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Journal
Journal of endourology, 33(1)

ISSN
0892-7790

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Publication Date
2019

DOI
10.1089/end.2018.0776

Peer reviewed

JOURNAL OF ENDOUROLOGY
Volume 33, Number 1, January 2019

Pp. 9–15
DOI: 10.1089/end.2018.0776

Factors Associated with Regional Adoption of Ureteroscopy in California from 2005 to 2016

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Abstract

Purpose: To explore regional adoption of ureteroscopy (URS) over extracorporeal shockwave lithotripsy (SWL) in the state of California (CA) and to identify factors associated with this adoption over time.
Materials and Methods: We used the California Office of Statewide Health Planning and Development (OSHPD) public data to identify URS and SWL procedures performed for renal and ureteral stones from 2005 to 2016. The level of analysis was the region wherein each procedure was performed, defined by the 19 CA labor market regions. OSHPD data were supplemented with the Area Health Resource File to provide information on regional characteristics. Generalized linear regression was used to determine procedural rates adjusted for age, gender and race. Choropleth time series maps were used to illustrate adoption of URS by region over time.
Results: A total of 328,795 URS and SWL procedures were identified from 2005 to 2016. The number of URS procedures surpassed the number of SWL procedures in 2011. Fourteen regions became URS predominant by 2016 and were characterized as having a higher per capita income, higher percentages with a college education and lower percentage of female heads-of-household (all p-values <0.05). A higher percentage of patients in these regions were male and had private or Medicare insurance ($p = 0.03$ for both).
Conclusions: From 2005 to 2016, most CA regions adopted URS as the primary renal and ureteral stone management strategy. These regions demonstrated characteristics of higher socioeconomic status compared to regions that remained SWL predominant. A better understanding of such differences in practice patterns will allow urologists to better negotiate for the capital expenditures required to conform to evolving standards of care and allow patients the ability to make more informed decisions on where they receive care.

Keywords: ureteroscopy, shockwave lithotripsy, regional factors, practice patterns, epidemiology

Introduction

Renal and ureteral stones are increasing in prevalence in the United States, affecting one in eleven individuals. Most stones can be surgically managed with either ureteroscopy (URS) or extracorporeal shockwave lithotripsy (SWL)[1,2]; where URS provides higher stone-free rates and SWL offers lower rates of complications. In 2007, the American Urological Association (AUA) guidelines on the management of ureteral calculi presented both types of procedures as equivalent first-line therapies.[3] Over time, however, population-based studies show increasing utilization of URS compared with SWL, with improved technology, visualization, and training cited as driving forces behind this change.[4–6] The updated 2016 AUA/Endourological Society guideline for the surgical management of stones recommend URS over SWL for patients with moderate to large stone burdens, especially in a lower pole location due to increased stone-free rates.[7]

Despite the trend toward increased URS utilization, studies differ as to when URS surpasses SWL in predominance, from 2001 based on national Medicare claims data to as late as 2010 in California (CA).[4,5,8,9] It is not clear whether these temporal differences are attributable to geographic factors (i.e., climate[10]), access to urologists, presence of academic urology programs, socioeconomic factors (education, urbanization, poverty, and so on), or patient factors (age, race, comorbidity, and so on). Given professional society statements,[3] tradeoffs in stone-free rates and complications,[7] need for complex and expensive equipment, and dissimilar learning curves, we aim to map differential uptake of URS over time and the factors associated with preferred adoption of URS (or lack thereof) in the state of CA.

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To address these questions, we used the CA Office of Statewide Health Planning and Development (OSHPD) public surgical databases 2005–2016. This study will inform our understanding of regional level drivers in the adoption of URS over SWL, help urologists to better negotiate for the capital expenditures required to conform to evolving standards of care, and allow patients the ability to make more informed decisions on where they receive care.

