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Geographic Variation in Costs of Transsphenoidal Pituitary Surgery in the United States

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■ BACKGROUND: **Geographic variations in health care costs have been reported for many surgical specialties.**

■ OBJECTIVE: **In this study, we sought to describe national and regional costs associated with transsphenoidal pituitary surgery (TPS).**

■ METHODS: **Data from the Truven-MarketScan 2010–2014 were analyzed. We examined overall total, hospital/facility, physician, and out-of-pocket payments in patients undergoing TPS including technique-specific costs. Mean payments were obtained after risk adjustment for patient-level and system-level confounders and estimated differences across regions.**

■ RESULTS: **The estimated overall annual burden was $43 million/year in our cohort. The average overall total payment associated with TPS was $35,602.30, hospital/facility payment was $26,980.45, physician payment was $4685.95, and out-of-pocket payment was $2330.78. Overall total and hospital/facility costs were highest in the West and lowest in the South (both $P < 0.001$), whereas physician reimbursements were highest in the North-east and lowest in the South ($P < 0.001$). There were no differences in out-of-pocket expenses across regions. On a national level, there were significantly higher overall total and hospital/facility payments associated with endoscopic compared with microscopic procedures (both $P < 0.001$); there were no significant differences in physician payments or out-of-pocket expenses between techniques. There were also significant within-region cost differences in overall total, hospital/facility, and physician payments in both techniques as well as in out-of-pocket expenses associated with microsurgery. There were no significant regional differences in out-of-pocket expenses associated with endoscopic surgery.**

■ CONCLUSIONS: **Our results show significant geographic cost disparities associated with TPS. Understanding factors behind disparate costs is important for developing cost containment strategies.**

INTRODUCTION

Given the current health care climate characterized by increasing costs, increasingly limited resources, and U.S. national health expenditures approximating 17.9% of the national gross domestic product, cost estimates have become crucial for making key decisions about allocating health care resources.[1,2] The increase in health care costs is also compounded by regional cost discrepancies.[3-5] Wide variations in utilization and costs have been described for major surgical procedures across different geographic regions of the United States.[6,7] In addition, variable costs have been reported across different facilities even within the same geographic region.[8,9]

Increasingly, regional cost variations are being reported in major neurosurgical procedures.[10-16] Regarding transsphenoidal pituitary surgery (TPS), there are limited studies reporting regional cost variation.[9,17] Specifically, Lee et al.[9] examined TPS costs across hospitals in 5 regions of New York State. Adjusting for length of hospital stay (LOS), these investigators found substantial variation in charges and costs of pituitary surgery across hospitals in the 5 defined regions. Svider et al.[17] using a national database examined regional

Key words
- Geographic variation
- Hospital/facility costs
- Out-of-pocket payments
- Physician reimbursements
- Regional disparities
- Socioeconomics
- Transsphenoidal pituitary surgery

Abbreviations and Acronyms
CCI: Charlson Comorbidity Index
CI: Confidence interval
CPT: Current Procedural Terminology, Fourth Edition
LOS: Length of hospital stay
SD: Standard deviation
SE: Standard error
TPS: Transsphenoidal pituitary surgery

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Table 1. Population Characteristics by Geographic Region

	North-East		North-Central		South		West		Total		
Total	**N = 1025**	**%**	**N = 1036**	**%**	**N = 2112**	**%**	**N = 1065**	**%**	**N = 5238**	**%**	***P***
Technique											<0.001
Microscopic	433	(42.24)	516	(49.81)	1264	(59.85)	629	(59.06)	2842	(54.26)	
Endoscopic	592	(57.76)	520	(50.19)	848	(40.15)	436	(40.94)	2396	(45.74)	
Age group											<0.001
<18 years	28	(2.73)	34	(3.28)	53	(2.51)	34	(3.19)	149	(2.84)	
18–34 years	201	(19.61)	171	(16.51)	379	(17.95)	242	(22.72)	993	(18.96)	
35–44 years	208	(20.29)	209	(20.17)	482	(22.82)	222	(20.85)	1121	(21.40)	
45–54 years	262	(25.56)	272	(26.25)	593	(28.08)	286	(26.85)	1413	(26.98)	
55–64 years	326	(31.80)	350	(33.78)	605	(28.65)	281	(26.38)	1562	(29.82)	
Gender											0.28
Male	481	(46.93)	486	(46.91)	928	(43.94)	477	(44.79)	2372	(45.28)	
Female	544	(53.07)	550	(53.09)	1184	(56.06)	588	(55.21)	2866	(54.72)	
Charlson Comorbidity Index											0.29
0	756	(73.76)	789	(76.16)	1592	(75.38)	815	(76.53)	3952	(75.45)	
1	158	(15.41)	147	(14.19)	282	(13.35)	155	(14.55)	742	(14.17)	
≥2	111	(10.83)	100	(9.65)	238	(11.27)	95	(8.92)	544	(10.39)	
Health plan											<0.001
Employer	368	(35.90)	490	(47.30)	1039	(49.20)	493	(46.29)	2390	(45.63)	
Nonemployer	657	(64.10)	546	(52.70)	1073	(50.80)	572	(53.71)	2848	(54.37)	
Capitated payment indicator											<0.001
No	993	(96.88)	1032	(99.61)	2079	(98.44)	994	(93.33)	5098	(97.33)	
Yes	4	(0.39)	0	0.00	11	(0.52)	70	(6.57)	85	(1.62)	
Missing	28	(2.73)	4	(0.39)	22	(1.04)	1	(0.09)	55	(1.05)	
Network payment indicator											<0.001
No	87	(8.49)	51	(4.92)	64	(3.03)	133	(12.49)	335	(6.40)	
Yes	763	(74.44)	936	(90.35)	1974	(93.47)	921	(86.48)	4594	(87.71)	
Missing	175	(17.07)	49	(4.73)	74	(3.50)	11	(1.03)	309	(5.90)	
Postoperative surgical complications											0.31
Nil	622	(60.68)	613	(59.85)	1251	(59.56)	667	(62.91)	3153	(60.52)	
Yes	403	(39.32)	416	(40.15)	854	(40.44)	395	(37.09)	2068	(39.48)	
Postoperative medical complications											0.48
Nil	983	(95.90)	996	(96.14)	2015	(95.41)	1028	(96.53)	5022	(95.88)	
Yes	42	(4.10)	40	(3.86)	97	(4.59)	37	(3.47)	216	(4.12)	
Discharge disposition											0.86
Alive	1024	(99.90)	1034	(99.81)	2108	(99.81)	1064	(99.91)	5230	(99.85)	
Died	1	(0.10)	2	(0.19)	4	(0.19)	1	(0.09)	8	(0.15)	
Mean length of stay (±standard deviation) (days)	3.42	(±3.20)	3.48	(±2.79)	3.98	(±3.23)	3.08	(±2.50)	3.59	(±3.02)	<0.001

Table 2. Comparison of National and Regional Average Costs (Risk-Adjusted) Associated With Microscopic and Endoscopic Transsphenoidal Pituitary Surgery

	Total (Mean ± SE)	Microscopic (Mean ± SE)	Endoscopic (Mean ± SE)	*P*
National				
Overall total payments	35,602.30 ± 239.66	34,037.82 ± 327.47	37,516.08 ± 363.25	<0.001
Hospital/facility payments	26,980.45 ± 214.85	25,949.14 ± 293.57	28,242.02 ± 325.65	<0.001
Physician payments	4685.95 ± 95.50	4565.49 ± 175.56	4833.30 ± 183.82	0.05
Out-of-pocket payments	2330.78 ± 80.90	2368.22 ± 109.44	2282.99 ± 124.09	0.51
Regional				
Overall total payments				
North-east	37,905.78 ± 527.16	36,577.61 ± 801.88	39,988.63 ± 847.77	0.97
North-central	36,720.65 ± 537.38	35,114.21 ± 697.89	38,894.94 ± 828.80	0.33
South	32,087.17 ± 376.81	29,505.91 ± 446.58	35,289.97 ± 646.50	<0.001
West	39,594.16 ± 523.63	36,118.33 ± 628.53	43,790.05 ± 890.18	<0.001
Hospital/facility payments				
North-east	27,094.65 ± 521.78	25,777.01 ± 726.66	28,927.41 ± 752.94	0.57
North-central	28,026.36 ± 481.65	27,022.64 ± 632.43	29,434.22 ± 736.09	0.38
South	24,363.66 ± 337.73	22,531.83 ± 404.69	26,625.83 ± 574.19	<0.001
West	30,968.69 ± 469.32	28,396.08 ± 569.57	34,230.47 ± 790.60	<0.001
Physician payments				
North-east	6016.89 ± 172.98	6617.80 ± 176.24	5126.16 ± 187.05	<0.001
North-central	5150.06 ± 162.27	4779.45 ± 165.60	5337.76 ± 182.86	0.06
South	4035.64 ± 103.51	3534.02 ± 105.96	4740.06 ± 142.64	<0.001
West	4729.08 ± 135.73	4455.41 ± 149.14	4683.26 ± 149.40	0.13
Out-of-pocket payments				
North-east	1992.58 ± 212.30	1772.28 ± 285.60	2218.62 ± 317.47	0.69
North-central	2508.38 ± 190.93	2337.05 ± 241.22	2674.85 ± 302.95	0.27
South	2444.46 ± 121.05	2611.84 ± 139.37	2189.45 ± 215.01	0.10
West	2170.40 ± 177.15	2115.49 ± 207.81	2207.77 ± 308.96	0.79

All payments are reported in 2018 U.S. dollars; *P* values represent comparisons between microscopic and endoscopic groups.
SE, standard error.

differences in Medicare part B costs in TPS. After correcting for regional variation in procedural volumes, this study reported regional differences in average costs in both endoscopic and microscopic procedures.[17] Our current study evaluates national and regional costs including overall total, hospital/facility, physician, and out-of-pocket payments in TPS.

