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General Research

Low Urologist Density Predicts High-Cost Surgical Treatment of Stone Disease

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Abstract

Introduction and Objectives: Lack of access to urologic specialists is approaching crisis levels as the number of urologists is decreasing, while the demand for urologic care is increasing. The financial implications of this have not been explored. The objective of this study is to examine the impact of access and other patient factors on cost to treat urolithiasis. We hypothesized that markers of poor access would associate with higher costs of surgical encounters for patients presenting with urolithiasis.

Methods: A retrospective review of prospectively collected data from the Registry for Stones of the Kidney and Ureter (ReSKU) from September 2015 to July 2018 was conducted to investigate characteristics of surgical patients treated for urinary stone disease. Univariate analysis was performed using the Welch two-sample *t*-test. Multivariate analysis was performed using logistic regression. Statistical analysis was performed in R version 3.5.

Results: When taking into account age, delayed presentation, procedure type, stone size >20 mm, American Society of Anesthesiologists (ASA) code, gender, race, income, distance, urologist density, body mass index, diabetes, infection, education, language, insurance, and stone complexity, patients undergoing percutaneous nephrolithotomy procedure ($p < 0.001$; odds ratio [OR] 12.9, confidence interval [CI] 4.05–48.5), urologist density in the bottom quartile ($p = 0.014$; OR 4.66, CI 1.40–16.9), diabetes ($p = 0.018$; OR 4.38, CI 1.32–15.6), and infection ($p = 0.007$; OR 4.51, CI 1.55–14.0) were the only variables statistically significant for association with top quartile of total cost.

Conclusions: Surgical encounter costs are largely dictated by patient clinical factors, but low regional urologist density appears to independently predicted for high-cost stone surgery. Increasing patients' access to a urologist may prove to be financially beneficial in the longitudinal reduction in health care costs for stone disease.

Keywords: cost, access, urolithiasis

Introduction

There is a looming crisis in unmet urologic disease. In 2009, there were 9775 urologists practicing in the United States.[1] Although this number has increased in the past decade, it is estimated that this increase has not paralleled the rising demand for urologic care as the population has aged. It is estimated that urologist supply will be 46% below need in 2035.[2] This limited supply of urologists is not without consequence. Low regional urologist density has been linked to a higher mortality rate for urologic cancers.[3,4] Low urologist density is also linked to higher stone burden at presentation to urologic referral centers.[5] However, the financial implications of this have not been explored. The objective of this study is to determine which social and clinical factors predict for high-cost kidney stone surgery. We hypothesize that markers of poor access will be more common among high-cost kidney stone patients.

Materials and Methods

A retrospective review of patient intake data from the Registry for Stones of the Kidney and Ureter (ReSKU) from 2015 to 2018 was conducted to evaluate characteristics among

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patients undergoing surgery for kidney stones at the University of California, San Francisco (UCSF). This prospectively collected registry records patient metrics on an ongoing basis and is integrated into the electronic medical record system.[6] The ReSKU study has been approved by the Committee on Human Research (Protocol 14-14533).

Variable characterization

ReSKU data were merged with encounter charges data obtained from the Finance Department at the UCSF Medical Center. These charges were multiplied by annual publicly available cost-to-charge ratios (CCRs) to calculate cost (https://www.dir.ca.gov/dwc/OMFS9904.htm). CCRs are created by the Agency for Healthcare Research and Quality to account for variations in payer policies, reporting policies, and hospital practices. The ratios assist in the conversion of what hospitals bill for services into costs.[7] Our outcome was total cost per encounter. From this we created a binary outcome variable as having an encounter in the top 25th percentile for total cost in our patient cohort. Operative costs were determined by isolating the subset of total costs derived from preoperative, operating room, and postanesthesia care charges. Nonoperative costs were calculated by subtracting operative costs from total costs.

We analyzed data on patient age, gender, race, education level, medical history, body mass index (BMI), presenting symptoms, American Society of Anesthesiologists (ASA) score, mean income based on tax return data by zip code, travel distance to referral center, primary spoken language, health insurance, date of symptom onset, urologist density by county, stone complexity (Guy stone score[8]), stone size (as determined by CT, ultrasound, or X-ray), complications, and hospitalization duration.

Binary variables were created for age (<65 years = 1; ≥65 years = 0), gender (female = 1; male = 0), race (nonwhite = 1; white = 0), obesity (BMI ≥30 = 1; BMI <30 = 0), diabetes (type 1 or type 2 = 1; no diabetes history = 0), education level (no college = 1; college = 0), language (non-English = 1; English = 0), underinsured (medicaid = 1; nonmedicaid = 0), and infectious symptoms (endorses = 1; denies = 0, fevers, chills, urinary tract infection [UTI], and/or pyelonephritis associated with stone episode).

