Costs and Their Predictors in Transsphenoidal Pituitary Surgery

Anthony O. Asemota, MD, MPH
Masaru Ishii, MD, PhD
Henry Brem, MD
Gary L. Gallia, MD, PhD

Department of Neurosurgery, Johns Hopkins Hospital, Baltimore, Maryland

Correspondence:
Gary L. Gallia, MD, PhD,
Department of Neurosurgery,
Johns Hopkins Hospital,
Baltimore, MD 21287.
E-mail: ggallia1@jhmi.edu

Received, February 8, 2018.
Accepted, August 17, 2018.
Published Online, October 18, 2018.

BACKGROUND: Contemporary surgical approaches to pituitary pathologies include transsphenoidal microsurgical and, more recently, endoscopic techniques. Data reporting direct costs in transsphenoidal pituitary surgery are limited.

OBJECTIVE: To examine direct costs (including overall total, hospital/facility, and physician payments) of microscopic and endoscopic pituitary surgery and evaluate predictors of differential costs in transsphenoidal pituitary surgery using a national database.

METHODS: The Truven MarketScan® database 2010-2014 (IBM, Armonk, New York) was queried and patients undergoing microscopic and/or endoscopic transsphenoidal pituitary surgery identified. Mean costs and predictors of differential costs were analyzed using analysis of variance and generalized linear models. Beta-coefficients (β) assessed relative contributions of independent predictors.

RESULTS: Mean overall total (\$34 943.13 [SD ± 19 074.54]) and hospital/facility (\$26 505.93 [SD ± 16 819.52]) payments were higher in endoscopic compared to microscopic surgeries (both $P < .001$). Lengths of hospital stay (LOS) were similar between groups. Predictors of overall total and hospital/facility payments were similar including surgical technique, age, geographical region, comorbidity index, postoperative surgical and medical complications, and LOS with LOS being the most significant predictor ($\beta = 0.27$ and $\beta = 0.29$, respectively). Mean physician payments (\$4549.24 [SD ± 3956.27]) were similar in microscopic and endoscopic cohorts ($P = .26$). Predictors of physician payments included age, health plan, geographical region, postoperative surgical complications, and LOS with health plan being the most significant predictor ($\beta = -0.21$).

CONCLUSION: Higher overall total and hospital/facility costs are associated with endoscopic transsphenoidal pituitary surgery compared to microsurgery. In contrast, physician reimbursements are similar between techniques. Whereas LOS was the strongest predictor of overall total and hospital/facility costs, health plan was the strongest predictor of differential physician reimbursements.

KEY WORDS: Costs, Endoscopic, Microscopic, Pituitary surgery, Pituitary tumor, Predictors, Transsphenoidal

Neurosurgery 85:695–707, 2019 DOI:10.1093/neuros/nyy441 www.neurosurgery-online.com

Surgical approaches to pituitary and sellar pathologies have evolved over the past century and contemporary surgical access to lesions in this region most commonly utilizes a transsphenoidal route.[1-3] Beginning in the 1960s and during the latter part of the 20th century, microsurgical transsphenoidal approaches became the principal procedure in the surgical management of pituitary and sellar lesions. In the 1990s, purely endoscopic transsphenoidal approaches for pituitary pathologies were reported,[4-8] and this technique has steadily increased in frequency.[9-11] In a recent analysis of a US database, endoscopic and microscopic transsphenoidal pituitary surgery were performed with roughly equivalent frequencies in 2013 and endoscopic procedures surpassed microsurgical transsphenoidal

ABBREVIATIONS: CCI, Charlson comorbidity index; **CPT,** Current Procedural Terminology; **ICD-9-CM,** International Classification of Diseases, Ninth Revision, Clinical Modification; **LOS,** length of hospital stay; **SD,** standard deviation

Supplemental digital content is available for this article at www.neurosurgery-online.com.

pituitary surgeries in 2014.[11] With this changing surgical landscape, there is significant interest in evaluating and comparing outcomes between these 2 surgical techniques.[11-20]

In addition to the quest for improved clinical outcomes, surgical resource utilization is an important outcome metric and health economics concern that has increasingly gained attention including in transsphenoidal pituitary surgery.[21-24] Measuring prices and costs of healthcare services is important for estimating value of medical care, quality improvement, and judicious health resource allocation. Additionally, identifying factors associated with price variation is also important.[25] Given these driving factors, it is not surprising there have been increasing reports examining costs of transsphenoidal pituitary surgery,[21-24,26-31] including a handful of studies focusing on comparative costs in endoscopic and microscopic techniques.[22,26,29-31] Some of these cost analysis studies have been limited in scope covering only a single or few centers which potentially constrains their generalizability.[22-24,26] Others which have evaluated national estimates have mostly relied on databases reporting hospital charges without actual payments received for services.[21,28] Here, employing a nationally representative database, we examine direct payments including overall total, hospital/facility, and physician payments associated with microscopic and endoscopic transsphenoidal approaches to pituitary pathologies. In addition, we evaluate predictors of differential costs in transsphenoidal pituitary surgery.

METHODS

Data

The study was conducted employing data from the Truven Health Analytics MarketScan® database (IBM, Armonk, New York).[32] The database is compliant with Health Insurance Portability and Accountability Act regulations and contains fully de-identified healthcare claims with unique identifiers to access individual patient health information.[32,33] The databases contain approximately 20 million inpatient records representing approximately 50% of US hospital discharges per year.[33] Individual claims are derived from more than 300 contributing employers and 40 contributing health plans with broad geographic coverage across the entire US. Thus, the data reflect a nationally representative sample of the US population.[33] The study was conducted using all-payer data collated from 2010 to 2014. Records from the inpatient file which contained hospital/facility and professional encounters and other services associated with inpatient admissions were deployed in our study.[32]

Study Population

All inpatient records were reviewed and records containing Current Procedural Terminology (CPT), Fourth Edition, procedural code CPT-61548 (hypophysectomy or excision of pituitary tumor, transnasal or transseptal approach), and/or CPT-62165 (neuroendoscopy, intracranial, with excision of pituitary tumor, transnasal or transsphenoidal approach) were included. The type of admission (medical, surgical, obstetric, etc) was identified and, to more accurately evaluate costs limited to surgical management, nonsurgical cases were excluded. Patient records containing both procedures in the same admission and those also undergoing a craniotomy for hypophysectomy or excision of a pituitary tumor (CPT-61546) were excluded from analyses. Only patients aged less than 65 yr were included for study. We excluded records with unreasonable (negative or zero) payments from analyses and those with the lowest and highest 1% of payments (ie, extreme outlying 1% of payments) from the final study sample. Our study did not require Institutional Review Board approval since it employed a publicly available de-identified database without direct patient contact.

Variables Included

Variables included were patient age, gender, health plan, geographical region, pre-existing medical comorbidities, postoperative complications, and length of hospital stay (LOS). Patient age was grouped into 5 categories (<18, 18-34, 35-44, 45-54, 55-64 yr). Health plan included 2 categories (employer and nonemployer-based plans). Principal admitting diagnoses were extracted using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. Pre-existing medical comorbidities were also extracted using ICD-9-CM codes and Charlson comorbidity index (CCI) scores were calculated based on predefined comorbid conditions.[34,35] Postoperative complications included both surgical and medical complications and were extracted using ICD-9-CM codes (**Table, Supplemental Digital Content 1**) and dichotomized into presence or absence of complications. Our main outcomes or dependent variables were payments associated with transsphenoidal pituitary surgery (including overall total, hospital/facility, and physician payments) which were all obtained from the database. Physician payments refer to the total of all payments made to the principal physician/surgeon associated with the admission.

