Original Investigation

Association of Surgeon Volume With Outcomes and Cost Savings Following Thyroidectomy
A National Forecast

Zaid Al-Qurayshi, MD, MPH; Russell Robins, PhD; Adam Hauch, MD, MBA; Gregory W. Randolph, MD; Emad Kandil, MD

IMPORTANCE Incidence of thyroidectomies is continuing to increase. Identifying factors associated with favorable outcomes can lead to cost savings.

OBJECTIVE To assess the association of surgeon volume with clinical outcomes and costs of thyroidectomy.

DESIGN, SETTING, AND PARTICIPANTS Cross-sectional analysis performed in October of 2014 of adult (≥18 years) inpatients in US community hospitals using the Nationwide Inpatient Sample for the years 2003 through 2009.

EXPOSURES Thyroidectomy.

MAIN OUTCOMES AND MEASURES Complications, length of stay, and cost following thyroidectomy in relation to surgeon volume. Surgeon volumes were stratified into low (1-3 thyroidectomies per year), intermediate (4-29 thyroidectomies per year), and high (≥30 thyroidectomies per year).

RESULTS A total of 77 863 patients were included. Procedures performed by low-volume surgeons were associated with a higher risk of postoperative complications compared with high-volume surgeons (15.8% vs 7.7%; OR, 1.55 [95% CI, 1.19-2.03]; $P = .001$). Mean (SD) hospital cost was significantly associated with surgeon volume (high volume, $6662.69 [$409.31]; intermediate volume, $6912.41 [$137.20]; low volume, $10 396.21 [$345.17]; $P < .001$). During the study period, if all operations performed by low-volume surgeons had been selectively referred to intermediate- or high-volume surgeons, savings of 11.2% or 12.2%, respectively, would have been incurred. On the basis of the cost growth rate, greater savings are forecasted for high-volume surgeons. With a conservative assumption of 150 000 thyroidectomies per year in the United States, referral of all patients to intermediate- or high-volume surgeons would produce savings of $2.08 billion or $3.11 billion, respectively, over a span of 14 years.

CONCLUSIONS AND RELEVANCE A surgeon's expertise (measured by surgical volume of procedures per year) is associated with favorable clinical as well as financial outcomes. Our model estimates that considerable cost savings are attainable if higher-volume surgeons perform thyroid procedures in the United States.

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Author Affiliations: Department of Surgery, Tulane University School of Medicine, New Orleans, Louisiana (Al-Qurayshi, Hauch, Kandil); A. B. Freeman School of Business, Tulane University, New Orleans, Louisiana (Robins); Division of Thyroid and Parathyroid Endocrine Surgery, Massachusetts Eye and Ear Infirmary, Boston, Massachusetts (Randolph).

Corresponding Author: Emad Kandil, MD, Department of Surgery, Tulane School of Medicine, 1430 Tulane Ave, SL-22, New Orleans, LA 70112 (ekandil@tulane.edu).

The surgical approach, as well as the number of thyroid procedures performed in the United States annually, has evolved dramatically over recent years. For the period of 1996 through 2006, there was a 39% increase in the number of patients undergoing thyroid surgery.[1-6]

Emerging evidence is showing that a surgeon's expertise and case volume has a substantial effect on the outcomes of thyroid procedures. Many studies have demonstrated improved clinical outcomes for different surgical interventions in patients treated by higher-volume surgeons.[7-17] These findings have established supporting evidence for the effectiveness of selective referral and the need for centralized health care services.[18-24] Previous studies have also shown that thyroidectomies performed by high-volume surgeons are associated with lower costs.[12,17] In the present study, we aimed to examine the cost-effectiveness related to surgical volume by extrapolating the findings to a national level and examining potential cost savings using a statistical model.

Methods

A cross-sectional analysis was performed in October of 2014 using the Nationwide Inpatient Sample (NIS) database for the years 2003 through 2009. The NIS database is publicly available deidentified data that are exempt from institutional review board approval. The NIS is part of the Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality. This is the largest all-payer inpatient care database publicly available in the United States. It contains data from approximately 8 million hospital stays from approximately 1000 hospitals sampled to approximate a 20% stratified sample of US community hospitals.[25] *International Classification of Diseases, Ninth Revision* (*ICD-9*), was used to define parameters of the study.

