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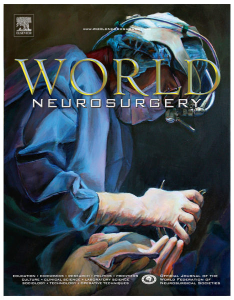

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Incidence and risk factors of delirium following brain tumor resection: A retrospective National Inpatient Sample database study

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Abstract

Objective: The aim of this study was to evaluate the occurrence and factors predisposing to delirium following brain tumor resection.

Materials and methods: Data from patients who underwent brain tumor resection surgery from 2016 to 2019 was extracted from the National Inpatient Sample (NIS) database and retrospectively analyzed. The difference between the two groups was compared by Wilcoxon rank test or Chi-square test were used to. Univariate and multivariate logistic regression analyses were used to identify the risk factors delirium after brain tumor resection.

Results: From 2016 to 2019, 28340 patients who underwent brain tumor resection were identified in the NIS database, with the incidence of delirium being 4.79% (1357/28340). It was found that increased incidence of delirium was significantly associated with aged over 75 years and males (all $P < 0.001$). Besides, patients with delirium were more likely to have multiple comorbidities and to receive elective surgery (all $P < 0.001$). The results of logistic regression analysis showed that self-pay (OR = 0.51; CI = 0.31-0.83; P = 0.007), elective admission (OR = 0.53; CI = 0.47-0.60; $P < 0.001$), obesity (OR = 0.77; CI = 0.66-0.92; P = 0.003), female (OR = 0.79; CI = 0.71-0.88; $P < 0.001$), and private insurance (OR = 0.80; CI = 0.67-0.95; P = 0.012) were associated with lower occurrence of delirium. Besides, delirium was related to extra total hospital charges ($P < 0.001$), increased length of stay ($P < 0.001$), higher inpatient mortality (P = 0.001), and perioperative complications (including heart failure, acute renal failure, urinary tract infection, urinary retention, septicemia, pneumonia, blood transfusion, and cerebral edema) ($P < 0.001$).

Conclusion: Many factors were associated with the occurrence of delirium after brain tumor resection. Therefore, clinicians should identify high-risk patients prone to delirium in a timely manner and take effective management measures to reduce adverse outcomes.

Keywords: Delirium, Risk factors, Brain tumor, Resection, National Inpatient Sample

Introduction

Delirium is a prevalent complication observed in old patients, with an incidence of 15% to 25% after elective surgery. It represents a sudden alteration in consciousness, cognitive function, and attention occurring within the initial seven days post-surgery[1, 2]. The Nomenclature Consensus Working Group has recently proposed the inclusion of postoperative delirium within the category of perioperative neurocognitive disorders[3]. Primary injury and surgery may cause damage to brain tissue, and patients after neurosurgery may be exposed to more risk factors for delirium[4]. It is reported that the probability of delirium after brain tumor surgery is 18.6-29.6 %[4-6]. Delirium is related to adverse outcomes, longer hospital stays, higher medical costs, and increased incidence of complications[7, 8]. The prevention and treatment of delirium remain challenging, and there is almost no evidence to support commonly used drug interventions, such as atypical antipsychotic drugs. Therefore, it is crucial to identify high-risk patients for delirium before surgery to improve postoperative results and avoid adverse events[9-11].

Numerous published studies have primarily focused on investigating delirium in elderly patients following orthopedic, spinal, and cardiovascular surgeries, given its prevalence in this demographic[1, 7, 11, 12]. Neurosurgical patients, who often necessitate prolonged intensive care unit (ICU) stay, frequent neurological assessments, and interruptions to their sleep patterns, are widely thought to be at an elevated risk of developing delirium[13, 14]. Additionally, these patients frequently contend with neurological or metabolic disorders associated with neurosurgical conditions and the possibility of neurological deficits that can impact mental status or communication[9, 15]. Although previous studies have identified various factors associated with delirium, such as age, level of education, use of anticholinergic drugs, etc. However, these studies are small sample retrospective studies[2, 4, 7, 8, 11, 12]. Therefore, it is still necessary to further study the incidence of postoperative delirium, clinical significance and risk factors associated with delirium, especially in patients after brain tumor resection.

To date, there has been a notable absence of the utilization of a comprehensive national database to investigate the occurrence and risk factors associated with delirium following brain tumor resection. Given the limited number of studies focusing on the evaluation of delirium in neurosurgical patients, there exists a scarcity of data specifically addressing post-craniotomy cases[9, 13, 14]. To bridge this knowledge gap, we sought to harness data from the National Inpatient Sample (NIS) database to assess both the occurrence and factors associated with delirium following brain tumor resection. Additionally, an additional hypothesis was put forth, seeking to identify specific factors that could aid in identifying patient populations requiring optimization prior to surgery.

Materials and methods

1. Data source

Data for this study was obtained from the National Inpatient Sample database, which is a component of the Healthcare Cost and Utilization Program under the Agency for

Healthcare Research and Quality. The NIS database represents the largest all-payer inpatient database, collecting stratified samples from over a thousand hospitals, accounting for about 20% of hospitalizations in the United States every year. It comprises a wealth of data encompassing both clinical and non-clinical factors. This extensive dataset includes information on diagnoses, demographics, payment details, hospital characteristics, and procedures for around 7 million inpatients annually. Extracted data encompass various elements, such as length of stay (LOS), patient demographics, and procedural and diagnostic codes based on the International Classification of Diseases (10th revision) Clinical Modification (ICD-10-CM)[12]. More information about the NIS and data access can be obtained from the website: www.hcup us ahrq.gov. This study is not subject to ethical committee regulations since it relied on anonymized public data.

2. Data collection

Data was collected from the National Inpatient Sample database from January 1, 2016, to December 31, 2019. The study encompassed all admissions that underwent a definitive craniotomy for brain tumor. These patients were identified based on the ICD-10-CM admission diagnostic code, including meningioma, glioma and brain metastases (Table S1). Patients undergoing craniotomy surgery were identified based on specific ICD-10-CM procedure codes, encompassing various surgical procedures related to the brain, cerebral meninges, dura mater, cerebral ventricle, cerebral hemisphere, pons, cerebellum, and medulla oblongata (Table S1). The identification of delirium patients was based on specific ICD-10-CM diagnostic codes (Table S1)[16-18]. Patients with missing data and those younger than 18 years were excluded from the analysis (Figure 1).