Statistical Methods

Descriptive analyses examined patient characteristics undergoing either microscopic or endoscopic transsphenoidal pituitary surgery. Comparisons of overall total, hospital/facility, and physician payments were made between both techniques. Graphical representation of all cost data with assessments of normality (employing Shapiro-Wilk test) was conducted. Means, standard deviations (SD), as well as medians and respective interquartile ranges were reported for continuous variables, while frequencies/percentages were reported for categorical variables. Standard t-tests examined significant differences between continuous variables while chi-squared tests were used for categorical variables. Individual LOS were included as continuous variables in the final regression models. Additional correlations were evaluated using Pearson's correlation.

Unadjusted Univariate Analysis

Initial assessments of associations between explanatory variables and outcome were performed using one-way analysis of variance and F-test/statistic assessed significance of the predictive models.

Multivariate Analysis

For evaluation of predictors of costs, adjusted multivariate regression analyses were performed using generalized linear models, a technique well described for modeling health expenditure data.[36,37] Predictors of differential costs were examined separately in both unmatched and matched adjusted multivariate regression models. Model suitability was evaluated using Akaike Information Criteria. Variables determined from univariate analyses were included in regression models using a stepwise approach. To obtain more robust estimates, we conducted propensity-score matching on patient demographics, CCI, comorbidities, surgery indications, geographical region, complications, and LOS and subsequent regression based on the generated propensity scores. This allowed for reduction of potential bias due to confounding in estimating differences in observed covariates from unmeasured differences between 2 individual groups, possibly due to the likelihood of treatment allocation rather than the effect of the observed treatment.[38,39] Nonparametric bootstrapped estimation and t-tests evaluated significant differences in unmatched and matched multivariate models.

In our analyses, all payments were logarithmically transformed (**Figure**, **Supplemental Digital Content 2**) as this method produces normalized costs and stabilizes variances, and is preferred over direct analysis of skewed continuous data of untransformed costs and expenditures.[40-42] Separate regression models were constructed for all log-transformed dependent variables adjusting in each case for potential confounders and regression coefficients (designated as "B") were obtained. We estimated adjusted beta (β) coefficients of regression for all independent explanatory variables in our multivariate models and their respective standard errors and deviations, 95% confidence intervals, and *P*-values. The standardized β coefficients compare the relative strengths of various explanatory variables and predictors within the model and are interpreted as the rate of change or increase in SD of the dependent variable (ie, overall total, hospital/facility, or physician payments) given a unit change in SD of the predictor or independent variable holding all other variables constant.[43] By comparing β-coefficients, we were able to assess the relative contributions of independent variables in outcome prediction.

An a priori alpha level was set at $P < .05$ in all analyses. All payments were adjusted in 2017 US dollars.

Sensitivity Analyses

Several independent sensitivity analyses were performed, including (1) restricting our analysis to specific pituitary pathologies (**Table**, **Supplemental Digital Content 3**), (2) including only noncapitated cases, and (3) excluding outlying payments (ie, overall total, hospital/facility, and physician payments) beyond 2.0, 2.5, and 3.0 SD from the mean. Results obtained from the various sensitivity analyses were compared with findings from our main analyses.

RESULTS

General Findings

A total of 6044 transsphenoidal pituitary surgery cases were identified in our initial query and 5354 met our inclusion criteria including 2911 microscopic and 2443 endoscopic cases (Figure). Population characteristics are summarized in Table 1. Mean patient age was 45.24 yr (SD ± 13.30). Age, gender, health plan type, capitation, and LOS did not differ significantly between microscopic and endoscopic procedural groups. There were no significant differences in CCI scores between microscopic and endoscopic groups; however, there was a significantly higher proportion of cerebrovascular disease in patients undergoing endoscopic compared to microscopic surgery ($P = .02$). The proportions of microscopic and endoscopic procedures differed significantly across geographical regions ($P < .001$). Postoperative surgical complications were higher among endoscopically treated patients compared to those undergoing microsurgical resection ($P < .001$); there were no significant differences in postoperative medical complications between both groups ($P = .13$). There was no significant correlation between age and technique (r = –0.01,

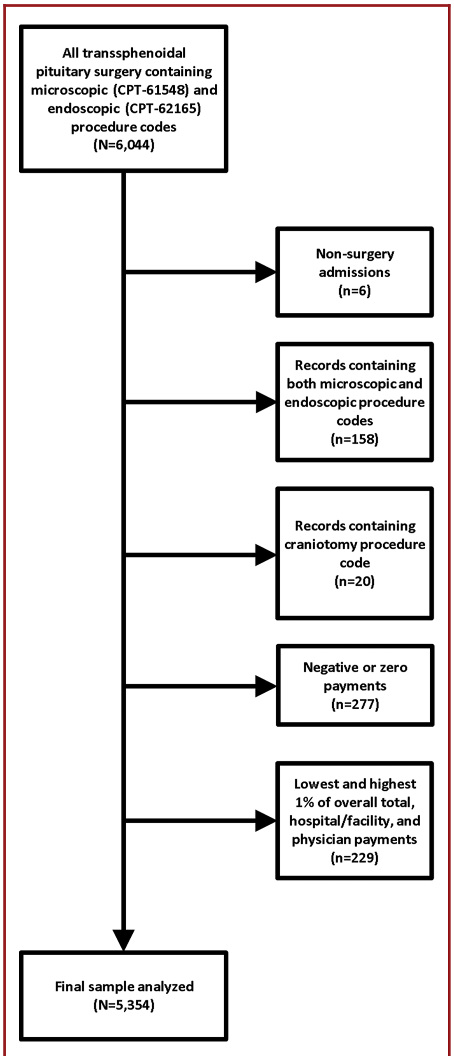

FIGURE. *Flow chart depicting sample inclusion and exclusion. A total of 6044 transsphenoidal pituitary surgery cases were identified in our initial query. From this cohort, 6 cases were excluded since they were admitted primarily as nonsurgical cases, 158 cases were excluded as they contained both microscopic and endoscopic procedure codes within the same record, 20 records were excluded as they contained either CPT-62165 or CPT-61548 and CPT-61546, and 277 records were excluded due to negative or zero payments. After exclusion of records with the highest and lowest 1% of payments, a total of 5354 records were included in our final study cohort with 2911 microscopic and 2443 endoscopic cases.*

