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Delirium after Spine Surgery in Older Adults: Incidence, Risk Factors, and Outcomes

Charles H Brown IV, MD, MHS¹, Andrew LaFlam, BS¹, Laura Max, BA¹, Julie Wryobek, MD¹, Karin J Neufeld, MD, MPH², Khaled M Kebaish, MD³, David B Cohen, MD³, Jeremy D Walston, MD⁴, Charles W Hogue, MD¹, and Lee H Riley, MD³

¹Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, 1800 Orleans St., Baltimore MD 21287

Corresponding Author: Charles H. Brown IV, MD MHS, Assistant Professor, Department of Anesthesiology & Critical Care Medicine, Johns Hopkins University School of Medicine, 1800 Orleans, Zayed 6208B, Baltimore, MD 21287, Telephone: 410-955-8465; Fax: 410-955-0994, cbrownv@jhmi.edu. Alternate Corresponding Author: Charles W. Hogue, Professor, Department of Anesthesiology & Critical Care Medicine, Johns Hopkins University School of Medicine, 1800 Orleans, Zayed 6208, Baltimore, MD 21287, Telephone: 410-955-7529; Fax: 410-955-0994, chogue2@jhmi.edu.

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Conflict of Interest

Elements of Financial/ Personal Conflicts	CB		AL		LM		JWy		KN		KK		DC		JWa		CH		LR	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Employment or Affiliation		X	X			X		X		X		X		X	X			X		X
Grants/Funds		X	X			X		X	X			X		X	X		X			X
Honoraria		X	X			X		X		X		X		X	X			X		X
Speaker Forum		X	X			X		X		X		X		X	X			X		X
Consultant		X	X			X		X		X		X		X	X			X		X
Stocks		X	X			X		X		X		X		X	X			X		X
Royalties		X	X			X		X		X		X		X	X			X		X
Expert Testimony		X	X			X		X		X		X		X	X			X		X
Board Member		X	X			X		X		X		X		X	X		X			X
Patents		X	X			X		X		X		X		X	X			X		X
Personal Relationship		X	X			X		X		X		X		X	X			X		X

Author Contributions

The corresponding author affirms that everyone who is listed has an author has contributed significantly to this work.

Charles Brown was involved in study design, methods, analysis, preparation of paper, and approved the final version.

Andrew LaFlam was involved in study design, methods, preparation of paper, and approved the final version.

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Jeremy Walston was involved in study design, data interpretation, preparation of paper, and approved the final version.

Charles Hogue was involved in study design, data interpretation, preparation of paper, and approved the final version.

Lee Riley was involved in study design, data interpretation, preparation of paper, and approved the final version.

²Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, 1800 Orleans St., Baltimore MD 21287

³Department of Orthopaedic Surgery, Johns Hopkins University School of Medicine, 1800 Orleans St., Baltimore MD 21287

⁴Department of Geriatric Medicine and Gerontology, Johns Hopkins University School of Medicine, 1800 Orleans St., Baltimore MD 21287

Abstract

Background—Although spine surgery is frequent in older adults, the incidence, risk factors, and consequences of delirium in this population have not been well characterized. This is important since spine surgery is increasingly common, pain is a prominent symptom, and postoperative delirium may be preventable.

Methods—We enrolled 89 adults >70 y/o undergoing spine surgery in a prospective observational study. Postoperative delirium and delirium severity were assessed using validated methods, including the Confusion Assessment Method (CAM), CAM-ICU, Delirium Rating Scale-Revised-98, and chart review. Hospital-based outcomes were obtained from the medical record, and hospital charges from data reported to the state.

Results—Thirty-six patients (40.5%) developed delirium after spine surgery, with 17 (47.2%) having purely hypoactive features. Independent predictors of delirium were lower baseline cognition, higher average baseline pain, more IV fluid administered, and baseline anti-depressant medication. In adjusted models, the development of delirium was independently associated with increased quintile of length of stay (OR 3.66; 95%CI 1.48–9.04; $p=0.005$), increased quintile of hospital charges (OR 3.49; 95%CI 1.35–9.00; $p=0.01$), and decreased odds of discharge to home (OR 0.22; 95%CI 0.07–0.69; $p=0.009$). The severity of delirium was associated with increased quintile of hospital charges and decreased odds of discharge to home.