Stone size was made into a binary variable. Patients having one or more kidneys carrying a total stone burden >2 cm in diameter at greatest dimension were assigned a value of 1, while the remaining patients were assigned a value of 0. Guy stone score was categorized into a binary variable: Guy stone score of 3 or more in any kidney was valued as 1, Guy stone score of 2 or less in both kidneys was valued as 0, and isolated ureteral stones were also valued as 0.

Income data were obtained from publicly available IRS tax return data based on ZIP code (https://www.irs.gov/statistics/soi-tax-stats-individual-income-tax-statistics-2016-zip-code-data-soi). Tax return counts were provided for each of the six adjusted gross income brackets ($1–$25,000; $25,001–50,000; $50,001–75,000; $75,001–100,000: $100,001–200,000; $200,001, or higher). A linear weighted mean income score for each ZIP code was calculated using the 2016 IRS income data. Patients were categorized as low income if the income in their ZIP code was in the bottom quartile of our patient cohort: bottom quartile = 1, all other quartiles = 0.

Distance data were obtained using a custom Google Spreadsheet function and Google Maps Application Program Interface data. Distance was then categorized as a binary variable: patients living >104.1 miles from our stone referral center (75th percentile of our patient cohort) were assigned a value of 1 and patients from distances ≤104.1 miles away were categorized as 0.

The days between patient-reported stone symptom onset (or stone diagnosis in asymptomatic cases) and date of presentation to the tertiary care clinic were used to determine the binary variable for delay to care. This variable was assigned a value of 1 in patients with a delay of more than 138 days, or the top quartile of patients in this category, and all other patients were assigned a value of 0.

Density of urologists per patient residential county was obtained using Area Health Resource File data available from 2015 and 2016 (https://data.hrsa.gov). This was merged with the official county population data for the state of California based on California Department of Finance data over the same time period (www.dof.ca.gov/Forecasting/Demographics/Estimates/E-1). We categorized density as a binary variable: patients from counties with <2.0 urologists per 100,000 people (which represented the bottom 25th percentile of our patient cohort) were categorized as 1 and patients from counties with urologist density ≥2.0 per 100,000 people were categorized as 0.

ASA score was assigned by practicing anesthesia staff at the UCSF Medical Center to patients at the time of preoperative surgical evaluation and categorized as a binary variable. Patients were divided by ASA scores of 3 or higher *vs* 2 or lower. An ASA score of 3 or higher was assigned a value of 1, and ASA scores of 2 or lower were assigned a value of 0.

Complications were classified as Clavien–Dindo grade 1 to 5. For our analysis, patients were categorized as 0 if they did not have a complication, and 1 if they had a Clavien–Dindo grade of 1 or higher. Hospital stay was categorized as prolonged if patients undergoing extracorporeal shockwave lithotripsy (SWL) were not discharged on or before postoperative day 1, patients undergoing ureteroscopy (URS) were not discharged on or before postoperative day 1, patients undergoing percutaneous nephrolithotomy (PCNL) were not discharged on or before postoperative day 2, and patients undergoing a laparoscopic procedure were not discharged on or before postoperative day 4. These hospitalization durations represent double the typical and expected hospitalization period. Predicted need for a second-stage surgery was based on surgeon assessment at the conclusion of the surgical case as to whether or not a second-stage surgery would be needed for the patient.

Statistical analysis

Univariate analysis was performed using Fisher's exact test and Student's *t*-test. Multivariate analysis was performed using logistic regression, and robust standard errors were used to construct 95% confidence intervals (CIs). In our multivariate analysis, adjustments were made for variables of patient age, gender, race, ASA score, obesity, diabetes, infection, stone complexity, stone size, urologist density, income, travel distance, language, education, and delayed presentation to clinic. Regularization using least absolute shrinkage and selection operator (LASSO) regression was performed to account for overfitting of the multivariate model. The tuning parameter (lambda) was selected such that the residual sum of squares was optimal. Sensitivity analysis was then performed with variables readded to the model to select for clinically relevant variables. Statistical analysis was performed using R version 3.6.

Results

Of the 1142 patients in ReSKU enrolled between September 2015 and August 2018, 437 patients underwent surgery. Of these surgical patients, complete cost data were available for 326 patients. Of these patients, complete imaging, demographic, and comorbidity data were available for 190 patients. Patient characteristics are shown in Table 1.

