Regional trends and the impact of various patient and hospital factors on outcomes and costs of hospitalization between academic and nonacademic centers after deep brain stimulation surgery for Parkinson's disease: a United States Nationwide Inpatient Sample analysis from 2006 to 2010

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Object. The aim of this study was to analyze the incidence of adverse outcomes, complications, inpatient mortality, length of hospital stay, and the factors affecting them between academic and nonacademic centers after deep brain stimulation (DBS) surgery for Parkinson's disease (PD). The authors also analyzed the impact of various factors on the total hospitalization charges after this procedure.

Methods. This is a retrospective cohort study using the Nationwide Inpatient Sample (NIS) from 2006 to 2010. Various patient and hospital variables were analyzed from the database. The adverse discharge disposition and the higher cost of hospitalization were taken as the dependent variables.

Results. A total of 2244 patients who underwent surgical treatment for PD were identified from the database. The mean age was 64.22 ± 9.8 years and 68.7% (n = 1523) of the patients were male. The majority of the patients was discharged to home or self-care (87.9%, n = 1972). The majority of the procedures was performed at high-volume centers (64.8%, n = 1453), at academic institutions (85.33%, n = 1915), in urban areas (n = 2158, 96.16%), and at hospitals with a large bedsize (86.6%, n = 1907) in the West or South. Adverse discharge disposition was more likely in elderly patients (OR > 1, p = 0.011) with high comorbidity index (OR 1.508 [95% CI 1.148–1.98], p = 0.004) and those with complications (OR 3.155 [95% CI 1.202–8.279], p = 0.033). A hospital with a larger annual caseload was an independent predictor of adverse discharge disposition (OR 3.543 [95% CI 1.781–7.048], p < 0.001), whereas patients treated by physicians with high case volumes had significantly better outcomes (p = 0.006). The median total cost of hospitalization had increased by 6% from 2006 through 2010. Hospitals with a smaller case volume (OR 0.093, p < 0.001), private hospitals (OR 11.027, p < 0.001), nonteaching hospitals (OR 3.139, p = 0.003), and hospitals in the West compared with hospitals in Northeast and the Midwest (OR 1.885 [p = 0.033] and OR 2.897 [p = 0.031], respectively) were independent predictors of higher hospital cost. The mean length of hospital stay decreased from 2.03 days in 2006 to 1.55 days in 2010. There was no difference in the discharge disposition among academic versus nonacademic centers and rural versus urban hospitals (p > 0.05).

Conclusions. Elderly female patients with nonprivate insurance and high comorbidity index who underwent surgery at low-volume centers performed by a surgeon with a low annual case volume and the occurrence of post-operative complications were correlated with an adverse discharge disposition. High-volume, government-owned academic centers in the Northeast were associated with a lower cost incurred to the hospitals. It can be recommended that the widespread availability of this procedure across small, academic centers in rural areas may not only provide easier access to the patients but also reduces the total cost of hospitalization.

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KEY WORDS • outcome • deep brain stimulation • surgery • regional • parkinson disease • hospitalization cost • Nationwide Inpatient Sample

BUCY and Case proposed the first surgical treatment for Parkinson's disease (PD) in 1939 when they excised the motor cortex to relieve tremors associated with this condition.⁵ However, with the introduction of levodopa therapy in 1967, the surgical treatment of PD

was largely abandoned.^{7,8} With an improved understanding of the basal ganglia pathophysiology and a better control of all motor symptoms of PD, pallidotomy was successfully reintroduced in 1992 for the management of drug-resistant or refractory PD.^{15,16} With the advent of deep brain stimulation (DBS) for PD in the last decade, lesional surgery has again fallen out of favor, and DBS has become the treatment of choice for refractory or advanced PD. Reversibility of side effects and the ability

Abbreviations used in this paper: DBS = deep brain stimulation; LOS = length of stay; NIS = Nationwide Inpatient Sample; OTR = other than routine; PD = Parkinson's disease.

to treat bilaterally and to optimize the treatment during programming are the key advantages of DBS over lesioning.^{14,20}

Other indications of DBS are dystonia and tremor in movement disorders, depression, obsessive-compulsive disorder, and Tourette's syndrome in psychiatry, epilepsy, cluster headache, pain from stroke, amputation, trigeminal neuralgia, and multiple sclerosis.^{1,12,17,21} The targets for DBS electrode implantation include globus pallidus internus and subthalamic nucleus for the treatment of refractory PD, pedunculopontine nucleus for the management of gait disorder in PD, the ventral intermediate nucleus of the thalamus for refractory essential tremors and globus pallidus internus for the treatment of dystonia.^{10,14,20,21,27,28}

Being a widely used treatment modality, it is important to understand the various patient and hospital-related factors that can affect outcome after DBS surgery for PD. It is also prudent to be aware of the practice patterns and regional variations associated with this procedure. To address these issues, we analyzed the Nationwide Inpatient Sample (NIS) to study the outcomes and socioeconomic trends of the DBS procedure for PD. Eskandar et al. showed that the large-volume hospitals had superior short-term outcomes and lower total cost of hospitalization following DBS surgery for PD, using the nationwide sample from 1996 to 2000.¹⁰ The aim of our study was to analyze the incidence of adverse outcomes, complications, inpatient mortality, length of hospital stay, and the factors affecting them between academic and non-academic centers after DBS surgery for PD using the US NIS from 2006 to 2010. We also analyzed the impact of various factors on the total hospitalization charges after this procedure.