TABLE 1. Population Characteristics

Population characteristics	Microscopic		Endoscopic		Total		*P*-value
	n	(%)	n	(%)	n	(%)	
Total	2911	(100.00)	2443	(100.00)	5354	(100.00)	
Age group							.55
<18 yr	77	(2.65)	74	(3.03)	151	(2.82)	
18-34 yr	545	(18.72)	471	(19.28)	1016	(18.98)	
35-44 yr	642	(22.05)	501	(20.51)	1143	(21.35)	
45-54 yr	767	(26.35)	670	(27.43)	1437	(26.84)	
55-64 yr	880	(30.23)	727	(29.76)	1607	(30.01)	
Gender							.81
Male	1325	(45.52)	1104	(45.19)	2429	(45.37)	
Female	1586	(54.48)	1339	(54.81)	2925	(54.63)	
Health plan							.61
Employer based	1294	(44.45)	1103	(45.15)	2397	(44.77)	
Nonemployer based	1617	(55.55)	1340	(54.85)	2957	(55.23)	
Region							<.001
North-East	433	(14.87)	592	(24.23)	1025	(19.14)	
North-Central	516	(17.73)	520	(21.29)	1036	(19.35)	
South	1264	(43.42)	848	(34.71)	2112	(39.45)	
West	629	(21.61)	436	(17.85)	1065	(19.89)	
Unknown	69	(2.37)	47	(1.92)	116	(2.17)	
Charlson comorbidity index							.82
CCI score of 0	1994	(68.50)	1656	(67.79)	3650	(68.17)	
CCI score of 1	518	(17.79)	450	(18.42)	968	(18.08)	
CCI score ≥ 2	399	(13.71)	337	(13.79)	736	(13.75)	
Preoperative medical comorbidities							
Acute myocardial infarction	30	(1.03)	23	(0.94)	53	(0.99)	.74
Congestive heart failure	15	(0.52)	13	(0.53)	28	(0.52)	.93
Peripheral vascular disease	5	(0.17)	6	(0.25)	11	(0.21)	.55
Cerebrovascular disease	133	(4.57)	147	(6.02)	280	(5.23)	.02
Chronic obstructive airway disease	194	(6.66)	134	(5.49)	328	(6.13)	.07
Rheumatoid disease	25	(0.86)	20	(0.82)	45	(0.84)	.87
Peptic ulcer disease	3	(0.10)	3	(0.12)	6	(0.11)	.83
Mild liver disease	4	(0.14)	3	(0.12)	7	(0.13)	.88
Diabetes	363	(12.47)	312	(12.77)	675	(12.61)	.74
Complicated diabetes	12	(0.41)	15	(0.61)	27	(0.50)	.30
Hemiplegia/paraplegia	8	(0.27)	5	(0.20)	13	(0.24)	.60
Renal disease	21	(0.72)	22	(0.90)	43	(0.80)	.47
Cancer	262	(9.00)	217	(8.88)	479	(8.95)	.88
Metastatic cancer	26	(0.89)	26	(1.06)	52	(0.97)	.53
Postoperative surgical complications							<.001
None	1931	(66.33)	1369	(56.04)	3300	(61.64)	
Yes	980	(33.67)	1074	(43.96)	2054	(38.36)	
Postoperative medical complications							.13
None	2853	(98.01)	2378	(97.34)	5231	(97.70)	
Yes	71	(1.99)	76	(2.66)	147	(2.75)	
Capitated service indicator							.81
No	2835	(97.39)	2379	(97.38)	5214	(97.39)	
Yes	48	(1.65)	37	(1.51)	85	(1.59)	
Unknown	28	(0.96)	27	(1.11)	55	(1.03)	
Mean length of stay ± SD (in days)	3.51	± 2.94	3.67	± 3.15	3.58	± 3.04	.05

$P = .56$) and between age and LOS ($r = 0.01$, $P = .36$); there were weak but significant correlations between patient age and postoperative surgical ($r = -0.04$, $P = .01$) and medical ($r = 0.06$; $P < .001$) complications.

Summary of Mean Payments in Endoscopic and Microscopic Techniques

The mean overall total payment associated with transsphenoidal pituitary surgery was \$34 943.13 (SD ± 19 074.54).

TABLE 2. Summary of Payments Comparing Microscopic and Endoscopic Transsphenoidal Surgery Techniques

Summary	Overall total payments[a]	Hospital/facility payments[a]	Physician payments[a]
All transsphenoidal			
Frequency	5354	5354	5354
Mean	34 943.13	26 505.93	4549.24
Standard error	260.68	229.87	54.07
Standard deviation	19 074.54	16 819.52	3956.27
Median	30 597.44	22 607.56	3403.29
Interquartile range	22 838.35; 41 523.55	16 233.45; 32 013.70	2243.80; 5440.88
First percentile	11 237.91	5213.72	912.08
99th percentile	111 620.81	93 528.43	21 917.94
Range	163 667.34	141 603.05	35 774.75
Minimum	9335.58	4109.39	340.94
Maximum	173 002.92	145 712.44	36 115.69
Microscopic			
Frequency	2911	2911	2911
Mean	32 671.36	24 905.07	4372.26
Standard error	326.47	292.22	70.58
Standard deviation	17 614.47	15 766.43	3808.28
Median	28 905.93	21 747.30	3461.80
Interquartile range	21 543.81; 38 414.90	1538.70; 30 093.03	2268.44; 5222.74
First percentile	10 818.58	5166.93	949.09
99th percentile	102 690.06	89 513.95	22 978.52
Range	148 985.14	140 527.49	35 774.75
Minimum	9335.58	4123.62	340.94
Maximum	158 320.72	144 651.11	36 115.69
Endoscopic			
Frequency	2443	2443	2443
Mean	37 650.09	28 413.47	4760.12
Standard error	411.83	360.34	83.29
Standard deviation	20 355.30	17 810.36	4116.54
Median	33 050.63	23 951.90	3313.15
Interquartile range	24 535.62; 45 285.00	17 176.20; 34 817.68	2218.00; 5961.91
First percentile	12 077.38	5877.19	820.23
99th percentile	115 279.04	101 867.07	21 639.49
Range	163 439.66	141 603.05	32 487.00
Minimum	9563.26	4109.39	355.86
Maximum	173 002.92	145 712.44	32 842.87

[a] All payments are adjusted in 2017 US dollars.

For patients undergoing microscopic and endoscopic pituitary surgery, the mean overall total payments were \$32 671.36 (SD ± 17 614.47) and \$37 650.09 (SD ± 20 355.30), respectively. The mean hospital/facility payment associated with transsphenoidal pituitary surgery was \$26 505.93 (SD ± 16 819.52); for microscopic and endoscopic cohorts, the mean hospital/facility payments were \$24 905.07 (SD ± 15 766.43) and \$28 413.47 (SD ± 17 810.36), respectively. The mean physician payment associated with transsphenoidal pituitary surgery was \$4549.24 (SD ± 3956.27); mean physician payments for microscopic and endoscopic procedures were \$4372.26 (SD ± 3808.28) and \$4760.12 (SD ± 4116.54), respectively. See Table 2 for a summary of overall total, hospital/facility, and physician payments.

Unadjusted Univariate Analyses of Predictors of Costs

Explanatory variables including surgical technique, patient age, gender, health plan, geographic region, CCI, and postoperative surgical and medical complications were next examined, initially with univariate analysis, as predictors of cost. These results are summarized in Table 3.

Overall Total Payments

Results of unadjusted univariate analysis revealed independent significant associations between overall total payments of transsphenoidal pituitary surgery and surgical technique ($P < .001$), patient age ($P < .001$), geographical region ($P < .001$), CCI score ($P < .001$), and postoperative surgical and medical complications (both $P < .001$). There were no

TABLE 3. Summary of Mean Payments and Unadjusted Univariate Associations of Predictors of Costs in Transsphenoidal Surgery