Based on the occurrence of delirium, patients were stratified into two categories. Demographic characteristics, such as race, age, and sex, were assessed. Outcome measures, including total hospitalization cost, mode of admission, length of stay, hospitalization mortality, preoperative comorbidities, and insurance type, were analyzed. To identify complications that might be independently associated with delirium, as well as surgical and medical perioperative complications before discharge, the ICD-10-CM diagnostic code was utilized. Perioperative medical complications included septicemia, pneumonia, heart failure, cardiac arrest, thrombocytopenia, pulmonary embolism, acute cerebrovascular disease, acute myocardial infarction, stroke, urinary tract infection, acute renal failure, urinary retention, respiratory failure, continuous trauma ventilation, deep vein thrombosis, convulsion, and cerebral edema. Perioperative surgical complications encompassed wound infection, wound dehiscence, and blood transfusion. A total of 32 preoperative comorbidities were collected from the NIS database (Table 1).

3. Data analysis

The statistical analyses were performed using R version 3.5.3 and SPSS version 25 statistical software. The distribution normality of continuous data was visually assessed using a normal quantile plot. For continuous data, the Wilcoxon rank test was applied, while categorical data underwent the Chi-square test to assess the significance of intergroup differences. Univariate logistic regression models and multivariate logistic regression models were generated to assess the association between delirium and other comorbidities or perioperative complications. In order to identify independent predictors of postoperative delirium and their associations with other surgical and medical complications, binary logistic regression analysis with stepwise regression was employed. The analysis encompassed all variables provided by the NIS, including preoperative comorbidities, hospital characteristics, and demographics. Statistical significance was set at $P < 0.05$.

Results

1. Delirium occurrence following brain tumor resection

From 2016 to 2019, 28340 patients who underwent brain tumor resection were screened from the NIS database, with the incidence of delirium being 4.79% (n=1357) (Table 2). The annual incidence of delirium after brain tumor resection fluctuated over the study period (Figure 2).

2. Patient demographics and hospital characteristics

The average age of patients with delirium was 67 years, which was significantly higher by 7 years compared to the mean age of 60 years in patients without delirium ($P < 0.001$) (Table 2). Besides, the age distribution between the two groups was significantly different. The occurrence of delirium was notably higher in cases aged over 75 years, with a 15.29% increase (26.75% vs. 11.46%, $P < 0.001$) (Figure 3A-B). Predictably, compared with patients without delirium, patients with delirium after brain tumor resection were associated with a 19.35% (63.04% vs. 82.39%, $P < 0.001$) higher likelihood of multiple comorbidities ($n \geq 3$) (Table 2) (Figure 3C-D). Besides, the occurrence of delirium in females was significantly lower than in males (45.47% vs. 54.53%, $P < 0.001$) (Table 2) (Figure 4A-B). As expected, compared with patients without delirium, patients with delirium after brain tumor resection were associated with a 20.91% (32.05% vs. 52.96%, $P < 0.001$) lower likelihood of elective surgery (Table 2) (Figure 4C-D).

3. Adverse outcomes of delirium after brain tumor resection

Besides, the in-hospital mortality associated with delirium was higher than non-delirium cases (2.36% vs. 1.28%, $P = 0.001$) (Table 2). The median LOS associated with delirium was extended by 4 days (9 days vs. 5 days; $P < 0.001$) (Table 2). Accordingly, delirium was also associated with higher medical expenses, with an increase of $41669 compared with non-delirium cases ($159042 vs. $117373, $P < 0.001$) (Table 2). When stratified by insurance type, the proportion of patients with Medicare insurance was significantly higher in the delirium group at 54.97% compared to 38.13% in the non-delirium group ($P < 0.001$) (Table 2). Conversely, the proportion with private insurance was significantly lower in the delirium group at 29.18% versus 44.17% in the non-delirium group ($P < 0.001$) (Table 2) (Figure 5).

4. Perioperative complications related to delirium following brain tumor resection

Univariate analysis showed that compared with patients without delirium, patients with delirium after brain tumor resection were more likely to have perioperative medical complications such as septicemia, urinary tract infection, pneumonia, stroke, acute renal failure, urinary retention, respiratory failure, heart failure, thrombocytopenia, acute cerebrovascular disease, and cerebral edema, or perioperative surgical complications such as blood transfusion (Table 3). Multivariate analysis showed that delirium after brain tumor resection was associated with urinary tract infection (odds ratio [OR] = 2.03; 95% confidence interval [CI] = 1.70-2.44; P = 0.001), urinary retention (OR = 1.89; 95% CI = 1.52-2.35; P < 0.001), cerebral edema (OR = 1.73; 95% CI = 1.52-1.96; P < 0.001), acute renal failure (OR = 1.56; 95% CI = 1.25-1.94; P < 0.001), septicemia (OR = 1.43; 95% CI = 1.01-2.04; P = 0.046), pneumonia (OR = 1.37; 95% CI = 1.00-1.87; P = 0.049), and blood transfusion (OR = 1.31; 95% CI = 1.03-1.67; P = 0.029) (Table 3).

5. Risk factors related to delirium following brain tumor resection

Logistic regression analysis was conducted to identify factors predisposing to delirium, including psychoses (OR = 2.89; 95% CI = 2.27-3.68; P < 0.001), other neurological disorders (OR = 2.77; 95% CI = 2.33-3.28; P < 0.001), multiple comorbidities (n ≥ 3; OR = 2.59; 95% CI = 1.56-4.29; P < 0.001), pulmonary circulation disorders (OR = 1.88; 95% CI = 1.18-2.98; P = 0.008), advanced age (≥65 years; OR = 1.67; 95% CI = 1.41-1.97; P < 0.001), alcohol abuse (OR = 1.59; 95% CI = 1.21-2.09; P = 0.001), peripheral vascular disorders (OR = 1.52; 95% CI = 1.17-1.96; P < 0.001), weight loss (OR = 1.44; 95% CI = 1.17-1.77; P < 0.001), hypertension (OR = 1.43; 95% CI = 1.27-1.62; P < 0.001), diabetes with chronic complications (OR = 1.41; 95% CI = 1.20-1.67; P < 0.001), fluid and electrolyte disorders (OR = 1.36; 95% CI = 1.19-1.55; P < 0.001), depression (OR = 1.30; 95% CI = 1.11-1.52; P = 0.001), paralysis (OR = 1.25; 95% CI = 1.09-1.44; P = 0.001), and smoking (OR = 1.15; 95% CI = 1.02-1.31; P = 0.024) (Figure 6). Multivariable logistic regression identified several factors associated with decreased odds of delirium, including self-pay (OR = 0.51; 95% CI = 0.31-0.83; P = 0.007), elective admission (OR = 0.53; 95% CI = 0.47-0.60; P < 0.001), obesity (OR = 0.77; 95% CI = 0.66-0.92; P = 0.003), female (OR = 0.79; 95% CI = 0.71-0.88; P < 0.001), and private insurance (OR = 0.80; 95% CI = 0.67-0.95; P = 0.012) (Figure 6).