METHODS

Data Source

The Truven-Health Analytics MarketScan databases were used. Nearly 23 million individual records representing approximately 50% of annual U.S. discharges and >40 health plans and 260 employers are included in the MarketScan databases, making them representative of the U.S. population.[18] The databases contain fully de-identified health care claims compliant with the Health Insurance Portability and Accountability Act.[18,19] This study was conducted using the 2010–2014 MarketScan Commercial Database, which contains data for several million individuals annually who are covered by employer-sponsored private health insurance in the United States.[18,19] Records from the inpatient file were accessed.[19]

Study Population

Patients undergoing microscopic (CPT-61548) or endoscopic (CPT-62165) TPS were identified using Current Procedural Terminology, Fourth Edition (CPT-4) procedure codes. The type of admission (e.g., medical, surgical, and obstetric) was identified and, to restrict our analyses to TPS-associated costs, nonsurgical cases were excluded. Records containing both microscopic and

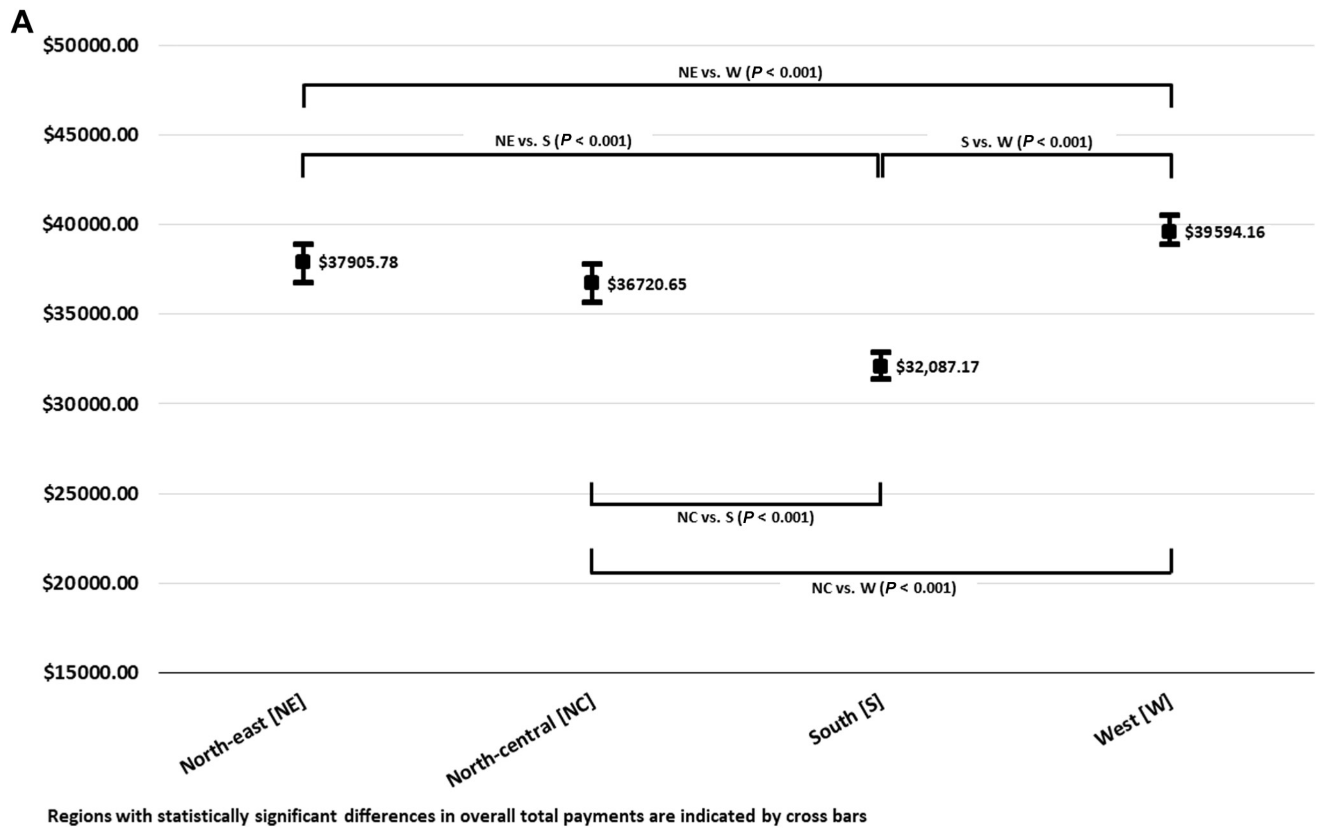


Figure 1. (**A**) Regional variation in overall total payments in transsphenoidal pituitary surgery. The average regional overall total payments were as follows: North-east (NE) ($37,905.78; 95% CI, $36,764.49–$38,847.07), North-central (NC) ($36,720.65; 95% CI, $35,667.13–$37,774.16), South (S) ($32,087.17; 95% CI, $31,348.45–$32,825.88), and West (W) ($39,594.16; 95% CI, $38,867.60–$40,520.71). Pairwise comparisons: NE vs. NC ($P = 0.10$), NE vs. S ($P < 0.001$), NE vs. W ($P < 0.001$), NC vs. S ($P < 0.001$), NC vs. W ($P < 0.001$), and S vs. W ($P < 0.001$). Significant regional differences are highlighted. (**B**) Regional variation in hospital/facility payments in transsphenoidal pituitary surgery. The average regional hospital/facility costs were as follows: North-east (NE) ($27,094.65; 95% CI, $26,071.73–$28,117.56), North-central (NC) ($28,026.36; 95% CI, $27,082.11–$28,970.61), South (S) ($24,363.66; 95% CI, $23,701.56–$25,025.75), and West (W) ($30,968.69; 95% CI, $30,048.60–$31,888.77). Pairwise comparisons: NE vs. NC ($P = 0.42$), NE vs. S ($P < 0.001$), NE vs. W ($P < 0.001$), NC vs. S ($P < 0.001$), NC vs. W ($P < 0.001$), and S vs. W ($P < 0.001$). Significant regional differences are highlighted. (**C**) Regional variation in physician payments in transsphenoidal pituitary surgery. The average regional physician payments were as follows: North-east (NE) ($6016.89; 95% CI, $5321.37–$6588.40), North-central (NC) ($5150.06; 95% CI, $4806.88–$5530.84), South (S) ($4035.64; 95% CI, $3865.17–$4195.30), and West (W) ($4729.08; 95% CI, $4227.32–$5306.05). Pairwise comparisons: NE vs. NC ($P = 0.12$), NE vs. S ($P < 0.001$), NE vs. W ($P = 0.10$), NC vs. S ($P < 0.001$), NC vs. W ($P = 0.28$), and S vs. W ($P < 0.001$). Significant regional differences are highlighted. (**D**) Regional variation in out-of-pocket payments in transsphenoidal pituitary surgery. The average regional out-of-pocket payments were as follows: North-east (NE) ($1992.58; 95% CI, $1576.35–$2408.82), North-central (NC) ($2508.38; 95% CI, $2134.04–$2882.71), South (S) ($2444.46; 95% CI, $2207.12–$2681.80), and West (W) ($2170.40; 95% CI, $1823.08–$2517.72). Pairwise comparisons: NE vs. NC ($P = 0.41$), NE vs. S ($P = 0.31$), NE vs. W ($P = 0.09$), NC vs. S ($P = 0.07$), NC vs. W ($P = 0.17$), and S vs. W ($P = 0.22$). There were no significant regional differences in out-of-pocket payments.

(Continues)

endoscopic codes in the same admission and those undergoing craniotomy for hypophysectomy/excision of pituitary tumor (CPT-61546) were excluded. Records containing unreasonable (negative or zero) payments and those with the lowest and highest 1% of overall total, hospital/facility, and physician payments were excluded. Patients with unknown geographic region were also excluded, generating the cohort analyzed for overall total, hospital/facility, and physician payments. For analyses of out-of-pocket expenses, records containing zero or negative out-of-pocket payments were excluded from this cohort. Our study included only patients younger than 65 years. This study did not require institutional review board approval.

Variables Included

We examined patient characteristics including age, gender, comorbidity, health plan, capitated payments, network payments, surgical technique (microscopic and endoscopic), geographic regions (North-east, North-central, South, and West, Supplementary Table 1), postoperative surgical and medical complications during admission (Supplementary Table 2), discharge disposition, and LOS. Comorbidity was quantified using the Charlson Comorbidity Index (CCI).[20] Capitated payments are fixed amounts paid per patient as agreed by the insurance company with the health care service provider.