Conclusion—Delirium is common after spine surgery in older adults, and baseline pain is an independent risk factor. Delirium is associated with increased length of stay, increased charges, and decreased odds of discharge to home. Thus, prevention of delirium after spine surgery may represent an important quality improvement goal.

Keywords

Delirium; Spine; surgery; Outcomes; Cost

INTRODUCTION

Postoperative delirium is a common and under recognized condition after surgery in older adults.¹ The consequences of delirium can be profound, including an increased risk of longer hospital length of stay,² need for extended care,³ functional decline,⁴ postoperative cognitive dysfunction,⁵ dementia,⁶ and mortality.^{7,8} Older adults are at particularly high risk for postoperative delirium,⁹ and the growing number of older adults undergoing surgery¹⁰ means that the prevalence of postoperative delirium and potential consequences will

continue to increase. Since delirium may be preventable in 30–40% of cases,^{11,12} the prevention of delirium represents a quality improvement goal.

Postoperative delirium has been most extensively investigated after cardiac surgery (incidence 6–52%^{7,13}) and hip fracture surgery (incidence 16–62%^{14,15}). Postoperative delirium after other surgeries has been less well-studied, but general estimates range between 10–30%.⁹ In the absence of a formal delirium assessment, the fluctuating nature of delirium and common prevalence of only hypoactive symptoms means that delirium is often under recognized. Overall, it is clear that differences in measurement of delirium, as well as differences in patients and types of surgeries, likely contribute to the wide range in reported delirium incidence, and therefore rigorous estimates of delirium are needed in particular surgical populations.

However, the incidence of delirium in patients undergoing spine surgery has not been well defined, even though spine surgery is increasingly common in older adults—ranking in the top 5 most frequent procedures for adults 65–80 years old.¹⁰ Two small studies from Japan suggest that the delirium incidence in older adults ranges between 12%–40%^{16,17} but these studies have not been replicated in U.S. populations nor have consequences of delirium been examined. Thus, there is likely a large population of older adults undergoing spine surgery who develop postoperative delirium that is unrecognized and not well treated. In this study, our objective was to examine the incidence, risk factors, and consequences of delirium in older adults after spine surgery, using a rigorous validated delirium assessment method. We hypothesized that delirium would be common and would be associated with increased hospital length of stay, increased hospital charges, and decreased direct discharge to home.

METHODS

Study Overview

This was a prospective observational study at one academic medical center, with approval by the Institutional Review Board and written patient informed consent. Patients were enrolled between February 2012–July 2014. Inclusion criteria were age ≥70 years old and undergoing lumbar spine surgery, posterior cervical spine surgery, or anterior cervical spine surgery >2 levels. Exclusion criteria were Mini Mental State Examination (MMSE) score <15, baseline delirium, non-English speaking, severe hearing impairment, and planned use of ketamine or remifentanyl (because of potential postoperative hyperalgesia and/or psychotropic effects), unless for airway management. During enrollment, 195 patients >70 y/o underwent spine decompression or fusion. Of these, 145 patients were screened and were eligible after review of records (34 presented for surgery without screening, 11 underwent ineligible surgery, 3 did not speak English, 1 was enrolled in another study, and 1 had dementia). Of the patients who met criteria, 122 were approached (8 were not approached due to staff/equipment availability, 11 due to anesthesiologist planned use of ketamine or reluctance to participate, 4 due to time constraints). A further 21 patients did not participate due to anxiety or disinterest, and so 101 patients were enrolled. Of the enrolled patients, 3 withdrew, 3 did not have surgery or underwent a modified ineligible surgery, 4 received ketamine, and 2 did not have an in-person delirium assessment due to staff unavailability, leaving a total of 89 patients for analysis.

Delirium assessment

Delirium was assessed using rigorous methodologies, including the Confusion Assessment Method (CAM)¹⁸, CAM-ICU¹⁹, and validated chart review.²⁰ The CAM assessment¹⁸ was performed in-person by trained research assistants and included a structured cognitive exam (MMSE, Digit Span Forwards/Backwards, timed Months-of-the-Year-Backwards). Additionally, research assistants queried the patient, nurses, families, and medical records for evidence of delirium—including confusion, agitation, sedation, hallucinations, and delusions—in the previous 24 hours. Evidence from this overall assessment was used to complete the CAM and determine a delirium diagnosis.

