Published in final edited form as:

World Neurosurg. 2020 October ; 142: e458–e473. doi:10.1016/j.wneu.2020.07.048.

Effect of Comorbid Depression on Surgical Outcomes Following Craniotomy for Malignant Brain Tumors: A Nationwide Readmission Database Analysis

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Abstract

Objective: Quality of life is paramount in advanced cancer patients and may be adversely affected by comorbid depression. We hypothesized that comorbid depression is associated with higher rates of postoperative complications, worse functional outcomes, and higher rates of readmission following craniotomy for resection of malignant intracranial tumors.

Methods: The National Readmissions Database (NRD) was queried from 2010–2014 to identify adult patients undergoing craniotomy for malignant brain tumor resection. The primary psychiatric disease assessed was major depressive disorder (MDD). Outcomes evaluated included neurological or other major complications, incidence of nonroutine discharge, and unplanned readmission at 30- and 90- days.

Results: Of the 57,621 craniotomies for malignant neoplasms included in the analysis, 11.32% of patients had clinically diagnosed MDD. The presence of MDD was associated with nonroutine discharge (OR 1.10–125, $p < 0.0001$) as well as higher rates of neurological complications (OR 1.03 – 1.18, $p = 0.003$). No association between MDD and 30- or 90- day readmissions was noted.

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Disclosures: The authors of this manuscript have no financial or industry connections relevant to the contents of this manuscript.

Disclosure-Conflict of Interest: The authors of this manuscript have no financial or industry connections relevant to the contents of this manuscript. We report no potential conflicts of interest.

Patients with major APR DRG severity and index length of stay greater than 7 days experienced higher rates of 30- and 90- day readmissions.

Conclusions: There is a clinically significant rate of comorbid MDD in patients with malignant intracranial tumors, and MDD is associated with worse perioperative outcomes. Given the wealth of behavioral and pharmaceutical therapies available, MDD is a modifiable risk factor in this cohort that clinicians should be vigilant in screening for and initiating appropriate treatment protocols.

Keywords

depression; major depressive disorder; malignant brain tumor; cancer; glioma; nationwide; outcomes

INTRODUCTION

Patients with cancer are vulnerable to psychiatric comorbidities, including depression. Clinical depression is estimated to affect ~13–22% of cancer patients, compared to ~5% of the general population.^{1–3} However, cancer patients with depression are less likely to be diagnosed and treated, with only 27% receiving adequate care.¹

Primary malignant brain tumors commonly arise sporadically and inflict a substantial degree of emotional and physical suffering in patients and families alike. Glioblastoma (grade IV astrocytoma, GBM) is the most common and aggressive of these tumors.⁴ Aggressive combination therapy is the standard of care, including surgical resection, adjunctive radiotherapy, and chemotherapy. Despite maximal therapy, 5-year survival remains below 5%.⁵ Therefore, treatment aims directed towards maximize quality of life through prolongation of functional and cognitive status are imperative.

Depression is prevalent in up to 38% of patients with malignant brain tumors, which is amongst the highest of all forms of cancer.^{6–8} We hypothesize that comorbid depression is a key modifiable risk factor associated with neurosurgical outcomes in malignant brain tumor patients. In this study, we explored this relationship from a novel perspective, leveraging the strengths of the Nationwide Readmissions Database (NRD), the largest all-payer inpatient database in U.S., which contains data from approximately ~36 million weighted discharges/year. The NRD contains patient linkage variables enable longitudinal tracking across multiple hospitalizations, rendering it superior to the commonly used Nationwide Inpatient Sample (NIS).

We hypothesized that comorbid depression was independently associated with a higher likelihood of post-operative complications, adverse discharge disposition, and 30- and 90-day readmission. This is the first nationally representative study of depression in patients undergoing surgery for malignant brain tumors.

METHODS

Data source

The Nationwide Readmissions Database (NRD) encompasses 27 states which comprise approximately 57.8% of the United States population. Utilizing anonymized identifiers, the NRD tracks patients within a given state over a calendar year. The 2010 to 2014 NRD cohorts were queried for this study.

Study population

Inclusion criteria consisted of patients > 18 years of age, diagnosed with a malignant brain tumor (ICD-9 codes 191.0–191.9, 198.3), who underwent craniotomy for tumor excision or ablation (1.53, 1.59). Patients with above criteria were identified using the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9CM) codes of diagnoses and procedures (Table 1). While the NRD allows longitudinal patient tracking, this is limited to a calendar year, with resetting of patient identification each calendar year. Therefore, patients with insufficient follow-up time were excluded from our analysis. The final cohorts only included patients discharged between January and November for the 30-day readmission analysis and patients discharged between January and September for the 90-day readmission analysis. Patients were also excluded from analysis if they died within index hospitalization or were missing key data such as length of stay (LOS).