Discussion

At present, little is known about the pathogenesis of delirium. Cognitive impairment and simultaneous slow activity of brain waves in patients with delirium are caused by a general decrease in brain oxidative metabolism. Any disease or toxic substance can cause delirium as long as it can reduce the supply, intake and utilization of substances related to brain metabolic activity. The decrease of cerebral oxidative metabolic rate can lead to the decrease of acetylcholine synthesis. Choline deficiency constitutes one of the characteristic manifestations of metabolic-toxic encephalopathy, namely delirium[19]. Both primary injury and surgery can cause brain tissue damage, and patients after neurosurgery may be exposed to more risk factors for delirium[4]. Brain tumors can lead to a variety of neurological disorders, including seizures, paralysis, language deficits and cognitive decline, which have a negative impact on the quality of life of patients. Surgical resection is essential for the establishment of pathological diagnosis, reduction of space occupying effect, and enhancement of neurological function and quality of life in patients with brain tumors. Therefore, patients undergoing brain tumor resection are inevitably at risk of delirium.

To our knowledge, no study has hitherto investigated the occurrence and factors predisposing to delirium following brain tumor resection using data from the NIS database. A recently published meta-analysis based on 24 studies about craniotomy surgeries revealed that the incidence of delirium ranged from 12% to 26%. Several reports have shown that the probability of delirium after brain tumor surgery is 18.6-29.6%[4-6]. This variability was attributed to differences in clinical characteristics and the methods employed for delirium evaluation. Notably, the incidence of delirium was observed to be the highest following neurovascular surgery[20]. This study utilized a comprehensive national database to perform an extensive health-economic evaluation of delirium occurring after brain tumor resection surgery. The incidence of delirium fluctuated from 4.71% to 4.87% from 2016 to 2019, it was lower than the above studies, and there were several possible reasons to explain this significant difference. Firstly, prior studies suffered from limited sample size and the inclusion of predominantly elderly participants, leading to a comparatively elevated occurrence rate[13]. Secondly, depending on the standards used, different institutions may also have differences in the definition and diagnosis of delirium[12]. Thirdly, the limitations of the NIS database, such as high specificity, low sensitivity, and providing only inpatient delirium, may lead to an underestimation of the incidence[7].

Age and gender are often associated with the occurrence of postoperative delirium[1, 12, 21, 22]. In this study, patients experiencing delirium tended to be 7 years older on average than those without delirium. Furthermore, when considering age distribution, the delirium group exhibited a higher proportion of elderly patients. Moreover, being aged 65 years or older was an independent predictor for delirium during logistic regression analysis, consistent with previous studies[1, 12, 21, 22]. Advanced age has the potential to induce cognitive impairment, and its underlying mechanism remains intricate and not fully understood. One plausible speculation is that aging is closely associated with atherosclerosis and endothelial dysfunction, thereby elevating the likelihood of cerebral embolism[23]. In addition, as suggested by earlier studies, an alternative explanation is that postoperative neurocognitive dysfunction in elderly patients may arise from the inhibition of cerebral blood flow, with postoperative inflammatory changes contributing to this inhibition[24, 25]. Moreover, we found that the proportion of females affected by delirium was significantly lower than males. During logistic regression analysis, being female was an independent protective factor for delirium. One potential factor contributing to the association between males and delirium is the potential severity of the underlying disease. In a prospective cohort study examining delirium and postoperative outcomes, males exhibited a slightly lower average age than females. However, their overall baseline health status was poorer, characterized by a higher number of comorbidities and elevated ASA scores[26]. Consequently, at the same age, elderly female patients tended to have a better health status than their male counterparts, resulting in a lower incidence of delirium. Predictably, the presence of multiple comorbidities (n ≥ 3) was correlated with a higher rate of delirium following brain tumor resection. This association is rational since a higher comorbidity score signifies a poorer preoperative health condition, potentially fostering the emergence of adverse events, such as postoperative delirium[27].

As expected, the number of delirium cases who underwent brain tumor resection during elective surgery was relatively small. During logistic regression analysis, we found that elective admission was an independent protective factor for delirium. This observation could be attributed to the fact that most elective cases generally present with favorable health conditions and undergo thorough pre-surgical preparations. In contrast, emergency cases often involve severe events such as brain edema or complex scenarios lacking meticulous preoperative evaluations[28]. When comparing patients with and without delirium, it was observed that those without delirium tended to opt for self-payment and private insurance. Furthermore, logistic regression analyses indicated that private insurance and self-payment were protective factors against delirium. One plausible explanation is that having private insurance or being able to self-pay often signifies better financial conditions for patients, which may play a significant role in averting delirium. Additionally, previous speculations by researchers suggested that clinical staff might consciously treat patients differently when disparities in insurance or income are detected among patients[29]. According to the previous reports, delirium has been linked to prolonged hospital stays, increased medical expenses, and elevated mortality rates[21, 30, 31]. Our research yielded similar findings. Delirium was associated with a median LOS extension of 4 days, and the total hospitalization cost for each admission increased by $41,669. This could be attributed to the fact that patients with delirium often experience impairments in consciousness, cognitive function, and perception, making it challenging to adhere to nursing and rehabilitation guidance[32]. Another contributing factor is the close association between delirium and the occurrence of perioperative complications, including septicemia, urinary tract infection, pneumonia, stroke, acute renal failure, urinary retention, respiratory failure, heart failure, thrombocytopenia, and acute cerebrovascular disease. These complications typically lead to delayed discharge, prolonged hospital stays, and increased mortality during hospitalization[33]. The escalation in total hospitalization costs for patients with delirium is not solely attributed to prolonged hospital stays; it also stems from the high costs associated with the treatment and care of delirium and its related complications. Consequently, the hospitalization mortality of patients with delirium was approximately twice that of those without delirium[34, 35].