Means and standard deviations	Overall total payments[a]	P-value	Hospital/facility payments[a]	P-value	Physician payments[a]	P-value
All transsphenoidal	34 943.13 ± 19 074.54		26 505.93 ± 16 819.52		4549.24 ± 3956.27	
Technique		<.001		<.001		<.001
Microscopic	32 671.36 ± 17 614.47		24 905.07 ± 15 766.43		4372.26 ± 3808.28	
Endoscopic	37 650.09 ± 20 355.30		28 413.47 ± 17 810.36		4760.12 ± 4116.54	
Age group		<.001		<.001		.01
<18 yr	44 754.75 ± 27 937.30		34 672.77 ± 24 662.91		5749.57 ± 4488.83	
18-34 yr	34 202.15 ± 16 960.32		25 857.54 ± 14 927.10		4603.20 ± 3955.14	
35-44 yr	34 428.42 ± 18 154.30		26 231.15 ± 16 066.16		4470.81 ± 3755.73	
45-54 yr	34 221.54 ± 18 420.70		25 842.62 ± 16 096.06		4458.46 ± 3816.60	
55-64 yr	35 501.02 ± 20 245.89		26 937.07 ± 17 969.99		4539.30 ± 4147.02	
Gender		.30		.78		.15
Male	35 241.56 ± 19 565.64		26 575.75 ± 16 970.50		4635.13 ± 4103.71	
Female	34 695.30 ± 18 656.63		26 447.96 ± 16 695.78		4477.92 ± 3828.76	
Health plan		.13		.67		<.001
Employer based	35 378.62 ± 19 387.41		26 616.62 ± 17 096.46		5173.91 ± 4402.76	
Nonemployer based	34 590.12 ± 18 812.99		26 416.21 ± 16 593.98		4042.88 ± 3472.64	
Region		<.001		<.001		<.001
North-East	36 616.13 ± 18 569.71		26 490.56 ± 14 335.04		5399.90 ± 5988.91	
North-Central	36 095.20 ± 19 075.09		27 450.29 ± 17 081.39		5011.25 ± 3951.62	
South	31 892.64 ± 18 566.59		24 273.73 ± 16 662.26		3982.90 ± 2985.86	
West	38 635.70 ± 19 831.12		30 264.82 ± 18 428.99		4503.31 ± 3006.25	
Unknown	31 509.00 ± 16 678.59		24 338.94 ± 15 449.78		3639.37 ± 2503.57	
Charlson comorbidity index		<.001		<.001		.36
CCI score of 0	33 494.94 ± 17 132.10		25 319.83 ± 15 112.06		4591.00 ± 3862.43	
CCI score of 1	37 405.59 ± 22 003.10		28 801.13 ± 19 679.67		4532.62 ± 4120.22	
CCI score ≥ 2	38 886.37 ± 22 841.70		29 369.43 ± 19 871.24		4364.00 ± 4189.43	
Postoperative surgical complications		<.001		<.001		.03
None	31 230.43 ± 15 264.65		23 333.67 ± 13 521.92		4472.93 ± 3925.33	
Yes	40 908.05 ± 22 726.45		31 602.61 ± 20 041.16		4671.85 ± 4003.39	
Postoperative medical complications		<.001		<.001		.50
None	34 477.35 ± 18 337.66		26 085.98 ± 16 121.82		4555.44 ± 3959.70	
Yes	51 442.61 ± 36 672.83		41 382.06 ± 29 584.63		4329.74 ± 3839.47	

[a] All means are adjusted in 2017 US dollars.

statistically significant associations between gender ($P = .30$) and health plan ($P = .13$) and overall total payments.

Hospital/Facility Payments

Similar to findings with overall total payments, results of unadjusted univariate analysis revealed independent significant associations between hospital/facility payments of transsphenoidal pituitary surgery and surgical technique ($P < .001$), patient age ($P < .001$), geographical region ($P < .001$), CCI score ($P < .001$), and postoperative surgical and medical complications (both $P < .001$). There were no statistically significant associations between gender ($P = .78$) and health plan ($P = .67$) and hospital/facility payments.

Physician Payments

Results of unadjusted univariate analysis revealed independent significant associations between physician payments of transsphenoidal pituitary surgery and surgical technique ($P < .001$), patient age ($P = .01$), health plan ($P < .001$), geographical region ($P < .001$), and postoperative surgical complications ($P = .03$). There were no statistically significant associations between physician payments and gender ($P = .15$), CCI score ($P = .36$), or postoperative medical complications ($P = .50$).

Length of Hospital Stay

Unadjusted assessments of LOS demonstrated significant moderate correlations with logarithmically transformed outcomes including overall total payments (r = 0.47, $P < .001$) and hospital/facility payments (r = 0.46, $P < .001$) and weak correlation with physician payments (r = 0.04, $P = .03$; **Figure**, **Supplemental Digital Content 4**).

Adjusted Multivariate Analysis of Predictors of Incremental Costs/Cost Differentials

Explanatory variables were next evaluated as predictors of incremental costs in unmatched and matched multivariate regression

TABLE 4. Predictors of Overall Total Payments in Matched Multivariate Regression

Overall total payments	Propensity matched regression			
	Coefficient [B]	[95% confidence interval]	Beta [β]	*P*-value
Technique				
Microscopic (REF)	REF	–	–	–
Endoscopic	0.07	[0.04; 0.09]	0.07	<.001
Age group				
<18 yr (REF)	REF	–	–	–
18-34 yr	−0.16	[−0.23; −0.09]	−0.13	<.001
35-44 yr	−0.14	[−0.21; −0.05]	−0.12	<.001
45-54 yr	−0.14	[−0.21; −0.09]	−0.14	<.001
55-64 yr	−0.13	[−0.20; −0.04]	−0.12	<.001
Health plan				
Employer based (REF)	REF	–	–	–
Nonemployer based	−0.04	[−0.07; 0.02]	−0.05	.10
Region				
North-East (REF)	REF	–	–	–
North-Central	0.01	[−0.02; 0.05]	0.01	.90
South	−0.13	[−0.16; −0.09]	−0.14	<.001
West	0.09	[0.05; 0.13]	0.08	<.001
Unknown	−0.06	[−0.15; −0.01]	−0.04	.01
Charlson comorbidity index				
CCI score of 0 (REF)	REF	–	–	–
CCI score of 1	0.04	[0.02; 0.08]	0.02	.01
CCI score ≥ 2	0.02	[0.01; 0.04]	0.03	.03
Postoperative surgical complications				
None (REF)	REF	–	–	–
Yes	0.09	[0.07; 0.12]	0.11	<.001
Postoperative medical complications				
None (REF)	REF	–	–	–
Yes	0.06	[0.02; 0.24]	0.04	<.001
Length of hospital stay	0.06	[0.02; 0.12]	0.27	<.001

All values represent log-transformed estimates; REF, reference group.

analyses after log transformation of the outcome variables (overall total, hospital/facility, and physician payments). These analyses generated similar findings; results of unmatched analyses are shown in **Table, Supplemental Digital Content 5** and of matched propensity analyses in Tables 4-6.

Overall Total Payments

After matched propensity-score adjustment and subsequent regression, overall total payments associated with transsphenoidal pituitary surgery were higher among patients undergoing endoscopic compared to microscopic surgery ($P < .001$). Overall total payments were significantly decreased among individuals in older age categories compared to patients <18 yr old (all $P < .001$). There were no significant differences in overall total costs comparing patients with nonemployer plans to those with employer-based plans ($P = .10$). Overall total payments were significantly lower in the South ($P < .001$), higher in the West ($P < .001$), and did not significantly differ in the North-Central region ($P = .90$), all compared to the North-East region. CCI scores of 1 and ≥ 2 were associated with significantly higher overall total costs ($P = .01$ and $P = .03$, respectively). Postoperative surgical and medical complications were also associated with significantly higher overall total costs (both $P < .001$). There were significantly higher overall total payments with each additional day in LOS ($P < .001$). The most significant predictor of overall total payments was LOS ($\beta = 0.27$). These results are presented in Table 4.