Materials and Methods

Databases and procedures

This is a retrospective cohort study utilizing the CA OSHPD database from 2005 to 2016. The OSHPD database consists of publicly available nonfederal inpatient and ambulatory surgical databases that track all surgical procedures performed at licensed acute care hospitals and ambulatory surgical centers in the state of CA, respectively. Separate inpatient and ambulatory databases are maintained at the level of the procedure. This study is deemed exempt by our institution's Internal Review Board.

Identification of URS and SWL procedures is based on International Classification of Diseases, 9th and 10th Revisions (ICD-9/10) procedure codes for inpatient procedures and Current Procedural Terminology, 4th Edition for outpatient procedures. Only procedures in which the patient has a diagnosis code for renal or ureteral stones (based on ICD-9/10 diagnosis codes) are included. URS with and without laser lithotripsy were grouped together as the decision to proceed with or without laser lithotripsy is often made intraoperatively and independent of the decision to perform SWL. Procedures in which the patient had a diagnosis code associated with renal or upper tract urothelial malignancy or ureteral stricture are excluded (Supplementary Table S1; Supplementary Data are available online at www.liebertpub.com/end).

Geographic region identification

The California Labor Market Information Division's economic regions and subregions are our level of geographic analysis.[11] This classification scheme separates the state of CA into 19 groups of counties where people live and work, as assessed by population centers, commute patterns, and industry analysis. Although not traditionally used in the context of epidemiologic research, this regional classification system benefits from consideration of county clusters as opposed to Health Service Areas and Zip Codes, which cross county lines. This regional classification system better accounted for urologist distribution and urology practice catchment area than county lines alone and prevents blinding in the event of low sample size, which necessarily occurs during county level analysis.

Regional characteristics/contextual factors

To better understand contextual regional characteristics associated with adoption of URS procedures over time, OSHPD data were merged with data from the Area Health Resource File (AHRF). The AHRF is collected by the United States Health Resources and Services Administration from more than 50 sources and includes data on county, state, and national level variables. Regional level data are extrapolated from county level data for population (sum), per capita income (mean), percent of households with a female head (mean), percent with college education or higher (mean), percent urban population (mean), and number of urologists per 100,000 population (sum of urologists in all counties). Data on the location of urology residency programs were obtained from the AUA website.[12]

Statistical analysis

To determine whether differences existed between patient characteristics for URS and SWL procedures, we performed Chi Square test for independence on categorical data of counts. The categories include expected payer (adequately insured [privately insured or Medicare] and underinsured [any other insurance status, including Medicaid and uninsured]), race group (white/nonwhite), and gender (Male/Female). Continuous data included mean age and standard deviation of age.

We created choropleth maps of adjusted rates of URS *vs* SWL procedures to better understand the geographic distribution of these procedures over time. Procedure counts were adjusted for age, race, and gender by region using generalized linear regression and multiplied by the adjustment factor. To examine changes in procedure-mix over time, we then rank ordered the regions by the adjusted ratio of URS to the total number of procedures for 2005 and compared, in the same order, this value for 2016. One region was excluded from adjustment in Figure 3 due to low sample size in 2005 requiring data masking.

To determine which regional level factors may be associated with performing URS in 2016, we split regions into a two by two contingency table. Categories were dependent on adoption of URS as the predominant (≤50% *vs* >50%) procedure by 2016 and if the regional characteristic was above the median value of that characteristic calculated across the 19 regions (≤median *vs* >median). Regional characteristics were then compared using the Fisher's exact test. Regression analysis was performed using SAS software and maps created using ArcGIS 10.5 software (ESRI, Redlands, CA).

Results

A total of 328,795 URS and SWL procedures were performed from 2005 to 2016 (Table 1). Characteristics of individuals undergoing each procedure are shown in Table 1, with small but statistically significant differences gender and race. Operative setting based on procedure type was significantly different, with 77% of URS and 93% of SWL being performed on an outpatient basis ($p < 0.01$).

Figure 1 illustrates trends in procedure utilization over time. Overall, the total number of stone procedures (URS and SWL combined) increased over time, whereby URS procedures accounted for 40% of stone procedures in 2005 and 66% of stone procedures in 2016, while SWL procedures accounted for 60% of stone procedures in 2006 and 34% of stone procedures in 2016. The number of URS procedures surpassed the number of SWL procedures between 2010 and 2011.