To mitigate the risk of delirium, it is crucial to assess potential risk factors prior to the operation. Utilizing logistic regression analysis, we identified risk factors and, upon comparison with previous studies, found a fundamental consistency in the identified risk factors[7, 12, 21, 27, 31]. In addition to the previously discussed risk and protective factors such as age, sex, type of insurance, elective admission, and number of comorbidities, other noteworthy risk factors were identified. The risk of delirium increased in patients with a history of other neurological and psychiatric disorders, such as psychoses, other neurological disorders, alcohol abuse, and depression. Other comorbidities were also identified as factors predisposing to delirium, including pulmonary circulation disorders, peripheral vascular disorders, weight loss, hypertension, diabetes with chronic complications, fluid and electrolyte disorders, paralysis, and smoking. Perioperative complications such as urinary tract infection, heart failure, urinary retention, cerebral edema, acute renal failure, septicemia, pneumonia, and blood transfusion were independently associated with delirium. Interestingly, we observed that obesity was identified as a protective factor. Contrary to our findings, a previous study showed that the incidence of postoperative delirium in elderly patients increased with the increase of BMI index[36]. However, consistent with our findings, a study on the relationship between BMI and postoperative delirium showed that BMI is a protective factor for postoperative delirium[37]. The research on obesity is mainly concentrated in the field of cardiovascular disease, which is considered to be an unfavorable factor in the occurrence of various diseases. However, in the recovery stage of the disease, obesity is beneficial and can help patients recover as soon as possible. In addition, our study has a large age range, in which young patients and middle-aged patients account for a large proportion, which can offset the negative impact of obesity to a certain extent and amplify the benefits of obesity. This might explain why our findings support obesity as a protective factor for postoperative delirium.

Nonetheless, the analysis of data from the National Inpatient Sample database comes with certain shortcomings that should be acknowledged. Firstly, the database only captured complications that occur before discharge, indicating that any complications arising after the patient leaves the hospital will go unrecorded, potentially leading to an underestimation of the incidence of delirium[21]. Secondly, our analysis was restricted to the data available in the NIS database. Notably absent from the database are other recognized risk factors, including but not limited to anesthesia type, surgical duration, drugs administered during the perioperative period (such as benzodiazepines, ketamine, and opioids), dysfunction, visual impairment, brain tumor location, brain tumor pathology, and similar factors[38]. Thirdly, the potential for misclassification or discrepancies in documentation and coding exists, as is typical with expansive databases. Consequently, administrative data tend to demonstrate high specificity but low sensitivity in identifying adverse events. However, it cannot be ignored that due to the correlation between drugs such as antiepileptic drugs and emotions and behaviors[39], there may be not only low sensitivity problems, but also low specificity. Thus, this phenomenon may lead to an underestimation of the incidence of delirium following brain tumor resection[27]. Fourthly, there is a relation between delirium and non-convulsive status epilepticus[40], and no data have been collected on this comorbidity, which is one of the limitations of this study. Finally, the occurrence of delirium in the NIS database is marked and recorded by the corresponding ICD-10-CM. However, delirium may also occur in patients with organic diseases in neurology patients, so it is difficult to specifically distinguish between delirium caused by surgery or organic diseases.

Conclusion

This study identified that self-pay, elective admission, obesity, being female, and private insurance were associated with lower occurrence of delirium. Besides, delirium was related to extra total hospital charges, increased LOS, higher inpatient mortality, and perioperative complications (heart failure, acute renal failure, urinary tract infection, urinary retention, septicemia, pneumonia, blood transfusion, and cerebral edema). Therefore, healthcare professionals should prioritize the identification of high-risk populations for delirium among cases undergoing brain tumor resection. In subsequent studies, researchers can develop and implement effective management measures to reduce the probability of postoperative delirium in patients with brain tumors.

Declarations

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Consent for publication

Not Applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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Authors' contribution

W.F., Y.L. and R.L. contributed to the study design, data acquisition and analysis, interpretation of results, and writing and revising the manuscript. J.W. contributed to data acquisition, data analysis, and reviewing of the manuscript. J.L., Y.W. and K.C. contributed to the study design, interpretation of results, and reviewing the manuscript. All authors read and approved the final manuscript.

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Figure legends

Figure 1. Flow diagram of exclusion criteria in patients with delirium following brain tumor resection.

Figure 2. Annual incidence of delirium following brain tumor resection.

Figure 3. Patient age and comorbidity number between the two surgical groups. (A) Age distribution analysis of non-delirium patients. (B) Analysis of age distribution of patients with delirium. (C) Number of comorbidity analysis of non-delirium patients. (D) Number of comorbidity analysis of patients with delirium.

Figure 4. Patient sex and elective admission analysis between the two surgical groups. (A) Gender analysis of non-delirium patients. (B) Gender analysis of patients with delirium. (C) Elective admission analysis of non-delirium patients. (D) Elective admission analysis of delirium patients.

Figure 5. Patient insurance types between the two surgical groups. (A) Analysis of insurance types for non-delirium patients. (B) Analysis of insurance types for patients with delirium.

Figure 6. Risk factors associated with delirium after brain tumor resection. AIDS: Acquired immunodeficiency syndrome, OR: Odds ratio, CI: Confidence interval.

Table 1 Variables used in binary logistic regression analysis

Variables Categories	Specific Variables
Patient demographics	Age (≤64 years and ≥65 years), sex (male and female), race (White, Black, Hispanic, Asian or Pacific Islander and Other)
Hospital characteristics	Type of admission (non-elective, elective), bed size of hospital (small, medium, large), teaching status of hospital (nonteaching, teaching), location of hospital (rural, urban), type of insurance (Medicare, Medicaid, private insurance, self-pay, other), location of the hospital (northeast, Midwest or north central, south, west)
Comorbidities	AIDS, alcohol abuse, deficiency anemia, rheumatoid arthritis, chronic blood loss anemia, congestive heart failure, chronic pulmonary disease, coagulopathy, depression, diabetes (uncomplicated), diabetes (with chronic complications), drug abuse, hypertension, hypothyroidism, liver disease, lymphoma, fluid and electrolyte disorders, metastatic cancer, other neurological disorders, obesity, paralysis, peripheral vascular disorders, psychoses, pulmonary circulation disorders, renal failure, solid tumor without metastasis, peptic ulcer disease, valvular disease, weight loss, smoke, epilepsy, and Parkinson's disease