Methods

Data Source and the Study Sample

Data were obtained from the NIS database, which is provided by the Healthcare Cost and Utilization Project (HCUP) Agency For Healthcare Research and Quality (AHRQ).^{9,25} This database represents an approximately 20% stratified sample of nonfederal community hospitals in the US. The NIS is the largest all-payer inpatient care database and contains data on 5–8 million hospital admissions from about 1000 hospitals in 45 states.

The data for PD from 2006 to 2010 were extracted from the NIS using the ICD-9 CM (International Classification of Diseases, 9th revision, Clinical Modification) diagnosis and treatment codes. In concordance with a previous study, all admissions with a primary diagnosis code of 332.0 (PD) or 332.1 (secondary parkinsonism) were included only when they were accompanied by the primary procedure codes for thalamotomy (ICD-9 CM code 01.41), pallidotomy (ICD-9 CM code 01.42), or implantation of a neurostimulator (ICD-9 CM code 02.93).¹⁰ Patients who underwent stereotactic radiosurgery (ICD-9 CM codes 92.30–92.33 and 92.39) for PD were excluded from this study, although this proportion constituted only 0.13% of all surgical admissions.

Patient and Hospital Characteristics

Patient Characteristics. Patient age, race, sex, primary payer (Medicare, Medicaid, private insurance, self-pay, no charge, or other), type of admission (emergency, urgent, or elective), day of admission (weekend/weekday), and median household income for patient ZIP code (ZIP-INC_QRTL) were extracted directly from the NIS.

The following variables were recoded into different categories to further aid in our analysis: 1) Patient age was categorized into ≤ 65 years and > 65 years. 2) Race was recoded as white, black, and other for the statistical analysis. This variable was missing in 22.9% of admissions. 3) Comorbidities were classified using the Charlson's Index and were dichotomized (low comorbidity [0 or 1] vs high ≥ 2) for the analysis.⁶ 4) Specific complications following the surgical treatment of patients with PD were extracted using the following ICD-CM diagnosis codes: a) postoperative infarction/hemorrhage (997.00–997.02 and 997.09); b) postoperative bleeding/hematoma/seroma complicating a procedure (998.1 and 998.11–998.13); c) mechanical complication of nervous system device, implant, and graft (996.2); d) infections due to nervous system device, implant, and graft (996.63); and e) removal of intracranial neurostimulator lead (01.22). Patients were then grouped into those with and without complications. 5) Type of admission was recoded as elective and non-elective for the analysis. Missing values in the variables were not taken into consideration for the analysis.

Hospital Characteristics. Hospital region (Northeast, Midwest, South, or West), hospital location (rural or urban), teaching status, hospital bed size (small, medium, or large), and hospital control (government, private non-profit, private, and investor owned) were coded in the NIS database. Hospital control was recoded into government and private for analysis. The number of cases at each hospital (hospital volume) was extracted from the NIS using the hospital identification number (HOSPID). Percentiles were calculated, and hospitals with case volumes greater than the 75th percentile were categorized into high-volume centers and recoded as high- and low-volume centers for analysis. Similarly, the number of surgically managed cases of PD for each surgeon (where available) were extracted from the NIS and were grouped into quartiles for analysis (1st quartile, 1 case; 2nd quartile, 2–3 cases; 3rd quartile, 4–12 cases; and 4th quartile, 13 or more cases). Both hospital and surgeon volume of cases showed significant positively skewed distribution, and therefore the logistic regression model was used while evaluating these variables for analysis.

Outcome Factors

The primary adverse end points in our study were discharge disposition to facilities other than home/self-care (DISPUniform), inhospital mortality, hospital length of stay (LOS), complications, and total hospital charges. As mentioned in the NIS, discharge disposition to home was considered as routine and discharges to all other places (transfer to short-term hospital, skilled nursing facility, intermediate care facility, another type of facil-

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ity, home health care, against medical advice, and death) were recoded as other than routine (OTR) disposition. The total cost of hospitalization was extracted using the variable total charges (TOTCHG) in the NIS, and percentiles were calculated. The total cost of hospitalization greater than the 75th percentile (\$75,612.00) was recoded as high cost and the rest as low cost (< 75th percentile) for the analysis. Hospital LOS was also extracted from the NIS and was stratified according to the calendar year and the hospital region.

Statistical Analysis

Statistical Analysis was carried out using SPSS (version 21, IBM, Inc.) and Microsoft Excel. The chi-square and Pearson's correlation tests were used to evaluate the association between the categorical variables. For non-parametric analysis, the Kruskal-Wallis test was used to compare the mean total hospital charges across the different categories of ordinal data. Comparisons were considered significant only if the p value was < 0.05. Univariate analysis was used to identify the covariates that might affect the outcome. Binary logistic regression analysis was used for the multivariate analysis to generate the probability value, odds ratio, and confidence interval. Two-tailed probability values were recorded. Variables with p < 0.1 in the univariate analysis were considered for the multivariate analysis. Discharge disposition, hospital charges, and inhospital mortality were the dependent variables used in the analysis.