The mean patient age was 53 with a range of 17 to 83. Only one patient was <18 years old. In total, 49.5% of our patients were female. Mean BMI was 28.8 with a range of 16.9 to 60.7. Furthermore, 39.5% of patients were nonwhite (2.6% black, 11.6% Latino or Hispanic, 11.6% Asian, and 13.7% other), and 30.5% of patients had a high school education or less. In addition, 15.8% of patients did not speak English as a primary language. Mean stone size was 29.4 mm with a range of 2 to 160 mm. Mean distance from patient zip code to the referral center was 68.2 miles with a range of 0 to 409 (standard deviation [SD] 74.2 miles). The mean urologist density per 100,000 was 3.7 with a range of 0 to 7.0 (SD 2.2). The average time between reported initiation of stone symptoms and presentation to the tertiary care clinic was 110 days with a range of 0 to 493 days. Thirty-eight patients were insured with Medicare, 45 with Medicaid, and 107 with commercial insurance. Three patients underwent SWL, 105 patients underwent URS, 78 patients underwent PCNL, and 4 patients underwent other procedures (3 laparoscopic pyeloplasties and 1 laparoscopic nephrectomy). Mean total cost for surgical encounter was 14,232 USD with a range of 4736 to 64,948 USD. Mean cost for SWL was 5529 USD, URS was 10,858 total, and PCNL was 18,698 USD (Table 1).

The binary variables of age ($p = 0.610$), gender ($p = 0.380$), ASA score ($p = 0.174$), hypertension ($p = 0.269$), asymptomatic ($p = 0.700$), language ($p = 0.230$), distance ($p = 0.080$), income ($p = 0.187$), urologist density ($p = 0.065$), underinsured ($p = 0.893$), or surgeon predicted need for a second-stage procedure ($p = 0.250$) did not impact total cost on univariate analysis. The binary variables of race ($p = 0.030$), obesity ($p = 0.018$), diabetes ($p = 0.037$), infection ($p = 0.013$), education ($p = 0.015$), stone size ($p < 0.001$), stone complexity ($p < 0.001$), delay to care ($p = 0.033$), complication ($p = 0.031$), and prolonged hospitalization ($p < 0.001$) were associated with total costs for treatment of stone disease on univariate analysis (Table 2 and Fig. 1).

Without adjustment for other variables, obesity ($p = 0.018$; odds ratio [OR] 2.33, CI 1.10–4.94), diabetes ($p = 0.003$; OR 3.43, CI 1.44–8.12), infection ($p = 0.002$; OR 4.23, CI 1.57–11.50), stone size >2 cm ($p < 0.001$; OR 5.39, CI 2.45–12.58), Guy stone score >2 ($p < 0.001$; OR 4.24, CI 1.97–9.25), urologist density in the bottom quartile ($p = 0.003$; OR 3.18, CI 1.40–7.18), and clinic delay in the top quartile ($p = 0.017$; OR 2.55, CI 1.16–5.57) were all associated with highest quartile

Table 1. Patient Characteristics

Mean ± SD (range) age, years	53 ± 14.9 (17–83)
Male/female, *n* (%)	96/94 (50.5/49.5)
Race, *n* (%)	
White	115 (60.5)
Black	5 (2.6)
Latino	22 (11.6)
Asian	22 (11.6)
Other	26 (13.7)
Mean ± SD (range) BMI	28.8 ± 8.0 (16.9–60.7)
Medical history, *n* (%)	
Diabetes	34 (17.9)
Hypertension	46 (24.2)
Symptoms, *n* (%)	
Asymptomatic	17 (8.9)
Infection	49 (25.8)
Mean ± SD (range) stone size, mm	29.4 ± 26.6 (2–160)
Guy stone score, *n* (%)	
Grade 3 or higher	56 (29.5)
Grade 2 or lower	134 (70.5)
ASA score, mean ± SD (range)	2.1 ± 0.60 (1–4)
Language	
English	160 (84.2)
Non-English	30 (15.8)
Education	
No college	58 (30.5)
Some college or more	132 (69.5)
Mean ± SD (range) distance from tertiary center, miles	68.2 ± 74.2 (0–409)
Mean ± SD (range) urologist density, per 100,000 people	3.7 ± 2.2 (0–7.0)
Low income, *n* (%)	50 (26.3)
Clinic delay, mean ± SD (range) days	110 ± 118 (0–493)
Insurance type, *n* (%)	
Commercial	107 (55.8)
Medicare	45 (23.7)
Medicaid	38 (20.0)
Need for second-stage surgery, *n* (%)	19 (10.0)
Complications, *n* (%)	21[a] (15.6)
Prolonged hospitalization, *n* (%)	33[b] (24.4)
Total cost overall and by procedure, mean ± SD (range), USD	
Total	14,232 ± 8202 (4736–64,948)
PCNL (*n* = 78, 41.1%)	18,698 ± 7680 (10,429–64,948)
URS (*n* = 105, 55.2%)	10,856 ± 6705 (4736–53,480)
SWL (*n* = 3, 1.6%)	5529 ± 287 (5198–5699)
Other[c] (*n* = 4, 2.1%)	22,247 ± 9366 (14,824–35,875)

[a]Out of 135 patients.
[b]Out of 135 patients.
[c]Three laparoscopic pyeloplasties, one laparoscopic nephrectomy.
ASA = American Society of Anesthesiologists; BMI = body mass index; PCNL = percutaneous nephrolithotomy; SD = standard deviation; SWL = extracorporeal shockwave lithotripsy; URS = ureteroscopy.