Patient and hospital characteristics

Patients and the index admission hospital variables were obtained from the NRD and analyzed using univariate and multivariate analyses. Hospital variables included procedural volume, ownership (government nonfederal, private nonprofit, private investor-owned), bed size (small, medium, large), and teaching status. Hospitals were categorized as high procedural volume hospitals if they were above the 90th percentile for annual tumor excisions. Patient variables from initial hospitalization included age, gender, payer status, household income quartile based on residence zip code, and whether they resided in the index hospital's state. The NRD lists age as a continuous variable, which we then categorized into the proceeding groups for analysis: 40, 45–59, 60–74, and >75 years of age, based on prior categorizations used in NRD studies.

The primary clinical variable assessed was major depression defined by ICD-9 codes 296.2x, 296.3x, 296.82, 300.4, 309.0, 309.1, and 311. The presence of any other psychiatric disease was grouped as a single variable, including anxiety (300.0x, 300.2x, 300.3, 309.21, 309.24), schizophrenia and other psychosis (295.xx, 297.x, 298.x), bipolar disorder (296.0x, 296.1x, 296.4x, 296.5x, 296.6x, 296.7, 296.8, 296.80, 296.81, 296.89), PTSD and acute stress disorders (300.12, 300.13, 300.14, 300.15, 300.6, 308.x, 309.81), personality disorders (301.xx), conversion, hypochondriasis, psychogenic conditions (300.10, 300.11, 300.16, 300.19, 300.5, 300.7, 300.8x, 307.8, 307.80, 307.89, 309.82), miscellaneous adjustment disorders (309, 309.2, 309.22, 309.23, 309.28, 309.29, 309.3, 309.4, 309.8, 309.83, 309.89, 309.9), and eating disorders (307.1, 307.5x). Other substance risk factors included alcohol or drug abuse disorder (303.xx), and tobacco use (305.1, V15.82).

General clinical variables included LOS, discharge quarter, Elixhauser comorbidity score, and discharge to a facility other than home. Elixhauser comorbidity score was measured using the Agency for healthcare Research and Quality's (AHRQ) software, which implements the Elixhauser comorbidity index using ICD-9 codes. Other variables included index admissions were categorized as elective vs nonelective or occurred through an emergency department. All patient refined disease related groups (APR-DRG) risk of disease severity is a risk classification scores for patients (minor, moderate, major, or extreme) used by multiple hospital systems, showing strong association with outcomes.⁹

Outcome variables queried included index admission occurrence of major complication, neurological complication, and nonroutine discharge, as well as unplanned readmission at 30 and 90 days. Of note, for outcomes of 30- and 90- day unplanned readmission, variables included in models included index admission incidence of major complications, neurological complications, and nonroutine discharge.

Statistical Analysis

Descriptive analysis was reported for all variables mentioned above. Multivariable logistic regression adjusting for depression was used for all outcomes, using generalized estimation equation to account for hospital clustering. All variables mentioned above were used in model initially, with variables not acting as confounders with $p > 0.05$ were excluded from the final models. All final models passed Hosmer-Lemeshow goodness of fit test. SAS 9.4 were used for all analysis.

RESULTS

Patient and hospital baseline characteristics

We identified 57,621 craniotomies for malignant neoplasms from 2010–2014 that met inclusion criteria for primary admission analysis. There was a comparable distribution of males (53%, $n=30,601$) to females (47%, $n=27,020$). The majority of patients were between the ages of 45 to 74 years old (68%, $n=39,047$) and most had one or more Elixhauser defined comorbidities (78%). 6,525 (11%) patients held a previous diagnosis of depression. Within the group of patients categorized with depression, 31% had a concurrent psychiatric disorder. A predominance of cases came from larger hospitals (79%) that were designated as teaching facilities (80%). The average length of stay was 9.2 days, following which most patients were discharged home (routine disposition, 61%). Patient and hospital baseline characteristics are further summarized in Table 2.

Association of depression with index admissions outcomes

Depression was associated with increased rates of neurological complications (OR 1.03–1.18, $p = 0.003$) and higher rates of non-routine disposition (OR 1.10–1.25, $p < 0.0001$). Of note, analysis of other risk factors revealed that hospitals with 90th percentile for procedural volume were associated with a higher rate of major complication (OR 1.35–1.68, $p < 0.0001$) upon index admission (OR 1.49–2.00, $p < 0.0001$). In addition, patients over the age of 59 years old (age 60–74 years: OR 1.23–1.69, $p < 0.0001$; 75+: OR 1.57–2.23, $p < 0.0001$) experienced higher rates of major complications. (Tables 3, 4, 5.)

30- and 90-day Readmissions demographics

There were 49,340 patients that met inclusion criteria for 30-day analysis, with 7,301 patients (%) readmitted within 30 days of index hospitalization. Of the 40,599 patients that met 90-day analysis inclusion criteria, 11,958 patients (%) were readmitted. 30- and 90- day readmissions shared the most frequent diagnoses upon readmission – postoperative infection (15.76% and 14.03%, respectively) or secondary malignant neoplasm of the brain or spine (7.4% and 8.2%, respectively) Table 6.