Results

Of 14,291 admissions with a diagnosis of PD in the database from 2006 to 2010, 2244 (15.7%) patients underwent surgical treatment of PD. Of these 2244 patients, only 5 (0.2%) had a diagnosis of secondary PD. Implantation of the intracranial neurostimulator was the most frequently used procedure in 99.3% (n = 2228) of the surgically treated patients. Other rare procedures such as thalamotomy, pallidotomy, and stereotactic radiosurgery were used in 0.3% (n = 7), 0.3% (n = 6), and 0.13% (n = 3) of the patients. The clinical characteristics of the patients who underwent surgical treatment of PD are shown in Table 1. The mean patient age was 64.22 ± 9.8 years (range 23–92 years); 49.6% (n = 1108) of the patients were older than 65 years. Overall, 68.7% (n = 1523) of the patients were male, and white was the dominant race (64.8%, n = 1454). Medicare was the primary payer for 62.8% (n = 1405) of the patients, whereas private insurance was the primary payer for only 32.1% (n = 718) of the cases. For median household income for the ZIP code, 18.8% (n = 411) and 28.4% (n = 622) of the patients were in the 1st quartile and the 4th quartile, respectively. Of admissions, 97.7% (n = 2193) were on weekdays and 80.21% (n = 1800) were an elective type. Overall, 74.3% (n = 1667) of the patients had 1 or fewer comorbidities, and only 1.02% (n = 23) of the patients experienced 1 or more complications after the procedure with the most common being postoperative hemorrhage or infarction (0.44%, n = 10) (Table 1). The annual case volume increased from 418 in

TABLE 1: Patient and hospital characteristics for 2244 patients who underwent surgical treatment for PD between 2006 and 2010 in the US*

Characteristic	Value
age in yrs	
mean ± SD	64.22 ± 9.803
median (range)	65.00 (23–92)
interquartile range	58–71
sex	
male	1523 (68.7)
female	694 (31.3)
race	
white	1454 (64.8)
black	20 (0.9)
Hispanic	133 (5.9)
Asian or Pacific Islander	44 (2.0)
Native American	5 (0.2)
other	75 (3.3)
missing	513 (22.9)
primary expected payer (uniform)	
Medicare	1405 (62.8)
Medicaid	44 (2.0)
private	718 (32.1)
self-pay	14 (0.6)
no charge	3 (0.1)
other	52 (2.3)
median household income quartile for pt's ZIP code	
\$1–38,999	411 (18.8)
\$39,000–47,999	561 (25.6)
\$48,000–62,999	595 (27.2)
≥\$63,000	622 (28.4)
hospital bedsize	
small	139 (6.3)
medium	156 (7.1)
large	1907 (86.6)
hospital vol	
high	1453 (64.8)
low	791 (35.2)
comorbidity index	
high	577 (25.7)
low	1667 (74.3)
treatment period	
2006	418 (18.6)
2007	368 (16.4)
2008	418 (18.6)
2009	463 (20.6)
2010	577 (25.7)
discharge	
routine	1972 (87.9)
OTR	272 (12)

(continued)

TABLE 1: Patient and hospital characteristics for 2244 patients who underwent surgical treatment for PD between 2006 and 2010 in the US (continued)*

Characteristic	Value
mean LOS in days	
Northeast	1.85
Midwest	2.31
South	1.69
West	1.74
overall	1.83
in-hospital mortality	
Northeast	2 (0.55)
Midwest	0 (0)
South	0 (0)
West	2 (0.26)
overall	4 (0.17)
overall complications	
neurological including postop hemorrhage/infarction	10 (0.44)
hemorrhage/hematoma/seroma complicating a procedure	4 (0.17)
mechanical complication of nervous system device/implant	5 (0.2)
infection due to nervous system implant	1 (0.4)
removal of intracranial neurostimulator lead	3 (0.13)
total	23 (1.02)
procedure type	
thalamotomy	7 (0.3)
pallidotomy	6 (0.3)
implantation of intracranial neurostimulator	2228 (99.3)

* Values are number of patients (%) unless otherwise noted. pt = patient.

2006 to 577 in 2010 (Fig. 1). The majority of the patients was discharged to home or self-care (87.9%, $n = 1972$). The inpatient hospital mortality rate was only 0.17% ($n = 4$) during the study period with none in the years 2008 and 2010 and 1 each in the years 2006 and 2009.

Patient Characteristics and Adverse Discharge Disposition (OTR)

Overall, 12% ($n = 272$) of the patients had an adverse discharge disposition. In univariate analysis, advanced patient age at admission (> 65 years) and female sex showed a positive correlation with the adverse discharge disposition ($p < 0.05$). In contrast, private insurance, lower comorbidity index, and absence of complications showed a negative correlation with the adverse discharge disposition (OTR) ($p < 0.05$). Adverse discharge disposition was 1.5 times more likely in patients with a high comorbidity index (OR 1.508 [95% CI 1.148–1.98], $p = 0.004$) and 3 times more likely in patients with complications (OR 3.155 [95% CI 1.202–8.279], $p = 0.033$) (Table 2).