Table 2. Mean Total Cost in USD

	No	*Yes*
Age ≥65 ($p = 0.610$)	14,351	13,787
Female gender ($p = 0.380$)	13,714	14,762
Nonwhite race ($p = 0.030$)	13,114	15,947
ASA score >2 ($p = 0.174$)	13,079	15,916
Obesity/BMI >30 ($p = 0.018$)	13,097	16,575
Diabetes ($p = 0.037$)	13,402	18,040
Infection symptoms ($p = 0.013$)	13,129	17,407
HTN ($p = 0.269$)	14,528	13,304
Asymptomatic ($p = 0.700$)	14,156	15,003
Stone size ≥2 cm ($p < 0.001$)	11,756	17,636
Guy stone score ≥2 ($p < 0.001$)	12,652	18,014
Non-English speaking ($p = 0.230$)	13,907	15,968
Less than college education ($p = 0.015$)	13,313	16,323
Distance traveled top 75th percentile ($p = 0.080$)	13,631	16,114
Income bottom 25th percentile ($p = 0.187$)	13,705	15,707
Urologist density bottom 25th percentile ($p = 0.065$)	13,602	16,520
Clinic delay top 75th percentile ($p = 0.033$)	13,352	16,765
Underinsured ($p = 0.893$)	14,196	14,347
Predicted need for second-stage surgery ($p = 0.250$)	13,940	16,862
Complication ($p = 0.031$)	13,081	18,150
Prolonged hospitalization ($p < 0.001$)	11,740	20,449

cost encounters. Complications ($p = 0.002$; OR 4.77, CI 1.57–14.58) and prolonged hospitalization ($p < 0.001$; OR 17.5, 5.98–56.34) were both associated with surgical encounters in the upper quartile of cost, while surgeon-reported need for a second-stage procedure was not ($p = 0.050$) (Table 3).

For the purpose of our multivariate analysis, we did not include the one patient <18 years of age and did not include the four patients who underwent laparoscopic procedures as these were demographic and procedural outliers for adult stone disease treatment that could potentially skew this analysis. When taking into account age, delayed presentation, procedure type, stone size >20 mm, ASA code, gender, race, income, distance, urologist density, BMI, diabetes, infection, education, language, insurance, and stone complexity, PCNL procedure ($p < 0.001$; OR 12.9, CI 4.05–48.5), urologist density in the bottom quartile ($p = 0.014$; OR 4.66, CI 1.40–16.9), diabetes ($p = 0.018$; OR 4.38, CI 1.32–15.6), and infection ($p = 0.007$; OR 4.51, CI 1.55–14.0) were the only variables statistically significant for association with top quartile of total cost. When changing stone size from a binary to a linear variable, stone size was significant for association with top quartile of total cost ($p = 0.040$) with an OR of 1.02 per mm increase in stone size (CI: 1.00–1.04), as was PCNL procedure ($p < 0.001$; OR 9.37, CI 2.94–34.6), urologist density in the bottom quartile ($p = 0.011$; OR 5.13, CI 1.51–19.0), diabetes ($p = 0.019$; OR 4.32, CI 1.30–15.4), and infection ($p = 0.016$; OR 3.87, CI 1.30–12.1).

LASSO regression was performed to remove least predictive variables from our initial multivariate model. Variables such as procedure type, stone size >2 cm, urologist density, diabetes, infection, and stone complexity were selected as predictive factors after applying LASSO regression. Age and gender were reintroduced to the model based on their clinical significance. When adjusting for these variables, diabetes, infection symptoms, low urologist density, and PCNL procedure were significantly predictive for high cost (Fig. 2). Existence of this sparse model is suggestive of multicollinearity between predictors.