Hospital/Facility Payments

Analysis of predictors in hospital/facility payments after matched propensity score adjustment and subsequent regression showed higher payments associated with endoscopic compared to microscopic techniques ($P < .001$). Adult patients (greater than 18 but less than 65 yr) versus patients <18 yr were more likely to incur lower hospital/facility payments (all $P < .001$). There was no significant association between health plan (ie, employer or nonemployer based) and the likelihood of increased hospital/facility payments ($P = .05$). There were lower hospital/facility payments in the South ($P < .001$) and higher payments in the West ($P < .001$) compared to the North-East;

TABLE 5. Predictors of Hospital/Facility Payments in Matched Multivariate Regression

Hospital/facility payments	Propensity matched regression			
	Coefficient [B]	[95% confidence interval]	Beta [β]	*P*-value
Technique				
Microscopic (REF)	REF	–	–	–
Endoscopic	0.04	[0.02; 0.08]	0.04	<.001
Age group				
<18 yr (REF)	REF	–	–	–
18-34 yr	−0.16	[−0.27; −0.08]	−0.13	<.001
35-44 yr	−0.13	[−0.23; −0.06]	−0.11	<.001
45-54 yr	−0.11	[−0.21; −0.04]	−0.13	<.001
55-64 yr	−0.14	[−0.22; −0.07]	−0.11	<.001
Health plan				
Employer based (REF)	REF	–	–	–
Nonemployer based	−0.03	[−0.06; 0.01]	−0.03	.05
Region				
North-East (REF)	REF	–	–	–
North-Central	0.03	[−0.01; 0.09]	0.02	.11
South	−0.11	[−0.15; −0.09]	−0.09	<.001
West	0.12	[0.08; 0.19]	0.10	<.001
Unknown	−0.09	[−0.20; 0.02]	−0.01	.09
Charlson comorbidity index				
CCI score of 0 (REF)	REF	–	–	–
CCI score of 1	0.04	[0.01; 0.05]	0.02	.04
CCI score ≥ 2	0.03	[0.01; 0.06]	0.01	.03
Postoperative surgical complications				
None (REF)	REF	–	–	–
Yes	0.11	[0.07; 0.13]	0.08	<.001
Postoperative medical complications				
None (REF)	REF	–	–	–
Yes	0.04	[0.01; 0.11]	0.02	<.001
Length of hospital stay	0.05	[0.04; 0.06]	0.29	<.001

All values represent log-transformed estimates; REF, reference group.

there were no significant differences in the North-Central region ($P = .11$). There were significantly higher hospital/facility payments in patients with a CCI score of 1 ($P = .04$) and ≥2 ($P = .03$). Likewise, significantly higher hospital/facility payments were incurred in patients with postoperative surgical and medical complications versus patients without complications (both $P < .001$). Patients with increased LOS demonstrated significantly higher hospital/facility payments ($P < .001$). The most significant predictor of hospital/facility payments was LOS ($\beta = 0.29$). These results are shown in Table 5.

Physician Payments

In contrast to overall total and hospital/facility payments, after propensity score adjustment and regression, there were no significant differences in physician payments between endoscopic and microscopic techniques ($P = .26$). Physician payments were significantly decreased among all older age categories (ie, 18-64 yr olds) compared to patients <18 yr (all $P < .001$). There were significantly lower physician payments associated with nonemployer-based plans compared to employer-based plans ($P < .001$). Physician payments were significantly lower in the South compared to the North-East ($P < .001$). There were no significant differences in physician payments in the North-Central ($P = .09$) and West ($P = .11$) compared to the North-East region. There were no significant associations between physician payments and the presence of pre-existing medical comorbidities (CCI). Postoperative surgical complications were associated with significantly higher physician payments ($P < .001$) whereas postoperative medical complications were not significantly associated with differential physician payments ($P = .67$). LOS was significantly associated with higher physician payments ($P = .02$). The most significant predictor of physician payments was health plan ($\beta = –0.21$). These results are presented in Table 6.

Sensitivity Analyses

Results of sensitivity analyses performed with specific pituitary pathologies (**Table, Supplemental Digital Content 3**) showed similar results with our original analyses (**Tables, Supplemental Digital Content 6-8**). Further sensitivity analyses performed

TABLE 6. Predictors of Physician Payments in Matched Multivariate Regression

Physician payments	Propensity matched regression			
	Coefficient [B]	[95% confidence interval]	Beta [β]	*P*-value
Technique				
Microscopic (REF)	REF	–	–	–
Endoscopic	0.05	[−0.01; 0.10]	0.04	.26
Age group				
<18 yr (REF)	REF	–	–	–
18-34 yr	−0.16	[−0.28; −0.05]	−0.09	<.001
35-44 yr	−0.23	[−0.34; −0.12]	−0.14	<.001
45-54 yr	−0.23	[−0.33; −0.14]	−0.15	<.001
55-64 yr	−0.24	[−0.36; −0.12]	−0.16	<.001
Health plan				
Employer based (REF)	REF	–	–	–
Nonemployer based	−0.22	[−0.26; −0.18]	−0.21	<.001
Region				
North-East (REF)	REF	–	–	–
North-Central	0.11	[−0.05; 0.17]	0.07	.09
South	−0.08	[−0.13; −0.03]	−0.06	<.001
West	0.05	[−0.01; 0.09]	0.03	.11
Unknown	−0.04	[−0.19; 0.10]	−0.01	.13
Charlson comorbidity index				
CCI score of 0 (REF)	REF	–	–	–
CCI score of 1	−0.01	[−0.05; 0.04]	−0.01	.93
CCI score ≥ 2	−0.04	[−0.10; 0.02]	−0.01	.10
Postoperative surgical complications				
None (REF)	REF	–	–	–
Yes	0.06	[0.02; 0.11]	0.04	<.001
Postoperative medical complications				
None (REF)	REF	–	–	–
Yes	0.01	[−0.13; 0.09]	0.01	.67
Length of hospital stay	0.10	[0.01; 0.19]	0.04	.02

All values represent log-transformed estimates; REF, reference group.

among the subset of cases with noncapitated payments also did not significantly alter findings from our original analyses that included both noncapitated and capitated payments. Additional sensitivity analyses with exclusion of outlying payments beyond 2.0, 2.5, and 3.0 SD of the mean did not result in any significant differences from our main analyses.

DISCUSSION

Predictors of Cost Differentials in Transsphenoidal Pituitary Surgery

In our study, we examined direct costs associated with microscopic and endoscopic pituitary surgery. We also evaluated predictors of costs differentials in transsphenoidal pituitary surgery in both unmatched multivariate regression and matched propensity score models. The variability in costs differentials was significantly larger when we compared costs in unadjusted univariate analyses and in unmatched multivariate analyses but were more modest after propensity score matching and adjustment for confounders. Therefore, in our analyses of predictors of cost differentials, we propose our dominant model to be the propensity matched and adjusted model (Tables 4-6). In our analyses, we found higher overall total and hospital/facility costs associated with endoscopic transsphenoidal pituitary surgery compared to microsurgery. In addition to surgical technique, other predictors of overall total and hospital/facility payments were age, geographical region, CCI score, postoperative surgical and medical complications, and LOS. Physician reimbursements, in contrast to overall total and hospital/facility payments, were similar between endoscopic and microscopic pituitary surgeries. Predictors of physician payments were age, health plan, geographical region, postoperative surgical complications, and LOS.

Results from our propensity-based model demonstrated that LOS was the strongest predictor of overall total ($\beta = 0.27$) and hospital/facility ($\beta = 0.29$) costs. Our results indicate that on average overall total and hospital/facility payments associated with inpatient transsphenoidal pituitary surgery increased by approximately 5 to 6% for each additional day in LOS.

Intuitively, increased LOS would be expected to culminate in more nightly rooming and boarding expenses resulting in increased hospital/facility and overall total costs. In view of the increasing need to moderate healthcare costs and improve efficiency in healthcare delivery, LOS is a potentially modifiable factor that could be the target of cost lowering initiatives.