Factors associated with 30-day readmission

Major (OR 1.06–1.27, $p = 0.0012$) and extreme (OR 1.18–1.49, $p < 0.0001$) APRDRG disease severity risk ratings, as well as presence of 1 or more comorbidities, was associated with a greater likelihood of readmission. Patients with length of stay greater than 7 days and non-routine disposition upon discharge (OR 1.25–1.40, $p < 0.0001$) were more likely to be readmitted within 30-days. Patients undergoing non-elective craniotomies had decreased odds of readmission compared to those undergoing elective craniotomies (OR 0.80–0.94, $p = 0.0003$). There was no association between a comorbid diagnosis of depression and 30-day readmissions (OR 0.94–1.10, $p < 0.6146$). 30-day readmissions factors are further summarized in Table 7.

Factors associated with 90-day readmissions

Patients with a major APR DRG disease severity rating (OR 1.05–1.23, $p = 0.0008$), LOS greater than 7 days (7–11 days: 1.09–1.27, $p < 0.0001$; 12+: OR 1.14–1.35, $p < 0.0001$), Elixhauser score greater than 0 (1 comorbidity: OR 1.14–1.32, $p < 0.0001$; 2: OR 1.29–1.51, $p < 0.0001$; 3+: OR 1.52–1.77, $p < 0.0001$), or a non-routine disposition upon discharge (OR 1.16–1.28, $p < 0.0001$) were at increased risk for readmission at 90 days. Patients older than 45 years old had an 18–30% increased risk of readmission (age 45–59 years: OR 1.13–1.30, $p < 0.0001$; 60–74: OR 1.19–1.39, $p < 0.0001$; 75+: OR 1.07–1.30, $p = 0.0009$). 90-day readmission factors are further summarized in Table 8.

DISCUSSION

The current study reports nationwide epidemiological rates and outcomes associated with comorbid depression in patients undergoing craniotomy for malignant brain tumors and shows a clear association between MDD and postoperative complication rates and discharge status in this highly susceptible cohort. The prevalence of comorbid depression in cancer patients has been previously reported in the ambulatory setting. However, research describing prevalence in the inpatient peri-operative environment is scarce. The rate of MDD in this particular malignant brain tumor cohort was amongst the highest (11.3%) when compared to rates of depression in other major cancer types, including lung (11.5%), breast (10.3%), head and neck (9.3%), colorectal (8.1%), and prostate cancer (4.9%).^{10,11} Furthermore, these rates reflect medical record diagnoses recorded by administrative billing codes, which have a tendency to underestimate the true burden of MDD. In a systematic review of depression in glioma patients, the median frequency of physician-diagnosed MDD was 15%.^{6,12} However, patient-reported rates of depression have been as high as 93%,^{6,12} demonstrating a notable disparity between patient perception of mood disturbances when

compared to clinically diagnosed psychiatric disorders. Although concerning, this may represent an opportunity for improved screening and intervention in this high risk population.

The aforementioned review found that across the literature, depression was consistently associated with functional impairment, cognitive dysfunction, and reduced quality of life.⁶ However, the pathogenesis of depression in brain tumors patients is not well understood. Prior literature suggests a multifactorial etiology of depression in these patients, including knowledge of prognosis, neurological deficits, chemotherapy, radiotherapy, cognitive decline, and exacerbation of underlying mental health disorders.¹³ Beyond the expected psychological distress of a cancer diagnosis,¹⁴ brain tumors are unique in that they may contribute to direct focal cerebral dysfunction and inherent neurodegenerative processes they may induce.¹⁵ In addition to the neurophysiological effects of brain tumor invasion on the surrounding native tissue, adjuvant chemotherapy and radiotherapy can also induce cerebral edema and necrosis in peri-tumoral tissue or accelerate vascular dementia.¹⁶ These neuropsychiatric effects can further contribute to the development of depression in malignant brain tumor patients.

In our study, MDD was not found to be directly associated with increased likelihood of readmission. However, depression was associated with adverse discharge disposition, such as to long-term assisted care facilities. When evaluating nonroutine discharge as an independent variable in multivariate analysis, however, it was noted to be associated with readmission. Discharge disposition is a readily utilized surrogate marker of functional status in administrative database studies.¹⁷ While the association between depression and worse functional status appears intuitive, a recent systematic review observed conflicting data regarding this association.⁶ In a study of 77 patients with primary brain tumors, Mainio A et al. found that preoperative depression diagnosis as defined by Beck Depression Index (BDI) was associated with lower functional status (Karnofsky Performance Status, KPS). Interestingly, this association was found to persist at 3 months and 1 year postoperatively, despite the cohort including lesions of both malignant and benign histology.¹⁸ By contrast, a retrospective cohort study of malignant astrocytomas by Gathinji et al. did not identify such an association.¹⁹ Notably, in the Gathinji et. al. study, the categorization of depression only captured patients that had been diagnosed by their primary care physician or a psychiatrist.

Depression was one of several factors associated with non-routine discharge disposition (our corollary for poor functional outcome) in patients surgically treated for malignant brain tumors. The other factors included older age, female sex, other psychiatric disease, other pre-existing comorbidities, hospital type (ownership, bed size, location), and prolonged length of stay which have previously been identified in the literature.^{20–22} Muhlestein et al. built a machine learning model to study predictors of discharge disposition in patients who underwent craniotomy for brain tumor in the Nationwide Inpatient Sample.²⁰ In their analysis, predictors of non-routine disposition included older age, female sex, pre-existing comorbidities, and extended hospitalization. However, the association between depression and non-routine discharge persisted even after adjusting for these aforementioned factors in a robust multivariate analysis.

