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Worse outcomes for patients undergoing brain tumor and cerebrovascular procedures following the ACGME resident duty-hour restrictions

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Abstract

Object—On July 1, 2003, the Accreditation Council for Graduate Medical Education (ACGME) implemented duty-hour restrictions for resident physicians due to concerns for patient and resident safety. Though duty-hour restrictions have increased resident quality of life, studies have shown mixed results with respect to patient outcomes. In this study, the authors have evaluated the effect of duty-hour restrictions on morbidity, mortality, length of stay, and charges in patients who underwent brain tumor and cerebrovascular procedures.

Methods—The Nationwide Inpatient Sample was used to evaluate the effect of duty-hour restrictions on complications, mortality, length of stay, and charges by comparing the pre-reform (2000–2002) and post-reform (2005–2008) periods. Outcomes were compared between nonteaching and teaching hospitals using a difference-in-differences (DID) method.

Results—A total of 90,648 patients were included in the analysis. The overall complication rate was 11.7%, with the rates not significantly differing between the pre –and post–duty hour eras ($p = 0.26$). Examination of hospital teaching status revealed that complication rates decreased in nonteaching hospitals (12.1% vs 10.4%, $p = 0.0004$) and remained stable in teaching institutions (11.8% vs 11.9%, $p = 0.73$) in the post-reform era. Multivariate analysis demonstrated a

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significantly higher complication risk in teaching institutions (OR 1.33 [95% CI 1.11–1.59], p = 0.0022), with no significant change in nonteaching hospitals (OR 1.11 [95% CI 0.91–1.37], p = 0.31). A DID analysis to compare the magnitude in change between teaching and nonteaching institutions revealed that teaching hospitals had a significantly greater increase in complications during the post-reform era than nonteaching hospitals (p = 0.040). The overall mortality rate was 3.0%, with a significant decrease occurring in the post-reform era in both nonteaching (5.0% vs 3.2%, p < 0.0001) and teaching (3.2% vs 2.3%, p < 0.0001) hospitals. DID analysis to compare the changes in mortality between groups did not reveal a significant difference (p = 0.40). The mean length of stay for all patients was 8.7 days, with hospital stay decreasing from 9.2 days to 8.3 days in the post-reform era (p < 0.0001). The DID analysis revealed a greater length of stay decrease in nonteaching hospitals than teaching institutions, which approached significance (p = 0.055). Patient charges significantly increased in the post-reform era for all patients, increasing from $70,900 to $96,100 (p < 0.0001). The DID analysis did not reveal a significant difference between the changes in charges between teaching and nonteaching hospitals (p = 0.17).

Conclusions—The implementation of duty-hour restrictions correlated with an increased risk of postoperative complications for patients undergoing brain tumor and cerebrovascular neurosurgical procedures. Duty-hour reform may therefore be associated with worse patient outcomes, contrary to its intended purpose. Due to the critical condition of many neurosurgical patients, this patient population is most sensitive and likely to be negatively affected by proposed future increased restrictions.

Keywords

brain tumor; cerebrovascular; complication; duty-hour restriction; outcome; resident

On July 1, 2003, the Accreditation Council for Graduate Medical Education (ACGME) implemented duty-hour restrictions for resident physicians because of concerns for patient and resident safety.[1,2] These changes placed a 24-hour limit on continuous duty, with 6 more hours allowed for transfer of care and educational activities, limited in-hospital call to occur no more frequently than every 3rd night, and required a minimum of 10 hours of rest between duty periods. Additionally, it limited resident hours to 80 hours per week averaged over 4 weeks, with 1 in 7 days free of patient care duties.

These policy changes were implemented to reduce resident fatigue and sleep deprivation, both of which can decrease cognitive functioning, clinical performance, and resident quality of life while increasing the risk of accidents such as motor vehicle crashes and percutaneous injuries.[3–6,16,21–24,28,34] However, though duty-hour restrictions have increased resident quality of life, studies have shown mixed results with respect to patient outcomes.[7,10–14,17,18,26,29,33,35–37] As duty-hour restrictions have increased the number of resident handoffs and reduced clinical experience due to decreased working hours, it is feared that the number of medical errors and complications may increase, resulting in worse patient outcomes.[15,18,19,25,27]

In this study, we evaluated the effect of duty-hour restrictions on morbidity and mortality rates in patients who underwent brain tumor and cerebrovascular procedures. Additionally, we also examined the effect on length of stay (LOS) and health care costs to determine

whether work hour restrictions have not only negatively affected patient outcomes but have also increased the burden on the health care system. We hypothesized that there would be a significant increase in intraoperative and postoperative complications in teaching hospitals following duty hour reform, reflecting the impact on resident operative and clinical management skills.

Methods

Data Source

Patient-related characteristics, hospital details, and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure and diagnosis codes were obtained from the Nationwide Inpatient Sample (NIS) database. The NIS has collected discharge data for approximately 8 million hospital admissions across 1000 hospitals in 45 states annually from 1988 to 2010. It is considered one of the largest publicly available all-payer inpatient databases representative of the US population and provides a unique opportunity to study and quantify policy decisions.

Study Sample

Patients with a diagnosis related to brain tumors (n = 75,334) and cerebrovascular disease (n = 15,314) were included in the analysis (Table 1). Brain tumor patients included those who underwent a cranial procedure related to malignant, benign, or uncertain neoplasms of the brain; pituitary gland; pineal gland; craniopharyngeal duct; choroid plexus; and/or other parts of the CNS. Additionally, patients who underwent excision of vestibular schwannomas were included. Cerebrovascular patients were defined as those who underwent clipping of an aneurysm or an extracranial-intracranial bypass. Those who underwent endovascular procedures were not included as these cases do not entail the same postoperative complication risk as open cranial surgeries. Additionally, as fellows and attending physicians typically perform these procedures, they are likely minimally affected by differences in resident training.

Select years were chosen to evaluate the restriction of resident work hours implemented nationally in July 2003. Patients admitted during January 1, 2000, to December 31, 2002, were chosen to represent the pre–duty hour restriction population. Post–duty hour restriction admissions included those from January 1, 2005, to December 31, 2008. The years 2003 and 2004 were excluded as this is considered a transitional period for the implementation of work hour restrictions. Additional analyses with multivariate models utilizing different time period cutoffs supported the use of the chosen time points.

Covariates

The multivariate analyses accounted for both patient and hospital covariates. Patient variables included age at admission, sex, primary payer status, patient median income, and Charlson Comorbidity Index (CCI), a measure of the burden of comorbidities. Hospital variables included hospital bedsize, hospital location and region, continuous hospital discharges, and hospital teaching status.