The study population consisted of adult (≥18 years) inpatients who underwent total thyroidectomy (*ICD-9*: 06.4) or unilateral thyroidectomy (*ICD-9*: 06.2, 06.3) as the primary procedure. Primary diagnosis was classified into malignant or uncertain behavior neoplasms of the thyroid (*ICD-9*: 193, 237.4), benign thyroid diseases (*ICD-9*: 245.0, 245.1, 245.2, 245.3, 245.4, 245.8, 245.9, 240.0, 240.9, 241.0, 241.1, 241.9, 246.0, 246.1, 246.2, 246.3, 246.8, 246.9, 242.10, 242.11, 242.20, 242.21, 242.30, 242.31, 242.80, 242.81, 242.90, 242.91, 226), or Graves disease (*ICD-9*: 242.0, 242.00, 242.01).

The main study outcomes included postoperative complications, hospital length of stay, and cost of health care services. Dichotomized complications were defined as the presence of 1 or more of the general or specific complications on the basis of the secondary diagnoses made during the hospital stay (eTable in the Supplement). Length of stay was categorized on the basis of the 75th percentile, which yielded a length of stay of 2 days as a cutoff value below which 75% of the study sample lay. Cost was adjusted for the inflation rate to reflect year 2014 dollar value. The independent factor of interest was surgeon volume. Surgeon volume was classified on the basis of the number of thyroidectomies performed by each surgeon per year into low (≤25th percentile, 1-3 thyroidectomies per year), intermediate (>25th to ≤75th percentiles, 4-29 thyroidectomies per year), and high (>75th percentile, ≥30 thyroidectomies per year).

Other secondary independent factors that were assessed as potential confounders were (1) patient demographic characteristics: age (<35, 35-65, >65 years), sex, and race (white, black, Hispanic, Asian/Pacific Islander, Native American, other); (2) socioeconomic factors: household income (quartile classification) and main payer of health care services (Medicare, Medicaid, private insurance, self-pay, no charge, other); (3) clinical factors: primary diagnosis (malignant, benign, Graves disease), thyroidectomy type (total, unilateral), overweight (body mass index [BMI, calculated as weight in kilograms divided by height in meters squared], ≥25), inpatient death, whether neck dissection was performed, and a modification of the Charlson comorbidity index score (CCIS) used to assess patient comorbidities (low score, 0-1; high score, ≥2)[26]; and (4) hospital characteristics: hospital volume (low [≤25th percentile], 1-20 thyroidectomies per year; intermediate [>25th to ≤75 percentiles], 21-90 thyroidectomies per year; high [>75th percentile], ≥91 thyroidectomies per year), geographic region (Northeast, Midwest, South, West), bed size (small, medium, large), location (urban, rural), and teaching status (teaching, nonteaching).

Statistical analysis used weighted data reflecting the national estimate. The records' weights are available in the NIS database.[25] Cross-tabulation and χ^2 tests were used to examine the association between each of the independent factors and the outcomes of interest. Factors with significant association were considered confounders and were included in multivariate logistic regression models. Multivariate logistic regression models were used for calculating odds ratios (ORs) and 95% confidence intervals. Analysis of variance was used to test for differences in cost.

Cost saving was estimated such that the total cost of patients' treatment by low-volume surgeons was compared hypothetically with that of patients who were to be treated by intermediate- or high-volume surgeons. The expected amount of cost saving at the national level was calculated with a conservative assumption that 150 000 thyroidectomies were performed per year in the United States and with controlling of the hospital volume. The significance level was set as $\alpha = .05$. All data analyses were performed using SAS, version 9.3 for Windows (SAS Institute).

Results

A total of 77 863 discharge records were identified between 2003 and 2009 (**Table 1**). The mean (SEM) age of the study population was 51.8 (0.11) years. The majorities of the study population were white (70.0%), female (80.6%) patients, and had private insurance (62.7%). Most patients had 1 or no comorbidities at time of hospitalization (99.2%). With regard to diagnosis, benign thyroid disease was the most common (63.3%), Graves disease was the least common (3.4%), and malignant conditions made up the rest. Complications occurred in 11.1% of patients, and 122 patients died during their hospi-

Table 1. Descriptive Statistics of the Study Population in Relation to Postoperative Complications[a]