Figure 2 illustrates the percent of cases performed using URS as opposed to SWL over the study period displayed in a time series choropleth map. The locations of urology

Table 1. Patient Demographics

	Total n = *328,795*	*Ureteroscopy* n = *168,587*	*Shockwave lithotripsy* n = *160,208*	p-*Value*
Gender, *N* (%)				
Male	181,747 (55%)	91,912 (55%)	89,835 (56%)	<0.01*
Female/NR	147,048 (45%)	76,675 (45%)	70,373 (44%)	
Age, *N* (%)				
<65	248,042 (75%)	126,196 (75%)	121,846 (76%)	0.22
≥65	80,753 (25%)	42,391 (25%)	38,362 (24%)	
Race, *N* (%)				
White	208,312 (63%)	105,691 (63%)	102,621 (64%)	0.02*
Nonwhite	120,483 (37%)	62,896 (37%)	57,587 (36%)	
Operative setting, *N* (%)				
Ambulatory	278,580 (85%)	129,878 (77%)	148,702 (93%)	<0.01*
Inpatient	50,215 (15%)	38,709 (23%)	11,506 (7%)	
Disposition, *N* (%)				
Home	320,492 (97%)	163,049 (97%)	157,443 (98%)	0.16
Admitted/other	8303 (3%)	5538 (3%)	2765 (2%)	
Insurance, *N* (%)				
Private/Medicare	273,771 (83%)	139,328 (83%)	134,443 (84%)	0.26
Medicaid/other	55,024 (17%)	29,259 (17%)	25,765 (16%)	

Chi-squared test.
*Statistically significant.
NR = not reported.

residency programs are indicated with dots in the top left panel. Metropolitan areas such as the San Francisco Bay Area are noted to adopt URS early, while less densely populated regions tend to lag behind. Areas transitioning from SWL to URS seem to occur radially from large metropolitan regions such as near Los Angeles County and the San Francisco Bay Area. One subregion of the Northern Economic Market region (the region located furthest to the north-east) was noted to suddenly transition to a >90% utilization of URS as of 2011, while some regions, such as Imperial county (the region located furthest to the south-east), persistently maintained low URS utilization at <10%. At the end of the study period, 14 regions perform ≥50% URS, and 5 perform <50% URS.

Significant differences in the proportion of URS adoption were noted across regions in CA over time after adjusting for age, race, and gender of the patients (Fig. 3). Thirteen regions transitioned from predominantly performing SWL to URS, and one region performed primarily URS for the duration of the study. The five remaining regions continued to perform a majority of SWL as of 2016.

Characteristics of the 14 regions performing a majority of URS in 2016 are compared to the remaining 5 regions using SWL in Table 2. Regions which performed a majority of URS