From our study, patient age was also found to be a significant predictor of differential costs in transsphenoidal pituitary surgery. Our findings suggest that transsphenoidal pituitary surgery among pediatric patients results in greater hospital utilization and constitutes a greater financial burden. Adult patients less than 65 yr old compared to pediatric patients (<18 yr old) demonstrated significantly reduced overall total costs, including hospital/facility costs and physician reimbursements. The independent association of patient age and costs in our study is particularly remarkable bearing in mind that we found no correlation between age and surgical technique, between age and LOS, and weak correlation between age and postoperative complications. It is indeed notable that the significant associations between patient age and overall total costs (ie, increased costs among pediatric patients), hospital/facility costs, and physician reimbursements seen in unadjusted analyses remained evident even after multivariate adjustment for the presence of postoperative complications and other confounders in both unmatched and matched analyses. Further research may be warranted to better unravel specific aspects by which age influences patient care costs.

Not surprisingly, the occurrence of postoperative complications were significant independent predictors of higher overall total and hospital/facility costs, consistent with other studies.[11,21] Interestingly, surgical complications, but not medical complications, were significantly associated with differential physician reimbursements. In addition, the presence of underlying pre-existing medical comorbidities was associated with higher overall total and hospital/facility costs. Although not directly evaluated in our analyses, it is conceivable that the higher costs in patients with pre-existing comorbidities in general may be related to the greater requirement and involvement of multidisciplinary team management and additional medications often required for management of comorbidities. Interestingly, a previous study demonstrated increased healthcare costs including inpatient, outpatient, and pharmacy costs among Cushing disease patients who had higher comorbidity compared to those with non-functioning pituitary adenomas and a control group.[27] Additional investigation will be required to better understand the relationship between comorbidities and healthcare costs.

In our analyses, health plan was found to be a significant predictor of differential physician payments in transsphenoidal pituitary surgery. Although not found to be significant predictors of overall total and hospital/facility costs, health plan was in fact the most significant predictor of differences in physician reimbursements (β = –0.21) after adjustment for confounders. In general, there were significantly lower physician reimbursements associated with nonemployer versus employer-based plans. We, however, did not find any significant differences in the distribution of health plan between patients who underwent microscopic and endoscopic procedures. Notably, significant associations between health insurance and impact on outcomes and costs of surgery have been previously reported.[44]

Findings from our study revealed that surgical technique was a significant predictor of differential costs in transsphenoidal pituitary surgery. Despite adjustment for multiple confounders, endoscopic techniques were associated with significantly higher overall total and hospital/facility costs. Although significant in unadjusted analysis, surgical technique was not a significant predictor of differential physician reimbursements after adjustment for confounders in multivariate analyses. Notably, our findings of increased overall total and hospital/facility costs are in contrast to prior studies reporting similar or reduced inpatient costs in endoscopic compared to microscopic pituitary surgery.[22,26] These discrepancies are likely due to methodological differences between our current study which reports direct (overall, hospital/facility, and physician) costs on a national scale and prior reports which are focused on single institutional analyses. There are indeed multiple factors that could potentially account for the increased costs associated with endoscopic procedures. For example, the increasing demand for advanced technologies such as in endoscopic skull base surgery could potentially lead to higher health care expenditures.[45] In addition, higher rates of complications associated with endoscopic techniques may contribute to increased costs.[11] Interestingly, even in the absence of complications, costs remained significantly higher in endoscopic procedures compared to microscopic suggesting that other cost drivers may play a substantial role in determination of costs.

Results from our analyses also identified geographical region as a significant predictor of differential costs of transsphenoidal pituitary surgery. Specifically, when compared to the North-East region, overall total and hospital/facility costs were lower in the South and higher in the West regions. Physician payments were also lower in the South compared to the North-East region. There were no significant differences in overall total costs, hospital/facility costs, and physician reimbursements between North-Central and North-East regions. It is however not readily apparent from the scope of this analysis if the observed regional cost discrepancies are consequential to the microscopic-endoscopic transition previously reported.[10,11] What is also not clear from this analysis is whether differences in insurance policies across various geographical regions may have influenced reimbursements and to what extent these differences may have impacted cost discrepancies in transsphenoidal pituitary surgery. Further studies are necessary to fully understand specific determinants of regional cost variations in transsphenoidal pituitary surgery.

Study Strengths and Limitations

A major strength of this study is the large population-based sample of patients analyzed who underwent transsphenoidal pituitary surgery which enhances the generalizability of our findings. In addition, the database employed is primarily a health claims database making it well suited for examining costs and evaluating drivers of costs. The analyses conducted therefore provide updated population-based data on costs and cost drivers associated with transsphenoidal pituitary surgery in the US.

Our study is not without limitations. One limitation is that since our study focused on patients under 65 yr of age, the findings must be cautiously applied to older patients. In addition, results from our study might be subject to bias from potential errors arising in the database, either at the point of data entry or unknowingly miscoded variables in patient records. The impact of these later limitations is, however, to a great extent compensated for by the large sample size analyzed.

There are also additional concerns regarding the sampling methodology and the nature of the sampled population in the MarketScan database (IBM). Due to its nonrandomness, concerns pertaining to its representativeness across different patient populations are plausible. It is however important to note that the MarketScan data with approximately 50 million patients in the main databases each year are based on a large convenience sample mostly obtained from a wide range of providers located across the US, and includes more than 300 employers and over 40 different health plans. The comparatively uniform sampling methodology employed in data collection in states across and within different geographical regions largely minimizes the potential for bias and ensures a fairly even representation of individual patient populations.

Additional methodological constraints relate to concerns of normality of the sample distribution. It is important to note that normality is generally less of a concern in large data samples.[46] In our analysis, however, additional steps were taken to enhance accuracy of our estimates including log transformation of cost estimates to correct for skewness prior to examining for significant differences.[40,41,46] In addition, exclusion of the lowest and highest 1% of payments in our main analysis and the subsequent exclusion of extreme payments outside of up to 3.0 SD of the mean also addressed the effect of outliers and their potential impact on estimated averages. The comparability of costs was further enhanced by propensity matching of our study cohort with multivariable adjustment for confounders. While the effect of outliers might be more likely to impact mean values, it is much less impactful on median values.[46] In our results, we thus present a comprehensive summary of all cost data including means, standard errors and standard deviations, medians and corresponding interquartile estimates, as well as upper and lower percentile ranges (Table 2). On the whole, in view of the large sample size of our studied cohort, we are confident our calculated estimates and effect size of predictor variables are representative of the national average.

Our study included patients covered by capitated and noncapitated plans. In one of our sensitivity analyses, patients with capitated plans were excluded, since this group of patients might have received services not captured by fee-for-service claims. Our sensitivity results however did not differ from the results of our original analysis thus making our original findings generalizable to all patients undergoing transsphenoidal pituitary surgery. In addition, some hospitals and other providers may bundle charges billed for different services into a single amount based on specific diagnosis or diagnosis-related groups, and as such payments in these instances may inaccurately reflect actual payments for individual services. This may specifically skew estimates of individual components of hospital/facility costs potentially resulting in errors in estimating various cost components. However, this is unlikely to impact our study since we do not examine individual components of costs, but rather collectively as hospital/facility costs.

The unavailability of information on hospital and/or provider volume also imposes limitations in our analyses as these also could have potentially affected compensations and reimbursement practices. It is uncertain whether surgeon experience and/or hospital volume might have affected the findings of this present study but surgeon experience and hospital volume have been shown to impact outcomes,[47,48] as well as influence costs of transsphenoidal pituitary surgery.[21] Additionally, the absences of clinical information on disease severity and duration which also could have affected course of management and costs are other important caveats to consider. In our analyses, however, we identify pre-existing medical comorbidities and adjust for the same in multivariate models. To also avoid possible confounding arising from surgery indications, we take into account variability due to case mix and adjust accordingly in multivariate analyses.