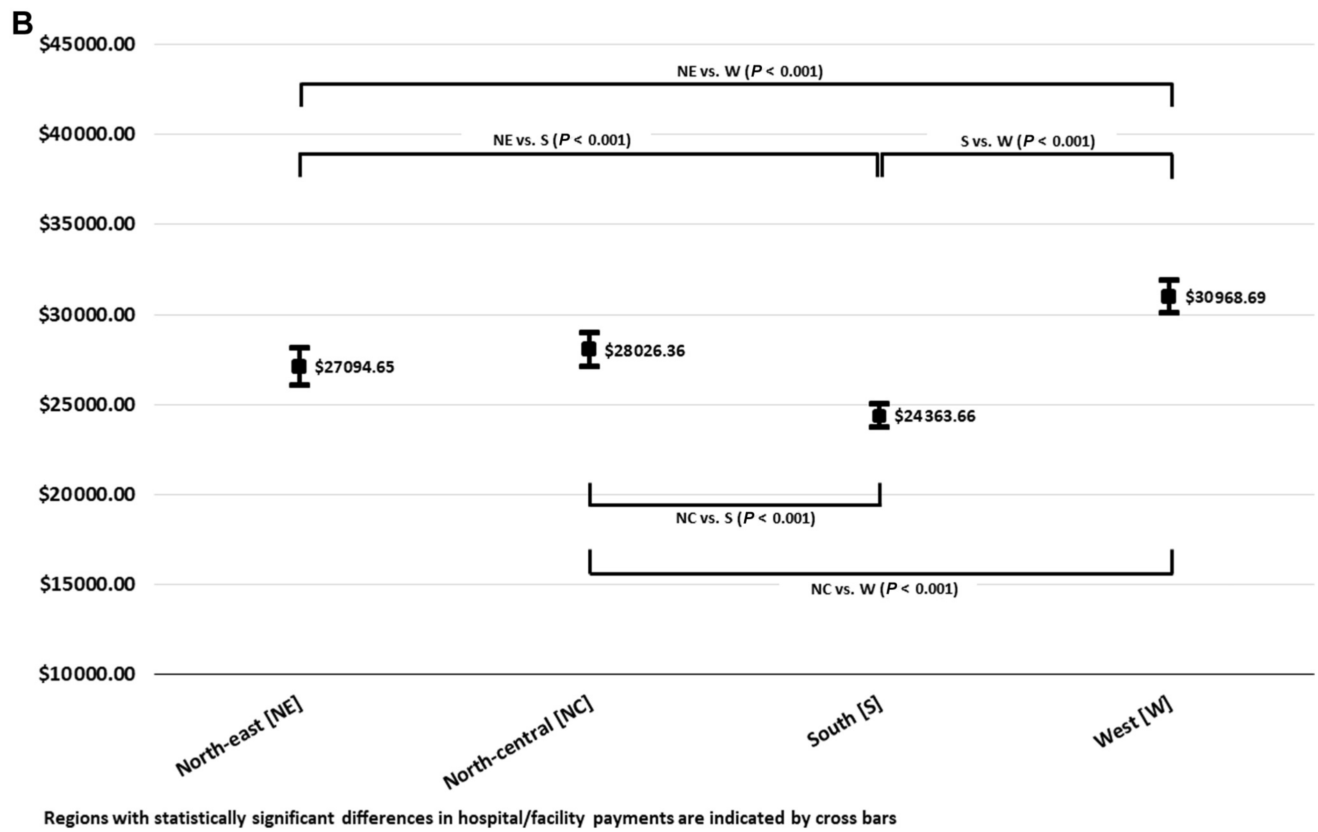


Figure 1. (*continued*).

Outcome Measures

Overall Total Payments. Overall total payments are total gross payments for all services per admission.[19] Overall total payments include payments received for the inpatient encounter comprising hospital/facility payments, physician payments, and all other provider payments.[19]

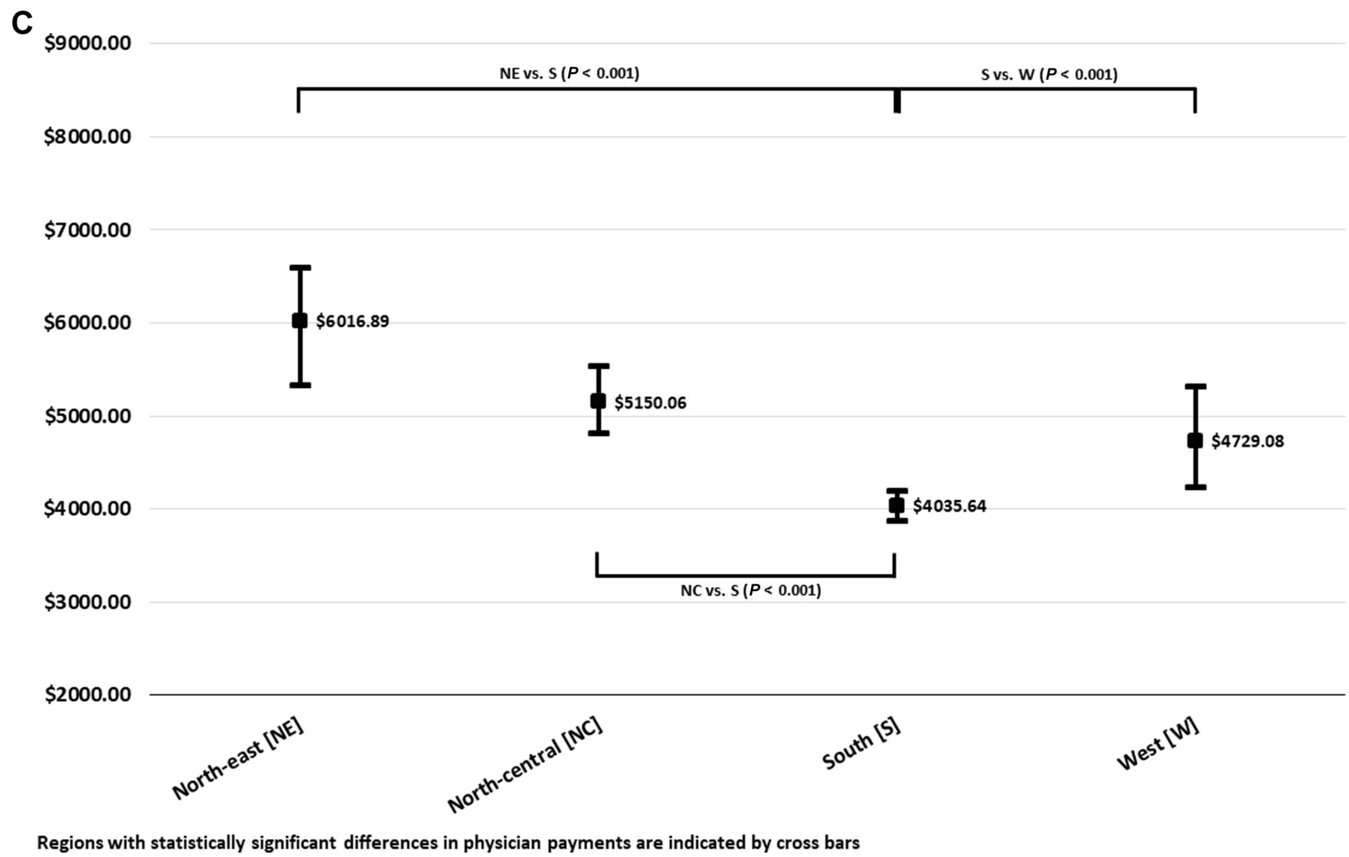
Hospital/Facility Payments. Hospital/facility payments comprise total gross payments to hospitals for covered services per admission. Hospital/facility payments are included in overall total payments.[19]

Physician Payments. Physician payments are total covered payments for services/procedures rendered by the principal physician/surgeon per admission. The principal physician/surgeon is the professional who charges the most during the admission. Physician payments as well as payments to physicians other than the principal physician/surgeon are included in overall total payments.[19]

Out-of-Pocket Payments. Out-of-pocket payments are part of the total claim/payments borne by patients unpaid for by insurance companies. The sum total of coinsurance, copayments, and other deductibles is included in this category.[19]

Statistical Analysis

Standard descriptive methods characterized our study sample. Risk-adjusted means with respective standard deviations (SD) and/or standard errors (SE), and 95% confidence intervals (CIs) were calculated and reported for continuous variables, whereas frequencies and percentages were reported for categorical variables. Standard t tests and χ^2 tests evaluated associations for continuous and categorical variables, respectively. National estimates of cost metrics including overall total, hospital/facility, physician, and out-of-pocket payments were obtained. Intraregional and interregional cost variations between microscopic and endoscopic techniques were examined. Pairwise comparisons and post hoc estimations used the Tukey honest significant difference. Multivariate linear regression and propensity score—matched models examined regional cost variability, and estimates of differential costs (actual difference in U.S. dollars between region with the lowest payments [reference group] and other geographic regions) adjusted for confounders were obtained in marginal differential analysis. In regression models, adjustments were made for age, gender, health plan, geographic region, LOS, CCI, postoperative complications, case mix, provider-network indicator, and year of surgery. Effect of clustering was accounted for in models assessing regional costs. In estimating overall economic



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burden of hospitalization (reported per year), overall total payments made by all patients identified in our initial TPS cohort were included. Costs were adjusted for inflation using the consumer price index (Bureau of Labor Statistics, U.S. Department of Labor) and reported in 2018 U.S. dollars.[21] All cost comparisons were performed with logarithmically transformed payments and statistical significance defined as $P < 0.05$.

Sensitivity Analyses

Secondary independent analyses were performed with 1) cases with specific pituitary diseases (Supplementary Table 3), 2) noncapitated based claims only, 3) exclusion of outlying payments beyond 2.0, 2.5, and 3.0 SD of the mean, and 4) inclusion of zero out-of-pocket payments.