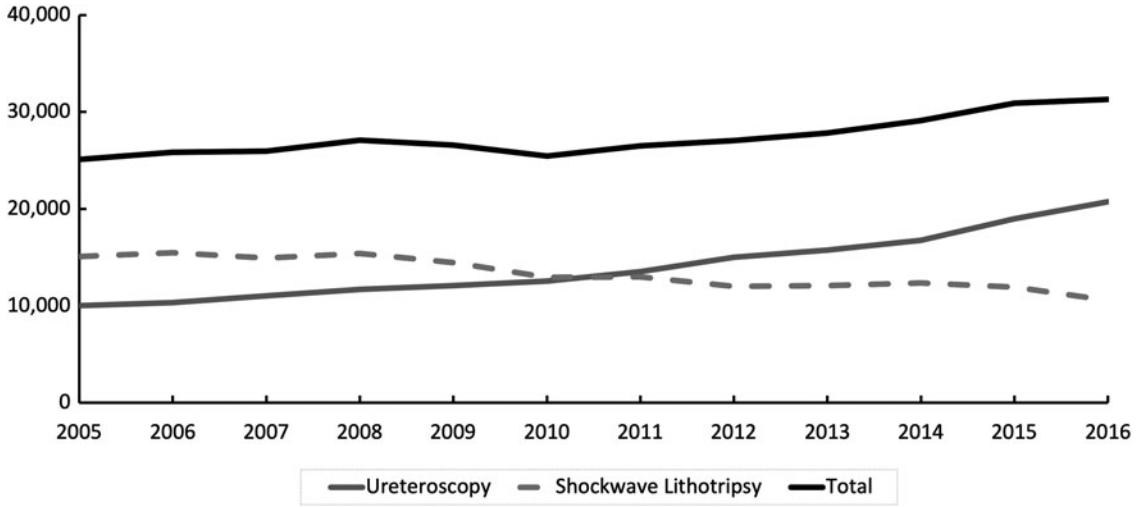

FIG. 1. Number of ureteroscopy and shockwave lithotripsy procedures reported to the California Office of Statewide Health Planning and Development for renal and ureteral stones from 2005 to 2016. The *black line* represents the total number of cases, while the *gray line* represents ureteroscopy procedures, and the *dashed line* represents shockwave lithotripsy procedures.