In multivariate regression analysis, elderly patients were more likely to have adverse outcomes when com-

FIG. 1. Graph showing the trends in the number of DBS surgeries for PD from 2006 to 2010.

pared with those younger than 65 years of age (OR 1.596 [95% CI 1.112–2.289], $p = 0.011$). Sex, race, high comorbidity index, presence of complications, type of insurance, and median household income did not show significant correlation with OTR discharges in the multivariate model (Table 3). Of these factors, only advanced age was an independent predictor of OTR discharge dispositions (Fig. 2).

Hospital Characteristics and Adverse Discharge Disposition

The surgical procedures for PD were performed at 150 hospitals by 91 identified surgeons in the database during the study period. The majority of the procedures were performed at centers with high case volume (64.8%, $n = 1453$), at academic institutions (85.33%, $n = 1915$), in urban areas ($n = 2158$, 96.16%), and at hospitals with a large bedsize (86.6%, $n = 1907$) in the West or South (Table 4).

Hospitals with a large bedsize showed a positive correlation with the favorable discharge disposition compared with the hospitals with medium or smaller bedsize ($p < 0.05$). Similarly, hospitals with high case volumes had a small number of patients with OTR discharge disposition than those with low case volumes (9.8% vs 16.3%, $p < 0.001$). Moreover, hospitals with a higher annual caseload were 3.5 times more likely to have a favorable discharge disposition than those with lower case volume (OR 3.543 [95% CI 1.781–7.048], $p < 0.001$), and this was an independent predictor of adverse discharge disposition (Table 5). There was no significant difference in the in-hospital mortality rates between the high- (4th quartile) and low-volume centers (0.2% vs 0.12%, $p = 0.734$). Any complication (neurological, mechanical/de-

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TABLE 2: Patient and demographic factors affecting adverse discharge disposition (OTR) in patients who underwent surgical treatment for PD

Variable	No. of Pts		Total	p Value*
	Routine	OTR		
age in yrs				<0.001
≤65	1027	99	1126	
>65	935	173	1108	
sex				0.009
male	1355	168	1523	
female	592	102	694	
race				0.176
white	1272	182	1454	
black	15	5	20	
other	229	28	257	
primary expected payer (uniform)				<0.001
Medicare	1200	205	1405	
Medicaid	39	5	44	
private	666	52	718	
self-pay	11	3	14	
no charge	3	0	3	
other	47	5	52	
median household income quartile for pt ZIP code				0.736
\$1–38,999	360	51	411	
\$39,000–47,999	485	76	561	
\$48,000–62,999	526	69	595	
≥\$63,000	549	73	622	
complications				0.033
no	1958	266	1958	
yes	14	6	14	
comorbidity index				0.004
low	1485	182	1667	
high	487	90	577	

* Values in boldface are statistically significant.

vice related, hematoma, infectious and requiring device removal) occurred in 1.2% (n = 18) of 1453 procedures performed at hospitals in the 4th quartile compared with 0.97% (n = 1) of 103 procedures performed at hospitals in the 1st quartile (p = 0.90). The hospital control, teaching status, hospital region, day of admission, admission type, and location of the hospital had no influence on the adverse discharge disposition (p > 0.05). In adjusted multivariate analysis, higher hospital caseload and government hospitals showed a significant correlation with favorable discharge outcomes. Similar to the effect of hospital caseload, the surgeon annual caseload had a positive correlation with the favorable discharge disposition. The procedures performed by surgeons with higher annual caseloads (4th quartile) had a better discharge disposition than those with lower case volumes (1st quartile) (p = 0.006); however, after adjustment for region, hospital bedsize, hospital location, admission day and type, there was no influence of surgeon caseload on discharge disposition. There was no significant correlation between

surgeon case volume and complication rates (p = 0.58) or surgeon case volume and inpatient mortality rates (p = 0.70) (Figs. 3 and 4).

Costs of Hospitalization and LOS

The mean total cost of hospitalization increased from \$56,534.30 in 2006 to \$59,875.27 in 2010 with the overall mean expenditure of \$61,362.93 ± \$36,016.21. Table 6 shows a difference of means in the total expenditure in different years that was found to be statistically significant (p < 0.001) using the Kruskal-Wallis test. The difference in mean hospital charges between hospitals with larger case volumes versus smaller case volumes (\$57,079.44 vs \$69,531.83), larger bedsize versus smaller bedsize hospitals (\$62,262.62 vs \$64,513.63), government versus private (\$61,239.29 vs \$65,849.29), teaching versus nonteaching hospitals (\$60,990.98 vs \$66,633.65), urban versus rural location (\$61,830.09 vs \$57,461.95), and elective versus nonelective admission type (\$56,568.88 vs \$82,571.73) was significant (p < 0.05) (Table 6). Among hospital re-

TABLE 3: Multivariate binary logistic regression analysis showing various patients and demographic factors affecting the adverse discharge disposition (OTR)

Variable*	B Value	p Value†	OR	95% CI	
				Lower Limit	Upper Limit
age (≤ 65 yrs)	0.467	0.011	1.596	1.112	2.289
sex (female)	0.310	0.048	1.364	1.003	1.856
race compared w/ white					
black	0.710	0.230	2.035	0.638	6.495
other	-0.067	0.768	0.935	0.599	1.460
primary expected payer compared w/ private insurance					
Medicare	0.278	0.183	1.320	0.877	1.989
Medicaid	0.209	0.710	1.233	0.410	3.706
median household income quartile for pt ZIP code					
<\$38,999 compared w/ others					
\$39,000–47,999	0.105	0.653	1.111	0.701	1.760
\$48,000–62,999	-0.013	0.955	0.987	0.624	1.560
$\geq 63,000$	-0.034	0.885	0.967	0.612	1.527
complications (yes)	1.052	0.083	2.862	0.871	9.401
comorbidity index (high)	0.270	0.103	1.310	0.947	1.813

* The dependent variable was an adverse discharge disposition (outcome) and the various factors mentioned were covariates.