RESULTS

General Findings

Our initial query yielded 6044 TPS cases and 5238 met our inclusion criteria (Supplementary Figure 1) including 2842 microscopic and 2396 endoscopic cases. From this cohort, there were 3992 records with greater than zero out-of-pocket payments. The mean patient age was 45.20 years (SD ±13.18). The proportions of endoscopic and microscopic procedures differed significantly across regions ($P < 0.001$). There were significant differences in age group composition, health plan, proportions of capitated versus noncapitated payments, and proportion of in-network payments across regions (all $P < 0.001$). There were no significant differences in gender distribution ($P = 0.28$), CCI ($P = 0.29$), postoperative surgical ($P = 0.31$) and medical ($P = 0.48$) complications, or discharge disposition ($P = 0.86$) across regions. LOS was highest in the South and lowest in the West ($P < 0.001$) (Table 1). Microscopic and endoscopic cohorts differed only in the proportion of postoperative surgical complications (Supplementary Table 4).

National and Regional Costs

Nationally, the mean overall total payment associated with TPS was $35,602.30 (SE ±239.66) (Table 2). Not surprisingly, most of this cost was from hospital/facility payments, which averaged $26,980.45 (SE ±214.85). Mean physician payment was $4685.95 (SE ±95.50) and mean out-of-pocket payment was $2330.78 (SE ±80.90). The estimated average burden of hospitalization in all patients identified in our initial cohort ($n = 6044$) was approximately $43,036,060 per year. Nationally, overall total and hospital/facility payments were significantly higher with endoscopic

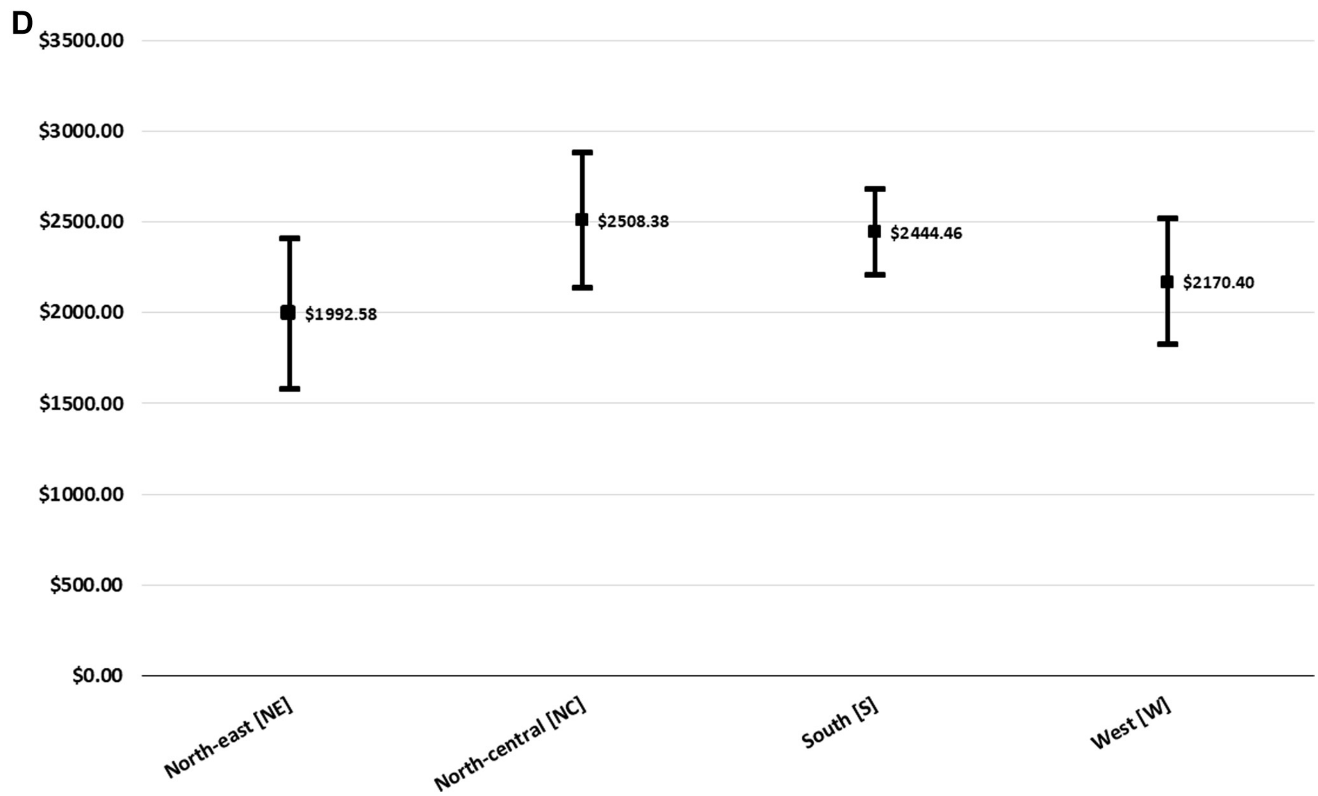

Figure 1. (*continued*).

compared with microscopic techniques (both $P < 0.001$); there were no significant differences in physician ($P = 0.05$) or out-of-pocket ($P = 0.51$) payments between techniques. Results from regional assessment as well as pairwise comparisons of overall total, hospital/facility, physician, and out-of-pocket payments associated with TPS are shown in Figure 1.

Regional Cost Comparisons Between Microscopic and Endoscopic Techniques

There were no significant differences in overall total payments between microscopic and endoscopic techniques in the North-east ($P = 0.97$) and North-central ($P = 0.33$) regions (Table 2). In contrast, overall total payments were significantly higher in endoscopic cases in the South ($P < 0.001$) and West ($P < 0.001$) regions. Similarly, hospital/facility payments showed no significant differences between techniques in the North-east ($P = 0.57$) and North-central ($P = 0.38$) regions, but were significantly higher in endoscopic techniques in the South ($P < 0.001$) and West ($P < 0.001$) regions. Whereas average physician payments were significantly higher with microscopic techniques in the North-east ($P < 0.001$) and endoscopic techniques in the South ($P < 0.001$), there were no significant differences in physician payments between techniques in the North-central ($P = 0.06$) and West ($P = 0.13$). There were no significant differences in out-of-pocket payments between microscopic and endoscopic procedures in the North-east ($P = 0.69$), North-central ($P = 0.27$), South ($P = 0.10$), and West ($P = 0.79$) (Table 2). Pairwise regional comparisons of overall total, hospital/facility, physician, and out-of-pocket costs in endoscopic and microscopic subsets are shown in Figures 2–5, respectively.

Differential Costs

Estimated differential costs (risk-adjusted) were also examined (Table 3). Because overall total, hospital/facility, and physician payments were lowest in the South, this region was used as reference. The estimated differential costs between regions with the highest and lowest (i.e., West and South, respectively) overall total payments was approximately $6835.87 (95% CI, 5656.67–8015.07; $P < 0.001$), and hospital/facility payments was approximately $6104.02 (95% CI, 5046.88–7161.16; $P < 0.001$). The estimated differential costs between the highest and lowest regions (i.e., North-east and South, respectively) in physician payments was approximately $1823.47 (95% CI, 1530.70–2116.24; $P < 0.001$). There were no significant differences in out-of-pocket payments across regions.

Sensitivity Analyses

Results of sensitivity analyses did not change our original findings.