To the authors' knowledge, this is the first study to identify an association between MDD and neurological complications during hospitalization for craniotomy for brain tumor. Tumor specifics, such as location, multi-focality and size > 4 cm have been associated with increased risk of depression.^{12,23} Specifically, anatomic involvement of the ventral frontal, temporoparietal, and limbic system have all been associated with worse mood states in patients with brain lesions.²⁴ Thus, the higher rates of neurological complications in patients with MDD may reflect increased complexity of tumor surgery. Whether there is a causative relationship between depression and neurologic deficits remains speculative. However, from a molecular perspective, serotonin receptors have been shown to modulate glioma invasion and migration.²⁵ Likewise, dysregulation in diurnal variation of cortisol in depression has been postulated to contribute to altered tumor catabolism.²⁶

We did not evaluate the association between comorbid MDD and survival, as previous literature suggests these effects are most appreciable when examining long term survival, an outcome not represented in the NRD, which only follows patients across a single calendar year. It is notable that in a retrospective study of 1,015 patients undergoing resection of malignant astrocytoma, independent of age, WHO histological grade, extent of resection, and adjuvant temozolomide, preoperative diagnosis of depression was associated with decreased survival (RR – 1.41).¹⁹ This difference, was most notable past 12 months and at 20 months, suggesting that the effects of depression are most prominent when evaluating long term survival. Similarly, in a 5-year study of 75 patients harboring solitary primary brain tumors, Mainio et. al. found depression to be a negative prognosticator of survival in patients with low grade gliomas. This did not hold true for those with a histologic diagnosis of high-grade glioma, reflecting the longer duration of survival in patients with low grade lesions (22.5 months versus 50.2 months).

The findings of our study within the context of prior literature suggest that diagnosis of depression is associated with surgical outcomes, including decreased functional status and postoperative neurological deficits, in patients with malignant brain tumors. Maximization of quality of life is paramount in these patients and is compromised by this potentially modifiable comorbidity. A multi-disciplinary and holistic approach to treating depression in brain tumor patients is essential. At present, several observational studies have found antidepressants to be under-prescribed in brain tumor patients (Armstrong). In the Glioma Outcomes Project, 93% of patients endorsed symptoms of depression, however only 15% of patients were diagnosed with clinical depression by their physicians, and of which only half (7%) were prescribed antidepressants.¹² Recent preclinical studies found that fluoxetine, in addition to treating depression, was also selectively toxic to glioma cells.²⁷ Many studies have also outlined non-pharmacological modalities for treating depression in brain tumor patients, including telephone-based support systems²⁸, exercise programs²⁹, and dyadic yoga³⁰. In a pilot trial of 20 glioma patients and their caregivers, Milbury K et al., found that a 12-session dyadic yoga program resulted in clinically significant improvements in depression, cancer-related symptoms, and quality of life.³⁰ Taken together, these data and ours support the integral role of mental health specialists, social workers and neuropsychologists into multidisciplinary brain tumor centers to provide routine screening and tailored treatment to this particularly vulnerable population.

Our study is subject to several limitations that are inherent to most large administrative database analyses. Particularly, the patient data identified in the NRD is limited to diagnoses and procedures identifiable through available ICD-9-CM codes. A large administrative dataset like the NRD does not have the granularity to capture all factors contributing to patient outcomes. Specifically, we could not identify several important clinical details including severity of depression (e.g., patient health questionnaire), pre-admission functional status, radiological imaging, peri-operative management, tumor specifics, surgical technique/approach variables or post-operative quality of life. This limits the number of confounding factors that we could adjust for in our analysis. Thus, the relationships between variables in our study are merely independent associations and cannot prove causality or temporality. The NRD patient linkage numbers do not track across calendar years, which may slightly underestimate readmission rates. However, we addressed this limitation by excluding the last 1-month and 3-months from the index cohorts when evaluating 30-d and 90-d readmission, respectively. Some limitations were specific to this particular study design and patient population. The available ICD-9 codes do not distinguish between primary and secondary brain tumors, which limits the specificity of our results. Furthermore, the coding schemes cannot stratify by tumor grade, tumor size, or type of malignancy. Nevertheless, the high volume of cases and readmissions studied in this major nationwide database provide a high degree of generalizability, and selective insight into the relation between MDD and malignant brain tumor surgery and recovery.

CONCLUSION

Our findings support the hypothesis that depression is associated with poor surgical outcomes in patients undergoing craniotomy for resection of malignant brain tumors. Attention to this modifiable comorbidity during preoperative evaluation and patient recovery is crucial, and a routine screening and intervention strategy may improve patient-centered outcomes. Given the limitations of an administrative database study, further investigation is warranted in the form of a prospective study design. A future study may aim to identify indications for screening and treatment of depression in this population.