Need for a second-stage procedure was not included in predictive analysis as it was thought to be associated with outcome rather than a predictor of cost of the initial surgical encounter. Prolonged hospitalization and complication variables were also not included in the multivariate regression as both variables were thought to be an associated outcome related to cost rather than a preoperative predictor of cost. However, among individuals with discharge and complication data, univariate analysis comparing patients from low urologist density counties with all other patients showed that patients from low urologist density counties had higher rates

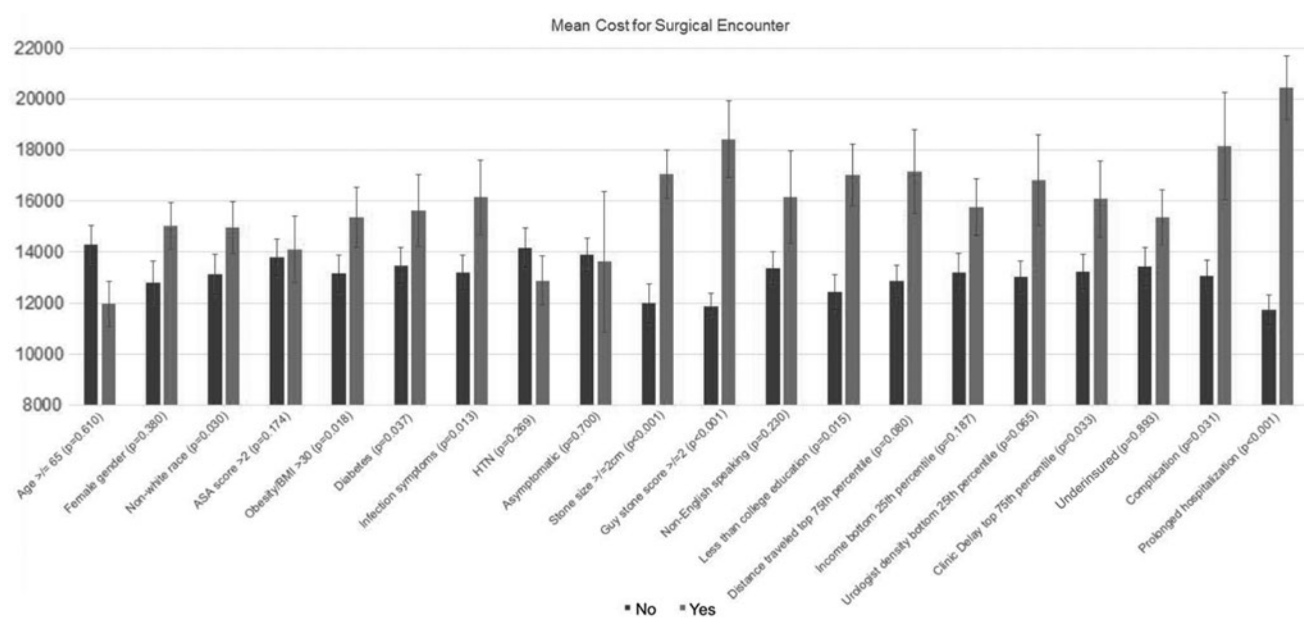

FIG. 1. Mean cost for surgical encounter. *X* axis, variable; *Y* axis, USD: no, yes.

TABLE 3. UNIVARIATE ANALYSIS FOR TOP QUARTILE OF COST

	Bottom three quartiles n = *146 (%)*	*Top quartile* n = *44 (%)*	p	*Unadjusted odds ratio (95% CI)*
Age (>65)	19	27	0.292	1.58 (0.65–3.64)
Gender (female)	47	59	0.17	1.65 (0.79–3.50)
Race (nonwhite)	37	48	0.221	1.55 (0.74–3.24)
ASA score (ASA 3 or higher)	21	32	0.16	1.73 (0.75–3.86)
Obesity (BMI >30)	21	32	0.018	2.33 (1.10–4.94)
Diabetes (with type 1 or 2 diabetes)	13	34	0.003	3.43 (1.44–8.12)
Hypertension (with diagnosis of hypertension)	24	25	0.999	1.06 (0.44–2.43)
Infection (with infectious symptoms)	17	46	0.002	4.23 (1.57–11.50)
Asymptomatic (without symptoms)	8	14	0.232	1.93 (0.55–6.15)
Stone size (>20 mm)	33	73	<0.001	5.39 (2.45–12.58)
Guy stone score (>2)	22	55	<0.001	4.24 (1.97–9.25)
Language (non-English)	14	20	0.35	1.53 (0.56–3.87)
Education (with no college)	37	48	0.221	1.55 (0.74–3.24)
Distance traveled to clinic (in top 75th percentile)	21	34	0.107	1.91 (0.84–4.28)
Income (in bottom 25th percentile)	23	35	0.135	1.73 (0.80–3.70)
Urologist density (in bottom 25th percentile)	16	39	0.003	3.18 (1.40–7.18)
Clinic delay (in top 75th percentile)	18	39	0.017	2.55 (1.16–5.57)
Underinsured (with medical)	23	25	0.841	1.10 (0.45–2.52)
Scheduling for second-stage procedure (yes)	8	16	0.05	3.61 (0.80–15.64)
	n = *107*	n = *28*		
Complications (with Clavien–Dindo complications)	10	36	0.002	4.77 (1.57–14.58)
Prolonged hospitalization (with prolonged hospitalization)	12	71	<0.001	17.5 (5.98–56.34)

