variables derived from electronic medical record review and verified with the patient during interview included alcohol use, smoking, prior diagnosis of cognitive impairment, prior stroke, anxiety, depression, sleep disorder, Obstructive Sleep Apnea (OSA), chronic opioid use, and the total number of medications.

Our center currently risk-stratifies all surgical patients for delirium risk using the AWOL-S tool.[21] AWOL-S calculates absolute predicted probability of delirium using age, ability to correctly spell WORLD backward, orientation to place, ASA classification, and an indicator of surgical invasiveness, for which all spine surgeries in this cohort were considered "moderate risk." The AWOL-S screen is done by the nurses on the day of the surgery (Supplemental Figure S1). Predicted probability of delirium of 5% or greater is considered a "high risk" AWOL-S screen, and is 75% sensitive and 60% specific for postoperative delirium in an unselected population of older adults undergoing surgery requiring at least 1 night of hospital stay.[21] AWOL-S screen result (low or high risk) was collected from the electronic medical record for comparison with the predictive model derived from this cohort.

Outcomes

The primary outcome was postoperative delirium measured daily by trained nursing staff using the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU)[29] when patients were in the ICU or with the Nursing Delirium Screening Scale (NuDESC)[30] when patients were in the hospital ward (Supplemental Figure S1). A composite delirium score was calculated and a patient was included in the delirium group if either CAM-ICU or NuDESC screenings were positive for delirium during the hospital stay.

Statistical Analysis

All statistical analyses were performed in Stata 17 (StataCorp, College Station, TX) using $p \leq 0.05$ as the criterion for statistical significance in the final models. In our primary model that evaluated preoperative characteristics as predictors of delirium, the variables of interest were: age, sex, level of education, body mass index (BMI), ASA classification ≥ 3, frailty, BHA-CS < -1.5, surgical invasiveness, alcohol use, smoking, diagnosis of cognitive impairment, stroke, anxiety, depression, sleep disorder, Obstructive Sleep Apnea (OSA), chronic opioid use, and the total number of medications. Variables were compared by delirium group using chi-squared for categorical variables and Student's independent group t-tests for continuous variables.

Statistically significant variables identified in univariable analyses as predictors with $p < 0.05$ were entered into a multivariable logistic regression model. Patient age was *a priori* included in the multivariable models due to its established relationship with delirium.[24] We assessed discrimination with receiver operator characteristic (ROC) curve and calibration curve.

RESULTS

During the study period, 220 eligible patients underwent spine surgery. Of these 220 patients, 161 consented to participate in the study, and 152 were included in analysis (Figure 1). The sample was 88% Non-Hispanic White, 4% Black, 3% Asian, 5% Latinx. Sample demographics are shown in Supplemental Table S1. The rate of baseline cognitive impairment based on the BHA-CS was 38%. Postoperative delirium was observed in 26% (n=39) of the patients.

In univariable analysis, education lower than college, higher BMI, depression, baseline cognitive impairment on the BHA-CS, ASA classification ≥ 3, and tier 4 surgical invasiveness were associated with postoperative delirium (Table 1). Using the Brain Health Assessment- Cognitive Score (BHA-CS) as a binary variable (impaired/not impaired) we found that 56% of delirious patients were cognitively impaired at baseline, compared to 32% in the group that was not impaired at baseline, which was statistically significant (p=0.006) (Table 1). When the BHA-CS was used as a continuous score, the mean score in the group that had delirium was −1.67 (SD 1.79) vs −0.93 (SD 1.19) in the not impaired group, this was also statistically significant (p=0.004). In multivariable analysis, baseline cognitive impairment on the BHA-CS was a significant independent predictor of postoperative delirium (odds ratio [OR] 2.45; 95% CI, 1.05-5.67; p=0.037, Table 2). Interaction analysis among the statistically significant variables and baseline BHA-CS impairment demonstrated no statistically or clinically significant interactions. In discrimination analyses, the area under the ROC curve for the multivariable model was 0.80 (95% CI, 0.71-0.89) (Supplemental Figure S1). At a cutoff of 26% predicted probability of delirium, a predictive model incorporating BHA-CS was 74% sensitive and 72% specific for delirium. The cutoff was selected to balance sensitivity and specificity, and achieved a high percentage of correctly classified patients (72% correctly classified). In contrast, the AWOL-S delirium risk stratification model currently in use at our institution was 74% sensitive and 36% specific for this subpopulation of older spine surgery patients with only 45% correctly classified.