An additional limitation is due to the nonspecificity in coding and utilization of CPT-62165 for broader indications. In an attempt to minimize the effect of confounding in this regard, we performed sensitivity analyses limited to patients with specific pituitary pathologies. The results from these sensitivity analyses confirmed the major findings from our main analyses which included all patients. Nonetheless, the imprecise accuracy of coding remains an important limitation of our analyses and we are unable to fully account for expanded endonasal endoscopic approaches coded with 62165.

Our study focused mainly on inpatient costs associated with transsphenoidal pituitary surgery without evaluating outpatient and/or long-term care costs. It is important to note that evaluation of the full complement of costs including inpatient, outpatient, and additional long-term care costs is crucial for an overall value estimation and assessment of transsphenoidal pituitary approaches. Interestingly, a couple studies examining long-term economic modeling have reported endoscopic pituitary surgery is more cost effective than microsurgery.[29-31] In addition, another study reported patients treated endoscopically were less likely to receive postoperative radiation therapy which could reduce overall longitudinal costs.[20] Additional studies are required to fully understand specific drivers of long-term care costs in transsphenoidal pituitary surgery.

In spite of the above-mentioned limitations, our study improves on previous studies that have examined costs associated with transsphenoidal pituitary surgery by providing comprehensive estimates on overall total costs, hospital/facility costs, and professional payments associated with both microscopic and endoscopic transsphenoidal pituitary surgery. Previous studies evaluating costs of pituitary surgery have mostly examined only facility charges by hospitals, without mention of physician charges and/or professional fees associated with surgery.[21,22,27,28] It is relevant to note that studies reporting hospital or facility-only costs without additional assessment of professional charges or fees underestimate the full components of costs involved with inpatient care which patients receive during admissions.

In evaluating costs, our study is particularly unique in that it employs a nationwide medical claims database which reports actual payments to hospitals and providers and evaluates direct payments or revenue received rather than estimated charges, thus obviating the need for conversion using cost-to-charge ratios. Finally, in addition to undertaking a comprehensive evaluation of factors associated with costs discrepancies, this study also provides a measure of the most important factors associated with cost discrepancies in overall total, hospital/facility, as well as professional reimbursements associated with transsphenoidal pituitary surgery across a wide spectrum of practice settings.

CONCLUSION

As interest in lowering health care costs continues to gain increased attention, there is need for continuous appraisal and understanding of factors contributing to increased costs of care. The total costs of inpatient care were significantly elevated among patients who underwent endoscopic procedures. Other predictors associated with increased overall total and hospital/facility costs of transsphenoidal pituitary surgery were LOS, patient age, geographical region, presence of comorbidities, and postoperative surgical and medical complications. The most important contributor to increased total costs including hospital/facility costs was LOS. Physician reimbursements were similar between endoscopic and microsurgical transsphenoidal pituitary surgery with health plan being the most significant predictor of differences in physician reimbursements. Other predictors of physician payments included age, geographical region, postoperative surgical complications, and LOS. Developing strategies for lowering costs necessitates adequate understanding the role of various predictors of costs and differential costs and implementing measures that minimize their impact.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Liu JK, Das K, Weiss MH, Laws ER, Couldwell WT. The history and evolution of transsphenoidal surgery. *J Neurosurg*. 2001;95(6):1083-1096.
2. Gandhi CD, Christiano LD, Eloy JA, Prestigiacomo CJ, Post KD. The historical evolution of transsphenoidal surgery: facilitation by technological advances. *Neurosurg Focus*. 2009;27(3):E8.
3. Solari D, Cavallo LM, Cappabianca P. Surgical approach to pituitary tumors. *Handb Clin Neurol*. 2014;124:291-301.
4. Jankowski R, Auque J, Simon C, Marchal JC, Hepner H, Wayoff M. Endoscopic pituitary tumor surgery. *Laryngoscope*. 1992;102(2):198-202.
5. Sethi DS, Pillay PK. Endoscopic management of lesions of the sella turcica. *J Laryngol Otol*. 1995;109(10):956-962.
6. Rodziewicz GS, Kelley RT, Kellman RM, Smith MV. Transnasal endoscopic surgery of the pituitary gland: technical note. *Neurosurgery*. 1996;39(1):189-193; discussion 192-193.
7. Jho HD, Carrau RL. Endoscopic endonasal transsphenoidal surgery: experience with 50 patients. *J Neurosurg*. 1997;87(1):44-51.
8. Cappabianca P, Alfieri A, de Divitiis E. Endoscopic endonasal transsphenoidal approach to the sella: towards functional endoscopic pituitary surgery (FEPS). *Minim Invasive Neurosurg*. 1998;41(02):66-73.
9. Svider PF, Keeley BR, Husain Q, et al. Regional disparities and practice patterns in surgical approaches to pituitary tumors in the United States. *Int Forum Allergy Rhinol*. 2013;3(12):1007-1012.
10. Rolston JD, Han SJ, Aghi MK. Nationwide shift from microscopic to endoscopic transsphenoidal pituitary surgery. *Pituitary*. 2016;19(3):248-250.
11. Asemota AO, Ishii M, Brem H, Gallia GL. Comparison of complications, trends, and costs in endoscopic vs microscopic pituitary surgery: Analysis from a US health claims database. *Neurosurgery*. 2017;81(3):458-472.
12. Rotenberg B, Tam S, Ryu WHA, Duggal N. Microscopic versus endoscopic pituitary surgery: a systematic review. *Laryngoscope*. 2010;120(7):1292-1297.
13. Goudakos JK, Markou KD, Georgalas C. Endoscopic versus microscopic trans-sphenoidal pituitary surgery: a systematic review and meta-analysis. *Clin Otolaryngol*. 2011;36(3):212-220.
14. Strychowsky J, Nayan S, Reddy K, Farrokhyar F, Sommer D. Purely endoscopic transsphenoidal surgery versus traditional microsurgery for resection of pituitary adenomas: systematic review. *J Otolaryngol*. 2011;40(2):175-185.
15. DeKlotz TR, Chia SH, Lu W, Makambi KH, Aulisi E, Deeb Z. Meta-analysis of endoscopic versus sublabial pituitary surgery. *Laryngoscope*. 2012;122(3):511-518.
16. Ammirati M, Wei L, Ciric I. Short-term outcome of endoscopic versus microscopic pituitary adenoma surgery: a systematic review and meta-analysis. *J Neurol Neurosurg Psychiatry*. 2013;84(8):843-849.
17. Gao Y, Zhong C, Wang Y, et al. Endoscopic versus microscopic transsphenoidal pituitary adenoma surgery: a meta-analysis. *World J Surg Oncol*. 2014;12 (1):94. doi:10.1186/1477-7819-12-94.
18. Singh H, Essayed WI, Cohen-Gadol A, Zada G, Schwartz TH. Resection of pituitary tumors: endoscopic versus microscopic. *J Neurooncol*. 2016;130(2):309-317.
19. Li A, Liu W, Cao P, Zheng Y, Bu Z, Zhou T. Endoscopic versus microscopic transsphenoidal surgery in the treatment of pituitary adenoma: a systematic review and meta-analysis. *World Neurosurg*. 2017;101:236-246. doi:10.1016/j.wneu.2017.01.022.
20. Azad TD, Lee Y-J, Vail D, et al. Endoscopic vs. microscopic resection of sellar lesions-a matched analysis of clinical and socioeconomic outcomes. *Front. Surg*. 2017;4:33. doi:10.3389/fsurg.2017.00033.
21. Little AS, Chapple K. Predictors of resource utilization in transsphenoidal surgery for Cushing disease. *J Neurosurg*. 2013;119(2):504-511.
22. Little AS, Chapple K, Jahnke H, White WL. Comparative inpatient resource utilization for patients undergoing endoscopic or microscopic transsphenoidal surgery for pituitary lesions. *J Neurosurg*. 2014;121(1):84-90.
23. McLaughlin N, Martin NA, Upadhyaya P, et al. Assessing the cost of contemporary pituitary care. *Neurosurg Focus*. 2014;37(5):E7.