Characteristic	All Patients (N = 77 863)	Postoperative Complications		P Value[b]
		Absent (n = 69 201)	Present (n = 8662)	
Age, y				
<35	14.1	14.2	13.7	<.001
35-65	65.0	65.7	59.0	
>65	20.9	20.1	27.3	
Sex				
Male	19.4	19.2	21.3	<.001
Female	80.6	80.8	78.7	
Race				
White	70.0	70.5	65.5	<.001
Black	12.4	12.0	15.7	
Hispanic	9.3	9.1	10.6	
Asian/Pacific Islander	4.5	4.5	4.5	
Native American	0.5	0.5	0.3	
Other	3.4	3.4	3.4	
Household income quartile, $				
<39 000	21.0	20.5	25.4	<.001
39 000-47 999	23.4	23.3	24.3	
48 000-62 999	25.0	25.1	24.3	
>62 999	30.6	31.2	26.0	
Service payer				
Medicare	23.6	22.8	30.5	<.001
Medicaid	7.7	7.6	9.1	
Private	62.7	63.8	54.3	
Self-pay	2.3	2.2	2.5	
No charge	0.6	0.6	0.7	
Other	3.0	3.0	3.0	
Thyroid diagnosis				
Graves disease	3.4	3.1	5.1	<.001
Benign	63.3	64.4	54.1	
Malignant	33.3	32.4	40.8	
Charlson Comorbidity Index score				
Low: 0-1	99.2	99.4	98.3	<.001
High: ≥2	0.8	0.6	1.7	
BMI				
<25	92.6	92.9	90.2	<.001
≥25	7.4	7.1	9.8	
Hospitalization				
Nonelective	11.3	10.4	18.6	<.001
Elective	88.7	89.6	81.4	
Thyroidectomy				
Unilateral/partial	50.4	52.3	35.6	<.001
Total/complete	49.6	47.7	64.4	
Neck dissection				
No	96.5	97.0	92.1	<.001
Yes	3.5	3.0	7.9	
Surgeon volume, thyroidectomies/y				
Low: 1-3	25.3	24.0	35.2	<.001
Intermediate: 4-29	50.0	50.3	48.1	
High: ≥30	24.7	25.7	16.8	

(continued)

Table 1. Descriptive Statistics of the Study Population in Relation to Postoperative Complications[a] (continued)

Characteristic	All Patients (N = 77 863)	Postoperative Complications		P Value[b]
		Absent (n = 69 201)	Present (n = 8662)	
Length of stay, d				
≤2	86.8	91.2	51.5	<.001
>2	13.2	8.8	48.5	
In-hospital mortality				
No	99.8	100	98.8	<.001
Yes	0.2	0	1.2	
Hospital volume, thyroidectomies/y				
Low: 1-20	25.6	24.8	32.1	<.001
Intermediate: 21-90	49.0	49.0	49.1	
High: ≥91	25.4	26.2	18.7	
Hospital region				
Northeast	28.1	29.1	19.9	<.001
Midwest	18.9	18.5	22.0	
South	28.9	27.9	37.4	
West	24.1	24.5	20.7	
Hospital bed size				
Small	10.5	10.7	8.9	.047
Medium	22.4	22.4	22.1	
Large	67.1	66.8	69.0	
Hospital location				
Rural	7.0	6.9	7.6	.16
Urban	93.0	93.1	92.4	
Hospital teaching status				
Nonteaching	42.7	42.6	43.9	.33
Teaching	57.3	57.4	56.1	

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] Percentages may not total 100 because of rounding.

[b] χ^2 Test.

tal stay. The mean (SEM) length of stay was 1.9 (0.03) days, while the mean (SEM) cost per case was $8087.52 ($130.57).

Hypocalcemia, pulmonary complications, and hematoma and/or bleeding accounted for 69.8% of postoperative complications (eFigure 1 in the Supplement). Compared with high-volume surgeons, patients treated by low-volume surgeons were more likely to experience 1 or more of the postoperative complications (OR, 1.55 [95% CI, 1.19-2.03]; $P = .001$) (**Table 2**) and to have a hospital stay of more than 2 days (OR, 2.19 [95% CI, 1.55-3.09]; $P < .001$). Furthermore, those patients had a higher prevalence of specific complications including pulmonary (OR, 3.32 [95% CI, 2.23-4.96]; $P < .001$), cardiovascular (OR, 3.22 [95% CI, 1.31-7.94]; $P = .01$), renal (OR, 4.12 [95% CI, 1.30-13.03]; $P = .02$), and bleeding (OR, 1.72 [95% CI, 1.20-2.45]; $P = .003$). Thyroidectomies performed by intermediate-volume surgeons were associated with almost double the risk of pulmonary complications compared with high-volume surgeons (OR, 2.06 [95% CI, 1.40-3.04]; $P < .001$). None of the patients treated by high-volume surgeons required a tracheostomy, while it was reported in other surgeon groups. A significant inverse relationship between volume and complications existed when stratifying by different patient characteristics including older age (>65 years old), body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) 25 or greater, CCIS 2 or greater, malignant disease, health care coverage, and receipt of treatment in teaching hospitals (eFigure 2 in the Supplement).