For intubated non-verbal patients in the ICU, the validated CAM-ICU¹⁹ was used. For patients who could not be assessed in person due to either patient or staff availability, a validated chart review methodology was used (sensitivity 74% and specificity 83%²⁰) in accordance with prior methodology.²¹ For the chart review, a trained research assistant searched all sections of the medical record for mention of key terms, with evidence of acute onset, to support a diagnosis of delirium. Pertinent evidence was based on the question: “Is there any evidence of acute confusional state (e.g. delirium, mental status change, inattention, disorientation, hallucinations, agitation, inappropriate behavior)?”²⁰ For each possible episode of delirium, the source of information, time of onset, and a verbatim description was recorded. An expert panel (KN, CB, LM) with training in formal delirium assessment reviewed the abstractions and determined the final delirium diagnosis.

The once-daily delirium assessments were limited to the first four postoperative days beginning on postoperative day 1 because of evidence that >90% of delirium occurs within this time.^{9,22} Overall, 70% (215/309) of delirium assessments during the first four in-hospital post-operative days were in-person (CAM or CAM-ICU), while 30% (94/309) used chart review. All patients eventually classified as delirious had at least one in-person positive CAM assessment.

To further classify delirium episodes, information from each assessment was used to evaluate delirium severity with the Delirium-Rating-Scale-Revised-98 (DRS-98-R).²³ Additionally, delirium subtypes were classified based on observations of motor retardation and/or agitation.²⁴

Quality assurance methods were several. First, delirium assessors underwent formal training with author KN, an expert in delirium diagnosis, past president of the American Delirium Society, and Director of The Johns Hopkins Hospital Psychiatric Consultation Service. Training included readings, videos, and delirium assessments of 10 patients with subsequent discussion. During the study, delirium assessors and author KN conducted co-ratings of patients every two weeks. Finally, research assistants met with delirium experts 1–2 times/month to discuss delirium assessments of non-study patients, to ensure consistent methods and judgment.

Covariate and Outcome Data

Patient and perioperative information were obtained through preoperative and postoperative interviews with patients and through review of medical records. The number of surgical

levels was defined as the number of vertebrae involved in the surgery. Length of stay was obtained from the medical record. Charge data was obtained from an administrative database used by the hospital billing department for reporting to the State of Maryland. The unique structure of medical reimbursement in Maryland means that payment rates for insurers (both public and private) are determined by a rate-setting commission and are uniform amongst payers, thus avoiding cost-shifting to privately insured patients.²⁵ There was no adjustment for inflation since all patients were enrolled within a 28-month period, and the incidence of delirium was similar across time in the study.

Perioperative Clinical Care

Patients received standard intraoperative monitoring. Anesthetic care generally consisted of propofol (induction), volatile anesthetic (maintenance), fentanyl and/or dilauidid (pain control), and a non-depolarizing muscle relaxant. Postoperatively, patients typically received patient-controlled analgesia (fentanyl or dilauidid) with >95% of patients receiving this modality on postoperative day 1. With adequate oral intake, patients transitioned to oral opioids, typically oxycodone. Long acting opioids were restarted if the patient was taking them at baseline. Although there was no formal delirium-prevention protocol at the time of this study, as part of routine clinical care, providers tried to limit use of benzodiazepines, encourage ambulation, encourage good sleep hygiene, ensure adequate hydration, and replete electrolytes. Management of delirium focused on considering potential etiologies, followed by supportive care, including an emphasis on reorientation, mobility, control of pain, medications, and fluid and electrolyte status. Patients with hyperactive delirium who were a danger to self or others could be treated with an antipsychotic drug and/or be placed in restraints. Psychiatric consult was available for refractory delirium.

Statistical Analysis

Statistical analyses were conducted using Stata 12.0 (College Station, TX). The sample size in this study was based on the sample size required to determine differences in the mean arterial pressure at the lower limit of cerebral blood flow autoregulation among delirious compared with non-delirious patients.