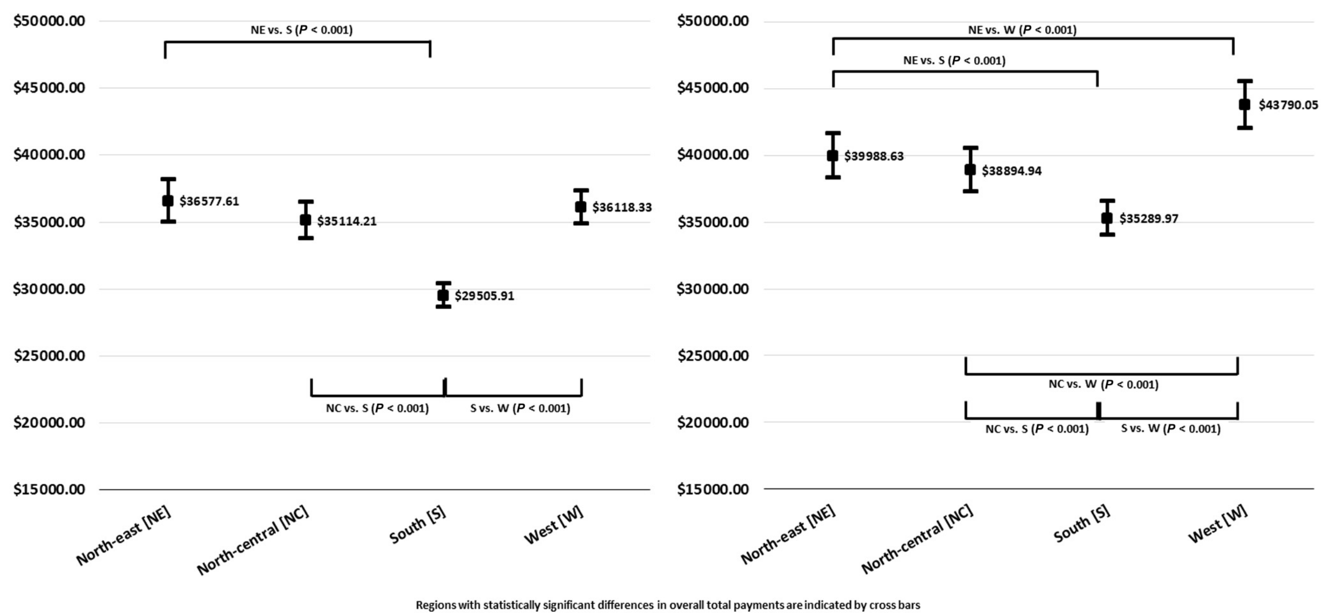

Figure 2. Regional variation in overall total payments in transsphenoidal pituitary surgery stratified by surgical technique. The average regional overall total payments in microscopic techniques (*left*) were as follows: North-east (NE) ($36,577.61; 95% CI, $35,005.24–$38,149.98), North-central (NC) ($35,114.21; 95% CI, $33,745.74–$36,482.67), South (S) ($29,505.91; 95% CI, $28,630.24–$30,381.59), and West (W) ($36,118.33; 95% CI, $34,885.88–$37,350.80). Pairwise comparisons: NE vs. NC ($P = 0.07$), NE vs. S ($P < 0.001$), NE vs. W ($P = 0.10$), NC vs. S ($P < 0.001$), NC vs. W ($P = 0.80$), and S vs. W ($P < 0.001$). The average regional overall total payments in endoscopic techniques (*right*) were as follows: NE ($39,988.63; 95% CI, $38,326.11–$41,651.14), NC ($38,894.94; 95% CI, $37,269.62–$40,520.25), S ($35,289.97; 95% CI, $34,022.15–$36,557.79), and W ($43,790.05; 95% CI, $42,044.38–$45,535.73). Pairwise comparisons: NE vs. NC ($P = 0.39$), NE vs. S ($P < 0.001$), NE vs. W ($P < 0.001$), NC vs. S ($P < 0.001$), NC vs. W ($P < 0.001$), and S vs. W ($P < 0.001$). Significant regional differences are highlighted.

DISCUSSION

Summary of Findings

In our study, we evaluated direct costs (including overall total, hospital/facility, physician, and out-of-pocket payments), analyzed regional cost variation, and estimated geographic cost differentials associated with TPS. Our results show significant regional cost variation in TPS. Overall total and hospital/facility costs were lowest in the South and highest in the West. In addition, physician reimbursements were highest in the North-east and lowest in the South. Out-of-pocket payments were similar across regions.

We also found cost differences between microscopic and endoscopic techniques. When examined nationally, overall total and hospital/facility payments were higher with endoscopic procedures; physician and out-of-pocket payments were similar between techniques. Significant regional cost differences were found in overall total, hospital/facility, and physician payments in both techniques, as well as in out-of-pocket payments in microsurgery. Putting regional costs in context of surgical technique, the higher average costs seen in the West seem to be driven by the higher unit cost of endoscopic techniques compared with microsurgery in that region. With respect to the South, where the average TPS cost was lowest, both microscopic and endoscopic techniques were the least expensive.

Overall Total and Hospital/Facility Payments

Overall total and hospital/facility costs associated with endoscopic techniques were more expensive than microsurgery in the South and West regions, with no differences noted in the North-east and North-central regions. One possible explanation for this finding is related to varying rates of utilization consequent to temporal trends in adoption of endoscopic techniques.[22,23] More specifically, in the North-east and North-central regions, with an earlier microscopic-endoscopic transition,[22] there were no significant differences in overall total and hospital/facility costs between techniques. However, these costs were both increased with endoscopic techniques in the South and West regions, which lag in this transition.[22] It is possible that over time as endoscopic techniques become more widely adopted, a reduction in cost differential in these regions might become evident.

The regional/national variability of costs may be affected by other factors. For example, nonuniformity in reimbursements by insurance payers across regions might be implicated.[24-26] Hospital/facility costs and physician reimbursements reportedly vary by payer and region.[25] In our study, we found significant regional differences in the distribution of employer-based versus non–employer-based health plans, and proportions of cases reimbursed within provider networks. Costs may also be influenced by the number and composition of participating providers

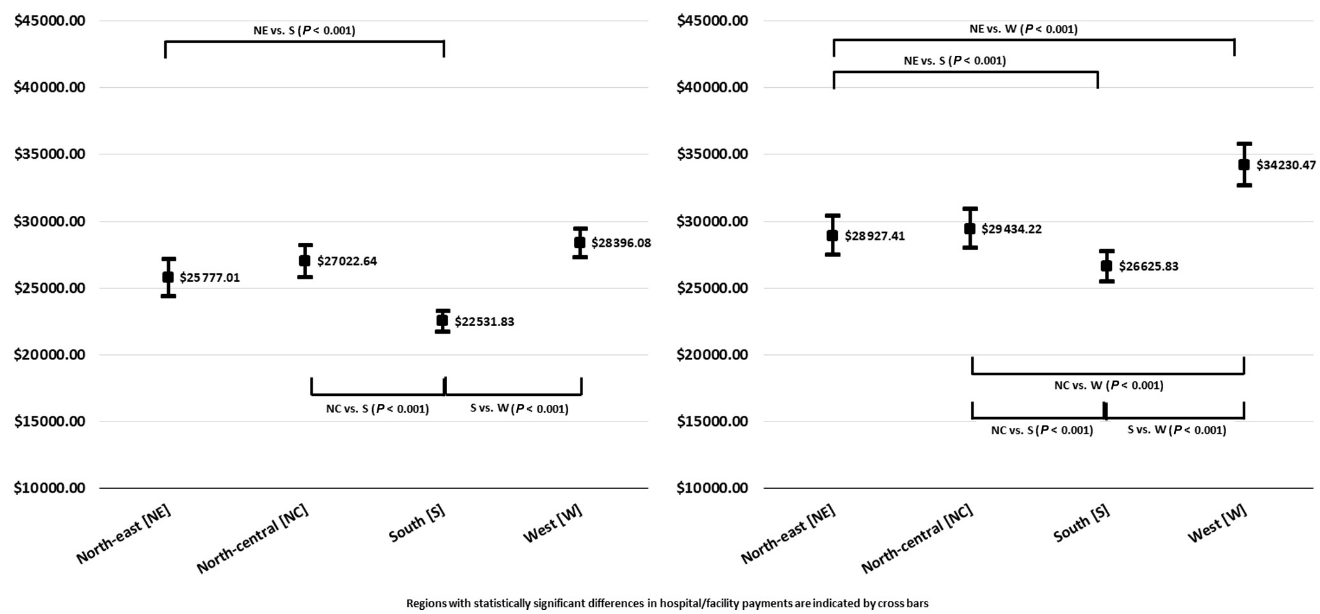

Figure 3. Regional variation in hospital/facility payments in transsphenoidal pituitary surgery stratified by technique. The average regional hospital/facility costs in microscopic techniques (*left*) were as follows: North-east (NE) ($25,777.01; 95% CI, $24,352.14–$27,201.87), North-central (NC) ($27,022.64; 95% CI, $25,782.55–$28,262.73), South (S) ($22,531.83; 95% CI, $21,738.30–$23,325.36), and West (W) ($28,396.08; 95% CI, $27,279.23–$29,512.92). Pairwise comparisons: NE vs. NC ($P = 0.27$), NE vs. S ($P < 0.001$), NE vs. W ($P = 0.34$), NC vs. S ($P < 0.001$), NC vs. W ($P = 0.84$), and S vs. W ($P < 0.001$). The average regional hospital/facility costs in endoscopic techniques (*right*) were as follows: NE ($28,927.41; 95% CI, $27,450.88–$30,403.95), NC ($29,434.22; 95% CI, $27,990.72–$30,877.72), S ($26,625.83; 95% CI, $25,499.83–$27,751.84), and W ($34,230.47; 95% CI, $32,680.08–$35,780.88). Pairwise comparisons: NE vs. NC (P=0.83), NE vs. S ($P < 0.001$), NE vs. W ($P < 0.001$), NC vs. S ($P < 0.001$), NC vs. W ($P < 0.001$), and S vs. W ($P < 0.001$). Significant regional differences are highlighted.

in individual health plans, which vary across regions.[24] In addition, larger specialty practices are often able to exert leverage with insurers and negotiate higher prices, culminating in greater overall health care expenditure.[27]

Variable costs and reimbursements might be driven, in addition to differences in insurance types, by hospital-related factors.[25,27] In general, whereas private insurance companies negotiate reimbursements directly with hospitals, Medicare reimbursements are usually based on factors including hospital location, volume of low-income patients treated at that hospital, and diagnosis-related groups.[28] Regional variation may be further accentuated by administrative costs, which vary widely depending on hospital policy, type, and ownership.[29]

Several studies on neurosurgical cost variation have similarly reported increased costs in the West, including after adjustments for inflation, wage indices, and other confounders.[12,14-16] This phenomenon might also be affected by varying health care policies such as mandated higher nurse/patient ratios in California,[30,31] and regional differences in practice patterns (e.g., variations in the tendency of physicians to intervene and in their use of diagnostic tests in higher-spending regions).[32]

We found significant regional differences in LOS. Although it is unclear why LOS varies across regions, it is unlikely to be the result of differences in comorbidity because there were no significant regional differences in CCI or in postoperative surgical/medical complications, factors that may prolong LOS. Previous studies have identified LOS as a driver of increased TPS costs.[33,34] In the South, where LOS was highest, surgery was least expensive, whereas in the West, where LOS was lowest, surgery was most expensive. Although at initial assessment, this finding might seem counterintuitive, on further consideration, it is probable that regional differences in LOS might be consequent to cost differences versus the converse. Patients undergoing surgery in regions with higher hospital/facility costs might be discharged earlier compared to regions with lower hospital/facility costs. Additional studies are needed to better understand regional differences in drivers of LOS and potential impact on TPS costs.