The mean (SD) cost of management per case was inversely related to surgeon volume (high-volume, $6662.69 [$409.31]; intermediate-volume, $6912.41 [$137.20]; low-volume, $10 396.21 [$345.17]; $P < .001$). Complications that were associated with the highest costs were tracheostomy, infection, and renal complications, with a mean cost of more than $75 000 (eFigure 3 in the Supplement), while complications such as hypocalcemia, tracheomalacia, and the development of hoarseness cost less than $15 000.

For the cost savings analysis using our financial model, if all cases treated by low-volume surgeons were to be treated by intermediate-volume surgeons, an estimated savings of 11.2% was expected throughout the study period, and the savings were even higher if patients were to be treated by high-volume surgeons (12.2%) (**Table 3**). By stratifying the patients treated by low-volume surgeons, we found that the highest savings (~50%) would have been achieved had higher-volume surgeons treated patients with CCIS of 2 or more. Savings were also high, approximately 20%, if older patients or those on Medicare received care by surgeons of higher volume. Slightly lower savings were observed in overweight patients, those with malignant thyroid diseases, and those treated in teaching hospitals. With the conservative assumption of 150 000 thyroid-

Table 2. Risk of Postoperative Complications by Surgeon Volume

Complication Type per Surgeon Volume[a]	Complication, %	aOR (95% CI)[b]	*P* Value
One or more			
Low	15.8	1.55 (1.19-2.03)	.001
Intermediate	10.9	1.25 (0.97-1.62)	.09
High	7.7	1 [Reference]	
Hypocalcemia			
Low	6.9	1.43 (0.95-2.17)	.09
Intermediate	6.3	1.32 (0.89-1.94)	.17
High	4.1	1 [Reference]	
Pulmonary			
Low	4.3	3.32 (2.23-4.96)	<.001
Intermediate	1.5	2.06 (1.40-3.04)	<.001
High	0.6	1 [Reference]	
Bleeding			
Low	2.4	1.72 (1.20-2.45)	.003
Intermediate	1.5	1.23 (0.87-1.73)	.25
High	1.0	1 [Reference]	
Tracheomalacia			
Low	1.7	1.31 (0.87-2.00)	.20
Intermediate	1.1	1.07 (0.71-1.62)	.75
High	1.0	1 [Reference]	
Vocal fold paralysis			
Low	1.2	1.55 (0.90-2.70)	.12
Intermediate	0.8	1.20 (0.73-1.97)	.48
High	0.7	1 [Reference]	
Hoarseness			
Low	0.7	0.94 (0.55-1.61)	.83
Intermediate	0.5	0.86 (0.54-1.37)	.53
High	0.5	1 [Reference]	
Renal			
Low	1.2	4.12 (1.30-13.03)	.02
Intermediate	0	0.84 (0.24-2.95)	.78
High	0	1 [Reference]	
Technical			
Low	0.4	1.43 (0.54-3.74)	.47
Intermediate	0.3	1.00 (0.42-2.34)	.99
High	0.3	1 [Reference]	
Infection/Sepsis			
Low	1.1	2.64 (0.81-8.60)	.11
Intermediate	0.1	0.52 (0.16-1.74)	.29
High	0.1	1 [Reference]	
Cardiovascular			
Low	0.5	3.22 (1.31-7.94)	.01
Intermediate	0.1	1.59 (0.69-3.68)	.28
High	0.1	1 [Reference]	
Tracheostomy			
Low	0.1		
Intermediate	0.02	NA[c]	
High	0		
Wound complication			
Low	0.04		
Intermediate	0.02	NA[c]	
High	0.01		
Cystitis			
Low	0.01		
Intermediate	0.04	NA[c]	
High	0		
Shock			
Low	0.03		
Intermediate	0	NA[c]	
High	0		

Abbreviation: aOR, adjusted odds ratio.