AIDS: Acquired immunodeficiency syndrome

Table 2 Patient characteristics and outcomes after brain tumor resection (2016-2019)

Characteristics	**No delirium**	**delirium**	**P**
Total (n=count)	26983	1357	
Total incidence (%)	4.79		
Age (median, years)	60(50, 69)	67(58, 75)	<0.001
Age group (%)			
18-44	17.35	8.40	<0.001
45-64	45.19	34.71	
65-74	26.00	30.14	
≥75	11.46	26.75	
Gender (%)			
Male	46.80	54.53	<0.001
Female	53.20	45.47	
Race (%)			
White	74.24	74.21	0.058
Black	9.51	11.86	
Hispanic	8.85	7.00	
Asian or Pacific Islander	3.21	3.39	
Other	4.18	3.54	
Number of Comorbidity (%)			
0	4.23	1.18	<0.001
1	13.15	4.94	
2	19.57	11.50	
⩾3	63.04	82.39	
LOS (median, d)	5(3, 8)	9(6, 14)	<0.001
Total charges (median, $)	117,373 (77,913-180,233)	159,042 (106,862-251,768)	<0.001
Type of insure (%)			
Medicare	38.13	54.97	<0.001
Medicaid	11.73	10.98	
Private insurance	44.17	29.18	
Self-pay	2.85	1.33	
Other	3.12	3.54	
Bed size of hospital (%)			
Small	6.81	7.00	0.599
Medium	18.74	19.75	
Large	74.45	73.25	
Elective admission (%)	52.96	32.05	<0.001
Type of hospital (teaching %)	91.50	91.30	0.803

Continue

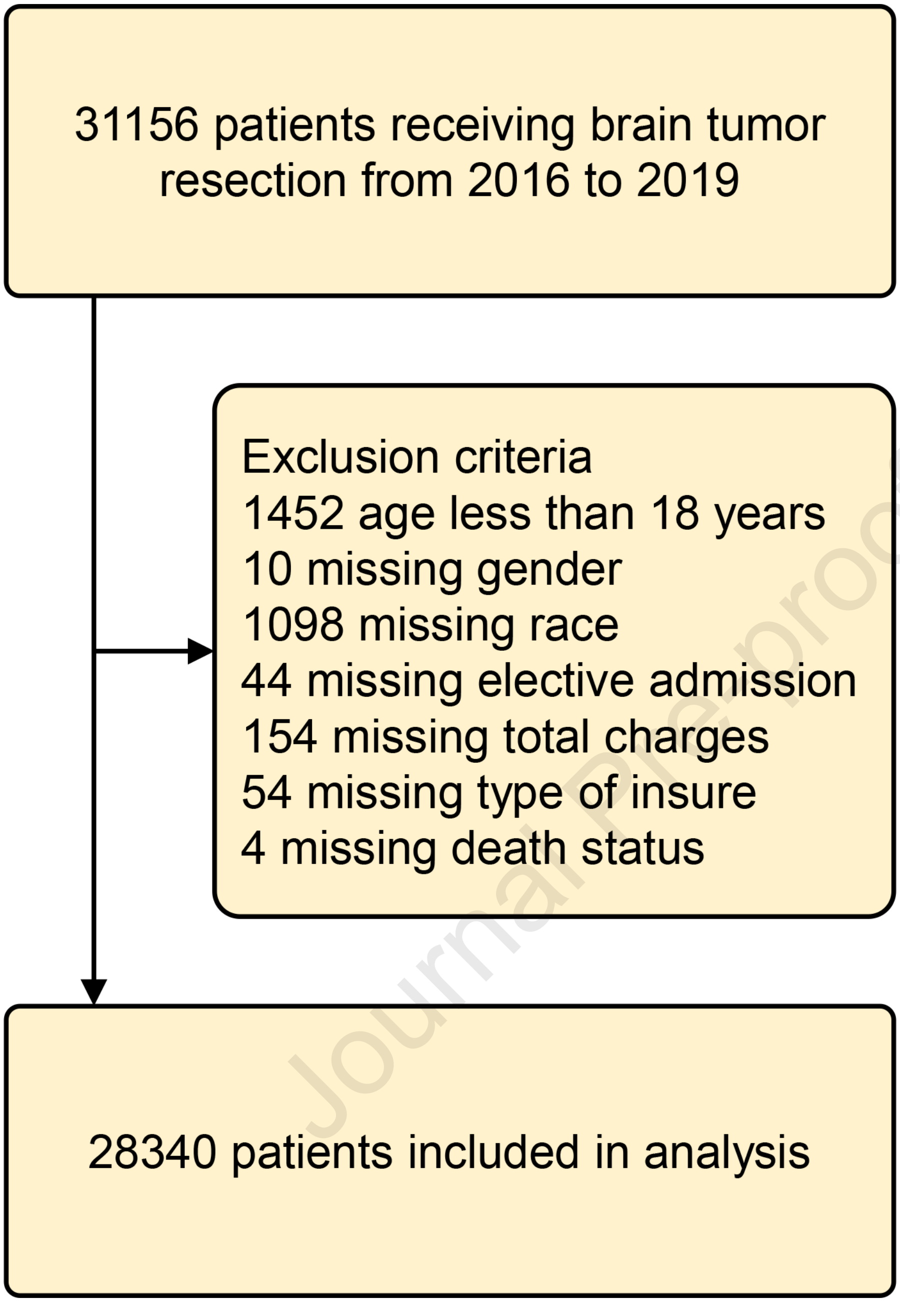
Characteristics	No delirium	delirium	P
Location of hospital (urban, %)	99.07	99.12	0.853
Region of hospital (%)			
Northeast	20.48	21.08	0.175
Midwest or North Central	20.62	20.71	
South	37.94	35.30	
West	20.96	22.92	
Died (%)	1.28	2.36	0.001