† The value in boldface is statistically significant.

gions, the West was associated with the highest cost of hospitalization whereas the South and the Northeast had the lowest total hospital charges (\$68,698.52, \$54,081.31, and \$58,678.28, $p < 0.001$). Day of admission, higher comorbidity index, and occurrence of complications had no effect on the mean total hospital charges ($p > 0.05$). Similar to the hospital case volume, surgeon case volume had an influence on the total hospital charges while those in the 4th quartile had the lowest cost of hospitalization

Fig. 2. Bar graphs showing the impact of postoperative complications and high comorbidity index on adverse discharge disposition after DBS surgery for PD from 2006 to 2010.

compared with those in the 1st quartile (\$51,922.31 vs \$71,336.32, $p < 0.001$). As mentioned in *Methods*, this variable was further dichotomized into high (> 75 th percentile) and low cost of hospitalization. None of the patient factors (age, sex, race, type of insurance, median income, complications, and comorbidities) had an influence on the total cost of hospitalization in both univariate and multivariate analyses (Table 7). Among hospital factors, the following factors were found to be independent predictors of higher hospital cost: hospitals with a lower case volume (OR 0.093, $p < 0.001$), private hospitals (OR 11.027, $p < 0.001$), nonteaching hospitals (OR 3.139, $p = 0.003$), and hospitals in the West compared with those in the Northeast and Midwest (OR 1.885 [$p = 0.033$] and OR 2.897 [$p = 0.031$], respectively). Nonelective admissions were associated with higher total hospital charges than elective admissions ($p < 0.001$), whereas the day of admission and the hospital bedsize had no influence on the total cost of hospitalization ($p = 0.127$ and 0.145 , respectively). Surgeons with case volumes in the 4th quartile had a lower cost incurred to the hospitals than those in the lower quartiles ($p < 0.001$) (Tables 8 and 9 and Fig. 5), from 2.03 days in 2006 to 1.55 days in 2010 (Fig. 6). The mean LOS was highest in the Midwest (2.31 days) with the overall mean stay of 1.83 days. Surprisingly, the annual hospital caseload had no influence on hospital LOS ($p = 0.990$), whereas hospitals with smaller bedsize and surgeons with higher annual case volume were associated with a shorter hospital stay than hospitals with larger bedsize and surgeons with the lower annual case volume ($p = 0.016$ and $p = 0.003$, respectively). Similarly private hospitals had a shorter hospital stay than government hospitals ($p < 0.001$).

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TABLE 4: Hospital factors affecting adverse discharge disposition (OTR) following surgical management of patients with PD

Variable	No. of Pts		Total	p Value*
	Routine	OTR		
hospital bedsize				0.022
small	121	18	139	
medium	126	30	156	
large	1684	223	1907	
hospital vol				<0.001
high	1310	143	1453	
low	662	129	791	
hospital control				0.207
government	1731	236	1967	
private	200	35	235	
teaching status of hospital				0.101
nonteaching	243	44	287	
teaching	1688	227	1915	
location of hospital				0.483
rural	37	7	44	
urban	1894	264	2158	
hospital region				0.115
Northeast	310	53	363	
Midwest	293	50	343	
South	702	88	790	
West	667	81	748	
admission day				0.665
weekday	1928	265	2193	
weekend	44	7	51	
admission status				0.417
elective	1587	213	1800	
nonelective	385	59	444	
surgeon case vol				0.006
1st quartile	18	7	25	
2nd quartile	52	8	60	
3rd quartile	106	21	127	
4th quartile	595	63	658	

* Values in boldface are statistically significant.

Discussion

In our study, we analyzed a representative sample of 2244 patients who underwent surgical treatment for PD in the US from 2006 to 2010. In the previous study, Eskandar et al. reported the practice patterns, short-term outcomes, and total hospital charges after surgery for PD in the US from 1996 to 2000.¹⁰ Similarly Lad et al. studied the socioeconomic trends in DBS surgery for all indications using the NIS from 1993 to 2006.¹⁴ However, no study has focused on the demographic and hospital-related factors that can affect the discharge disposition and the total cost of hospitalization in the recent years.