[a] Surgeon volume is the number of thyroidectomies per year: low, 1 to 3; intermediate, 4 to 29; high, 30 or more.

[b] The models include age, sex, race, household income, service payer, diagnosis, comorbidity status, overweight status, hospitalization type, thyroidectomy type, neck dissection, surgeon volume, hospital volume, hospital region, and hospital bed size.

[c] Not applicable due to low sample size.

ectomies being performed annually in the United States, these estimates would translate into $842 258 066 in annual savings if intermediate-volume surgeons were to treat cases treated by low-volume surgeons and $1 145 483 264 in savings if these patients were to be treated by high-volume surgeons (**Table 4**). The estimated annual cost savings for the subpopulations considered in this study were highest for patients with multiple comorbidities ($2.5 billion), while the savings were more than $1 billion for older patients (>65 years), overweight patients, those with malignant diseases, and for those with Medicare health coverage.

The estimated amount of savings was extrapolated to the year 2016 by assuming that the mean rate of cost increase seen during the study period continues through 2016; this is a conservative assumption because we did not let the cost increases compound. The cost savings if intermediate-volume surgeons were to perform all 150 000 thyroidectomies each year would be $2 084 027 923.07, while high-volume surgeons would produce savings of $3 113 970 133.07. There was an exponential increase in savings with time resulting from a higher rate of cost increase in low-volume surgeons ($518.51/case/y) compared with that of intermediate-volume surgeons ($235.85/case/y) and high-volume surgeons ($424.52/case/y) (**Figure**).

Discussion

In this study, we have demonstrated that thyroid surgical procedures performed by higher-volume surgeons are associated with more favorable clinical outcomes. These observa-

tions are in accord with previously reported findings by our group and others.[12,17] We also found that certain complications following thyroidectomies, such as tracheostomy, infections, or renal complications, were associated with substantially higher costs to the health care system than other complications.

In addition, we found that significantly lower costs of health care services were associated with advanced surgeon experience, consistent with previously published reports on thyroidectomy, as well as those for other procedures including those involving the colon, pancreas, and uterus.[16,17,27-31] In 2007, Williams et al[32] estimated potential cost savings of $28.7 million if all patients who required radical prostatectomy were referred to higher-volume surgeons. Notwithstanding the different patient populations, procedures, and study period, our study found comparable potential savings of $1.1 billion at the national level with high-volume surgeons over a span of 7 years.

We also observed that substantially greater savings are related to patient intrinsic characteristics, such as BMI and comorbidity status, rather than factors related to surgical or technical characteristics. This finding may indicate that selective referral of patients based on factors such as comorbidity status is more cost-effective regardless of the nature and features of the surgical intervention. On the other hand, the finding might be confounded by inconsistency in coding comorbidities across settings. It is assumed that advanced centers are more efficient in coding secondary diagnoses, and this could introduce differential bias.

By examining the savings that could be produced by selective referral of higher-risk populations, such as patients older than 65 years, overweight patients, or those with more than 2 comorbidities, to higher-volume surgeons, we demonstrated greater attainable savings than in the general population. Sosa et al,[13] in studying thyroidectomy outcomes using the same national database for the years 2003 through 2004, reported lower risk of complications and costs for high-volume surgeons (≥30 thyroidectomies per year), when treating older patients (>65 years) with either low or high CCIS (≤2 vs ≥3). On the basis of these observations, our cost-saving

Table 3. Savings if Patients Treated by Low-Volume Surgeons Were Treated by Higher-Volume Surgeons, 2003 Through 2009

Patients	Savings by Surgeon Volume, %	
	Intermediate[a]	High[b]
All	11.2	12.2
Age, >65 y	20.1	19.4
BMI, ≥25	13.0	14.0
Charlson Comorbidity Index score, ≥2	50.3	51.0
Malignant disease	10.5	10.7
Medicare	20.2	19.7
Teaching hospital	10.5	11.9

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] Intermediate-volume surgeon is defined as one who performs 4 to 29 thyroidectomies per year.

[b] High-volume surgeon is defined as one who performs at least 30 thyroidectomies per year.