Main Outcome Measures

The primary outcomes in this study were perioperative mortality and complications. Complications included an accidental puncture or laceration, intra- or postoperative hematoma, medical care or postoperative nervous system complication, postoperative respiratory complications such as pulmonary embolism, cardiac complications such as acute myocardial infarction, a foreign body inadvertently left in the wound, misadministration of medication, peripheral vascular complications, complications of the operative wound, postoperative infection, CSF leak, carotid or vertebral artery injury, and/or injury to cranial or sympathetic nerves (Table 1). We also examined the LOS and inpatient costs inflated to 2009 dollars with the Consumer Price Index. All outcome measures were compared between patients in the pre– and post–duty hour eras to evaluate the impact of work hour restrictions on patient outcome.

Statistical Analysis

The policy change to restrict resident work hours can be modeled with a quasi-experimental method, often referred to as the difference-in-differences (DID) method. The method compares the differences in outcomes before and after an intervention in 2 groups. One group acts as a control and is assumed to be unaffected by the intervention. The primary analysis for this study tested the association of time period (pre– and post–duty hour restrictions) with 4 different outcomes using nonteaching hospitals as a control. This was performed for all outcomes to evaluate the differences in risk change between nonteaching and teaching hospitals.

A generalized linear mixed effects model was constructed for each of the following 4 outcomes: mortality, binary complications, LOS in days, and continuous patient charges. Appropriate link functions were selected for each outcome. Mortality and complications used a logit link function, LOS used a Poisson link, and patient charges used a log normal link to adjust for the structure and distribution of the outcomes. Each model included continuous age at admission, hospital discharges, and time of admission in years and months. Categorical covariates included sex, CCI, primary payer status, patient median income, hospital bedsize, hospital location, region, hospital teaching status, and a time period indicator for pre– and post–work hour restrictions. To adjust for the correlation between patients from the same hospital, a random intercept was included in all models. Lastly, an interaction between teaching status and time period was included.

This method accounts for improvements in the standard of care and natural increases in health care cost by assuming a common linear trend across time. Models were constructed with the GLIMMIX procedure (version 9.3, SAS Institute). Reported p values were calculated from a t-test for continuous variables and Pearson chisquare test for categorical variables. All analyses were conducted using (version 9.3, SAS Institute).

Results

Patient Cohort

A total of 90,648 patients were included in the analysis, consisting of 36,685 (40.5%) from the pre–duty hour restriction era and 53,963 (59.5%) from the post–duty hour restriction era (Tables 2 and 3). The nonteaching hospital cohort consisted of 18,606 patients, while the teaching institution cohort comprised 72,026 patients (Tables 4, 5, 6, and 7). Patients treated for brain tumors included 29,475 and 45,912 patients in the pre– and post–duty hour cohorts, respectively. The cerebrovascular cohort consisted of 7245 treated in the pre–work hour era and 8083 treated in the post–work hour era. Various patient and hospital variables differed significantly between those in the overall pre– and post–duty hour restriction cohorts due to the large sample collected (Table 3). However, examination of the estimates did not indicate major imbalances between the 2 groups.

Complications

The overall complication rate was 11.7%, with the rates not significantly differing between the pre– and post–duty hour eras (11.9% vs 11.6%, p = 0.26) (Table 2). Examination of hospital teaching status revealed complication rates to decrease in nonteaching hospitals (12.1% vs 10.4%, p = 0.0004) while remaining stable in teaching institutions (11.8% vs 11.9%, p = 0.73) in the post-reform era (Tables 6 and 7). Brain tumor patients experienced a similar complication rate in nonteaching hospitals (10.6% vs 9.9%, p = 0.13) but more complications in teaching hospitals (10.4% vs 11.0%, p = 0.013) in the post-reform era. The complication rate for cerebrovascular patients did not significantly differ in the post–duty hour reform era in nonteaching (18.2% vs 15.9%, p = 0.14) or teaching (17.7% vs 16.5%, p = 0.076) hospitals, though they trended to be lower.

The most common complications were postoperative nervous system complications (2.6%), carotid or vertebral artery injuries (2.4%), and dysphagia (1.8%) (Table 8). In nonteaching hospitals, the incidence of therapeutic misadventures and operative wound complications increased in the post-reform era, while the incidence of hematomas, postoperative respiratory complications, and other specified complications decreased (Table 9). Examination of teaching hospitals revealed a significant decrease in the incidence of postoperative respiratory complications, other specified complications, and dysphagia, while there was an increase in medical care or postoperative nervous system complications, foreign body left in wound incidents, therapeutic misadventures, and operative wound complications (Table 10).

Multivariate logistic regression of complications revealed year of admission, CCI, primary payer, hospital region, and time period to significantly affect the risk of postoperative complications (Table 11). Teaching status was not seen to impact the likelihood of complications. However, examination of the duty-hour-restriction effect given teaching status revealed a significantly higher complication risk in teaching institutions (OR 1.33 [95% CI 1.11–1.59], p = 0.0022), with no significant change in nonteaching hospitals (OR 1.11 [95% CI 0.91–1.37], p = 0.31) (Table 12). The DID analysis to compare the magnitude in change between teaching and nonteaching institutions revealed that teaching hospitals had

a significantly greater increase in complications during the post-reform era than nonteaching hospitals (p = 0.040). These trends occurred in both brain tumor and cerebrovascular cohorts.

Mortality

The overall mortality rate was 3.0%, with a significant decrease occurring in the post-reform era in both nonteaching (5.0% vs 3.2%, p < 0.0001) and teaching (3.2% vs 2.3%, p < 0.0001) hospitals (Tables 2, 6, and 7). This effect was seen in all brain tumor and cerebrovascular cohorts with the exception of cerebrovascular patients treated at nonteaching hospitals in which no significant decrease was seen.

Multivariate logistic regression of mortality revealed age, sex, CCI, primary payer, and median income to signifcantly affect mortality risk (Table 13). While teaching status was significantly associated with a decreased risk of mortality (OR 0.85 [95% CI 0.74–0.97], p = 0.019), the post-reform period did not significantly affect this risk (OR 0.81 [95% CI 0.61–1.08], p = 0.15). Evaluation of the effect of duty-hour restrictions on nonteaching institutions revealed a decrease in mortality risk, which trended toward significance (OR 0.76 [95% CI 0.55–1.04], p = 0.086) (Table 12). This effect in teaching institutions was not signifcant (OR 0.83 [95% CI 0.62–1.12], p = 0.18). The DID analysis to compare the changes in mortality between groups did not reveal a significant difference (p = 0.40).