DISCUSSION

In this prospective observational study of older patients undergoing spine surgery, we found that baseline cognitive impairment on the TabCAT-BHA, depression, and surgical invasiveness Tier 4 surgery were associated with postoperative delirium, and a model incorporating these variables performs well for preoperative delirium risk stratification in spine surgery patients. Undiagnosed cognitive impairment was common in our sample, emphasizing the importance of preoperative cognitive testing in this population. Whereas only 3% of our participants had a pre-existing cognitive diagnosis documented in the medical record, using the BHA-CS, we found that 38% of the cohort had baseline cognitive impairment. These results are consistent with previous reports that showed that older patients undergoing spine surgeries have a high incidence of undiagnosed baseline cognitive impairment ranging from 23-38%.[26, 31]

The BHA-CS odds ratio for delirium was similar or greater than in studies with paper-based assessments,[11, 26] and outperformed our existing delirium risk stratification instrument. Importantly, this digital assessment has additional advantages for cognitive care. It is more accurate at detecting mild cognitive impairment and dementia than commonly used paper-based assessments, and can be used to support diagnosis of cognitive impairment.[18-20] Second, long-term stability at 1-year follow-up is excellent, such that it is more precise than traditional paper-based assessments (e.g., MoCA) at detecting reliable decline or improvement.[19] Patients assessed preoperatively with the TabCAT-BHA have a robust baseline to monitor for future postoperative decline. Third, digital assessments provide opportunities for efficient and scalable workflow integration: the TabCAT-BHA takes

10-minutes, requires less training than most paper-based assessments for standardized administration, has automated scoring to produce the BHA-CS, and instantly generates a clinical report that can be integrated with the electronic medical record to guide care.

LIMITATIONS

This was a single-center study performed in a tertiary care center in California. The population in this cohort is predominantly non-Hispanic White; a number of groups are underrepresented in this sample, including Blacks, Latinx, and Asians, suggesting that greater outreach was needed. As noted in the patient demographics, most patients were ASA 2 and ASA 3, either pre-frail or frail, undergoing long-duration spine surgeries, and thus the results may not be generalizable to patients outside of these characteristics. Seventeen percent of the patients who were eligible for the study declined participation, which could lead to potential selection bias. The potential stress of completing the TabCAT-BHA prior to surgery in the hospital may have led to a higher false-positive rate for baseline cognitive impairment. The delirium assessments were performed daily, but since delirium fluctuates substantially throughout the day, these assessments may not have captured some episodes of postoperative delirium, which could have led to an underestimation of the actual rate of postoperative delirium. Finally, while we performed a comprehensive multivariable regression analysis, it is possible that additional variables that were not captured in this study may play a role in postoperative delirium.

CONCLUSION

The TabCAT-BHA cognitive assessment can be pragmatically administered to older spine surgery patients, detect undiagnosed cognitive impairment, and contribute to a predictive model for delirium with characteristics suitable for clinical use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Sponsor's Role:

The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Conflicts of Interest:

Dr. Barreto Chang reported receiving grants from National Institute of Health (2T32GM008440) and the National Institute of Neurological Disorders and Stroke (UH3NS10557-03S1) during the conduct of the study, the Weill Pilot Award for Junior Investigators in Neurosciences, the Patricia Sander Award for Anesthesia Researchers, the UCSF Department of Anesthesia and Perioperative Care RFA, and serving as a clinical investigator for the clinical trial OLIVER from Medtronic. Dr. Whitlock received research funding from the National Institute of Health (KL2TR001870). Dr. Tsoy received research funding from Alzheimer's Association (AARF-21-851552). Dr. Miller reported serving on the Cambridge National Institute for Health Research Biomedical Research Centre advisory committee and its subunit, the Biomedical Research Unit in Dementia; serving as a board member for the American Brain Foundation; serving on John Douglas French Alzheimer's Foundation board of directors; serving on the Safely You board of directors; serving as scientific director for the Tau Consortium; serving as medical advisor for and receiving a grant from The Bluefield Project for Frontotemporal Dementia Research; serving as a consultant for Rainwater Charitable Foundation, Stanford Alzheimer's Disease Research Center, Buck Institute SAB, Larry L. Hillblom Foundation, University of Texas Center for Brain Health, University of Washington Alzheimer's Disease Research Center EAB, and Harvard University Alzheimer's Disease Research Center EAB; receiving royalties from Guilford Press, Cambridge University Press, Johns Hopkins Press, and Oxford University Press; serving as editor for Neurocase; serving as section editor for Frontiers in Neurology; and receiving grants P30 AG062422, P01 AG019724, R01 AG057234, and T32 AG023481 from the NIH. Dr. Possin reported receiving grants from the National Institute of Neurological Disorders and Stroke (UH3NS10557) during the conduct of the study; grants from the National Institute on Aging, Global Brain Health Institute, Quest Diagnostics, Administration for Community Living, Rainwater Charitable Trust, and Merck Foundation outside the submitted work. No other disclosures were reported.

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Key Points

- Baseline cognitive impairment occurs frequently in older patients undergoing spine surgery.
- Baseline cognitive impairment, depression, and tier of surgery are associated with postoperative delirium.
- Brief, digital cognitive assessments that are accurate for detecting cognitive impairment could provide a preoperative baseline for predicting older patients at high risk for developing postoperative delirium.

Why does this matter?

The detection of preoperative cognitive impairment among older adults using accurate and reliable tools could improve brain health outcomes. Baseline cognitive impairment is frequently undetected, yet is a risk factor for postoperative delirium and subsequent higher cost of care and increased morbidity. In addition, the differential diagnosis and monitoring of postoperative cognitive decline, versus preexisting cognitive impairment, is imprecise without a baseline assessment that can be repeated with reliable results. Digital assessments that are integrated with the electronic medical record (EMR) could be used to identify patients at risk for delirium and to provide a baseline for cognitive trajectories.

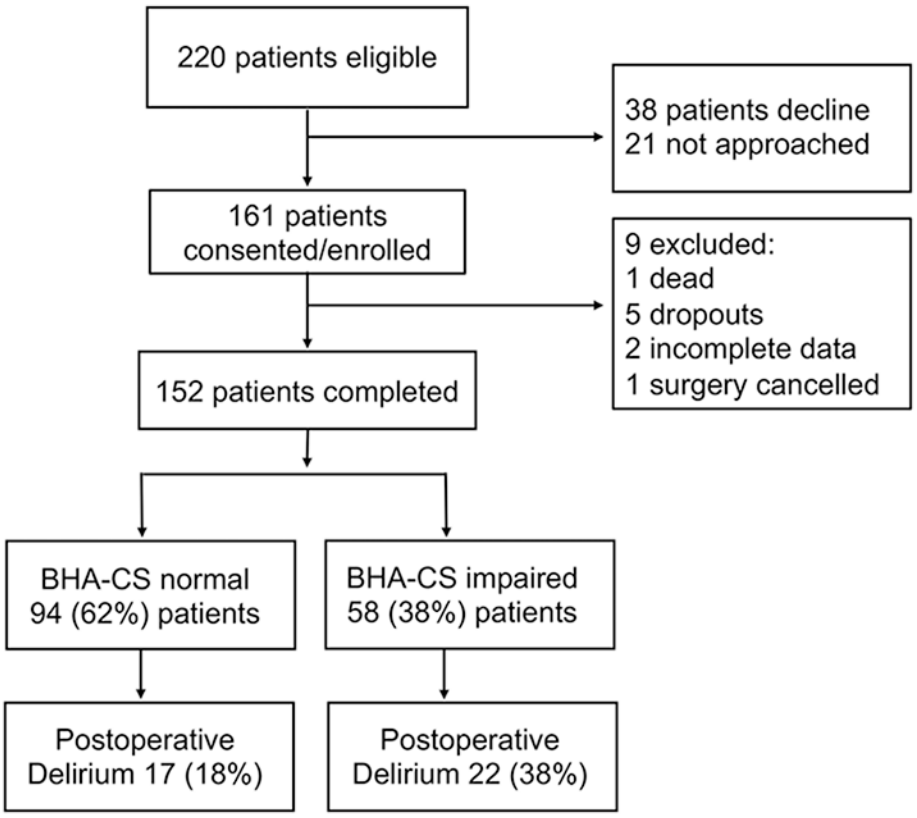

Figure 1.
Flowchart of recruitment

Table 1.