Physician Reimbursements

There were no significant differences in physician reimbursements between microscopic and endoscopic techniques on a national level. However, regional differences were noted and physician reimbursements were highest in the North-east and lowest in the South. This differential seems, given technique-specific reimbursements, to be driven by the wider regional variation in payments for microsurgery. Further assessment of within-region reimbursements showed significantly higher payments for microsurgery in the North-east and in endoscopic surgery in the South.

There are other factors likely relevant to the observed discrepancies in professional reimbursements. For example, differences in medical malpractice insurance premiums/claims across

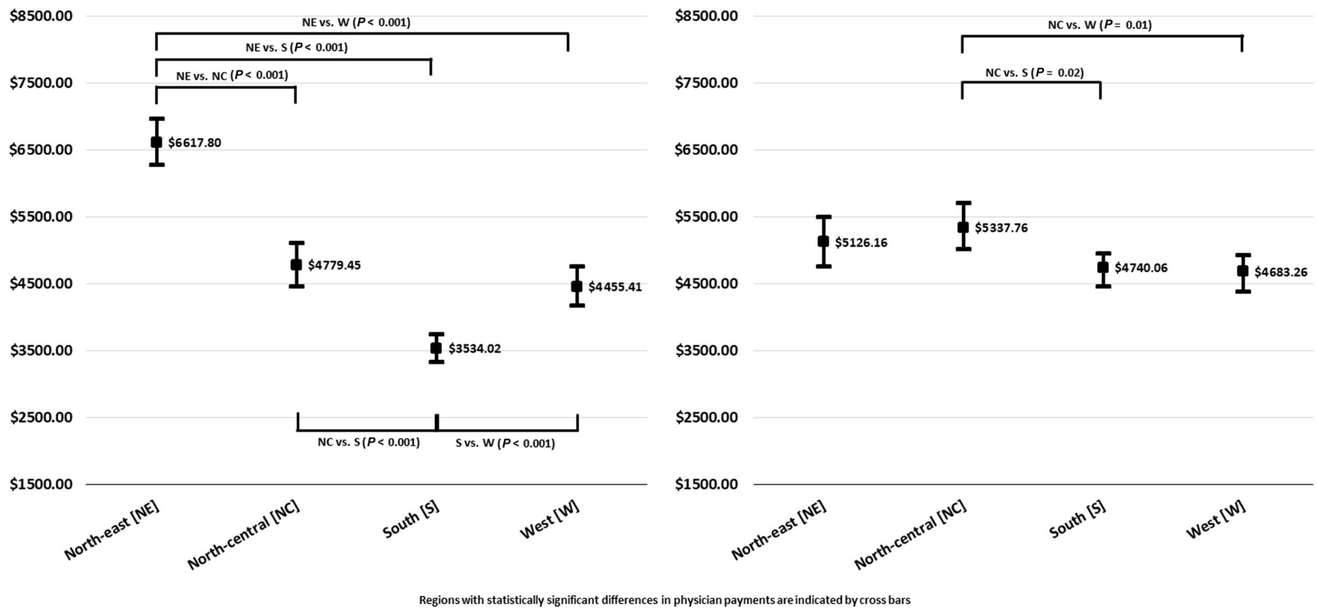

Figure 4. Regional variation in physician payments in transsphenoidal pituitary surgery stratified by technique. The average regional physician payments in microscopic techniques (*left*) were as follows: North-east (NE) ($6617.80; 95% CI, $6272.21–$6963.39), North-central (NC) ($4779.45; 95% CI, $4454.74–$5104.16), South (S) ($3534.02; 95% CI, $3326.24–$3741.80), and West (W) ($4455.41; 95% CI, $4162.97–$4747.85). Pairwise comparisons: NE vs. NC ($P < 0.001$), NE vs. S ($P < 0.001$), NE vs. W ($P < 0.001$), NC vs. S ($P < 0.001$), NC vs. W ($P = 0.64$), and S vs. W ($P < 0.001$). The average regional physician payments in endoscopic techniques (*right*) were as follows: NE ($5126.16; 95% CI, $4759.35–$5492.96), NC ($5337.76; 95% CI, $5019.17–$5696.36), S ($4740.06; 95% CI, $4460.34–$4949.78), and W ($4683.26; 95% CI, $4372.10–$4881.41). Pairwise comparisons: NE vs. NC ($P = 0.36$), NE vs. S ($P = 0.94$), NE vs. W ($P = 0.55$), NC vs. S ($P = 0.02$), NC vs. W ($P = 0.01$), and S vs. W ($P = 0.56$). Significant regional differences are highlighted.

geographic regions may affect physician payments.[35] In a previous survey,[35] physician reimbursements were higher in states within the top quartile of malpractice payments. All the states within the North-east region, the region with the highest physician reimbursement, have a grade of D or F with respect to medical liability.[36] Regional differences in medical malpractice liability have important ramifications for specialist access, particularly for high-risk surgery, as well as overall health care costs.[37,38]

Regional differences in reimbursements might also be affected by market forces of supply and demand (e.g., prices for physician services may vary based on provider and/or physician density).[39,40] Regional cost discrepancies in TPS may be related to regional differences in availability/supply of pituitary surgeons. We are unable to examine these factors and effect on regional TPS costs because of absence of these variables in the database.

From our study, it is uncertain whether surgeon experience is related to disparate physician reimbursements and its impact on overall total costs of surgery. It is conceivable that decreasing overall hospitalization costs might be expected with greater surgeon experience as a result of shorter operating times and fewer postoperative complications.[41] In our analyses, we are unable to account for surgeon experience and its influence on variable reimbursements in TPS and hence regional discrepancies. Nonetheless, our findings highlight obvious existing regional disparities and opportunities for uniformity and standardization of reimbursements in TPS.

Out-of-Pocket Payments

We did not find any regional differences in out-of-pocket payments on the national level despite regional differences in proportions of out-of-network providers. These findings are particularly notable given that out-of-network providers are associated with higher out-of-pocket expenses for patients, which affects affordability and access to specialist services.[42] When further analyzed by technique, aside from higher payments in the South compared with the North-east for microsurgery, there were no significant regional differences. There were no within-regional differences in out-of-pocket payments between microsurgery and endoscopic surgery. Additional studies examining these associations and impact on pituitary specialist access are needed.

In this study, we presented the average out-of-pocket payments made by patients when payments were made. In the database, 1246 patients (24% of 5238) had zero or negative out-of-pocket payments. One of our sensitivity analyses specifically included zero out-of-pocket payments and these analyses were consistent with our initial findings.