Length of Stay

The mean length of stay for all patients was 8.7 days, with hospital stay decreasing from 9.2 days to 8.3 days in the post-reform era (p < 0.0001) (Table 2). A significant decrease in LOS was seen in brain tumor and cerebrovascular patients treated at both nonteaching and teaching hospitals.

Multivariate Poisson regression demonstrated that age, sex, primary payer, CCI, hospital size and region, number of discharges, median income, and complication count significantly affected the LOS (Table 14). Teaching status was associated with an increased LOS (relative risk [RR] 1.13 [95% CI 1.04–1.22], p = 0.0025) while the post-reform era was associated with decreased patient stay (RR 0.92 [95% CI 0.86–0.99], p = 0.023). Analysis of the impact of duty-hour restrictions on LOS in teaching hospitals revealed a decrease in the LOS, which approached significance (RR 0.93 [95% CI 0.87–1.00], p = 0.062), with a more significant decrease occurring in nonteaching hospitals (RR 0.87 [95% CI 0.80–0.95], p = 0.0022) (Table 12). The DID analysis to compare the differences in change between teaching and nonteaching hospitals revealed a greater decrease in nonteaching hospitals, which approached significance (p = 0.055).

Health Care Cost

Patient charges significantly increased in the post-reform era for all patients, increasing from $70,900 to $96,100 (p < 0.0001) (Table 2). Costs increased from $58,200 to $83,000 for brain tumor patients (p < 0.0001) and from $123,400 to $171,600 for those undergoing cerebrovascular procedures (p < 0.0001). These changes occurred in both nonteaching and teaching hospitals.

Multivariate log linear regression revealed year of admission, age, sex, CCI, primary payer, hospital region, median income, and complications to affect patient charges (Table 15). Teaching status and time period did not significantly affect total charges. Examination of the time period effect demonstrated an increase in charges in teaching hospitals, which trended toward significance (RR 1.07 [95% CI 1.00–1.14], p = 0.065), with no effect seen in nonteaching hospitals (RR 1.01 [95% CI 0.92–1.11], p = 0.79) (Table 12). The DID analysis did not reveal a significant difference between the changes in charges between teaching and nonteaching hospitals (p = 0.17). These trends were seen in brain tumor and cerebrovascular patients.

Discussion

Duty-hour restrictions were implemented to improve resident safety and quality of life by limiting work hours. This reduction in work demands were intended to reduce resident fatigue and sleep deprivation, thereby also potentially reducing medical errors. However, the effects of these work hour restrictions on patient outcomes have been unclear as some studies have shown improvements in mortality and morbidity while others have shown no change or significantly worse outcomes.[7,10,11,13,14,17,29,35–37] In this study, we have analyzed a large cohort of patients to examine the effect of these restrictions on complications, mortality, LOS, and health care costs following cranial surgery for brain tumors and cerebrovascular disorders.

Previous studies have shown the effects of work hour restrictions on patient outcomes to vary by patient population. An analysis of mortality among Medicare patients following hospitalization for medical and surgical conditions demonstrated similar outcomes in the pre– and post–duty hour eras.[36] However a similar analysis of patients in the Veterans Affairs health care system showed significantly decreased odds of mortality for medical patients in post-reform Year 2, while there was no significant reduction in mortality for surgical patients.[35] Other studies have also demonstrated improvements in mortality for medical patients but not in surgical patients, indicating that duty-hour restrictions may have been beneficial in the management of nonsurgical patients.[30]

Poorer outcomes in surgical patients following duty hour reform may be due to a variety of factors. Reduced work time may have resulted in less resident experience with managing acute complications that may occur in the immediate postoperative period and critically ill trauma patients. Also, these duty-hour restrictions may have led to less operative time, resulting in poorer operative skills. However, the effects of these restrictions on operative volume is unclear as some surgical specialties have experienced an increase in resident operative volume while others have noticed unchanged or decreased volume.[31,32]

While studies from a variety of surgical specialties have demonstrated worse outcomes following duty hour reform, few have evaluated outcomes following neurosurgical procedures.[7,9,10,13,17] The analysis of neurosurgical procedures provides unique insights into the effects of duty hour reform. First, neurosurgical training differs from other specialties as procedures are generally highly technical and require considerable exposure for the development of adequate surgical skills. Second, neurosurgical patients are frequently

critically ill and may experience significant morbidity following extensive procedures. These patients thus require close monitoring and prompt management for conditions such as postoperative intracerebral hemorrhage and cerebral swelling. Finally, neurosurgical training programs are among the smallest of all specialties, thereby placing significant responsibilities on each resident to manage a number of complex patients. In recognition of the added difficulty placed by duty hour re-form, neurosurgery residents and program directors have concluded that duty hour guidelines have adversely affected resident training and continuity of care.[8,19]

Current studies evaluating neurosurgical procedures have uniformly demonstrated poorer outcomes in the post-reform era. One study that evaluated outcomes following the implementation of work hour restrictions in a single institution demonstrated significantly more avoidable morbidities in the post-reform era ($p = 0.017$).[9] Another study that examined neurosurgical trauma patients using the NIS database also demonstrated a significantly higher risk of complications following reform in teaching hospitals, while there was no difference in nonteaching hospitals.[17] However, that study did not perform a DID analysis to compare the magnitudes in change between teaching and nonteaching hospitals, making the proposed outcomes uncertain. Finally, another study that evaluated patients who underwent craniotomy for meningiomas demonstrated increased complications in patients treated after 2003.[10] However, the multivariate analysis only accounted for a limited number of covariates, and other outcomes such as mortality and health care costs were not examined.

In this study, we have comprehensively analyzed a variety of patient outcomes following brain tumor and cerebrovascular neurosurgical procedures. Additionally, we have used rigorous statistical analyses to compare the changes in outcomes between teaching and nonteaching hospitals. Evaluation of postoperative complications revealed a significantly greater increase in complications in the post-reform era in teaching institutions ($p = 0.040$). Analysis of complication type revealed work hour reform to potentially affect both resident operative and postoperative care skills. Significant increases were seen in the incidence of operative wound complications and incidents involving foreign bodies being left in the wound in teaching institutions. However, as operative wound complications also increased in the nonteaching cohort, it is unclear whether these complications are a result of reduced resident operative experience. It may be expected that intraoperative complications be unaffected by work hour reform as residents typically do not have a primary role in these procedures. As they typically function as assistants, they may only minimally affect intraoperative outcomes. The incidence of medical care or postoperative nervous system complications and therapeutic misadventures also significantly increased following reform. Although a rise in the incidence of the latter was also seen in nonteaching hospitals, the former may be due to postoperative management errors. Examination of mortality revealed duty-hour restrictions to result in a nonsignificant decrease in mortality risk in teaching and nonteaching hospitals. Though this difference trended toward significance in nonteaching hospitals ($p = 0.086$), DID analysis did not reveal a significant difference between the groups ($p = 0.40$). The post–duty hour reform era was seen to result in a decrease in patient stay in teaching ($p = 0.062$) and nonteaching ($p = 0.0022$) hospitals. The DID analysis revealed a greater decrease in nonteaching hospitals, though this did not reach significance ($p = 0.055$). Patient charges were seen to rise in both teaching and nonteaching hospitals in

the post-reform era. However, DID analysis did not reveal a significant difference between cohorts ($p = 0.17$).