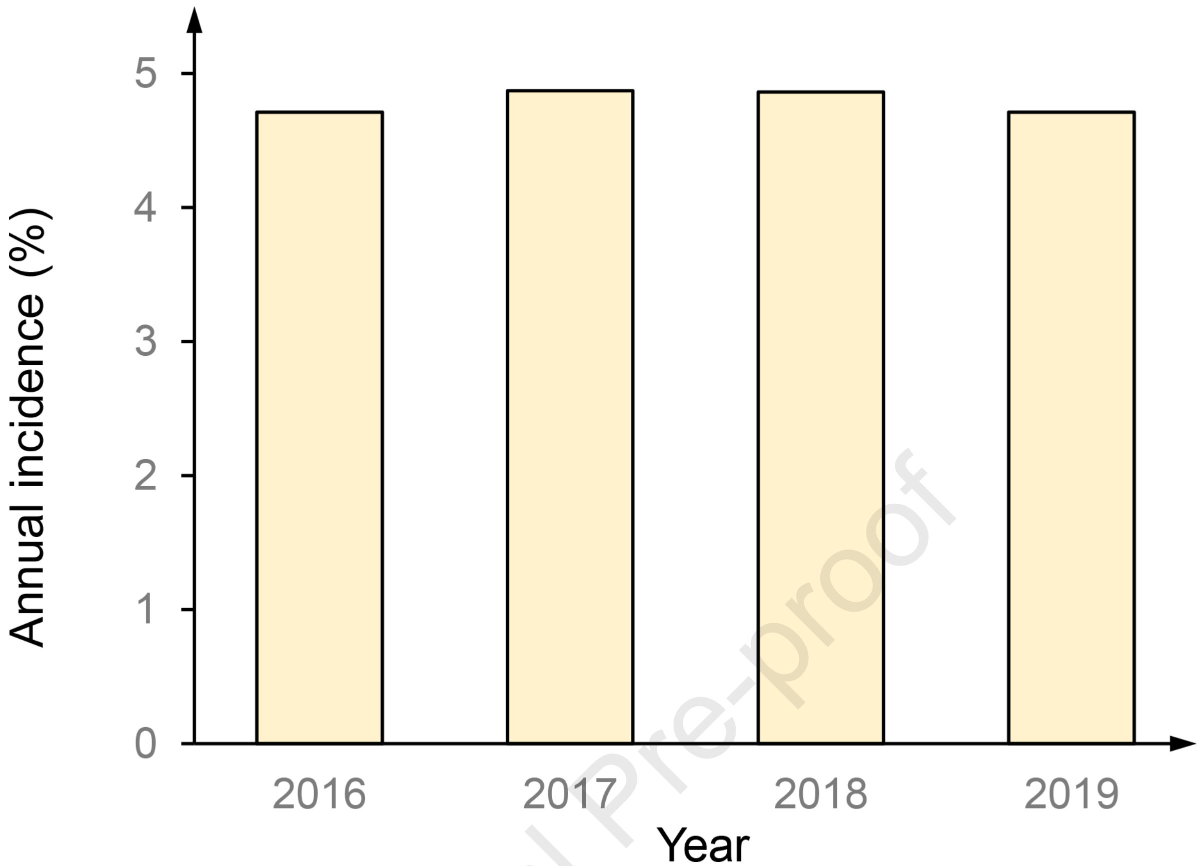
LOS: Length of stay

Table 3 Relationship between delirium and other postoperative complications

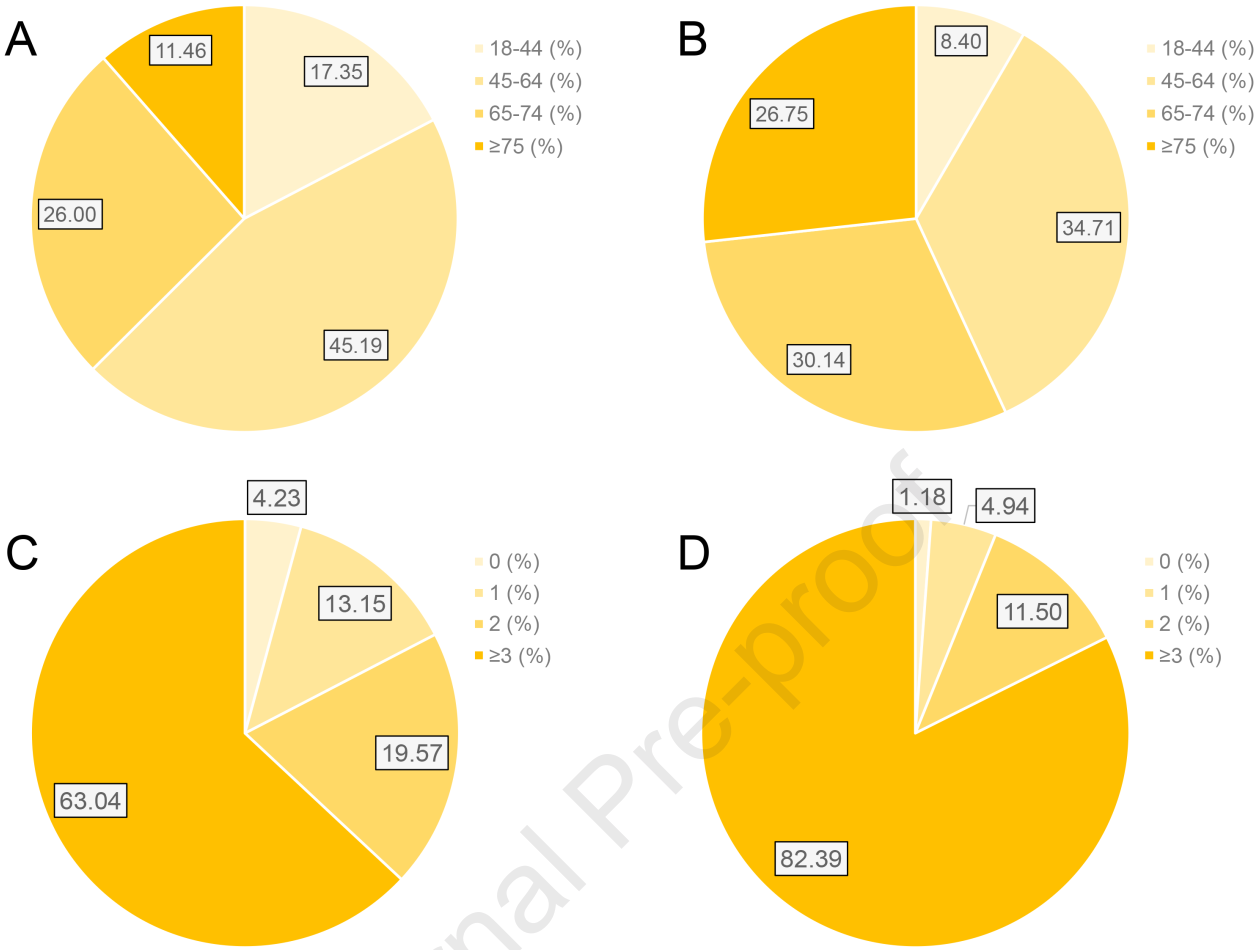
Complications	Univariate Analysis			Multivariate Logistic Regression		
	No delirium	**Delirium**	**P**	**OR**	**95% CI**	**P**
Medical complications						
Septicemia	337 (1.25%)	44 (3.24%)	<0.001	1.43	1.01-2.04	0.046
AMI	94 (0.35%)	12 (0.88%)	0.002	1.47	0.78-2.78	0.237
Deep vein thrombosis	416 (1.54%)	37 (2.73%)	0.001	1.21	0.84-1.75	0.294
Urinary tract infection	1296 (4.8%)	161 (11.86%)	<0.001	2.03	1.70-2.44	<0.001
Cardiac arrest	65 (0.24%)	7 (0.52%)	0.086	1.46	0.65-3.27	0.358
Pneumonia	499 (1.85%)	52 (3.83%)	<0.001	1.37	1.00-1.87	0.049
Stroke	2487 (9.22%)	198 (14.59%)	<0.001	1.90	0.77-4.65	0.162
Acute renal failure	988 (3.66%)	109 (8.03%)	<0.001	1.56	1.25-1.94	<0.001
Urinary retention	907 (3.36%)	102 (7.52%)	<0.001	1.89	1.52-2.35	<0.001
Respiratory failure	567 (2.10%)	53 (3.91%)	<0.001	1.26	0.94-1.71	0.127
Continuous trauma ventilation	186 (0.69%)	11 (0.81%)	0.600	0.86	0.46-1.60	0.631
Heart failure	366 (1.36%)	44 (3.24%)	<0.001	1.93	1.39-2.68	<0.001
Pulmonary embolism	266 (0.99%)	17 (1.25%)	0.335	0.68	0.40-1.15	0.151
Thrombocytopenia	1075 (3.98%)	81 (5.97%)	<0.001	1.12	0.88-1.42	0.376
Convulsion	2666 (9.88%)	128 (9.43%)	0.589	0.94	0.78-1.14	0.530
Acute cerebrovascular disease	2567 (9.51%)	200 (14.74%)	<0.001	0.69	0.28-1.67	0.407
Cerebral edema	16535 (61.28%)	1021 (75.24%)	<0.001	1.73	1.52-1.96	<0.001
Surgical complications						
Wound infection	137 (0.51%)	5 (0.37%)	0.478	0.69	0.27-1.77	0.443
Wound dehiscence	112 (0.42%)	3 (0.22%)	0.273	0.47	0.14-1.54	0.210
Blood transfusion	991 (3.67%)	83 (6.12%)	<0.001	1.31	1.03-1.67	0.029