Acknowledgments

Funding: FJA is supported by a NIH SC CTSI KL2 Clinical and Translational Research Scholar Award.

Abbreviations:

AHRQ	Agency for Healthcare Research and Quality
APR-DRG	all patient refined diagnosis related groups
GBM	glioblastoma multiforme
HCUP	Healthcare Cost and Utilization Project
ICD-9CM	International Classification of Disease, Ninth Edition, Clinical Modification
LOS	length of stay

MDD	major depressive disorder
NRD	Nationwide Readmission Database
OR	Odds Ratio

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Table 1.

International Classification of Diseases, Ninth Edition, Clinical Modification Diagnosis Codes and Procedural Codes used for querying patients from the Nationwide Readmission Database for the cohort selection of the present study.

	ICD-9 Diagnosis Code	Procedure Code
Malignant Intracranial Tumor	191.0–191.9	01.53, 01.59
	198.3	1.59
	192.0, 192.8, 192.9, 198.3, 198.4	1.53
Psychiatric Diagnosis		
Major Depression	296.2x, 296.3x, 296.82, 300.4, 309.0, 309.1, 311	
Anxiety	300.0x, 300.2x, 300.3, 309.21, 309.24	
Schizophrenia, Psychosis	295.xx, 297.x, 298.x	
Bipolar Disorder	296.0x, 296.1x, 296.4x, 296.5x, 296.6x, 296.7, 296.8, 296.80, 296.81, 296.89	
Post Traumatic Stress Disorder, Acute Stress Disorder	300.12, 300.13, 300.14, 300.15, 300.6, 308.x, 309.81	
Personality Disorders	301.xx	
Conversion, Hypochondriasis, Psychogenic Conditions	300.10, 300.11, 300.16, 300.19, 300.5, 300.7, 300.8x, 307.8, 307.80, 307.89, 309.82	
Adjustment Disorders	309, 309.2, 309.22, 309.23, 309.28, 309.29, 309.3, 309.4, 309.8, 309.83, 309.89, 309.9	
Eating Disorders	307.1, 307.5x	
Alcohol or Drug Abuse Disorder	303.xx	
Tobacco Use	305.1, V15.82	
Major Complications		
Pneumonia	481–482, 482.1–482.3, 482.30–482.32, 482.39–482.41, 482.49, 482.80–482.84, 482.89, 482.90, 483.0, 483.1, 483.8, 485–487.0, 997.3, 507.0	
Pulmonary Embolism	415.1–415.9	
Renal Failure	584, 584.5–584.9	
Cerebrovascular Accident	433.01, 433.11, 433.21, 433.31, 433.81, 433.91	
Myocardial Infarction, Cardiac Arrest	410.00–410.90, 410.01, 410.11–410.91, 427.5	
Sepsis, Septic Shock	995.91, 995.92	
Neurological Complications		
Intracerebral Hemorrhage	431, 998.11–12	
Seizures	345.xx	
Neurological Complications After Procedure	997.01–997.09	

Table 2.

Patient demographics of the 30-day readmission cohort.

		Total	Depression			
			No		Yes	
		N	N	%	N	%
	Total	57621	51096	88.68	6525	11.32
Died during hospitalization	Missing	19	16	0.03	DS	DS
	No	56550	50114	98.08	6436	98.64
	Yes	1052	966	1.89	86	1.32
Major complication	No	54847	48650	95.21	6197	94.97
	Yes	2774	2446	4.79	328	5.03
Neuro complication	No	44960	39997	78.28	4963	76.06
	Yes	12661	11099	21.72	1562	23.94
Other psychiatric disease	No	50449	45916	89.86	4533	69.47
	Yes	7172	5180	10.14	1992	30.53
Alcohol and drug abuse disorder	No	56942	50554	98.94	6388	97.9
	Yes	679	542	1.06	137	2.1
Smoking	No	37508	33715	65.98	3793	58.13
	Yes	20113	17381	34.02	2732	41.87
Age	44	12038	11092	21.71	946	14.5
	45–59	17969	15621	30.57	2348	35.98
	60–74	21078	18457	36.12	2621	40.17
	>75	6536	5926	11.6	610	9.35
Sex	Male	30601	28019	54.84	2582	39.57
	Female	27020	23077	45.16	3943	60.43
Insurance	Missing	164	151	0.3	13	0.2
	Medicare	20387	17835	34.9	2552	39.11
	Medicaid	7193	6422	12.57	771	11.82
	Private insurance	25986	23198	45.4	2788	42.73
	Self-pay	1646	1488	2.91	158	2.42
	No charge	162	147	0.29	15	0.23
	Other	2083	1855	3.63	228	3.49
All Patient Refined DRG: Risk of Mortality Subclass	No class	DS	DS	DS	DS	DS
	Minor	17728	15946	31.21	1782	27.31
	Moderate	19275	17038	33.35	2237	34.28
	Major	13770	12059	23.6	1711	26.22
	Extreme	6844	6050	11.84	794	12.17
All Patient Refined DRG: Severity of Illness Subclass	No class	DS	DS	DS	DS	DS
	Minor	10836	9867	19.31	969	14.85
	Moderate	23687	20999	41.1	2688	41.2