This study has evaluated a large cohort of patients who underwent brain tumor and cerebrovascular procedures to examine patient outcomes and help elucidate the potential causes for the resulting outcomes. However, this study has several limitations. Firstly, as with all large administrative databases, miscoding may be present. This bias would affect all groups of patients equally and are thus likely to be uniformly distributed. However, there may be coding and documentation differences between teaching and nonteaching hospitals, which may affect the incidences of complications in each group. Second, this study does not imply causality, but rather has demonstrated an association. Third, the NIS does not contain clinical variables such as patient neurological status, which may affect patient outcome and confound the results. Similarly, we could not control for surgery complexity. As teaching hospitals are referral centers and may perform more complex surgeries than nonteaching hospitals, this group may be biased toward worse outcomes. The increasing complication rate seen in teaching hospitals may therefore be reflective of increasing surgical complexity and changes in referral patterns. However, we evaluated the effect of duty-hour restrictions on each hospital type individually, and then compared these outcomes using DID analysis. As the patient population in teaching and nonteaching hospitals before and after duty-hour restrictions has likely remained relatively similar, the effect of changes in surgical complexity may be minimal. Also due to advancements in medical and neurosurgical care, it is possible that both teaching and nonteaching hospitals have experienced a greater increase in surgery complexity. Fourth, variables such as the number of residents, adherence to the duty hour guidelines, and presence of ancillary clinical staff (nurse practitioners and physician assistants) is not present in the database and thus could not be controlled. Fifth, the NIS database only records in-hospital complications and mortality; thus, any adverse outcomes occurring after discharge could not be included in the analysis. Finally, some analyses may be affected by Type II error or may be overpowered, resulting in differences in significance despite similar magnitudes in change. As a result, clinical significance should be considered when evaluating changes in patient outcomes. Nonetheless, this study has evaluated a large cohort of brain tumor and cerebrovascular patients and has used rigorous statistical analyses to demonstrate significantly higher complications in teaching institutions in the post-reform era.

Conclusions

The implementation of duty-hour restrictions correlated with an increased risk of postoperative complications for patients undergoing neurosurgical procedures. Additionally, though not significant, mortality, LOS, and patient charges tended to be higher in teaching institutions than in nonteaching hospitals. Duty hour reform may therefore be associated with worse patient outcomes, contrary to its intended purpose. While medical patients have experienced improved outcomes following duty hour reform, the negative effect on surgical patients deserves greater focus. These often more ill patients require health care providers with substantial clinical experience. As residents provide the majority of the postoperative care received by surgical patients, adequate exposure to procedures and complications during training is essential for the creation of highly skilled clinicians who will become the

leaders in their respective fields. Any further limit placed on work hours is likely to increase the risk of worsening patient outcomes as evidenced by increased mortality and complications in Switzerland following the implementation of a 50-hour work week limit.[20] Because of the critical condition of many neurosurgical patients, this patient population is most sensitive and more likely to be negatively affected by proposed future increased restrictions. Creative strategies that reduce the negative consequences of work hour reform are therefore needed to ensure delivery of continued high-quality health care.

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Abbreviations used in this paper

ACGME	Accreditation Council for Graduate Medical Education
CCI	Charlson Comorbidity Index
DID	difference-in-differences
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
LOS	length of stay
NIS	Nationwide Inpatient Sample
RR	relative risk

Table 1

ICD-9 diagnosis and procedure codes utilized for this study*

ICD-9 Code	Description
01.14	open biopsy of brain
01.23 – 01.25	reopening of craniotomy site, other craniotomy/craniectomy
01.31	incision of cerebral meninges
01.39	other incision of brain
01.51	excision of lesion or tissue of cerebral meninges
01.59	other excision or destruction of lesion or tissue of brain
02.14	choroid plexectomy
04.01	excision of acoustic neuroma
07.51–07.59	op on pineal gland
07.61–07.69	excision of pituitary gland
07.71, 07.72, 07.79	op on hypophysis & pituitary fossa
437.3, 747.81	aneurysm, brain
430	hemorrhage, subarachnoid
191.0–191.9	malignant neoplasm of brain
192.0, 192.1, 192.8, 192.9	malignant neoplasm of brain (other)
198.3, 198.4	secondary neoplasm of brain & spinal cord
225.0–225.2	benign neoplasm of brain
225.8, 225.9	benign neoplasm of CNS, unspecified
239.6	neoplasm of uncertain nature of brain
194.3	malignant neoplasm of pituitary gland & craniopharyngeal duct
194.4	malignant neoplasm of pineal gland
227.3	benign neoplasm of pituitary gland & craniopharyngeal duct
227. 4	benign neoplasm of pineal gland
237.0, 237.1, 237.5, 237.6, 237.9	neoplasm of uncertain behavior of pituitary & pineal gland
39.51	clipping of aneurysm
39.28	EC-IC bypass
998.2, E870.0	accidental puncture or laceration
998.1, 998.11–998.13	hematoma (intraop or postop)
997.0, 997.00, 997.01, 997.09	medical care or postop nervous system complications
415.1, 997.3	postop respiratory complications
998.4	foreign body inadvertently left in wound
999.9	therapeutic misadventure, NEC
998.9	therapeutic misadventure, surgical treatment
997.1, 410.0–410.9, 998.0	cardiac complications, acute myocardial infarction
997.2	peripheral vascular complications
998.3, 998.31, 998.32, 998.83	complication of operative wound

ICD-9 Code	Description
998.5, 999.3, 998.51, 998.59	postop infection
998.8, 998.89	other specified complications
349.0, 998.6	CSF leak
954.0	injury to cervical sympathetic nerves
787.2	dysphagia
478.30–478.34, 784.4	hoarseness due to paralysis of vocal cords
900.00–900.03, 900.82, 900.89, 900.9, 997.02	carotid or vertebral artery injury

* EC-IC = extracranial-intracranial; NEC = not elsewhere classifed.