For analytic purposes, delirium was defined as any delirious episode after surgery, as assessed by CAM, CAM-ICU, or chart review. Delirium severity was considered as the highest severity score. Hospital length of stay and charges were skewed in distribution, so were treated as quintiles. Complications were defined a priori as postoperative stroke or transient ischemic attack, seizure, myocardial infarction, arrhythmias, congestive heart failure, pneumonia, re-intubation, acute renal failure, sepsis, urinary tract infection, deep venous thrombosis or pulmonary embolism, fall, surgical site infection, and return to the operating room.

Characteristics of the study population were compared using t-tests, rank-sum tests, chi-squared tests, and Fisher's exact tests. To identify independent risk factors for delirium, characteristics with a p-value <0.2 in univariate comparison by delirium status were entered into a forward stepwise regression model. Independent risk factors were considered to have a p-value <0.05 in this model, and goodness of fit was assessed with the Hosmer and

Lemeshow test. In terms of outcomes, multivariable logistic regression was used to determine the association of delirium and discharge location, and multivariable ordinal logistic regression was used for the outcomes of hospital length of stay (quintiles) and charges (quintiles). Covariates to include in adjusted models were chosen a priori based on literature demonstrating an independent association of each factor with increased postoperative hospital length of stay²⁶—age, functional status (acts of daily living), American Society of Anesthesiologists (ASA) risk score, surgery length, intraoperative red blood cell transfusion, return to the operating room, and any complication.

RESULTS

Patient and Delirium Characteristics

Eighty-nine patients were included in this study, with a median age of 74 years old (IQR 72–78). The majority of surgeries involved the lumbar spine (84%, all lumbar procedures in the prone position) and the median number of levels was 4 (IQR 3–6). One patient had a minimally invasive lumbar procedure.

Overall, 36/89 (40.5%) of patients developed delirium, with a median severity score of 4 (IQR 2–9). The majority of delirious episodes were first diagnosed on postoperative day 1 (44%) or day 2 (42%). The prevalence of delirium was highest on postoperative day 2 (28.1%). Specifically, the prevalence of delirium on postoperative day 1–4 was 18.0%, 28.1%, 20.2%, and 7.9% respectively. The majority (78% [28/36]) of delirium lasted 2 days. For patients admitted to the ICU compared to patients only admitted to the floor, both the incidence (49% vs. 26%; $p=0.04$) and severity of delirium (median 6; IQR 3–13 vs. median 1; IQR 1–5.5) were greater. For patients with length of surgery <3 hours, the incidence of delirium was 18.7% (3/16), while for patients with surgery 3–5 hours, the incidence was 40.7% (11/27) and for >5 hours was 47.8% (22/46).

Episodes of delirium were classified into subtypes based on psychomotor features. Of 36 patients with delirium, 17 (47.2%) had purely hypoactive features across their hospital stay, 8 (22.2%) had purely hyperactive features, and the remainder had mixed features (7 [19.4%]) or normal psychomotor activity (4 [11.1%]). Thus, the overall incidence of delirium with any hyperactive features (the most clinically apparent subtype) in the entire study sample was 16.8% (15/89). Antipsychotic medications (haloperidol or quetiapine) were prescribed in 7 patients, and restraints in 5 patients.

Risk Factors

As shown in Table 1, at baseline, the MMSE score was lower among delirious patients, and average pain, current pain, maximum pain at assessment, and ASA scores were higher among delirious patients. Delirious patients were more likely to be on opioid and antidepressant medications. Additionally, several characteristics indicating a more complex surgery were associated with delirium, including length of surgery, number of levels treated, reoperation, blood loss, IV fluid, and phenylephrine requirements. (Each of these latter variables was also independently associated with increased length of surgery, as expected [all $p<0.05$]).