The number of patients who underwent surgical treatment for PD in the US increased from 1761 in

1996–2000 to 2244 in 2006–2010 with an increase in the number of reporting hospitals and surgeons from 71 and 61 to 150 and 91, respectively.¹⁰ The choice of surgical procedure between ablative (pallidotomy and thalamotomy) and neurostimulation for PD underwent a paradigm shift in the last decade. In 1996 all procedures performed for PD were ablative in nature and changed to DBS (88% of the procedures) in 2000.¹⁰ In our study, 99.3% of the procedures performed for PD were DBS and only 0.6% of the procedures were ablative in nature. The incidence of adverse discharge disposition (OTR) had increased from 8.1% in 1996–2000 to 12% in 2006–2010; this is in contrast to the inhospital mortality rates, which had decreased from 0.2% to 0.17% during the same treatment periods.¹⁰ Similarly, compared with the results of an ear-

TABLE 5: Multivariate binary logistic regression analysis showing various hospital factors affecting adverse discharge disposition (OTR)

Variable*	B Value	p Value†	OR	95% CI	
				Lower Limit	Upper Limit
hospital bedsize compared w/ small					
medium	0.307	0.660	1.359	0.347	5.325
large	0.678	0.228	1.971	0.654	5.935
high hospital vol (yes)	1.265	<0.001	3.543	1.781	7.048
government hospital control	-2.016	0.004	0.133	0.034	0.524
teaching status of hospital (yes)	-0.352	0.469	0.703	0.271	1.826
urban location of hospital (yes)	-0.058	0.932	0.944	0.252	3.530
hospital region compared w/ West					
Northeast	-0.527	0.135	0.591	0.296	1.179
Midwest	-0.493	0.358	0.611	0.213	1.747
South	-0.352	0.283	0.703	0.370	1.338
weekend admission day (yes)	1.625	0.089	5.077	0.781	32.995
elective admission status (yes)	0.616	0.197	1.851	0.726	4.720
surgeon case vol compared w/ those in the 4th quartile					
1st quartile	0.887	0.089	2.429	0.874	6.747
2nd quartile	-0.249	0.607	0.780	0.303	2.009
3rd quartile	0.441	0.229	1.554	0.758	3.187

* The dependent variable was an adverse discharge disposition (outcome) and the various factors mentioned were covariates.

† Values in boldface are statistically significant.

lier study of surgically treated patients with PD in the US between 1996 and 2000, the incidence of postoperative neurological complications, hematoma complicating the procedure, and mechanical complications decreased from 1.5%, 0.5%, and 1% to 0.44%, 0.17%, and 0.2%, re-

spectively. Pilitis et al. reported that the in-hospital complications following DBS for PD or essential tremors in the US from 1998 to 2007 had decreased from 3.8% to 2.8%.²² In our study, only 1 patient (0.4%) developed DBS electrode/implant-related infection. However, since there is always a delay between implant surgery and the onset of infection, NIS-based studies may underestimate the

FIG. 3. Bar graphs showing the impact of hospital volumes (high vs low) and surgeon case volumes (by quartiles, 1st quartile, 1 case; 2nd quartile, 2 or 3 cases; 3rd quartile, 4–12 cases; and 4th quartile, 13 or more cases) on adverse discharge disposition following DBS surgery for PD from 2006 to 2010.

FIG. 4. Bar graphs showing the impact of hospital bedsize on adverse discharge disposition after DBS surgery for PD from 2006 to 2010.

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TABLE 6: Difference between the mean total hospital charges among various groups (Kruskal-Wallis test)

Variable	Mean Total Charges (\$)	p Value*
year of treatment		<0.001
2006	56,534.30	
2007	65,072.41	
2008	62,867.82	
2009	63,271.76	
2010	59,875.27	
complications		0.886
yes	59,109.32	
no	61,382.55	
comorbidity index		0.865
low	61,420.86	
high	61,193.16	
hospital bedsize		0.002
small	64,513.63	
medium	53,006.67	
large	62,262.62	
hospital control		0.020
government	61,239.29	
private	65,849.29	
teaching status of hospital		<0.001
nonteaching	66,633.65	
teaching	60,990.98	
location of hospital		0.001
rural	57,461.95	
urban	61,830.09	
hospital region		<0.001
Northeast	58,678.28	
Midwest	65,812.40	
South	54,081.31	
West	68,698.52	
admission day		0.901
weekday	61,492.37	
weekend	55,556.79	
admission type		<0.001
elective	56,568.88	
nonelective	82,571.73	
surgeon case vol		<0.001
1st quartile	71,336.32	
2nd quartile	63,347.05	
3rd quartile	63,590.17	
4th quartile	51,922.31	
hospital case vol		<0.001
1st quartile	69,531.83	
2nd quartile	66,292.80	
3rd quartile	70,099.02	
4th quartile	57,079.44	

* Values in boldface are statistically significant.

true incidence of this complication as the outcomes can be measured only at the time of discharge. Similarly, the mean LOS after DBS for PD had decreased from 2 days in 1996–2000 to 1.83 days in 2006–2010.¹⁰ These results reflect the advances in neurosurgical techniques, imaging modalities, intraoperative monitoring, and improvement in postoperative care.