Table 2

Outcomes of brain tumor and cerebrovascular patients by time period*

Parameter	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	Test Statistic (p value)
total no. of patients (%)	36,685 (100.0)	53,963 (100.0)	
no. who died in hospital (%)	1333 (3.64)	1342 (2.49)	101.48 (<0.0001)
no. of complications (%)	4350 (11.86)	6266 (11.61)	1.28 (0.2582)
complication count (%)			5.73 (0.0167)
none	32,335 (88.14)	47,697 (88.39)	
1	3554 (9.69)	5276 (9.78)	
2	642 (1.75)	815 (1.51)	
≥3	154 (0.42)	175 (0.32)	
LOS in days			14.05 (<0.0001)
mean ± SD	9.2 ± 10.64	8.3 ± 9.69	
median (IQR)	6.0 (4.0–11.0)	5.0 (3.0–10.0)	
adjusted charges in $ × 10^3			−173.83 (<0.0001)
mean ± SD	70.9 ± 81.08	96.1 ± 101.10	
median (IQR)	47.1 (30.9–78.4)	66.1 (42.6–109.6)	

* IQR = interquartile range.

Table 3
Baseline characteristics of brain tumor and cerebrovascular patients by time period

	Value*		
Parameter	**Pre–Duty Hour Restriction: 2000–2002**	**Post–Duty Hour Restriction: 2005–2008**	**Test Statistic (p value)**
total no. of patients	36,685 (100.0)	53,963 (100.0)	
age in yrs at admission			−32.79 (<0.0001)
mean ± SD	52.0 ± 17.91	52.1 ± 18.04	
median (IQR)	53.0 (42.0–65.0)	54.0 (42.0–65.0)	
female sex	20,495 (55.88)	29,283 (54.93)	7.93 (0.0049)
CCI			82.47 (<0.0001)
0	12,182 (33.21)	17,593 (32.60)	
1	8176 (22.29)	10,687 (19.80)	
2	10,776 (29.37)	15,866 (29.40)	
≥3	5551 (15.13)	9817 (18.19)	
bedsize			29.31 (<0.0001)
small	2621 (7.15)	2947 (5.46)	
medium	5612 (15.30)	8950 (16.59)	
large	28,436 (77.55)	42,066 (77.95)	
hospital location			101.02 (<0.0001)
rural	987 (2.69)	925 (1.71)	
urban	35,682 (97.31)	53,038 (98.29)	
hospital region			49.57 (<0.0001)
Northeast	6854 (18.68)	10,610 (19.66)	
Midwest	8104 (22.09)	10,182 (18.87)	
South	13,365 (36.43)	18,846 (34.92)	
West	8362 (22.79)	14,325 (26.55)	
total discharges in $ × 10^2			−65.96 (<0.0001)
mean ± SD	257.1 ± 131.45	301.4 ± 183.04	
median (IQR)	230.6 (164.9–330.0)	257.3 (192.1–360.7)	
primary payer			0.03 (0.8541)
Medicare	9678 (26.41)	14,468 (26.85)	
Medicaid	3209 (8.76)	5693 (10.56)	
private insurance	21,079 (57.52)	29,149 (54.09)	
self-pay	1439 (3.93)	2276 (4.22)	
no charge	132 (0.36)	265 (0.49)	
other	1109 (3.03)	2038 (3.78)	
median income			6448.76 (<0.0001)

Parameter	Value*		Test Statistic (p value)
	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	
low	1658 (4.62)	11,551 (21.99)	
low to middle	7272 (20.26)	12,480 (23.76)	
middle to high	9141 (25.4 6)	13,539 (25.78)	
high	17,829 (49.66)	14,951 (28.47)	

*Values are number of patients (%) unless indicated otherwise. Data are missing from some categories. In these instances the percentages are based on the known data.

Table 4

Baseline characteristics of brain tumor and cerebrovascular patients in nonteaching hospitals by time period

	Value*		
Parameter	**Pre–Duty Hour Restriction: 2000–2002**	**Post–Duty Hour Restriction: 2005–2008**	**Test Statistic (p value)**
total no. of patients	8583 (100.0)	10,023 (100.0)	
age in yrs at admission			−32.79 (<0.0001)
mean ± SD	56.2 ± 16.34	57.3 ± 16.03	
median (IQR)	57.0 (46.0–69.0)	59.0 (48.0–69.0)	
female sex	4854 (56.55)	5404 (54.50)	7.83 (0.0051)
CCI			20.33 (<0.0001)
0	2521 (29.37)	3009 (30.02)	
1	1859 (21.66)	1718 (17.14)	
2	2503 (29.16)	2881 (28.74)	
≥3	1700 (19.81)	2415 (24.09)	
bedsize			72.25 (<0.0001)
small	77 (0.90)	117 (1.17)	
medium	846 (9.86)	1407 (14.04)	
large	7660 (89.25)	8499 (84.79)	
hospital location			235.28 (<0.0001)
rural	560 (6.52)	205 (2.05)	
urban	8023 (93.48)	9818 (97.95)	
hospital region			15.47 (<0.0001)
Northeast	719 (8.38)	1009 (10.07)	
Midwest	1290 (15.03)	1506 (15.03)	
South	4601 (53.61)	4349 (43.39)	
West	1973 (22.99)	3159 (31.52)	
total discharges in $ × 10^2			−65.96 (<0.0001)
mean ± SD	181.7 ± 80.72	190.6 ± 91.16	
median (IQR)	176.3 (119.4–222.8)	177. 8 (122.1–244.4)	
primary payer			5.48 (0.0192)
Medicare	2954 (34.43)	3638 (36.35)	
Medicaid	703 (8.19)	816 (8.15)	
private insurance	4256 (49.60)	4820 (48.16)	
self-pay	341 (3.97)	358 (3.58)	
no charge	47 (0.55)	39 (0.39)	
other	279 (3.25)	338 (3.38)	

	Value*		
Parameter	**Pre–Duty Hour Restriction: 2000–2002**	**Post–Duty Hour Restriction: 2005–2008**	**Test Statistic (p value)**
median income			1118.27 (< 0.0 0 01)
low	354 (4.22)	2162 (22.09)	
low to middle	2157 (25.72)	2438 (24.91)	
middle to high	2277 (27.15)	2689 (27.47)	
high	3599 (42.91)	2500 (25.54)	

*Values are number of patients (%) unless indicated otherwise.