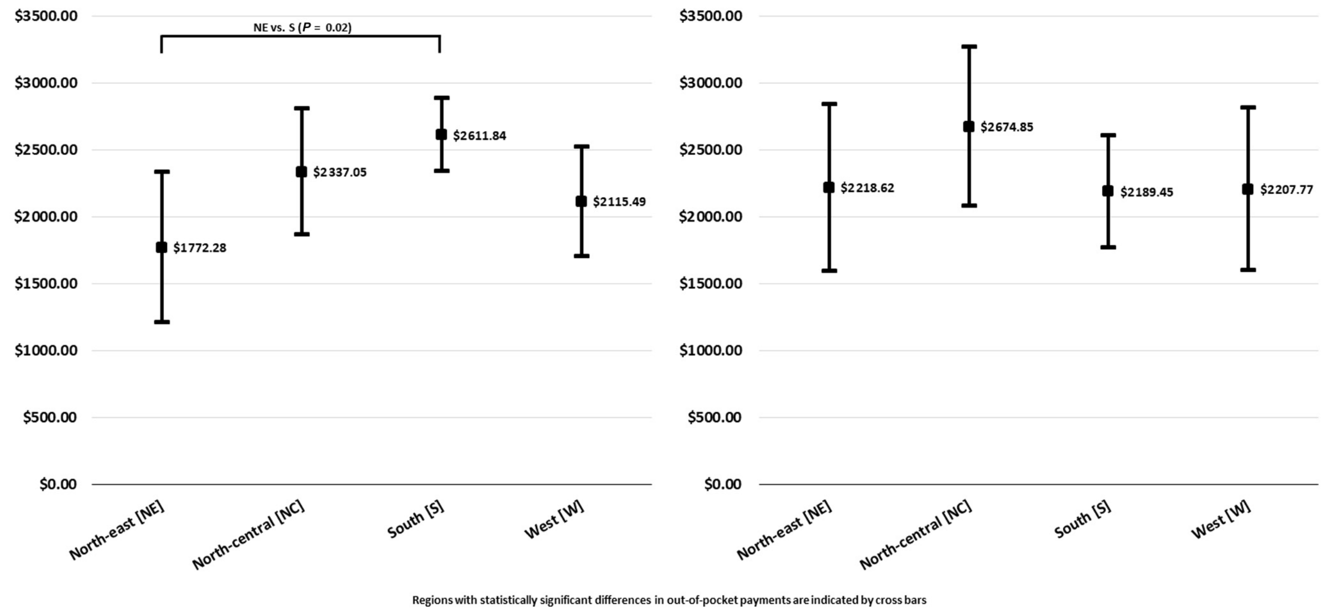

Figure 5. Regional variation in out-of-pocket payments in transsphenoidal pituitary surgery stratified by technique. The average regional out-of-pocket payments in microscopic techniques (*left*) were as follows: North-east (NE) ($1772.28; 95% CI, $1212.20–$2332.37), North-central (NC) ($2337.05; 95% CI, $1864.01–$2810.10), South (S) ($2611.84; 95% CI, $2338.53–$2885.15), and West (W) ($2115.49; 95% CI, $1707.97–$2523.02). Pairwise comparisons: NE vs. NC ($P = 0.91$), NE vs. S ($P = 0.02$), NE vs. W ($P = 0.22$), NC vs. S ($P = 0.53$), NC vs. W ($P = 0.15$), and S vs. W ($P = 0.23$). The average regional out-of-pocket payments in endoscopic techniques (*right*) were as follows: NE ($2218.62; 95% CI, $1595.94–$2841.31), NC ($2674.85; 95% CI, $2080.64–$3269.05), S ($2189.45; 95% CI, $1767.74–$2611.17), and W ($2207.77; 95% CI, $1601.78–$2813.77). Pairwise comparisons: NE vs. NC ($P = 0.13$), NE vs. S ($P = 0.24$), NE vs. W ($P = 0.41$), NC vs. S ($P = 0.26$), NC vs. W ($P = 0.37$), and S vs. W ($P = 0.35$). Significant regional difference is highlighted.

Study Strengths and Limitations

Our findings may be affected by database coding errors. These errors are compensated by the vast numbers of cases analyzed. Because our study included only patients younger than 65 years, comparative analyses are needed to evaluate regional costs of TPS in older patients. Additional concerns pertain to the sampled population in the MarketScan database: specifically, its representativeness and generalizability across different patient populations.[18] In addition, the nonrandomness of sampling could lead to exaggerated margins in regional variability; however, propensity matching adjusts for much of this variability, enhancing comparability within and across regions. In addition, the sampling methodology is relatively uniform across and within geographic regions, largely minimizing this concern, ensuring an even regional representation of diverse patient populations.

Our study included patients covered by capitated and noncapitated plans. In sensitivity analyses, patients with capitated plans were excluded because they might have received services uncaptured by fee-for-service claims. Our sensitivity results did not differ from our original analyses, making our findings applicable across the spectrum of patients undergoing TPS. In addition, hospitals/providers may bundle charges for different services into a single amount based on specific diagnosis-related groups, and hence, payments in these instances may inaccurately reflect payments for individual services. However, in our study, we do not examine individual components of hospital/facility costs. It is also possible that regional differences in hospital designation (i.e., academic vs. nonacademic centers) and procedure-specific differences across hospital type (e.g., more endoscopic in academic institutions and longer operating room time with trainees) may in addition affect costs. Additional biases originate from the data obtained from different hospital accounting systems, which may differ in methodology and be nonuniform across facilities. In addition, with respect to physician payments, our analyses are not robust to identify payments for nonpituitary procedures performed by the same principal physician/surgeon during the inpatient stay or payments to additional physicians/surgeons (i.e., such as a cosurgeon). Studies examining these limitations including components of hospital/facility payments, hospital type/designation, and involvement of cosurgeon(s)/trainees and their impact on cost variation of TPS are important for future consideration. In addition, our study does not capture longitudinal costs of care (e.g., costs associated with readmissions and/or postdischarge care/treatment) and we are unable to adequately examine cost benefit/effectiveness.

In addition, surgery indications could introduce confounding; therefore, we took into account variability caused by case mix and adjusted accordingly in multivariate regression and propensity-matched analyses. To address confounding from nonspecificity in CPT-62165, which may be used for broader indications other than pituitary surgery, additional sensitivity analyses were limited to patients

Table 3. Risk-Adjusted Estimates of Regional Cost Differentials

		95% Confidence Interval		
	Differential	**Lower Limit**	**Upper Limit**	***P***
Overall total				
North-east	5387.61	4118.84	6656.38	<0.001
North-central	4295.13	3102.98	5487.28	<0.001
South (reference)				
West	6835.87	5656.67	8015.07	<0.001
Hospital/facility				
North-east	2531.67	1394.23	3669.12	<0.001
North-central	3390.02	2321.27	4458.77	<0.001
South (reference)				
West	6104.02	5046.88	7161.16	<0.001
Physician				
North-east	1823.47	1530.70	2116.24	<0.001
North-central	930.79	655.70	1205.88	<0.001
South (reference)				
West	443.72	171.62	715.82	<0.001
Out-of-pocket				
North-east	−403.87	−849.37	41.63	0.44
North-central	44.66	−365.80	455.13	0.18
South (reference)				
West	−251.35	−642.74	140.05	0.10

All estimates of regional differential payments are with reference to payments in the South region (reference group). All payments are reported in 2018 U.S. dollars.

with specific pituitary diseases. Our findings from these sensitivity analyses confirmed the major findings inclusive of all patients. Further sensitivity analyses to counter the influence of outliers excluded cases with the lowest and highest (≤3 SD from the mean) payments, results of which also confirmed our original findings.

Regardless of these limitations, our study is notable in providing comprehensive national and regional assessments of overall total, hospital/facility, and physician payments, and in addition, in examining out-of-pocket expenses and impact from the patient-payer perspective. Our analyses, which included risk-adjusted cost estimates for confounders and propensity matching of our study cohort, enhance comparability across regions. Our findings of average TPS costs differ from previous reports using other national databases, likely because of methodological differences, including patient cohort examined.[17,33,43] In addition to analyzing costs of TPS broadly, the nationwide medical claims database used in the current study contains direct payments, eliminating the need for conversion using cost/charge ratios and improving accuracy of cost estimates.[44] These ratios might vary substantially across institutions and even within the same institution, increasing likelihood of error.[44] Also, estimates of average costs reported in our study might be affected by extreme outlying payments, resulting in skewness. To further enhance accuracy, additional steps including log-transformation were undertaken to correct for skewness before examining for significant differences. Exclusion of the lowest and highest 1% of payments in our main analysis and subsequent exclusion of extreme payments outside ≤3.0 SD of the mean also addressed the effect of outliers and their potential impact on estimated averages. However, although the reported average payments might differ from modal payments because of skewness and extreme outlying payments, findings of regional variation in TPS costs remain compelling. Moreover, the large population-based sample of patients analyzed enhances the generalizability of our study and provides updated population-based data on costs associated with TPS. Previous analyses have mostly examined hospital/facility charges, with minimal reporting of physician/professional fees and/or out-of-pocket expenses, thus underestimating the full components of inpatient care costs. In our study, these cost components are fully represented.

Further Insights

Differences across regions among patients undergoing the same procedure (i.e., either microscopic or endoscopic) highlight limitations of costing systems and represent viable opportunities for intervention. Moreover, the implications of variable regional costs include not only estimating value of surgery defined as outcome per unit cost but also evaluating how variation influences regionalization of care cost. The association between utilization volume and cost is pertinent in contemporary pituitary care, especially regarding regional planning of highly specialized pituitary care and centers of excellence.[45]

The regional cost margins in TPS put into perspective with the marginal costs of other neurosurgical procedures provide important benchmarks for evaluating and developing cost-reduction strategies across the spectrum of neurologic surgery. However, although these comparisons are possible, they should be cautiously interpreted given that methodologies differ across studies. Despite the increasing importance of cost considerations in patient care, the decision regarding surgical technique should primarily be driven by the procedure that the surgeon believes will achieve the best patient outcome. In addition, policies that decrease out-of-pocket expenses and enhance affordability and timely access to expert and quality care when required should be pursued. Further research to define and better understand factors underlying cost differences are recommended to effectively address existing disparities and standardize costs of TPS.

CONCLUSIONS

This study examines costs and cost discrepancies associated with TPS across different U.S. geographic regions. Overall total and hospital/facility payments are highest in the West and lowest in the South. Physician reimbursements are highest in the North-east and lowest in the South. No significant regional differences were seen in out-of-pocket payments. There is evidence of variable costs of microscopic and endoscopic techniques across different geographic regions. These findings warrant concerted efforts that address existing disparities and standardize TPS-associated costs across different geographic regions of the United States.