Patient Factors and Outcome

Eskandar et al. showed that the young, male Caucasian patients with private insurance and higher median household income and fewer comorbidities were more likely to undergo implantation of neurostimulators than lesion therapy for PD in the US from 1996 to 2000.¹⁰ However, in our study from 2006 to 2010, DBS was performed equally in patients younger or older than 65 years of age (50.17% vs 49.37%), and the majority of patients had nonprivate insurance. Apart from these 2 variables the rest of the variables were in concordance with the previous study. Similarly Lad et al. showed that DBS was performed in 56% of males compared with 43% of females in the US from 1993 to 2006.¹⁴ In another study, patients with PD who underwent DBS in the 2007 in the US were older and had significantly higher comorbidities.²² These findings reflect a change in the pattern of DBS surgery for PD in the US, which initially used to be performed in younger healthier patients. The fact that the majority of DBS procedures for PD were performed in male Caucasian patients with a higher median income can be attributed to the biases by the treating physician or the patients themselves.¹⁰ In our study, favorable discharge disposition was seen in young, male patients with a private insurance, low comorbidity index, and without postoperative complications. In our study, inhospital mortality was seen in 8.69% of the patients with complications and in 0.09% of the patients without complications, which was statistically significant ($p < 0.001$). Therefore, appropriate measures to avoid them and prompt diagnosis and management of these complications cannot be overemphasized. Apart from these demographic factors, other described factors that can affect the outcome such as preoperative neurological status cannot be evaluated due to the limitations of using the NIS database.

Hospital Factors and Outcome

Similar to other studies, the majority of DBS procedures for PD were performed at large, high-volume, urban, and academic centers.^{10,14,22} However, contrary to the finding that 75.2% of the total DBS procedures in the US were performed at private nonprofit centers in 2006, the majority (87.6%) of the DBS procedures for PD were carried out at government-owned hospitals from 2006 to 2010 in the US.¹⁴ The concept of “volume effect” has been explained in earlier studies on the NIS and was extensively investigated for carotid endarterectomy and aneurysm surgery.^{2–4,10,11,13,19,23} Various studies have shown superior outcomes at high-volume centers and large bedsize hospitals. In concordance with this concept, our study showed that the hospitals with large bedsize and high case volumes were 1.7 and 3.5 times more likely to have

TABLE 7: Patient and demographic factors affecting total hospital charges after surgical treatment of PD

Variable	No. of Pts		Total	p Value
	High Cost (>75th percentile)	Low Cost		
age in yrs				0.136
≤65	262	841	1103	
>65	282	808	1090	
sex				0.209
male	375	1116	1491	
female	161	526	687	
race				0.643
white	373	1052	1425	
black	5	14	19	
other	72	176	248	
primary expected payer (uniform)				0.307
Medicare	352	1031	1383	
Medicaid	11	33	44	
private	165	533	698	
self-pay	6	8	14	
no charge	2	1	3	
other	13	39	52	
median household income quartile for pt ZIP code				0.735
\$1–38,999	102	305	407	
\$39,000–47,999	144	410	554	
\$48,000–62,999	136	449	585	
≥\$63,000	152	448	600	
complications				0.535
no	545	1637	2182	
yes	5	14	19	
comorbidity index				0.99
low	410	1231	1641	
high	140	420	560	

a favorable discharge disposition than those with small bedsize and low case volumes, respectively. However, the fact that high-volume centers are more likely to perform simultaneous bilateral implantation of DBS electrodes for PD may underestimate the total number of procedures performed and overestimate the risk of adverse outcomes per procedure at such centers. Similarly, transfer of postoperative patients to inpatient rehabilitation care may skew adverse discharge disposition to favor those hospitals where such facilities are available and cannot be coded separately in the NIS database. Therefore, due to the inherent limitations of the NIS database, these results should be cautiously interpreted. Similarly, surgeons with higher annual case volumes were less likely to have an adverse discharge disposition than those with lower case volumes ($p < 0.05$). These findings reinforce the fact that superior outcomes correlate with increased surgeon experience. However, the incidence of postoperative complications and in-hospital mortality was not different between high- and low-volume centers or between surgeons with high- and low-volume caseloads. This in contrast to the findings of Eskandar et al., who showed that

the mortality and neurological complications were more likely after surgery at low-volume centers than at high-volume centers. This difference can be attributed to the very low incidence of complications and mortality rates in recent years. There was no difference in the discharge disposition among academic versus nonacademic centers and rural versus urban hospitals. However, nonacademic centers were associated with a higher cost of hospitalization than academic centers, and there was no difference in the cost between rural and urban centers. Similar to the findings of Pilitsis et al. and Lad et al., the majority of the DBS procedures for PD were performed at hospitals in the West and South.^{14,22}

Hospital Factors and Costs

The cost of DBS surgery for PD increased from \$56,534.30 in 2006 to \$59,875.27 in 2010. This is in concordance with the finding of Lad et al. who reported that the hospital charges of DBS had gradually increased over a period of 14 years with a total expenditure of \$291 million in 2006.¹⁴ This may be either due to an overall increase in the cost of the technology or the hospital charges over this

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TABLE 8: Hospital factors affecting the total cost of hospitalization after surgical management of patients with PD

Variable	No. of Pts		Total	p Value*
	High Cost (75th percentile)	Low Cost		
hospital bedsize				0.145
small	35	98	133	
medium	29	125	154	
large	486	1386	1872	
hospital vol				<0.001
high	284	1134	1418	
low	266	517	783	
hospital control				0.001
government	468	1456	1924	
private	82	153	235	
teaching status of hospital				<0.001
nonteaching	102	185	287	
teaching	448	1424	1872	
location of hospital				0.490
rural	9	35	44	
urban	541	1574	2115	
hospital region				<0.001
Northeast	57	306	363	
Midwest	86	257	343	
South	167	621	788	
West	240	467	707	
admission day				0.127
weekday	543	1610	2153	
weekend	7	41	48	
admission status				<0.001
elective	349	1449	1798	
nonelective	201	202	403	
surgeon case vol				<0.001
1st quartile	11	14	25	
2nd quartile	13	47	60	
3rd quartile	32	95	127	
4th quartile	105	553	658	