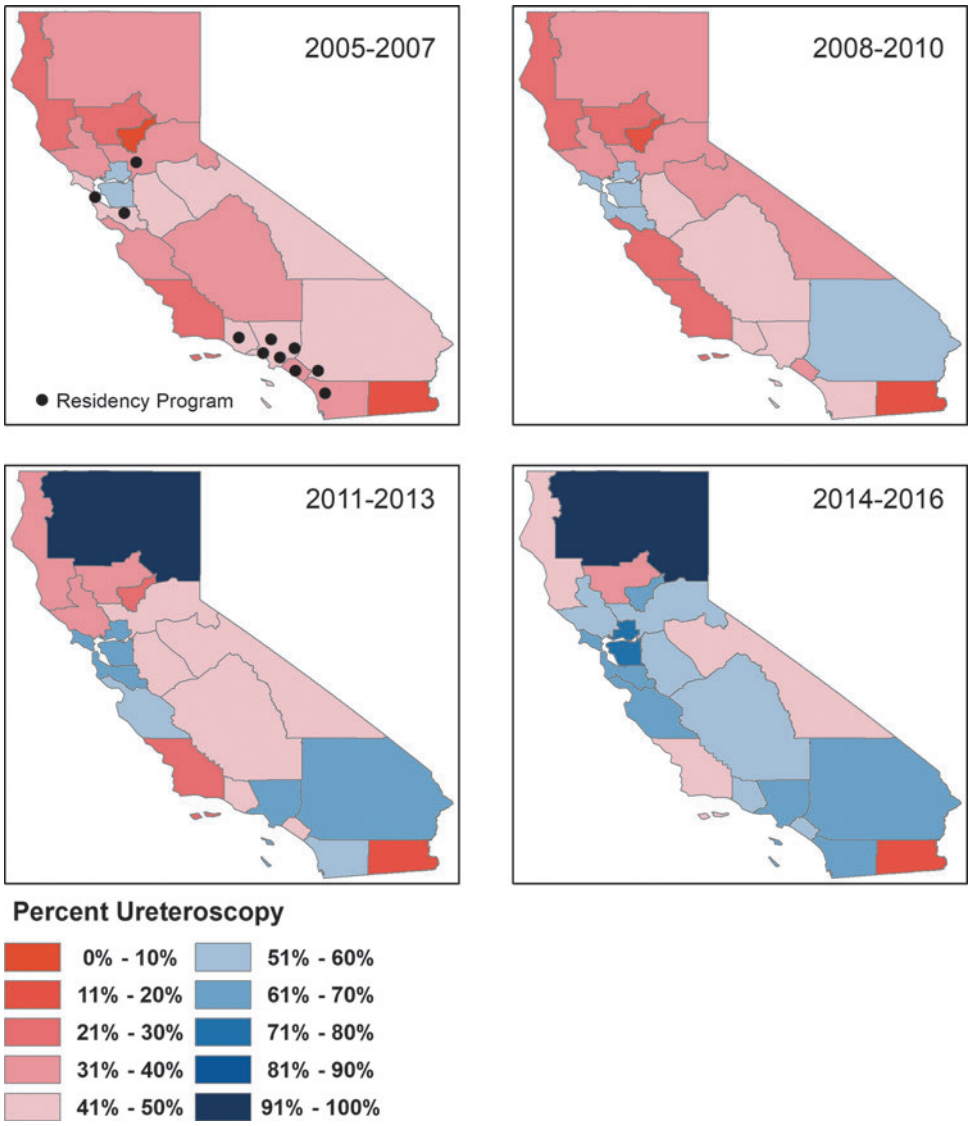

FIG. 2. Time series choropleth map of the State of California, United States, illustrating the relative proportion of ureteroscopy to shockwave lithotripsy procedures reported to the California Office of Statewide Health Planning and Development for renal and ureteral stones from 2005 to 2016. The locations of urology residency programs are indicated with *dots* in the *top left panel*. Areas represented in *blue* perform ≥50% ureteroscopy, while areas in *red* perform <50% ureteroscopy with *darker colors* being further from 50% ureteroscopy procedures.

procedures in 2016 were observed to have a lower than median percentage of households with female heads (median 4%, $p = 0.01$) and a higher than median percentage of college-educated population (median 17%, $p = 0.03$), per capita income (median $40,124, $p = 0.03$), percentage of male patients (median 54%, $p = 0.03$), and percentage of patients who are adequately insured (privately insured or on Medicare) (median 80%, $p = 0.03$). Nonsignificant regional factors included total and percent urban population, number of urologists per 100,000 population, presence of a urology residency program, age of the urologists in the region, and the total number of procedures performed.

Discussion

This study demonstrated that URS utilization increased statewide in relationship to SWL and surpassed SWL in 2011, establishing a trend increasingly favoring URS *vs* SWL over time for the diagnosis codes associated with renal and ureteral stones. While URS became the predominantly performed procedure in most regions, as of 2016, five regions continued to rely on SWL as the principal method of management for renal and ureteral stones. The 14 regions performing a majority of URS procedures were characterized by factors associated with higher socioeconomic status, including higher per-capita income, higher percentage of college graduates, lower percentage of households with female heads, and higher percentage of Medicare or privately insured individuals.

Nationally, the relative proportion of small renal and ureteral stones treated with URS as opposed to SWL has increased due to a number of factors, including technologic advances (e.g., increasingly powerful Holmium:YAG lasers, improved fibers, and smaller and more sophisticated ureteroscopes) and increased exposure to URS techniques during residency training.[4–6] This shift has been endorsed as standard of care by professional organizations such as the AUA for a number of clinical situations.[7] Studies have differed, however, as to when the number of URS procedures surpasses the number of SWL procedures based on the cohort, ranging from before 2001 (according to national Medicare claims) to as late as 2010 in CA according to the OSHPD.[4,5,8,9] CA apparently lags well behind the curve