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SUPPLEMENTARY DATA

Supplementary Table 1. List of Geographic Regions and Constituent States

North-east Region
Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont
New Jersey
New York
Pennsylvania
North-central region
Illinois
Indiana
Michigan
Ohio
Wisconsin
Iowa
Kansas
Minnesota
Missouri
Nebraska
North Dakota
South Dakota
South region
Washington, DC
Delaware
Florida
Georgia
Maryland
North Carolina
South Carolina
Virginia
West Virginia
Alabama
Kentucky
Mississippi
Tennessee
Arkansas
Louisiana
Oklahoma
Texas
West region
Arizona
Colorado
Idaho
Montana
Nevada
New Mexico
Utah
Wyoming
Alaska
California
Hawaii
Oregon
Washington

The geographic regions and states are as obtained from the MarketScan database user guide.[19]

Supplementary Table 2. List of International Classification of Diseases, Ninth Revision, Clinical Modification Codes Used

Complications	International Classification of Diseases, Ninth Revision Codes
Surgical Complications	
Disorders of the pituitary	2535, 2536, 2537
Diabetes insipidus	2535
SIADH	2536
Iatrogenic pituitary disorders	2537
Fluid and electrolyte disorders	2760—2769
Hypoosmolality/hyponatremia	2761
Hyperosmolality/hypernatremia	2760
Ophthalmologic complications	36841—36847, 3682, 37850—37856
Visual field defects	36841—36847
Diplopia	3682
Paralytic strabismus	37850—37856
Postoperative CSF leak/dural tear	34981, 34931, 34939
CSF—rhinorrhea	34981
Other CSF leak	99709
Dural tear	34931, 34939
Intracranial vascular complications	431, 99702
Intracranial hemorrhage	431
Iatrogenic cerebrovascular infarction or hemorrhage	99702
Mental status changes	2930, 2939, 78001, 78009, 78097
Delirium and transient mental disorders	2930, 2939
Alteration of consciousness	78001, 78009
Altered mental status	78097
Hemorrhage/hematoma complicating a procedure	99811, 99812
Epistaxis	7847
Postoperative nausea ± vomiting	78701, 78702
Bacterial meningitis	3201—3209
Medical Complications	
Pulmonary insufficiency	51851, 51852, 51853, 51881, 51882
Acute kidney failure	5845—5849
Cardiac complications	9971
Deep vein thrombosis	45340, 45341, 45342, 45380—45389
Pulmonary embolism	4151, 41511, 41512, 41513, 41519
Acute myocardial infarction	4100—4109
Postoperative hypertension	99791
Respiratory complications	99731, 99732, 99739

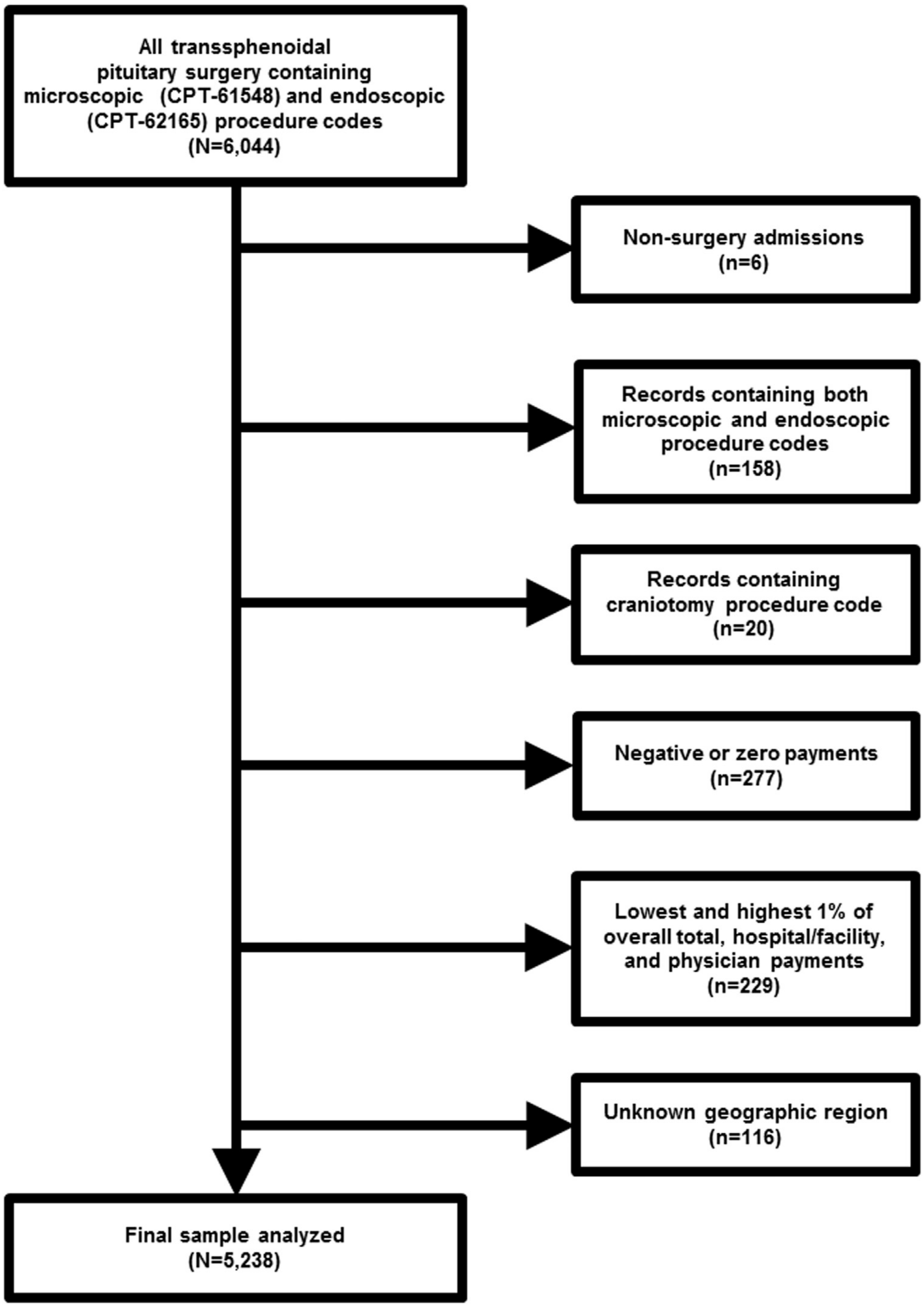
CSF, cerebrospinal fluid; SIADH, syndrome of inappropriate antidiuretic hormone secretion.

Supplementary Table 3. List of International Classification of Diseases, Ninth Revision, Clinical Modification Codes Used in Sensitivity Analyses for Specific Pituitary Diseases

Principal Diagnosis	International Classification of Diseases, Ninth Revision Codes	Frequency, n (%) (N = 5238)	Cumulative (%)
Benign neoplasm of pituitary	227.3	4806 (76.55)	82.46
Uncertain behavior neoplasm of pituitary	237.0	252 (4.01)	86.81
Other disorders of the pituitary	253.8	253 (4.03)	91.09
Endocrine/nervous system neoplasm	239.7	97 (1.55)	92.73
Cushing syndrome	255.0	71 (1.13)	93.84
Malignant neoplasm of pituitary	194.3	24 (0.38)	94.22
Cerebral cysts	348.0	17 (0.27)	94.49
Acromegaly and gigantism	253.0	13 (0.25)	94.74
Pituitary disorder not specified	253.9	13 (0.25)	94.98

Supplementary Table 4. Population Characteristics (by Surgical Technique)

Total	Microscopic N = 2842	%	Endoscopic N = 2396	%	Total N = 5238	%	*P*
Age group							0.70
<18 years	76	(2.67)	73	(3.05)	149	(2.84)	
18–34 years	533	(18.75)	460	(19.20)	993	(18.96)	
35–44 years	626	(22.03)	495	(20.66)	1121	(21.40)	
45–54 years	757	(26.64)	656	(27.38)	1413	(26.98)	
55–64 years	850	(29.91)	712	(29.72)	1562	(29.82)	
Gender							0.87
Male	1290	(45.39)	1082	(45.16)	2372	(45.28)	
Female	1552	(54.61)	1314	(54.84)	2866	(54.72)	
Charlson Comorbidity Index							0.70
0	2154	(75.79)	1798	(75.04)	3952	(75.45)	
1	392	(13.79)	350	(14.61)	742	(14.17)	
≥2	296	(10.42)	248	(10.35)	544	(10.39)	
Health plan							0.67
Employer	1289	(45.36)	1101	(45.95)	2390	(45.63)	
Nonemployer	1553	(54.64)	1295	(54.05)	2848	(54.37)	
Capitated payment indicator							0.81
No	2766	(97.33)	2332	(97.33)	5098	(97.33)	
Yes	48	(1.69)	37	(1.54)	85	(1.62)	
Missing	28	(0.99)	27	(1.13)	55	(1.05)	
Network payment indicator							0.38
No	192	(6.76)	143	(5.97)	335	(6.40)	
Yes	2520	(88.67)	2074	(86.56)	4594	(87.71)	
Missing	130	(4.57)	179	(7.47)	301	(5.90)	
Postoperative surgical complications							<0.001
Nil	1851	(65.13)	1319	(55.05)	3170	(60.52)	
Yes	991	(34.87)	1077	(44.95)	2068	(39.48)	
Postoperative medical complications							0.05
Nil	2739	(96.38)	2283	(95.28)	5022	(95.88)	
Yes	103	(3.62)	113	(4.72)	216	(4.12)	
Discharge disposition							0.64
Alive	2837	(99.82)	2393	(99.87)	5230	(99.85)	
Died	5	(0.18)	3	(0.13)	8	(0.15)	
Mean length of stay (±standard deviation) (days)	3.50	(±2.90)	3.68	(±3.16)	3.59	(±3.02)	0.05



Supplementary Figure 1. Flowchart showing the sample inclusion and exclusion. A total of 6044 transsphenoidal pituitary surgery cases were identified in our initial query. From this cohort, 6 patients were excluded because they were admitted primarily as nonsurgical cases, 158 cases were excluded because they contained both microscopic and endoscopic procedure codes within the same record, 20 records were excluded because they contained either Current Procedural Terminology, Fourth Edition (CPT)-62165 or CPT-61548 and CPT-61546, 277 records were excluded because of negative or zero overall total, hospital/facility, and physician payments, and 229 records with the highest and lowest 1% of payments were excluded. After exclusion of records with unknown geographic region, 5238 records were included in our final study cohort with 2842 microscopic and 2396 endoscopic cases. From this cohort, there were 3992 records with greater than zero out-of-pocket payments analyzed.