CI = confidence interval.

of complications (12% *vs* 27%, $p = 0.083$) and prolonged hospitalizations (21% *vs* 37%, $p = 0.093$), although these differences were not statistically significant. Patients from low urologist density counties were significantly more likely be from the lowest income quartile based on zip code ($p = 0.002$; OR 4.19, CI 1.62–11.0), to have less than a college education ($p = 0.045$; OR 2.39, CI 0.95–6.01), to have delayed presentation to the tertiary clinic ($p = 0.045$; OR 2.60, CI 0.96–6.93), and to travel long distances for tertiary care ($p < 0.001$; OR 15.0, CI 5.33–45.8). Being in the upper quartile group were operating room cost ($p = 0.031$, OR 2.64, CI 1.00–6.90), nonoperating room cost ($p = 0.042$; OR 2.51, CI 0.99–6.35), and total cost ($p < 0.001$; OR 5.59, CI 2.06–15.5), each significantly more frequent among patients from low urologist density counties (Table 4).

Discussion

This study has two main findings. First, procedure type is a predominant driver of cost of surgical treatment for stone disease at the tertiary referral center in this study. Of note, as a linear variable, stone size was also independently found to influence cost on multivariate analysis, even when procedure type was considered in the analysis. This is not surprising given that PCNL procedures for larger stones likely require more operative time, resources, and therefore cost relative to PCNL procedures for smaller stones. Although procedure type was found to be the predominant driver of cost in our analysis, the decision to perform a PCNL procedure *vs* SWL or URS is also largely dictated by stone size.

Second, coming from a county with low urologist density (<2 urologists per 100,000 people) is an independent predictor for overall cost of surgical encounter for kidney stone treatment. This was true even when accounting for suspected confounders such as race, income, education, distance traveled for care, language, delay to treatment, medical comorbidities, procedure type, stone size >2 cm, and stone complexity. Additional clinical factors such as diabetes and infection both independently predicted for higher cost surgical encounters.

Previous research has shown that chronic medical conditions are associated with higher cost over time among Medicare patients.[9] For surgical patients, medical comorbidities before surgery can be used to predict the cost of future surgical encounters for coronary artery bypass grafting, colectomy, and orthopedic joint replacement surgery.[10] In a series of 200 consecutive PCNL patients, Bagrodia and colleagues demonstrated that surgery was more costly among patients with preoperative UTI, but only stone size was significantly associated with high cost on multivariate analysis.[11] In a similar study, Bagrodia and colleagues showed no statistically significant increase in surgical encounter costs related to increasing patient BMI.[12]

Many studies have investigated the relationship between social factors predicting surgical access and cost of surgery. In a review of the California Office of Statewide Health Planning and Development data set from 2010 to 2012, researchers found increased frequency of deferred management of stone disease among underinsured and minority patients.[13] They concluded that this also equated to higher cost of surgical stone treatment for these patients, given their need for multiple surgeries to completely treat their stone episode. In a series of over 300 patients undergoing bariatric surgery, patients who were underinsured were significantly more likely to be in the upper quartile of cost for their surgical encounter.[14]