In the final multivariable model, lower baseline MMSE score (OR 1.96; 95%CI 1.23–3.13; $p=0.005$), higher average baseline pain (1.89; 95%CI 1.27–2.82; $p=0.002$), more liters of IV fluid (OR 1.52; 95%CI 1.04–2.23; $p=0.03$), and baseline anti-depressant medications (OR 4.70; 95%CI 1.03–21.5; $p=0.046$) were all independently associated with postoperative delirium. Each of these variables was further examined in relation to delirium severity. As shown in Figure 1, there was a significant association of both lower baseline MMSE score and higher baseline average pain with increasing delirium severity score. Interestingly, for patients with baseline MMSE score ≥ 24 , postoperative delirium severity scores ranged from 9–26, implying that patients with low MMSE scores are at high risk for severe forms of delirium.

The Association of Delirium with Hospital Outcomes

Length of Stay—Patients who developed delirium had longer length of stay (6.5 days [IQR 5–8] vs. 4 days [IQR 3–6] vs. $p<0.001$) compared to patients who did not develop delirium. In fully adjusted models (adjusted for age, baseline acts of daily living score, ASA score, surgery length, intraoperative red blood cell transfusion, any complication, and return to operating room), the odds of having a higher quintile of length of stay were significantly higher for delirious compared with non-delirious patients (OR 3.66; 95%CI 1.48–9.04; $p=0.005$).

As shown in Figure 2A, delirium severity score was also associated with increased length of stay in a dose-response relationship in univariate models ($p<0.001$). However, in adjusted models the association between delirium severity and increased quintile of length of stay was attenuated and not significant (OR 1.09; 95%CI 0.96–1.25; $p=0.18$).

When stratified by subtype, hypoactive delirium (OR 3.3; 95%CI 1.12–9.53; $p=0.03$) and hyperactive or mixed delirium (OR 3.7; 95%CI 1.05–13.0; $p=0.04$) were both independently associated with increased quintile of length of stay, compared to patients without delirium.

Hospital Charges—Patients who developed delirium had greater hospital charges (\$34,166[IQR \$19,576–\$50,922] vs. \$51,984[IQR \$38,802–\$85,224]; $p=0.003$) compared to patients who did not develop delirium. In fully adjusted models, the odds of being in a higher quintile of hospital charges were significantly higher for delirious compared with non-delirious patients (OR 3.49; 95%CI 1.35–9.0; $p=0.01$).

As shown in Figure 2B, delirium severity score was also associated with increased hospital charges in a dose-response relationship ($p<0.001$). In adjusted models, each point of higher delirium severity score was associated with a 12% higher odds of being in a higher quintile of hospital charges (OR 1.12; 95%CI 1.02–1.23; $p=0.02$).

When stratified by subtype of delirium, hypoactive delirium (OR 4.19; 95%CI 1.33–13.2; $p=0.01$) was independently associated with increased quintile of hospital charges, compared to patients without delirium. There was a trend towards a similar association with hyperactive or mixed delirium (OR 3.47; 95%CI 0.96–12.6; $p=0.06$).

Discharge Location—Discharge to home was achieved significantly less often in patients who developed delirium (47% went home) compared with patients who did not develop delirium (83% went home; $p=0.001$). Since 96% of patients were living in their own or family home at baseline, this difference predominantly reflects a new discharge location. In fully adjusted models, the odds of being discharged home were significantly lower for delirious compared with non-delirious patients (OR 0.22; 95%CI 0.07–0.69; $p=0.009$).

As shown in Figure 2C delirium severity score was also associated with lower odds of being discharged home in a dose-response relationship ($p=0.003$). In adjusted models, each point of higher delirium severity score was associated with 11% lower odds of being discharged home (OR 0.89; 95%CI 0.80–0.98; $p=0.02$).

When stratified by subtype of delirium, only hyperactive delirium was associated with lower odds of discharge home (OR 0.14; 95%CI 0.03–0.62; $p=0.01$).

Complications—There were no differences in incidence of any predefined complications between delirious and non-delirious patients (16.7[6/36] vs. 9.4%[5/53]; $p=0.31$). Complications were new arrhythmias ($n=3$), urinary tract infections ($n=5$), deep vein thrombosis or pulmonary embolism ($n=3$), fall ($n=1$), and reoperation ($n=1$).

Readmissions—Four patients with delirium were readmitted to the hospital within 30 days (4/36[11%]), compared with 1 patient without delirium (1/53[1.9%]; $p=0.06$).