Table 4. Expected Savings With an Assumption of 150 000 Thyroidectomies per Year if Patients Were Treated by Higher-Volume Surgeons as Compared With Current Surgeon Volume Distribution, 2003 Through 2009

Patients	Savings by Surgeon Volume, $	
	Intermediate[a]	High[b]
All	842 258 066	1 145 483 264
Age, >65 y	1 138 547 821	1 132 081 378
BMI, ≥25	1 218 432 155	1 222 069 635
Charlson Comorbidity Index score, ≥2	2 554 553 648	2 554 916 762
Malignant disease	906 324 251	910 614 804
Medicare	1 099 458 034	1 094 259 530
Teaching hospital	556 603 190	605 981 549

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] Intermediate-volume surgeon is defined as one who performs 4 to 29 thyroidectomies per year.

[b] High-volume surgeon is defined as one who performs at least 30 thyroidectomies per year.

Figure. Rate of Cost Increase by Surgeon Volume

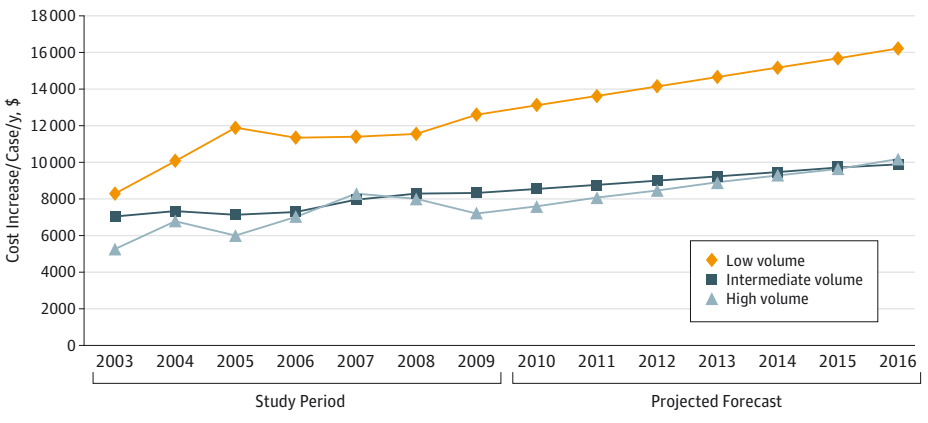

Figure shows low (1-3 procedures per year), intermediate (4-29 procedures per year), and high surgeon volume (≥30 procedures per year).

model estimated net savings of more than $2.5 billion at the national level in patients with multiple comorbidities, and savings of $1.1 billion for older patients that could be derived from selective referral to higher-volume surgeons during the study period.

This study is limited by the administrative nature of the database and the cross-sectional design. Additionally, it is limited by a population that includes inpatient thyroidectomies only. This presents a considerable limitation on extrapolating and generalizing the outcomes, given that most thyroid procedures are currently performed in outpatient settings. It is anticipated that outpatient procedures are associated with a lower cost to the health care system and this may undermine the cost findings in this study; however, it is likely that a cost difference may still exist among the different surgeon volumes even in the outpatient practice. Another limitation is that the database has information on patients during their hospital stay only and there is a lack of follow-up for outcomes that could develop after hospital discharge. Because this is especially the case for certain and substantial surgical complications, such as recurrent laryngeal nerve paralysis that may not necessarily manifest or be diagnosed during an inpatient encounter, we may underestimate the percent of patients experiencing postoperative complications. We expect, however, that the reporting of these types of complications will be similarly stratified over different surgical volumes; and because the main focus of this study is a cost analysis rather than a clinical one, administrative data adequately serve our purpose. The study has several strengths represented by the long study period, large sample size, and the application of a weighted analysis that reflects more accurate estimates at the national level. Because these national estimates have not been presented before, it would be useful to replicate this study using different and more sophisticated resources.

Conclusions

The anticipated outcomes associated with higher-volume surgeons extend beyond the important clinical quality imperatives to include a substantial potential economic impact as well. We have demonstrated that centralization and selective referral of patients who require thyroidectomy to high-volume surgeons hold conceivable savings potentials for the general patient and especially for certain vulnerable patient populations. A public health initiative to facilitate referral of patients with higher CCIS scores, patients older than 65 years, and patients with thyroid cancer to higher-volume surgical environments is warranted. These findings regarding a widely performed procedure such as thyroidectomy may be used to improve the effectiveness of the health care system and decrease the burden of unnecessary expenses.

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Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Al-Qurayshi, Hauch, Randolph, Kandil.
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