OR: Odds ratio, CI: Confidence interval, AMI: Acute myocardial infarction

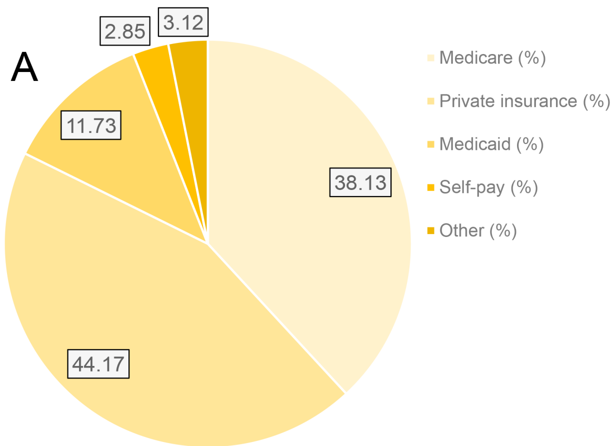

31156 patients receiving brain tumor resection from 2016 to 2019
Exclusion criteria
1452 age less than 18 years
10 missing gender
1098 missing race
44 missing elective admission
154 missing total charges
54 missing type of insure
4 missing death status
28340 patients included in analysis

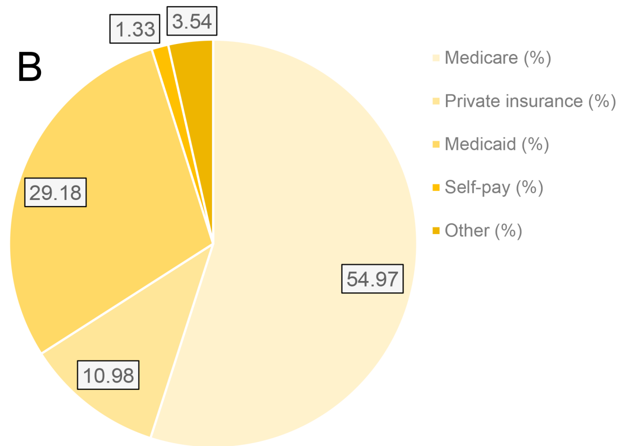


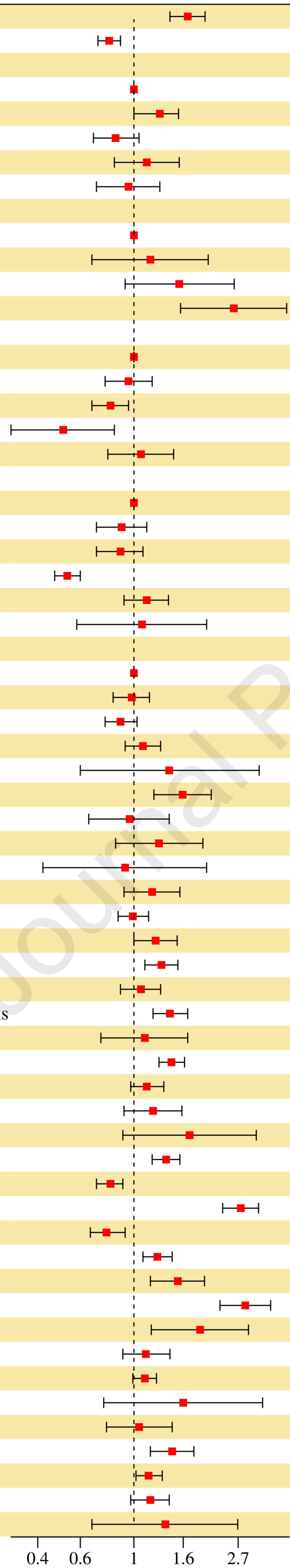
5
4
3
2
1
0
Annual incidence (%)
2016
2017
2018
2019
Year