DISCUSSION

We found a 40.5% incidence of delirium in adults >70 years old undergoing spine surgery. Independent risk factors for postoperative delirium were baseline factors (MMSE score, average pain, baseline anti-depressant medication) and one intraoperative factor (intraoperative IV fluid). Postoperative delirium was associated with increased hospital length of stay, increased hospital charges, and decreased odds of being discharged home.

Spine surgery is increasing in frequency as the population ages and degenerative diseases with painful manifestations become more prevalent. Between 1998–2008, the annual number of spinal fusion discharges increased by 2.4-fold, a substantially greater increase than that of other common surgeries, such as joint arthroplasty or coronary artery bypass.²⁷ As with any surgery in older adults, avoiding complications is a paramount goal, as older adults have been shown to tolerate complications poorly compared to younger patients.²⁸

Delirium is a potentially preventable complication¹ that may represent an area for quality improvement in spine surgery. Our study demonstrates a high incidence of delirium in older adults, even among patients with length of surgery <3 hours, a surgical time generalizable to many centers. Our findings are consistent with prior studies demonstrating that delirium is common after many types of surgery in older adults when rigorous diagnostic criteria are used. However, the high frequency of spine surgery in older adults means that more older adults are at risk for delirium after spine surgery, compared to other less frequent surgeries.

Identification of high-risk patients is critical to targeting prevention efforts. Prior studies in non-cardiac general surgery have identified age, poor cognitive or functional status, alcohol abuse, abnormal electrolytes, and thoracic or aortic surgery as risk factors.⁹ In our study, we found that average pain was an independent risk factor for delirium. In the spine surgery population, pain is often prominent, and our results highlight that pain is an important risk factor for delirium, which needs to be carefully considered. One implication is that perioperative pain optimization may be a strategy to reduce the risk of delirium, although further research is needed to test this hypothesis. Cognitive status is infrequently assessed at baseline but likely has profound impact on recovery,²⁹ and recommendations from the American College of Surgeons/American Geriatrics Society recommend a preoperative cognitive assessment. The amount of IV fluid during surgery likely reflects the complexity of surgery, but does raise the intriguing possibility that fluid balance, a modifiable factor, may play a role in the development of delirium. In our study, we did not measure frailty status in a rigorous manner at baseline. However, since functional status was associated with delirium, the addition of frailty measurements in future studies might refine risk-stratification for delirium, as has been shown in other surgical populations.³⁰

Importantly, and similar to other studies,³¹ 47% of delirious patients in our study had purely hypoactive features, the subtype of delirium that is generally not recognized.²⁰ Since outcomes have been shown to be poor after either hypoactive or hyperactive delirium,²⁴ preventing, recognizing, and treating hypoactive delirium should be a focus of quality improvement strategies.

Even after high-risk patients have been identified, a particular challenge is to optimize delirium-prevention strategies. In 2014, the American Geriatric Society (AGS) released evidenced based guidelines to assist clinicians in evaluating delirium prevention strategies after surgery.³² An important recommendation was multicomponent nonpharmacologic interventions, such as the Hospital Elder Life Program, which has been associated with a 40% reduction in the incidence of delirium.¹¹ Components of this program include early-mobilization, sleep protocols, avoidance of dehydration, orientation activities, and return of vision and hearing aids. Although the HELP program was developed in the medical population, it has been extended into surgical patients with promising results.³³ Other strong recommendations from the AGS guidelines include adequate pain management and avoidance of medications that could precipitate delirium (benzodiazepines). Anesthetic-based interventions, such as injection of regional anesthetic or avoidance of excess depth of anesthesia, were either weak recommendations or had insufficient evidence to justify a recommendation, although these areas are being actively investigated and may represent modifiable factors. Similarly, promising single-drug interventions, such as steroids,³⁴ statins,³⁵ and acetylcholinesterase inhibitors,³⁶ have proven ineffective to prevent postoperative delirium in well-done randomized trials. Further research is needed in this area.