* Values in boldface are statistically significant.

time period. The West had the highest and Northeast had the lowest cost of hospitalization ($p < 0.001$). This finding was consistent with our previous study and can be attributed to the increased cost of living in this region.²⁴ Nonteaching hospitals were 3.1 times ($p < 0.001$) more likely to have a higher cost of hospitalization than teaching hospitals, which was in contrast to the findings of earlier studies by Taylor et al. and McGuire et al. with no difference in outcomes.^{18,26} Low-volume hospitals, private hospitals, and nonacademic centers in the West were the independent predictors of higher hospital charges.

Advantages and Limitations of the NIS Database

The foremost advantage of the NIS database is that it provides a comprehensive sampling of the entire US nonfederal hospital community. This database avoids

the selection bias at both the individual and institutional levels and provides the largest representative sample to estimate the inpatient averages. Moreover, it also allows an accurate estimation of the hospital case volumes by providing annual discharges from each hospital. Apart from the inherent limitations of a retrospective study, there are some specific limitations of the NIS data set, such as coding errors and underreporting of events because of the inability to include outpatients. The NIS may also underestimate mortality and overestimate morbidity because the outcomes can be measured only at the time of discharge. Moreover, the duration and severity of PD before surgery as well as the severity of postoperative complications cannot be extracted from the data set. In addition, the outcome measures such as long-term functional outcome and QOL cannot be evaluated from the

TABLE 9: Multivariate binary logistic regression analysis showing various hospital factors affecting total hospital charges

Variable*	B Value	p Value†	OR	95% CI	
				Lower Limit	Upper Limit
hospital bedsize compared w/ small					
medium	-0.111	0.835	0.895	0.314	2.545
large	-0.255	0.553	0.775	0.333	1.800
high hospital vol (yes)	-2.373	<0.001	0.093	0.050	0.175
government hospital control	2.400	<0.001	11.027	3.658	33.236
teaching status of hospital (yes)	1.144	0.003	3.139	1.469	6.706
urban location of hospital (yes)	-21.340	0.998	0.000	0.000	
hospital region compared w/ West					
Northeast	0.634	0.033	1.885	1.052	3.378
Midwest	1.064	0.031	2.897	1.104	7.603
South	0.513	0.064	1.670	0.970	2.876
weekend admission day (yes)	-0.936	0.348	0.392	0.055	2.775
elective admission status (yes)	-0.596	0.158	0.551	0.241	1.261
surgeon case vol compared w/ those in the 4th quartile					
1st quartile	-0.410	0.416	0.664	0.247	1.782
2nd quartile	1.203	0.004	3.331	1.477	7.510
3rd quartile	0.380	0.272	1.463	0.742	2.883

* The dependent variable was a high cost of hospitalization (outcome) and the various factors mentioned were covariates.

† Values in boldface are statistically significant.

FIG. 5. Graphs showing the trends in the cost of DBS surgery for PD from 2006 to 2010 (**A**), impact of hospital region on total hospital charges (**B**), impact of surgeon case volumes (by quartiles: 1st quartile, 1 case; 2nd quartile, 2–3 cases; 3rd quartile, 4–12; and 4th quartile, 13 and greater) on hospital costs (**C**), and impact of hospital case and volumes (by quartiles: 1st quartile, 1–3; 2nd quartile, 4–9; 3rd quartile, 10–19; and 4th quartile, 20 and greater) on the total cost of hospitalization (**D**) after DBS surgery for PD from 2006 to 2010.

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Fig. 6. Graph showing the trends in hospital stay after DBS surgery for PD from 2006 to 2010.

NIS database, necessitating further prospective studies. Some centers perform bilateral DBS as staged procedures in separate admissions; therefore, it is possible that such patients were counted twice in this study, underestimating the LOS and cost and overestimating the total number of discharges. However, the majority of the centers perform bilateral DBS in a single admission; therefore, this limitation is unlikely to affect the outcomes.¹⁴ Nonetheless, it helps to understand the regional trends, short-term outcomes, and practice patterns in the US.

Conclusions

Our study provides an overview of the outcome, the total cost of hospitalization, and the regional variations associated with DBS surgery for PD within the US from 2006 to 2010. Elderly female patients with a nonprivate insurance and higher comorbidity index who underwent surgery at low-volume centers with a smaller bedsize and by a surgeon with a lower annual case volume and the occurrence of postoperative complications were correlated with adverse discharge dispositions. High-volume, government-owned academic centers in the Northeast with elective admissions were associated with a lower cost incurred to the hospitals. These findings suggest that there may be a disparity in terms of accessibility to the centers that are performing DBS surgery for PD. Therefore, it can be recommended that the widespread availability of this procedure across small academic centers in rural areas may not only provide an easier access to the patients but also may reduce the total cost incurred to the hospitals. Moreover, in the current scenario with the rapidly expanding novel indications for DBS, it is prudent to study the socioeconomic impact of this procedure on outcome, patient access, and the overall costs incurred.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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