		Total	Depression			
			No		Yes	
		N	N	%	N	%
	Major	17010	14863	29.09	2147	32.9
	Extreme	6084	5364	10.5	720	11.03
Lenth of stay	3 days	17144	15658	30.64	1486	22.77
	4–6 days	13804	12418	24.3	1386	21.24
	7–11 days	13506	11993	23.47	1513	23.19
	> 12 days	13167	11027	21.58	2140	32.8
Discharge quarter	Jan-March	14542	12895	25.24	1647	25.24
	Apr-Jun	14699	13062	25.56	1637	25.09
	July-Sep	14158	12556	24.57	1602	24.55
	Oct-Dec	14222	12583	24.63	1639	25.12
Elixhauser comorbidity score	0	12900	12126	23.73	774	11.86
	1	14092	12728	24.91	1364	20.9
	2	11958	10555	20.66	1403	21.5
	3	18671	15687	30.7	2984	45.73
Median hosehold income for patient's ZIP code, based on current year	Missing	1130	1015	1.99	115	1.76
	0–25 percentile	11924	10585	20.72	1339	20.52
	26–50 percentile	12835	11354	22.22	1481	22.7
	51–75 percentile	14754	13050	25.54	1704	26.11
	76–100 percentile	16978	15092	29.54	1886	28.9
Elective versus non-elective admission	Missing	86	78	0.15	DS	DS
	Non elective	31134	27421	53.67	3713	56.9
	Elective	26401	23597	46.18	2804	42.97
Patient State is the same as Hospital State	No	5790	5232	10.24	558	8.55
	Yes	51831	45864	89.76	5967	91.45
Volume	90th percentile (73 / year)	29969	26472	51.81	3497	53.59
	Above 90th percentile	27652	24624	48.19	3028	46.41
Control/ownership of hospital	Government, nonfederal	9557	8572	16.78	985	15.1
	Private, not-profit	43724	38652	75.65	5072	77.73
	Private, invest-own	4340	3872	7.58	468	7.17
Bed size of hospital	Small	3393	3057	5.98	336	5.15
	Medium	8710	7720	15.11	990	15.17
	Large	45518	40319	78.91	5199	79.68
Teaching status	Non teaching	11576	10183	19.93	1393	21.35
	Teaching	46045	40913	80.07	5132	78.65
Metropolitan	Other	18315	16163	31.63	2152	32.98
	Major metropolitan	39306	34933	68.37	4373	67.02
HCUP used Emergency	No	34818	31028	60.72	3790	58.08

		Total	Depression			
			No		Yes	
		N	N	%	N	%
	Yes	22803	20068	39.28	2735	41.92
Disposition	Missing	62	57	0.11	DS	DS
	Routine	35432	32007	62.64	3425	52.49
	Other	22127	19032	37.25	3095	47.43

* DS = Data suppressed in accordance with the HCUP/NRD guidelines

Table 3:

Predictors of major complication upon index admission for malignant brain tumor craniotomy. Values for odds ratio, confidence interval, and p-value are included.

Variable		OR	95% CI		p-value
Depression	Yes	0.956858	0.832851	1.099439	0.5342
	No	Ref			
Other Psychiatric disease	Yes	0.766822	0.662987	0.88692	0.0003
	No	Ref			
Alcohol and drug abusedisorder	Yes	0.706452	0.497828	1.002503	0.0517
	No				
Smoking	Yes	0.801957	0.725931	0.885857	<.0001
	No	Ref			
Age	44	Ref			
	45–59	1.104508	0.928857	1.313243	0.2607
	60–74	1.441811	1.231459	1.687925	<.0001
	>75	1.869928	1.568626	2.229105	<.0001
Sex	Female	Ref			
	Male	1.674643	1.517554	1.848177	<.0001
APRDRG Mortality risk	Minor	Ref			
	Moderate	2.709597	1.608175	4.565829	0.0002
	Major	13.28187	7.950223	22.19129	<.0001
	Extreme	69.95135	41.62912	117.5425	<.0001
LOS	3 days	Ref			
	4–6 days	1.691643	1.266681	2.259176	0.0004
	7–11 days	2.124847	1.615267	2.79519	<.0001
	> 12 days	3.997623	3.055368	5.230464	<.0001
Elixhauser comorbidity score	0	Ref			
	1	1.677492	1.274304	2.208249	0.0002
	2	2.069072	1.573496	2.721001	<.0001
	3	3.912983	3.017112	5.074865	<.0001
Volume	90th percentile (73 / year)	1.508024	1.351885	1.682028	<.0001
	Above 90th percentile	Ref			
Control/ownership of hospital	Government, nonfederal	Ref			
	Private, not-profit	0.985506	0.861828	1.126933	0.8313
	Private, invest-own	1.417649	1.168826	1.719442	0.0004

Table 4:

Predictors of neurological complication upon index admission for malignant brain tumor craniotomy. Values for odds ratio, confidence interval, and p-value are included.