There are several limitations to this study. First, this is a single center study, in which many patients underwent long procedures involving multiple spine levels. All patients were also older than 70 years old—all factors that limit generalizability. Second we could not conduct rigorous delirium assessments on all days of a patient's hospitalization, but prior work has

shown that 90% of delirium generally occurs within the first 4 postoperative days.^{9,22} Third, we relied on hospital charge data as a surrogate for cost. As mentioned, unique to the State of Maryland, the Maryland Health Services Cost Review Commission determines payment rates for insurers—both public and private. The rate for charge payments at the authors' institutions has historically been cost plus 1–3%, and thus charges approximate cost.²⁵ Finally, our results may be due to confounding, but we adjusted for potentially important factors that were chosen a priori based on literature review.

In conclusion, delirium is common in older adults undergoing spine surgery, and is associated with increased hospital length of stay, increased hospital charges, and decreased odds of discharge to home. Delirium prevention after spine surgery represents an important target for quality improvement measures.

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Figure 1.
The Association of Baseline MMSE score (A) and Baseline Average Pain (B) with Postoperative Delirium Severity Scores. The line represents a lowess-smoothed curve using non-parametric regression models.

Figure 2.
The Association of Delirium Severity with Increased Length of Stay (A), Increased Hospital Charges (B), and Decreased Discharge to Home (C)

Table 1

Characteristics of Patients According to Development of Postoperative Delirium

	No Delirium (n=53)	Delirium (n=36)	P-value
Age, med (IQR)	74 (71–77)	75 (72–78)	0.38
Male, n (%)	30 (56.6)	17 (47.2)	0.38 ^a
Race, n (%)			0.44 ^b
White, n (%)	49 (92.5)	31 (86.1)	
African American, n (%)	4 (7.6)	4 (11.1)	
Other, n (%)	0 (0)	1 (2.8)	
Education, n(%)			0.45 ^b
Some high school, n (%)	2 (3.8)	4 (11.4)	
High school diploma, n (%)	13 (24.5)	7 (19.4)	
Vocational school, n (%)	4 (7.6)	3 (8.3)	
College degree, n (%)	14 (26.4)	13 (36.1)	
Graduate degree, n (%)	20 (37.7)	9 (25.0)	
Retired, n (%)	48 (90.6)	31 (86.1)	0.75 ^b
Baseline MMSE, median (IQR)	29 (28–29)	27 (26–29)	0.003
Ever smoking, n (%)	30 (56.6)	23 (63.9)	0.49 ^a
Number of alcoholic drinks per day, med (IQR)	2 (0–7)	0 (0–3)	0.38
Current pain, med (IQR)	3 (1–6)	6 (2.5–8)	0.02
Average pain, med (IQR)	5 (4–6)	7 (6–8)	<0.001
Acts of daily living, med (IQR)	10 (10–10)	10 (9–10)	<0.001
Living in own home, n (%)	50 (94.3%)	33 (91.7%)	0.37 ^a
Living arrangement			0.47
Self, n (%)	8 (15.4)	9 (25.7)	
Spouse, n (%)	40 (76.9)	23 (65.7)	
Family, n (%)	1 (1.9)	2 (5.7)	
Other, n (%)	3 (5.8)	1 (2.9)	
Glasses, n (%)	45 (84.9)	32 (88.9)	0.59 ^a
Hearing aids, n (%)	9 (17.0)	5 (13.9)	0.69 ^b
ASA score, med (IQR)	3 (2–3)	3 (3–3)	0.03
Comorbidities, n (%)			
Dementia, n (%)	0 (0)	0 (0)	N/A
Depression, n (%)	8 (15.1)	10 (27.8)	0.14 ^a
Other psychiatric history, n (%)	2 (3.8)	1 (2.8)	1.0 ^b
Stroke or TIA, n (%)	2 (3.8)	1 (2.8)	1.0 ^b
Obstructive sleep apnea, n (%)	13 (24.5)	6 (16.7)	0.37 ^a
Atrial fibrillation, n (%)	3 (5.7)	6 (16.7)	0.15 ^b
Coronary artery disease, n (%)	5 (9.4)	7 (19.4)	0.21 ^b
Congestive heart failure, n (%)	5 (9.4)	6 (16.7)	0.34 ^b