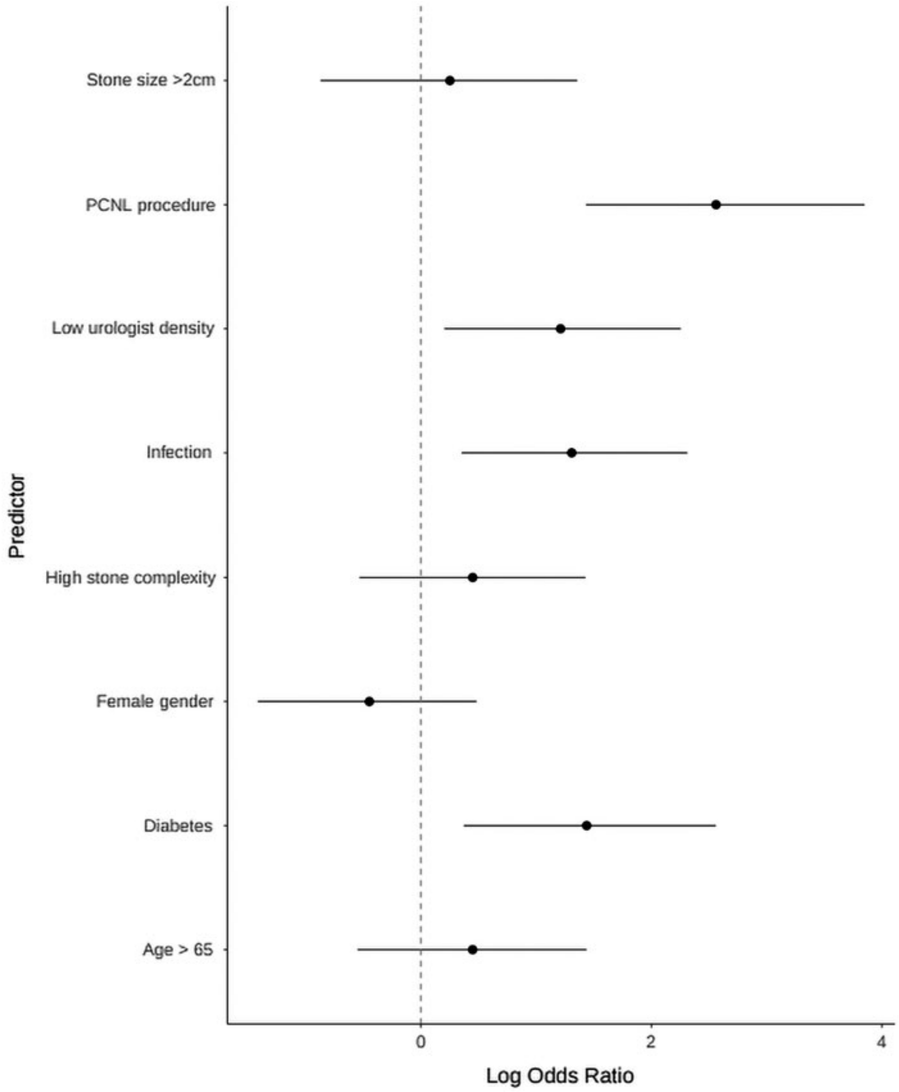

FIG. 2. Adjusted log ratios of LASSO regression selected factors predicting high-cost surgery. Dashed vertical line designates zero on the x-axis. LASSO, least absolute shrinkage and selection operator.

Numerous examples both in the United States and internationally have demonstrated a relationship between surgical access and surgical disease outcome. In France, for example, increased residential distance from surgical referral centers was correlated with worsening prognosis for rectal cancer patients.[15] In the United States, access to surgery often falls along socioeconomic lines. For instance, counties with higher percentages of minorities, rural, and uninsured patients have less access to emergency general surgery.[16] Specific to urology, patients presenting with prostate cancer to a health net hospital are more likely to present with advanced disease.[17] Greater than 60% of counties in the United States have no urologists.[18] Low urologist density has been linked to advanced stone burden[5] and increased mortality rates for urologic oncology patients.[3,4]

Although previous publications have investigated cost of surgery or access to surgery, this study is unique in that it bridges the relationship between cost and access in urology. We found that patients with kidney stones coming from counties with fewer urologists were more likely to be high-cost surgical patients independent of all other social and clinical factors.

Many referrals to tertiary care stone centers are placed because local urologists without specialized training in endourology do not have the capacity to treat patients with large complex stone disease. Consequently, these patients may be more likely to undergo larger procedures (PCNL) that are more costly. Our analysis showed that independent of stone size, stone complexity, and procedure type, individuals from low urologist density counties were consistently higher cost patients. In looking at the comparison between patients living in counties with higher urologist densities compared with low urologist densities, patients in low urologist density counties have more than double the rate of complications and nearly double the rate of prolonged hospitalizations. Although these differences were not found to be statistically significant possibly due to limited sample size, it is likely that increased rates of complications and prolonged hospitalizations are both drivers of higher cost in patients coming from low urologist density counties.

These findings do not definitively demonstrate that increasing regional density of urologists will directly reduce costs associated with treatment of kidney stones. These findings do suggest that coming from a county with low