Variable		OR	95% CI		p-value
Depression	Yes	1.104287	1.034067	1.179157	0.0031
	No	Ref			
Smoking	Yes	0.92118	0.878008	0.966378	0.0008
	No	Ref			
Age	44	Ref			
	45–59	0.761321	0.715052	0.810584	<.0001
	60–74	0.52482	0.488166	0.564226	<.0001
	>75	0.394791	0.355653	0.438191	<.0001
Sex	Female	Ref			
	Male	1.264656	1.210702	1.321147	<.0001
LOS	3 days	Ref			
	4–6 days	1.056858	0.986295	1.132469	0.1165
	7–11 days	1.250196	1.155808	1.352426	<.0001
	> 12 days	1.797685	1.652022	1.956388	<.0001
Elixhauser comorbidity score	0	Ref			
	1	0.970154	0.907193	1.037486	0.3764
	2	0.990149	0.916036	1.070151	0.8024
	3	1.102742	1.021222	1.19077	0.0125
Volume	90th percentile (73 / year)	0.80284	0.748338	0.861311	<.0001
	Above 90th percentile	Ref			
Control/ownership of hospital	Government, nonfederal	Ref			
	Private, not-profit	1.2532	1.151425	1.364107	<.0001
	Private, invest-own	1.256588	1.107937	1.42504	0.0004
Insurance	Medicare	1.209854	1.111711	1.316662	<.0001
	Medicaid	Ref			
	Private insurance	1.10186	1.02296	1.186728	0.0105
	Self-pay	1.056224	0.918512	1.214582	0.4425
	No charge	0.955902	0.599955	1.52318	0.8496
	Other	1.119072	0.984915	1.271503	0.0841
Discharge quarter	Jan-March	Ref			
	Apr-Jun	1.003707	0.944027	1.067159	0.9058
	July-Sep	0.976969	0.918237	1.039459	0.4606
	Oct-Dec	0.907284	0.850526	0.967732	0.0031
Median household income for patient's ZIP code, based on current year	0–25 percentile	Ref			
	26–50 percentile	0.942895	0.881703	1.008234	0.0855

Variable		OR	95% CI		p-value
	51–75 percentile	1.016434	0.946391	1.091661	0.6545
	76–100 percentile	1.082962	1.008133	1.163229	0.029
Elective versus non-elective admission	Non elective	0.656587	0.620456	0.694752	<.0001
	Elective	Ref			
Teaching status	Non teaching	1.102963	1.02891	1.182345	0.0057
	Teaching	Ref			
Metropolitan	Other	0.831936	0.780126	0.887275	<.0001
	Major metropolitan	Ref			

Table 5:

Predictors of non-routine disposition upon discharge upon index admission for malignant brain tumor craniotomy. Values for odds ratio, confidence interval, and p-value are included.

Variable		OR	95% CI		p-value
Depression	Yes	1.171166	1.100209	1.246575	<.0001
	No	Ref			
Other psychiatric disease	Yes	1.097242	1.027882	1.171283	0.0053
	No	Ref			
Smoking	Yes	0.890297	0.850271	0.932301	<.0001
	No	Ref			
Age	44	Ref			
	45–59	1.87311	1.731867	2.025872	<.0001
	60–74	2.641112	2.424439	2.877437	<.0001
	>75	4.813382	4.31458	5.369313	<.0001
Sex	Female	Ref			
	Male	0.803884	0.772132	0.836942	<.0001
APRDRG Mortality risk	Minor	Ref			
	Moderate	1.203098	1.127046	1.284411	<.0001
	Major	1.580751	1.467558	1.702674	<.0001
	Extreme	2.533242	2.291943	2.799946	<.0001
LOS	3 days	Ref			
	4–6 days	3.026177	2.815951	3.252097	<.0001
	7–11 days	5.566687	5.120745	6.052068	<.0001
	> 12 days	9.560117	8.70067	10.50446	<.0001
Elixhauser comorbidity score	0	Ref			
	1	1.271249	1.189342	1.358661	<.0001
	2	1.389022	1.298098	1.486315	<.0001
	3	1.650701	1.537719	1.771984	<.0001
Elective	Elective	Ref			
	Non elective	0.7719	0.730665	0.815544	<.0001
Control/ownership of hospital	Government, nonfederal	Ref			
	Private, not-profit	1.287239	1.162299	1.42561	<.0001
	Private, invest-own	1.53526	1.347836	1.748748	<.0001
Insurance	Medicare	1.897619	1.745428	2.06308	<.0001
	Medicaid	Ref			
	Private insurance	1.076161	0.994913	1.163927	0.0667
	Self-pay	0.70321	0.601096	0.82267	<.0001
	No charge	0.700192	0.448476	1.093299	0.117
	Other	0.946769	0.830108	1.079826	0.4146
Hospital bedsize	Small	0.712269	0.576085	0.880734	0.0017

Variable		OR	95% CI		p-value
	Medium	0.970251	0.87293	1.078531	0.5762
	Large	Ref			
Metropolitan	Other	0.883027	0.817585	0.95361	0.0015
	Major metropolitan	Ref			

Table 6.