Table 5

Baseline characteristics of brain tumor and cerebrovascular patients in teaching hospitals by time period

	Value*		
Parameter	**Pre–Duty Hour Restriction: 2000–2002**	**Post–Duty Hour Restriction: 2005–2008**	**Test Statistic (p value)**
total no. of patients	28,086 (100.0)	43,940 (100.0)	
age in yrs at admission			−32.79 (<0.0001)
mean ± SD	50.7 ± 18.17	50.9 ± 18.27	
median (IQR)	52.0 (41.0–64.0)	53.0 (41.0–64.0)	
female sex	15,632 (55.67)	23,879 (55.03)	2.88 (0.0896)
CCI			83.65 (<0.0001)
0	9658 (34.39)	14,584 (33.19)	
1	6313 (22.48)	8969 (20.41)	
2	8266 (29.43)	12,985 (29.55)	
≥3	3849 (13.70)	74 02 (16.8 5)	
bedsize			118.51 (<0.0001)
small	2544 (9.06)	2830 (6.44)	
medium	4766 (16.97)	7543 (17.17)	
large	20,776 (73.97)	33,567 (76.39)	
hospital location			1.53 (0.2162)
rural	427 (1.52)	720 (1.64)	
urban	27,659 (98.48)	43,220 (98.36)	
hospital region			75.47 (<0.0001)
Northeast	6135 (21.84)	9601 (21.85)	
Midwest	6814 (24.26)	8676 (19.75)	
South	874 8 (31.15)	14,497 (32.99)	
West	6389 (22.75)	11,166 (25.41)	
total discharges in $ × 10^2			−65.96 (<0.0001)
mean ± SD	280.2 ± 135.25	326.6 ± 189.25	
median (IQR)	256.0 (185.8–348.1)	277.0 (210.9–402.3)	
primary payer			0.00 (0.9982)
Medicare	6719 (23.95)	10,830 (24.68)	
Medicaid	2505 (8.93)	4877 (11.11)	
private insurance	16,817 (59.95)	24,329 (55.44)	
self-pay	1094 (3.90)	1918 (4.37)	
no charge	85 (0.30)	226 (0.52)	
other	830 (2.96)	1700 (3.87)	

	Value*		
Parameter	**Pre–Duty Hour Restriction: 2000–2002**	**Post–Duty Hour Restriction: 2005–2008**	**Test Statistic (p value)**
median income			5424.91 (<0.0001)
low	1304 (4.74)	9389 (21.97)	
low to middle	5109 (18.58)	10,042 (23.50)	
middle to high	6857 (24.94)	10,850 (25.39)	
high	14,228 (51.74)	12,451 (29.14)	

*Values are number of patients (%) unless indicated otherwise.

Table 6

Outcomes of brain tumor and cerebrovascular patients in nonteaching hospitals by time period

Parameter	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	Test Statistic (p value)
total no. of patients (%)	8583 (100.0)	10,023 (100.0)	
no. who died in hospital (%)	424 (4.97)	325 (3.24)	35.23 (<0.0001)
no. of complications (%)	1035 (12.06)	1045 (10.43)	12.41 (0.0004)
complication count (%)			12.26 (0.0005)
none	7548 (87.94)	8978 (89.57)	
1	869 (10.12)	895 (8.93)	
2	140 (1.63)	119 (1.19)	
≥3	26 (0.30)	31 (0.31)	
LOS in days			14.05 (<0.0001)
mean ± SD	9.4 ± 9.71	8.0 ± 8.10	
median (IQR)	7.0 (4.0–11.0)	6.0 (3.0–10.0)	
adjusted charges in $ × 10^3			−173.83 (<0.0001)
mean ± SD	71.6 ± 80.25	91.0 ± 86.78	
median (IQR)	47.9 (30.9–80.6)	66.0 (41.4–108.2)	

Table 7

Outcomes of brain tumor and cerebrovascular patients in teaching hospitals by time period

Parameter	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	Test Statistic (p value)
total no. of patients (%)	28,086 (100.0)	43,940 (100.0)	
no. who died in hospital (%)	909 (3.24)	1017 (2.32)	56.48 (<0.0001)
no. of complications (%)	3313 (11.80)	5221 (11. 8 8)	0.12 (0.7270)
complication count (%)			1.34 (0.2472)
none	24,773 (88.20)	38,719 (88.12)	
1	2683 (9.55)	4381 (9.97)	
2	502 (1.79)	696 (1.58)	
≥3	128 (0.46)	144 (0.33)	
LOS in days			14.05 (<0.0001)
mean ± SD	9.2 ± 10.91	8.4 ± 10.02	
median (IQR)	6.0 (3.0–11.0)	5.0 (3.0–10.0)	
adjusted charges in $ × 10^3			−173.83 (<0.0001)
mean ± SD	70.7 ± 81.35	97.3 ± 104.14	
median (IQR)	46.8 (30.9–78.0)	66.1 (43.0–110.0)	

Table 8
Complication types of brain tumor and cerebrovascular patients by time period

Parameter	Value*		Test Statistic (p value)
	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	
total no. of complications (%)	4350 (11.86)	6266 (11.61)	1.28 (0.2582)
mean no. of complications/patient (± SD)	0.1 ± 0.43	0.1 ± 0.42	3.39 (0.0007)
complications by type			
accidental puncture or laceration	239 (0.65)	378 (0.70)	0.78 (0.3786)
hematoma (intraop or postop)	604 (1.65)	902 (1.67)	0.08 (0.7720)
medical care or postop nervous system	877 (2.39)	1465 (2.71)	9.12 (0.0025)
postop respiratory	430 (1.17)	416 (0.77)	38.03 (<0.0001)
foreign body inadvertently left in wound	2 (0.01)	13 (0.02)	4.59 (0.0322)
therapeutic misadventure, NEC	12 (0.03)	60 (0.11)	16.95 (<0.0001)
therapeutic misadventure, surgical treatment	1 (0.00)	3 (0.01)	0.40 (0.5285)
cardiac &/or acute MI	373 (1.02)	522 (0.97)	0.55 (0.4600)
peripheral vascular	105 (0.29)	137 (0.25)	0.86 (0.3543)
op wound	70 (0.19)	170 (0.32)	12.76 (0.0004)
postop infection	341 (0.93)	502 (0.93)	0.00 (0.9910)
other specified	376 (1.02)	389 (0.72)	24.13 (<0.0001)
CSF leak	69 (0.19)	94 (0.17)	0.23 (0.6279)
carotid or vertebral artery injury	857 (2.34)	1311 (2.43)	0.81 (0.3667)
hoarseness due to paralysis of vocal cords	135 (0.37)	171 (0.32)	1.70 (0.1928)
dysphagia	742 (2.02)	897 (1.66)	15.97 (<0.0001)

*Values are number of complications (%) unless noted otherwise. MI = myocardial infarction.