Comparison of baseline demographic characteristics between patients with or without delirium

	No Delirium N=113 (74%)	Delirium N=39 (26%)	*P*-value
Age, yr	70 (67, 75)	73 (68, 75)	0.377
Sex			
Female	48 (43)	22 (56)	0.132
Education (≥ 16 years)	72 (63.7)	17 (43.6)	**0.028**
Body mass index, kg/m^2	27 (24, 30)	29 (25, 34)	**0.028**
ASA classification ≥ 3	59 (52.2)	29 (74)	**0.016**
Alcohol	69 (61.1)	20 (51)	0.285
Smoking	4 (4)	1 (3)	0.768
Former smoker	49 (43)	19 (49)	0.562
Cognitive Impairment diagnosis	5 (4.4)	0 (0)	0.182
History of stroke	8 (7)	5 (13)	0.269
Anxiety	21 (19)	10 (26)	0.346
Depression	22 (20)	16 (41)	**0.007**
Sleep disorder	35 (31)	9 (23)	0.348
Obstructive Sleep Apnea	33 (29)	17 (44)	0.099
Chronic opioid use	38 (34)	16 (41)	0.405
Total number of medications	7 (4, 10)	8 (6, 11)	0.070
BHA-CS impaired	36 (32)	22 (56)	**0.006**
FRAIL scale[a]			0.637
Robust	25 (22)	6 (15)	
Pre-frail	49 (43)	17 (44)	
Frail	39 (35)	16 (41)	
Surgical invasiveness[a]			**0.032**
Tier 1	30 (27)	6 (15)	
Tier 2	35 (31)	13 (33)	
Tier 3	33 (29)	7 (18)	
Tier 4	15 (13)	13 (33)	
AWOL-S high-risk screen	69 (64)	25 (74)	0.300

N=152. Data are median (25th, 75th percentile), or n (%).

[a]Fisher's exact. Bold text represents $p < 0.05$. Abbreviations: ASA, American Society of Anesthesiologists; TabCAT-BHA, TabCAT-Brain Health Assessment. Tier 1: microdissection, Tier 2: lumbar laminectomy, anterior cervical procedure or minimal invasive fusion (simple laminectomy either anterior or posterior) ACDF, Tier 3: lumbar fusion, trauma, posterior cervical procedure and Tier 4: tumor, infection, deformity or combined anterior and posterior cervical procedures; AWOL-S, Age, WORLD backwards, Orientation, iLlness severity, Surgery-specific risk. 10 patients are missing AWOL-S score.

Table 2.

Multivariable analysis of significant variables associated with Postoperative Delirium

	Odds Ratio (95% CI)	*P*-value
Age (yr)	1.09 (1.00, 1.19)	**0.048**
Education (≥ 16 years)	0.56 (0.23, 1.34)	0.192
Body mass index	1.08 (1.00, 1.16)	0.065
ASA ≥ 3	1.62 (0.62, 4.19)	0.322
Depression	4.54 (1.73, 11.89)	**0.002**
BHA-CS impaired	2.45 (1.05, 5.67)	**0.037**
Surgical invasiveness		
Tier 1		
Tier 2	2.12 (0.63, 7.19)	0.228
Tier 3	1.20 (0.31, 4.64)	0.790
Tier 4	5.88 (1.55, 22.26)	**0.009**

N=152. Bold text represents $p < 0.05$.

Abbreviations: ASA, American Society of Anesthesiologists; BHA-CS, Brain Health Assessment-Cognitive Score. Tier 1: microdissection, Tier 2: lumbar laminectomy, anterior cervical procedure or minimal invasive fusion (simple laminectomy either anterior or posterior) ACDF, Tier 3: lumbar fusion, trauma, posterior cervical procedure and Tier 4: tumor, infection, deformity or combined anterior and posterior cervical procedures.