The most frequent primary diagnoses upon 30-day and 90-day readmission.

ICD-9 primary diagnosis	Diagnosis Code	Frequency (%)	
		30-day	90-day
Post-operative infection	998.59, 0389, 486, 5990	15.76	14.03
Secondary malignant neoplasm of brain/spine	198.3	7.4	8.18
Other pulmonary embolic infarct	41519	3.92	4.41
Malignant neoplasm of brain, unspecified	191.9	2.53	3.27
Malignant neoplasm of frontal lobe	1911	2.49	2.84
Other nervous system complications	997.09	1.99	1.28
Other convulsions	780.39	1.66	1.54
DVT/EMB of proximal lower extremity	453.41	1.6	1.61
Malignant neoplasm of other parts of brain	191.8	1.49	1.36
Malignant neoplasm of temporal lobe	191.2	1.48	1.94

Table 7.

Predictors of 30-day all-cause readmissions for malignant brain tumor craniotomy. Values for odds ratio, confidence interval, and p-values are included.

Variable		OR	95% CI		p-value
Depression	Yes	1.020303	0.943461	1.103404	0.6146
	No	Ref			
Sex	Female	Ref			
	Male	1.187203	1.126708	1.251071	<.0001
APRDRG Mortality risk	Minor	Ref			
	Moderate	1.018978	0.940071	1.104508	0.6482
	Major	1.160673	1.060775	1.270106	0.0012
	Extreme	1.318903	1.177037	1.478015	<.0001
LOS	3 days	Ref			
	4–6 days	1.081663	0.992925	1.17845	0.0723
	7–11 days	1.213611	1.10949	1.327503	<.0001
	> 12 days	1.392638	1.270614	1.526382	<.0001
Elixhauser comorbidity score	0	Ref			
	1	1.155808	1.06173	1.258222	0.0008
	2	1.300046	1.191008	1.419068	<.0001
	3	1.509532	1.38805	1.641811	<.0001
Elective	Elective	Ref			
	Non elective	0.863553	0.797	0.935756	0.0003
Resident of the state	Yes	Ref			
	No	0.675164	0.605077	0.753444	<.0001
Insurance	Medicare	0.859074	0.791045	0.93286	0.0003
	Medicaid	Ref			
	Private insurance	0.768358	0.708291	0.833518	<.0001
	Self-pay	0.711272	0.596426	0.848318	0.0002
Metropolitan	No charge	0.946959	0.614774	1.458633	0.8046
	Other	0.678684	0.575567	0.800275	<.0001
	Other	0.866754	0.817177	0.919247	<.0001
	Major metropolitan	Ref			
HCUP used Emergency	Yes	Ref			
	No	0.908192	0.841979	0.979513	0.0126
Disposition	Routine	Ref			
	Other	1.322072	1.248696	1.399759	<.0001

Table 8.

Predictors of 90-day all-cause readmissions for malignant brain tumor craniotomy. Values for odds ratio, confidence interval, and p-values are included.

Variable		OR	95% CI		p-value
Depression	Yes	1.029836	0.961558	1.102963	0.4005
	No	Ref			
Other psychiatric disease	Yes	0.926631	0.869793	0.987084	0.0181
	No	Ref			
Age	44	Ref			
	45–59	1.215433	1.133715	1.30304	<.0001
	60–74	1.29072	1.194467	1.394589	<.0001
	>75	1.179629	1.06844	1.302258	0.0011
Sex	Female	Ref			
	Male	1.083395	1.033447	1.135871	0.0009
APRDRG Mortality risk	Minor	Ref			
	Moderate	1.00441	0.940635	1.072508	0.895
	Major	1.137804	1.054957	1.227034	0.0008
	Extreme	1.093518	0.988764	1.20925	0.0818
LOS	3 days	Ref			
	4–6 days	1.070365	1.002603	1.142821	0.0416
	7–11 days	1.176801	1.094393	1.265415	<.0001
	> 12 days	1.240978	1.144537	1.345681	<.0001
Elixhauser comorbidity score	0	Ref			
	1	1.224093	1.138487	1.316267	<.0001
	2	1.397661	1.294339	1.509231	<.0001
	3	1.636566	1.515583	1.767206	<.0001
Teaching status	Teaching	Ref			
	Non teaching	1.084805	1.024495	1.148779	0.0053
Resident of the state	Yes	Ref			
	No	0.543242	0.489388	0.602963	<.0001
Insurance	Medicare	0.855987	0.787415	0.930531	0.0003
	Medicaid	Ref			
	Private insurance	0.720507	0.668112	0.776934	<.0001
	Self-pay	0.628198	0.538537	0.732714	<.0001
	No charge	0.752993	0.507428	1.117395	0.1588
Metropolitan	Other	0.716555	0.623442	0.823493	<.0001
	Other	0.903843	0.857272	0.952943	0.0002
	Major metropolitan	Ref			
HCUP used Emergency	Yes	Ref			
	No	0.90529	0.859418	0.95361	0.0002

Variable		OR	95% CI		p-value
Disposition	Routine	Ref			
	Other	1.219572	1.158586	1.283769	<.0001

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