Table 9

Complication types of brain tumor and cerebrovascular patients in nonteaching hospitals by time period

Parameter	Value*		Test statistic (p value)
	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	
total no. of complications (%)	1035 (12.06)	1045 (10.43)	12.41 (0.0004)
mean no. of complications/patient (± SD)	0.1 ± 0.42	0.1 ± 0.39	3.39 (0.0007)
complications by type			
accidental puncture or laceration	45 (0.52)	62 (0.62)	0.72 (0.3965)
hematoma (intraop or postop)	153 (1.78)	135 (1.35)	5.76 (0.0164)
medical care or postop nervous system	135 (1.57)	142 (1.42)	0.77 (0.3807)
postop respiratory	139 (1.62)	81 (0.81)	26.05 (<0.0001)
foreign body inadvertently left in wound	1 (0.01)	3 (0.03)	0.72 (0.3965)
therapeutic misadventure, NEC	3 (0.03)	12 (0.12)	4.12 (0.0423)
therapeutic misadventure, surgical treatment	1 (0.01)	1 (0.01)	0.01 (0.9126)
cardiac &/or acute MI	9 4 (1.10)	82 (0.82)	3.79 (0.0516)
peripheral vascular	25 (0.29)	24 (0.24)	0.47 (0.4917)
op wound	15 (0.17)	38 (0.38)	6.80 (0.0091)
postop infection	69 (0.80)	105 (1.05)	2.96 (0.0852)
other specified	100 (1.17)	78 (0.78)	7.30 (0.0069)
CSF leak	15 (0.17)	18 (0.18)	0.01 (0.9379)
carotid or vertebral artery injury	205 (2.39)	211 (2.11)	1.70 (0.1926)
hoarseness due to paralysis of vocal cords	14 (0.16)	13 (0.13)	0.36 (0.5506)
dysphagia	198 (2.31)	219 (2.18)	0.31 (0.5755)

*Values are number of complications (%) unless noted otherwise.

Table 10

Complication types of brain tumor and cerebrovascular patients in teaching hospitals by time period

Parameter	Value*		Test statistic (p value)
	Pre–Duty Hour Restriction: 2000–2002	Post–Duty Hour Restriction: 2005–2008	
total no. of complications (%)	3313 (11.80)	5221 (11. 8 8)	0.12 (0.7270)
mean no. of complications/patient (± SD)	0.1 ± 0.44	0.1 ± 0.42	3.39 (0.0007)
complications by type			
accidental puncture or laceration	194 (0.69)	316 (0.72)	0.20 (0.6572)
hematoma (intraop or postop)	451 (1.61)	767 (1.75)	2.01 (0.1559)
medical care or postop nervous system	741 (2.64)	1323 (3.01)	8.55 (0.0035)
postop respiratory	291 (1.0 4)	335 (0.76)	14.90 (0.0001)
foreign body inadvertently left in wound	1 (0.00)	10 (0.02)	4.14 (0.0420)
therapeutic misadventure, NEC	9 (0.03)	48 (0.11)	12.91 (0.0003)
therapeutic misadventure, surgical treatment	—	2 (0.00)	1.28 (0.2582)
cardiac &/or acute MI	279 (0.99)	440 (1.00)	0.01 (0.9162)
peripheral vascular	80 (0.28)	113 (0.26)	0.49 (0.4835)
op wound	55 (0.20)	132 (0.30)	7.24 (0.0071)
postop infection	272 (0.97)	397 (0.90)	0.79 (0.3755)
other specified	275 (0.98)	311 (0.71)	15.63 (<0.0001)
CSF leak	54 (0.19)	76 (0.17)	0.35 (0.5517)
carotid or vertebral artery injury	652 (2.32)	1100 (2.50)	2.39 (0.1221)
hoarseness due to paralysis of vocal cords	121 (0.43)	158 (0.36)	2.25 (0.1333)
dysphagia	544 (1.94)	678 (1.54)	15.94 (<0.0001)

*Values are number of complications (%) unless noted otherwise.

Table 11

Multivariate logistic regression of complications for brain tumor and cerebrovascular patients

Parameter	Test Statistic (p value)	OR (95% CI)
time (1 yr)	15.2 (<0.0001)	0.95 (0.92–0.97)
age (10 yrs)	2.3 (0.1306)	1.02 (1.00–1.04)
sex		
female	0.7 (0.4190)	reference
male		1.02 (0.97–1.07)
CCI		
0	380.8 (<0.0001)	reference
1		1.57 (1.46–1.69)
2		1.01 (0.94–1.09)
>3		1.90 (1.75–2.07)
primary payer		
Medicare	70.4 (<0.0001)	reference
Medicaid		1.01 (0.91–1.11)
private insurance		0.83 (0.78–0.88)
self-pay		0.78 (0.69–0.89)
no charge		0.77 (0.48–1.23)
other		0.86 (0.75–0.98)
bedsize		
small	0.1 (0.9453)	reference
medium		1.01 (0.85–1.20)
large		1.03 (0.86–1.24)
hospital location		
rural	0.8 (0.3779)	reference
urban		1.13 (0.86–1.48)
hospital region		
Northeast	23.7 (<0.0001)	reference
Midwest		0.97 (0.87–1.10)
South		0.87 (0.78–0.98)
West		1.17 (1.03–1.32)
hospital discharges × 10^2	2.5 (0.1107)	1.00 (1.00–1.00)
median income		
low	3.1 (0.3826)	reference
low to middle		0.94 (0.88–1.02)
middle to high		0.95 (0.89–1.02)

Parameter	Test Statistic (p value)	OR (95% CI)
high		0.97 (0.90–1.04)
teaching status		
nonteaching	0.9 (0.3434)	reference
teaching		0.96 (0.84–1.11)
time period		
pre–duty hour restriction: 2000–2002	4.8 (0.0288)	reference
post–duty hour restriction: 2005–2008		1.11 (0.91–1.37)
interaction (time period, teaching status)	4.2 (0.0401)	

Table 12
Effect of time period on complications, mortality, LOS, and patient charges