A
11.46
17.35
26.00
45.19
18-44 (%)
45-64 (%)
65-74 (%)
≥75 (%)
B
8.40
26.75
34.71
30.14
18-44 (%)
45-64 (%)
65-74 (%)
≥75 (%)
C
4.23
13.15
19.57
63.04
0 (%)
1 (%)
2 (%)
≥3 (%)
D
1.18
4.94
11.50
82.39
0 (%)
1 (%)
2 (%)
≥3 (%)


A
Male (%)
Female (%)
46.80
53.20
B
Male (%)
Female (%)
45.47
54.53
C
Elective (%)
No elective (%)
47.04
52.96
D
Elective (%)
No elective (%)
32.05
67.95


A
2.85
3.12
11.73
38.13
44.17
Medicare (%)
Private insurance (%)
Medicaid (%)
Self-pay (%)
Other (%)


B
1.33
3.54
29.18
54.97
10.98
Medicare (%)
Private insurance (%)
Medicaid (%)
Self-pay (%)
Other (%)



Variable	OR (95% CI)	P value
Age ≥65 years old	1.67 (1.41 - 1.97)	<0.001
Female	0.79 (0.71 - 0.88)	<0.001
Race		
White	Reference	
Black	1.28 (1.00 - 1.53)	0.056
Hispanic	0.84 (0.68 - 1.05)	0.133
Asian or Pacific Islander	1.13 (0.83 - 1.54)	0.450
Other	0.95 (0.70 - 1.28)	0.733
Number of Comorbidity		
0	Reference	
1	1.17 (0.67 - 2.03)	0.578
2	1.54 (0.92 - 2.60)	0.103
≥3	2.59 (1.56 - 4.29)	<0.001
Type of insurance		
Medicare	Reference	
Medicaid	0.95 (0.76 - 1.19)	0.653
Private insurance	0.80 (0.67 - 0.95)	0.012
Self-pay	0.51 (0.31 - 0.83)	0.007
Other	1.07 (0.78 - 1.46)	0.689
Bed size of hospital		
Small	Reference	
Medium	0.89 (0.70 - 1.13)	0.338
Large	0.88 (0.70 - 1.09)	0.239
Elective admission	0.53 (0.47 - 0.60)	<0.001
Teaching hospital	1.13 (0.91 - 1.39)	0.266
Urban hospital	1.08 (0.58 - 2.00)	0.817
Region of hospital		
Northeast	Reference	
Midwest or North Central	0.98 (0.82 - 1.16)	0.807
South	0.88 (0.76 - 1.03)	0.115
West	1.09 (0.92 - 1.29)	0.342
AIDS	1.40 (0.60 - 3.30)	0.437
Alcohol abuse	1.59 (1.21 - 2.09)	0.001
Deficiency anemia	0.96 (0.65 - 1.40)	0.829
Rheumatoid arthritis	1.27 (0.84 - 1.93)	0.252
Chronic blood loss anemia	0.92 (0.42 - 2.00)	0.836
Congestive heart failure	1.19 (0.91 - 1.55)	0.202
Chronic pulmonary disease	0.99 (0.86 - 1.15)	0.937
Coagulopathy	1.23 (1.00 - 1.51)	0.052
Depression	1.30 (1.11 - 1.52)	0.001
Diabetes, uncomplicated	1.07 (0.88 - 1.29)	0.508
Diabetes with chronic complications	1.41 (1.20 - 1.67)	<0.001
Drug abuse	1.11 (0.73 - 1.67)	0.627
Hypertension	1.43 (1.27 - 1.62)	<0.001
Hypothyroidism	1.13 (0.97 - 1.33)	0.124
Liver disease	1.20 (0.91 - 1.58)	0.203
Lymphoma	1.70 (0.90 - 3.21)	0.100
Fluid and electrolyte disorders	1.36 (1.19 - 1.55)	<0.001
Metastatic cancer	0.80 (0.70 - 0.90)	<0.001
Other neurological disorders	2.77 (2.33 - 3.28)	<0.001
Obesity	0.77 (0.66 - 0.92)	0.003
Paralysis	1.25 (1.09 - 1.44)	0.001
Peripheral vascular disorders	1.52 (1.17 - 1.96)	0.001
Psychoses	2.89 (2.27 - 3.68)	<0.001
Pulmonary circulation disorders	1.88 (1.18 - 2.98)	0.008
Renal failure	1.12 (0.90 - 1.41)	0.309
Solid tumor	1.11 (0.99 - 1.24)	0.064
Peptic ulcer disease	1.60 (0.75 - 3.41)	0.226
Valvular disease	1.05 (0.77 - 1.44)	0.765
Weight loss	1.44 (1.17 - 1.77)	<0.001
Smoke	1.15 (1.02 - 1.31)	0.024
Epilepsy	1.17 (0.97 - 1.40)	0.101
Parkinson's disease	1.35 (0.67 - 2.69)	0.398

Table S1: International Classification of Diseases (10^{th} revision) Clinical Modification (ICD-10-CM) codes that were used

Diagnosis/ Procedure	ICD-10 CM code
Delirium	F05, F06, F0390, R410, R418
Brain tumor	D320, D330, D331, D332, C700, C709, C71, C7931, C7932
Surgical procedure	00500ZZ, 00B00ZZ, 00C00ZZ, 00510ZZ, 00B10ZZ, 00C10ZZ, 00D10ZZ, 00520ZZ, 00B20ZZ, 00C20ZZ, 00D20ZZ, 00560ZZ, 00B60ZZ, 00C60ZZ, 00570ZZ, 00B70ZZ, 00C70ZZ, 00T70ZZ, 005B0ZZ, 00BB0ZZ, 00CB0ZZ, 005C0ZZ, 00BC0ZZ, 00CC0ZZ, 005D0ZZ, 00BD0ZZ, 00CD0ZZ

List of abbreviations

NIS	National Inpatient Sample
LOS	Length of stay
OR	Odds ratio
CI	Confidence interval
ICD-10-CM	International Classification of Diseases (10^{th} revision) Clinical Modification

Conflict of interest statement

The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.