	No Delirium (n=53)	Delirium (n=36)	P-value
Hypertension, n (%)	35 (66.0)	32 (88.9)	0.02 <i>b</i>
Systolic blood pressure preoperatively (mm Hg), mean±SD	146.3±20.1	146.9±20.1	0.87
Myocardial infarction, n (%)	5 (9.4)	4 (11.1)	1.0 <i>b</i>
Chronic obstructive pulmonary disease, n (%)	0 (0)	3 (8.3)	0.06 <i>b</i>
Chronic renal insufficiency, n (%)	2 (3.8)	3 (8.3)	0.39 <i>b</i>
Diabetes, n (%)	12 (22.6)	9 (25.0)	0.80 <i>a</i>
Steroids in past year, n (%)	13 (24.5)	10 (27.8)	0.73 <i>a</i>
Hemoglobin (mg/dL), mean±SD	13.6±1.9	13.3±1.5	0.38
Medications			
Opioid			0.09 <i>b</i>
None	37 (69.8)	17 (47.2)	
Short-Acting, n (%)	12 (22.6)	12 (33.3)	
Long-Acting, n (%)	4 (7.6)	7 (19.4)	
Benzodiazepine, n (%)	8 (15.1)	9 (25.0)	0.24 <i>a</i>
Anti-depressant, n (%)	10 (18.9)	16 (44.4)	0.009 <i>a</i>
Other psychiatric medications, n (%)	4 (7.6)	4 (11.1)	0.71 <i>b</i>
Beta adrenergic blocking agent, n (%)	19 (35.9)	16 (44.4)	0.42 <i>b</i>
ACE inhibitor, n (%)	11 (20.8)	11 (30.6)	0.29 <i>b</i>
Calcium channel blocker, n (%)	12 (22.6)	11 (30.6)	0.41 <i>b</i>
Surgical characteristics			
Lumbar, n (%)	43 (81.1)	32 (88.9)	0.39 <i>a</i>
Fusion, n (%)	36 (67.9)	30 (83.3)	0.10 <i>a</i>
Number of levels ^C , med (IQR)	4 (2–5)	5 (4–8.5)	0.002
Length of surgery (min)	296.9±131.6	344.8±122.8	0.09
Reoperation, n (%)	13 (24.5)	18 (50.0)	0.01 <i>a</i>
Anesthesia characteristics			
Hydromorphone (mg), med (IQR)	1.6 (1–3)	2 (1–3.6)	0.45
Fentanyl (mcg), med (IQR)	250 (225–529)	250 (250–565)	0.68
Midazolam (mg), med (IQR)	2 (2–2)	2 (2–2)	0.25
Phenylephrine (mcg), med (IQR)	200 (0–700)	500 (50–1300)	0.02
Ephedrine (mg), med (IQR)	10 (0–20)	10 (0–20)	0.36
Steroids, n (%)			0.02 <i>b</i>
None, n (%)	23 (43.3)	26 (72.2)	
Dexamethasone 4 mg, n (%)	11 (20.8)	5 (13.9)	
Dexamethasone 8 mg–20mg, n (%)	18 (34.0)	4 (11.1)	
Hydrocortisone 100–200 mg, n (%)	1 (1.9)	1 (2.8)	
Intravenous fluid (mLs), mean±SD	3500±1589	4582±1826	0.004
Estimated blood loss (mLs), med (IQR)	500 (150–1200)	750 (400–1650)	0.03
Transfusion of packed red blood cells intraoperatively, n (%)	23 (43.4)	20 (55.6)	0.26

	No Delirium (n=53)	Delirium (n=36)	P-value
Number of units of packed red blood cell transfusions intraoperatively, med (IQR)	0 (0–2)	1 (0–2)	0.32
ICU admission, n (%)	28 (52.8)	27 (75.0)	0.04 ^a
Maximum pain score (0–10 scale) at delirium assessment, mean±SD	4.7±2.4	6.2±2.2	0.007

Abbreviations: med=median; IQR= inter-quartile range; MMSE= mini-mental state examination; ASA= American Society of Anesthesiologists; TIA= transient ischemic attack; ICU=intensive care unit;

^aChi-squared test;

^bFisher's exact test;

^cLevels was defined as the number of vertebrae involved in the surgery.