Parameter	OR/RR (95% CI)	p Value
complications		
time period effect given teaching	1.33 (1.11–1.59)	0.0022
time period effect given nonteaching	1.11 (0.91–1.37)	0.3072
interaction (time period, teaching st at us)		0.0401
mortality		
time period effect given teaching	0.83 (0.62–1.12)	0.2326
time period effect given nonteaching	0.76 (0.55–1.04)	0.0856
interaction (time period, teaching st at us)		0.4009
LOS		
time period effect given teaching	0.93 (0.87–1.00)	0.0619
time period effect given nonteaching	0.87 (0.80–0.95)	0.0022
interaction (time period, teaching st at us)		0.0545
patient charges		
time period effect given teaching	1.07 (1.00–1.14)	0.0645
time period effect given nonteaching	1.01 (0.92–1.11)	0.7889
interaction (time period, teaching st at us)		0.1726

Table 13

Multivariate logistic regression for mortality for brain tumor and cerebrovascular patients

Parameter	Test Statistic (p value)	OR (95% CI)
time (1 yr)	3.0 (0.0837)	0.96 (0.92–1.01)
age (10 yrs)	107.0 (<0.0001)	1.20 (1.16–1.25)
sex		
female	8.6 (0.0033)	reference
male		0.88 (0.81–0.96)
CCI		
0	592.3 (<0.0001)	reference
1		7.43 (6.21–8.88)
2		3.90 (3.26–4.67)
≥3		6.60 (5.55–7.85)
primary payer		
Medicare	76.1 (<0.0001)	reference
Medicaid		1.35 (1.14–1.60)
private insurance		0.89 (0.79–1.00)
self-pay		1.86 (1.52–2.29)
no charge		1.55 (0.78–3.07)
other		1.31 (1.01–1.71)
bedsize		
small	2.0 (0.3666)	reference
medium		1.23 (0.92–1.63)
large		1.19 (0.89–1.58)
hospital location		
rural	3.5 (0.0606)	reference
urban		1.38 (0.99–1.92)
hospital region		
Northeast	2.5 (0.4772)	reference
Midwest		0.93 (0.78–1.11)
South		0.88 (0.75–1.04)
West		0.94 (0.79–1.12)
hospital discharges ($\times 10^2$)	1.7 (0.1871)	1.00 (1.0 0–1.0 0)
median income		
low	19.7 (0.0002)	reference
low to middle		0.85 (0.74–0.96)
middle to high		0.82 (0.72–0.95)

Parameter	Test Statistic (p value)	OR (95% CI)
high		0.73 (0.64–0.84)
teaching status		
nonteaching	5.5 (0.0191)	reference
teaching		0.85 (0.74–0.97)
time period		
pre–duty hour restriction: 2000–2002	2.0 (0.1523)	reference
post–duty hour restriction: 2005–2008		0.81 (0.61–1.08)

Table 14
Multivariate Poisson regression of LOS for brain tumor and cerebrovascular patients

Parameter	Test Statistic (p value)	RR (95% CI)
time (1 yr)	0.0 (0.8882)	1.00 (0.99–1.01)
age (10 yrs)	10.1 (0.0015)	1.02 (1.01–1.03)
sex		
female	16.9 (<0.0001)	reference
male		0.97 (0.95–0.98)
primary payer		
Medicare	379.5 (<0.0001)	reference
Medicaid		1.25 (1.20–1.31)
private insurance		0.90 (0.88–0.93)
self-pay		1.20 (1.11–1.29)
no charge		1.07 (0.90–1. 26)
other		1.03 (0.95–1.10)
CCI		
0	2054.1 (<0.0001)	reference
1		1.70 (1.65–1.74)
2		1.38 (1.34–1.42)
≥3		1.81 (1.76–1.87)
bedsize		
small	9.8 (0.0075)	reference
medium		1.06 (0.97–1.16)
large		1.14 (1.04–1.26)
hospital location		
rural	0.0 (0.8903)	reference
urban		1.01 (0.92–1.10)
hospital region		
Northeast	33.5 (<0.0001)	reference
Midwest		0.83 (0.78–0.89)
South		0.89 (0.83–0.95)
West		0.84 (0.79–0.90)
hospital discharges ($\times 10^2$)	5.7 (0.0173)	1.00 (1.0 0–1.00)
median income		
low	37.1 (<0.0001)	reference
low to middle		0.97 (0.94–0.99)
middle to high		0.94 (0.92–0.97)
high		0.91 (0.89–0.94)

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Parameter	Test Statistic (p value)	RR (95% CI)
complication count	2085.7 (<0.0001)	1.59 (1.56–1.62)
teaching status		
nonteaching	9.1 (0.0025)	reference
teaching		1.13 (1.04–1.22)
time period		
pre–duty hour restriction: 2000–2002	5.2 (0.0227)	reference
post–duty hour restriction: 2005–2008		0.92 (0.86–0.99)

Table 15

Multivariate log linear regression of adjusted patient charges of brain tumor and cerebrovascular patients

Parameter	Test Statistic (p value)	Exp Beta (95% CI)
time (1 yr)	46.9 (<0.0001)	1.05 (1.04–1.07)
age (10 yrs)	7.5 (0.0063)	1.01 (1.00–1.01)
sex		
female	45.8 (<0.0001)	reference
male		0.97 (0.96–0.98)
primary payer		
Medicare	247.8 (<0.0001)	reference
Medicaid		1.14 (1.11–1.17)
private insurance		0.98 (0.96–1.00)
self-pay		1.20 (1.14–1.26)
no charge		1.05 (0.94–1.17)
other		1.04 (1.00–1.08)
CCI		
0	1335.8 (<0.0001)	reference
1		1.50 (1.46–1.54)
2		1.25 (1.22–1.28)
≥3		1.51 (1.47–1.55)
bedsize		
small	2.5 (0.2874)	reference
medium		1.05 (0.98–1.12)
large		1.07 (0.98–1.16)
hospital location		
rural	0.0 (0.9860)	reference
urban		1.00 (0.89–1.12)
hospital region		
Northeast	137.9 (<0.0001)	reference
Midwest		0.96 (0.89–1.05)
South		0.89 (0.81–0.97)
West		1.43 (1.29–1.58)
hospital discharges ($\times 10^2$)	0.1 (0.7551)	1.00 (1.00–1.00)
median income		
low	37.1 (<0.0001)	reference
low to middle		0.99 (0.98–1.01)
middle to high		0.97 (0.96–0.98)

Parameter	Test Statistic (p value)	Exp Beta (95% CI)
high		0.96 (0.94–0.97)
complication (1 unit)	1559.1 (<0.0001)	1.51 (1.48–1.54)
teaching status		
nonteaching	0.8 (0.3777)	reference
teaching		1.04 (0.96–1.12)
time period		
pre–duty hour restriction: 2000–2002	2.5 (0.1172)	reference
post–duty hour restriction: 2005–2008		1.06 (0.99–1.13)