24. Karsy M, Brock AA, Guan J, Bisson EF, Couldwell WT. Assessment of cost drivers in transsphenoidal approaches for resection of pituitary tumors using the value-driven outcome database. *World Neurosurg*. 2017;105:818-823. doi:10.1016/j.wneu.2017.05.148.
25. Fisher ES, Bynum JP, Skinner JS. Slowing the growth of health care costs–lessons from regional variation. *N Engl J Med*. 2009;360(9):849-852.
26. Oosmanally N, Paul JE, Zanation AM, Ewend MG, Senior BA, Ebert CS. Comparative analysis of cost of endoscopic endonasal minimally invasive and sublabial-transseptal approaches to the pituitary. *Int Forum Allergy Rhinol*. 2011;1(4):242-249.
27. Swearingen B, Wu N, Chen S-Y, Pulgar S, Biller BMK. Health care resource use and costs among patients with cushing disease. *Endocr Pract*. 2011;17(5):681-690.
28. Zaidi HA, Chapple K, Little AS. National treatment trends, complications, and predictors of in-hospital charges for the surgical management of craniopharyngiomas in adults from 2007 to 2011. *Neurosurg Focus*. 2014;37(5):E6.
29. Rudmik L, Starreveld YP, Vandergrift WA, Banglawala SM, Soler ZM. Cost-effectiveness of the endoscopic versus microscopic approach for pituitary adenoma resection. *Laryngoscope*. 2015;125(1):16-24.
30. Jethwa PR, Patel TD, Hajart AF, Eloy JA, Couldwell WT, Liu JK. Cost-effectiveness analysis of microscopic and endoscopic transsphenoidal surgery versus medical therapy in the management of microprolactinoma in the United States. *World Neurosurg*. 2016;87:65-76.
31. Ament JD, Yang Z, Khatchadourian V, Strong EB, Shahlaie K. Cost-effectiveness of endoscopic versus microscopic transsphenoidal surgery for pituitary adenoma. *World Neurosurg*. 2018;110:e496-e503..
32. MarketScan Research Databases Healthcare Claims Data. http://truvenhealth.com/your-healthcare-focus/analytic-research/marketscan-research-databases. Accessed August 18, 2017.
33. Hansen L. The MarketScan databases for life sciences researchers. *Truven Health Analytics* 2016. Life Sciences Research Data and Analytic Tools. Available at: http://truvenhealth.com/markets/life-sciences/products/data-tools/marketscan-databases. Accessed June 20, 2016.
34. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.
35. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *J Clin Epidemiol*. 1992;45(6):613-619.
36. Blough DK, Ramsey SD. Using generalized linear models to assess medical care costs. *Health Serv Outcomes Res Methodol*. 2000;1(2):185-202.
37. Barber J, Thompson S. Multiple regression of cost data: use of generalised linear models. *J Health Serv Res Policy*. 2004;9(4):197-204.
38. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrika*. 1983;70(1):41-55.
39. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivar Behav Res*. 2011;46(3):399-424.
40. Keene ON. The log transformation is special. *Stat Med*. 1995;14(8):811-819.
41. Diehr P, Yanez D, Ash A, Hornbrook M, Lin DY. Methods for analyzing health care utilization and costs. *Annu Rev Public Health*. 1999;20(1):125-144.
42. Dodd S, Bassi A, Bodger K, Williamson P. A comparison of multivariable regression models to analyse cost data. *J Eval Clin Pract*. 2006;12(1):76-86.
43. Blalock HM. Evaluating the relative importance of variables. *Am Sociol Rev*. 1961;26(6):866-874.
44. Wilson D, Jin DL, Wen T, et al. Demographic factors, outcomes, and patient access to transsphenoidal surgery for Cushing's disease: analysis of the Nationwide Inpatient Sample from 2002 to 2010. *Neurosurg Focus*. 2015;38(2):E2.
45. Bodenheimer T. High and rising health care costs. Part 2: technologic innovation. *Ann Intern Med*. 2005;142(11):932-937.
46. Lumley T, Diehr P, Emerson S, Chen L. The importance of the normality assumption in large public health data sets. *Annu Rev Public Health*. 2002;23(1):151-169.
47. Ciric I, Ragin A, Baumgartner C, Pierce D. Complications of transsphenoidal surgery: results of a national survey, review of the literature, and personal experience. *Neurosurgery*. 1997;40(2):225-237; discussion 236-237.
48. Barker FG, Klibanski A, Swearingen B. Transsphenoidal surgery for pituitary tumors in the united states, 1996–2000: mortality, morbidity, and the effects of hospital and surgeon volume. *J Clin Endocrinol Metab*. 2003;88(10):4709-4719.

***Supplemental digital content** is available for this article at www.neurosurgery-online.com.*

Supplemental Digital Content 1. Table. List of ICD-9-CM codes used for identification of complications.

Supplemental Digital Content 2. Figure. Graphical presentation of payments (ie overall total, hospital/facility, and physician) before [top row], and after logarithmic transformation [bottom row].

Supplemental Digital Content 3. Table. List of ICD-9-CM codes used in sensitivity analyses.

Supplemental Digital Content 4. Figure. Relationship between lengths of hospital stay and logarithmically transformed payments (overall total, hospital/facility, and physician).

Supplemental Digital Content 5. Table. Unmatched multivariate analysis of predictors of overall total, hospital/facility, and physician payments.

Supplemental Digital Content 6. Table. Analysis of predictors of overall total payments among subset of patients with specific pituitary pathologies.

Supplemental Digital Content 7. Table. Analysis of predictors of hospital/facility payments among subset of patients with specific pituitary pathologies.

Supplemental Digital Content 8. Table. Analysis of predictors of physician payments among subset of patients with specific pituitary pathologies.

COMMENT

The authors are to be commended for their review of the differences in costs between microscopic transsphenoidal versus endoscopic resection of pituitary tumors. Their data is derived from the Truven MarketScan database (IBM) between 2010 and 2014, which is a time period wherein the endoscopic techniques have clearly been refined.

The authors find that the overall total and hospital facility costs are higher with endoscopic transsphenoidal pituitary surgery. Physician reimbursements were essentially equal between the two techniques. Length of the stay was the strongest predictor of overall total and hospital facility costs, which appeared slightly higher in the endoscopic group due to the slightly higher complication rate. Health plan was the strongest predictor of differential for physician reimbursement.

This is an insightful data-driven article; however, it is difficult to determine whether the minor differences in costs between the techniques will actually alter the recommendations of physicians. From a market standpoint, the patients are driven to the aspect of the minimally invasive surgery as described and associated with endoscopic procedure, and therefore, they tend to gravitate towards that technique. In addition, one would hope that a physician would utilize the technique that they are most comfortable with, as this will clearly result in better patient outcomes. The cost differences are clear but not of significant magnitude, and one would hope that this will not become a major driving force in our healthcare delivery for the treatment of pituitary tumors.

This type of analysis is extremely important; however, the data must always be interpreted in the light of high-quality outcomes and the patient's satisfaction.

Philip E. Stieg
New York, New York