Table 4. Comparative Univariate Analysis for Urologist Density

	Urologist density ≥2/100,000, n = 105 (%)	*Urologist density <2/100,000, n = 30 (%)*	p	*Unadjusted odds ratio (95% CI)*
Age (>65)	21	10	0.285	0.42 (0.07–1.57)
Gender (female)	44	63	0.066	2.20 (0.89–5.67)
Race (nonwhite)	42	33	0.527	0.70 (0.26–1.74)
ASA score (ASA 3 or higher)	20	27	0.455	1.45 (0.49–4.01)
Obesity (BMI >30)	29	47	0.078	2.17 (0.87–5.44)
Diabetes (with type 1 or 2 diabetes)	15	30	0.107	2.37 (0.81–6.67)
Hypertension (with diagnosis of hypertension)	22	27	0.625	1.29 (0.44–3.53)
Infection (with infectious symptoms)	19	37	0.052	2.44 (0.90–6.47)
Asymptomatic (without symptoms)	9	7	0.999	0.763 (0.08–4.00)
Stone burden (>20 mm)	35	43	0.521	1.40 (0.56–3.46)
Guy stone score (>2)	28	40	0.26	1.74 (0.68–4.38)
PCNL procedure	39	33	0.671	0.78 (0.30–1.96)
Language (non-English)	18	20	0.794	1.13 (0.33–3.38)
Education (with no college)	18	35	0.045	2.39 (0.95–6.01)
Distance traveled to clinic (in top 75th percentile)	11	67	<0.001	15.0 (5.33–45.8)
Income (in bottom 25th percentile)	19	50	0.002	4.19 (1.62–11.0)
Clinic delay (in top 75th percentile)	18	37	0.045	2.60 (0.96–6.93)
Underinsured (with medical)	20	33	0.143	1.99 (0.72–5.29)
Scheduling for second-stage procedure (yes)	8	10	0.708	1.34 (0.22–6.12)
Complications (with Clavien–Dindo complications)	12	27	0.083	2.55 (0.81–7.65)
Prolonged hospitalization (with prolonged hospitalization)	21	37	0.093	2.17 (0.81–5.68)
Operating room cost (in top 75th percentile; mean cost USD ± SD)	20; 7332 ± 2126	40; 8369 ± 3005	0.031	2.64 (1.00–6.90)
Nonoperating room cost (in top 75th percentile; mean cost USD ± SD)	26; 5696 ± 4744	47; 8443 ± 8924	0.042	2.51 (0.99–6.35)
Total cost (in top 75th percentile)	13%; 13,028 ± 6224	47%; 16,812 ± 9777	<0.001	5.59 (2.06–15.5)

urologist density is an indicator of limited access to care. Indeed, patients from low urologist density counties are significantly more likely to travel long distances for care (11% *vs* 67%, $p < 0.001$) and have delayed presentation to clinic (18% *vs* 37%, $p = 0.045$). Coming from a county of <2 urologists per 100,000 may also be a marker of lower socioeconomic status as these patients have lower levels of education (18% *vs* 35%, $p = 0.045$) and come from lower income zip codes (19% *vs* 50%, $p = 0.002$). This combined with a trend toward higher rates of underinsurance, diabetes, obesity, and infections among patients coming from low urologist density areas suggests that improved access to nonurologic health care providers and improved management of medical comorbidities before surgery can reduce complications and prolonged hospitalization in this high-cost group. In addition, this study may also reflect a need for improved discharge planning coordination with these patients' local provider or referral to a local primary care physician before surgery if they do not have one.

This study is limited by small sample size and single referral center patient population. However, it compares in size with previous studies looking at in-depth individualized cost data for surgical disease.[11,12,14] We are also limited by lack of long-term cost data associated with the need for multiple surgical procedures. Nevertheless, we were able to show that the predicted need for scheduling for a second-stage procedure was only a 10% occurrence among this patient cohort.

Going forward, more research is needed to explore the relationship between social factors, access to health care, and cost for surgical treatment of stone disease. Multicentered studies may expose gaps in regional access to care and local provider coverage resulting in higher costs for eventual surgical treatment. Increasing access to and quantity of midlevel specialist providers as urologist extenders in rural and underserved areas may ultimately prove to be large-scale cost saving interventions. Leveraging telehealth technology to augment outpatient care coordination can limit the treatment burden on the operative facility and may prove to be a cost-effective investment for health care networks.

Conclusion

This study uniquely shows that when accounting for a variety of other variables, urologist density is a key independent predictor of cost for stone surgery. It also reveals that low socioeconomic status and indicators of poor access to health care are higher among patients in counties with low urologist density. Improving access to and perioperative coordination of care in these patients may reduce complications, prolonged hospitalizations, and cost in this high-risk population.

Author Disclosure Statement

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Abbreviations Used

ASA = American Society of Anesthesiologists
BMI = body mass index
CCRs = cost-to-charge ratios
CI = confidence interval
CT = computed tomography
LASSO = least absolute shrinkage and selection operator
OR = odds ratio
PCNL = percutaneous nephrolithotomy
ReSKU = Registry for Stones of the Kidney and Ureter
SD = standard deviation
SWL = extracorporeal shockwave lithotripsy
UCSF = University of California, San Francisco
URS = ureteroscopy
UTI = urinary tract infection