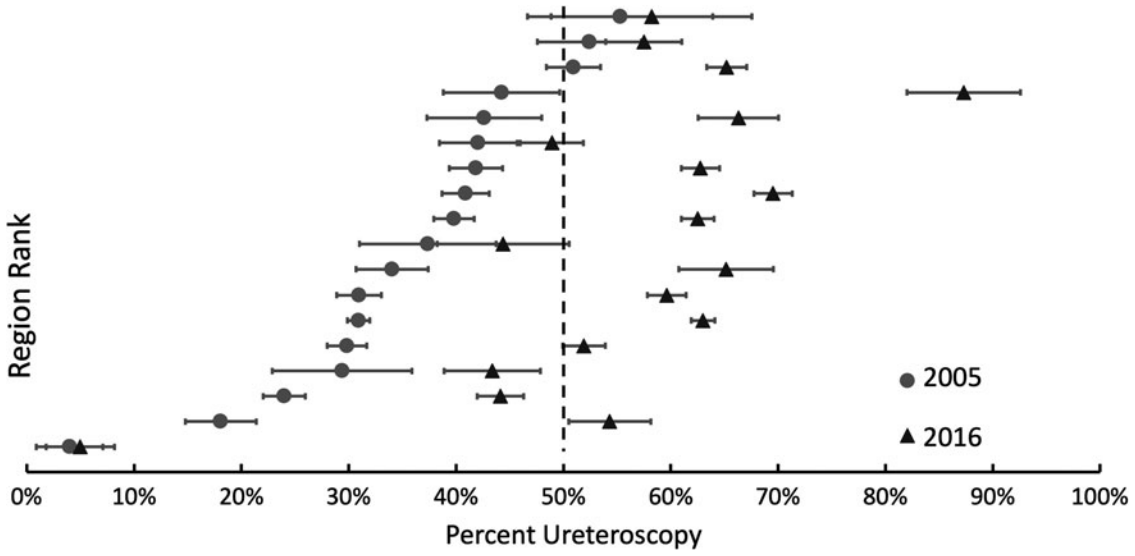

FIG. 3. Caterpillar chart illustrating the relative proportion of ureteroscopy to shockwave lithotripsy procedures reported to the California Office of Statewide Health Planning and Development for renal and ureteral stones for 2005 (*circle*) and 2016 (*triangle*) after adjusting for age, race, and gender of the patients. California Labor Division Economic subregions were rank ordered by proportion of ureteroscopy procedures *vs* shockwave lithotripsy procedures in 2005; this order was maintained for 2016. *Horizontal bars* represent the standard error calculation.

nationally with regard to adoption of URS. However, previous studies have not investigated the relative distribution of URS and SWL across CA on a regional level.

Not only is the development of new technologies and techniques important, but it also is equally important that patients have uniform access to the evolving standard of care irrespective of system, socioeconomic, and regional level factors beyond their immediate control, such as where they live. In light of financial pressures and health care reform, studies on the regional variability of health care delivery (such as the Dartmouth Atlas[13]) are becoming increasingly important in the national discourse. Geographic variation in utilization of surgical technique has been shown between robotic, laparoscopic, and open surgery for prostatectomy, radical and partial nephrectomy, and pyeloplasty.[14] Surgical technique choice for each disease process was influenced in a significant manner by factors, including race, zip-code income quartile, hospital type (urban, rural, or teaching), hospital volume, and hospital geographic region. However, concerning renal and ureteral stones, the only previous study comparing URS and SWL in CA assumed homogenous practice patterns across the state,[4] one of the nation's largest and most diverse states. To date, there has been one study examining surgical management of stones in CA on a county level, which did not compare URS to SWL, but instead hypothesized that environmental factors drive differences in per-capita surgical rate irrespective of the particular procedure.[10] While it is certainly possible that precipitation and climate drive operative stone burden, it is prudent to recognize that urologists do not practice in many counties in CA,[15] and that patients will therefore be required to travel to regional hubs for care and sometimes will travel great distances.

Differences in practice patterns surrounding treatment of ureteral and renal stones are not surprising, as geographic regions (be they nations, states, or counties) can be expected to have many differences, including in climate,[10] cultural, socioeconomic, and patient level factors (race, age, and so on) as evident by the AHRF data (Table 1). These factors could possibly play an exaggerated role in more sparsely populated areas where equipment availability (due to the large capital expenditures needed to purchase ureteroscopes or a shockwave lithotripter, and the prompt availability of mobile lithotripsy units) and the influx or loss of a small number of providers facile in URS can shift regional level practice patterns to a large degree. With 63% of counties in the United States having no practicing urologist, and a majority of younger urologists practicing in metropolitan areas,[15] rural or low affluence regions may be less likely to make the large capital investments necessary to adopt newer technologic advances.

One possible interpretation of the results of the present study is that patients who live in regions with characteristics related to lower socioeconomic status may be preferentially treated with SWL or not have access to URS to the same degree as patients in more affluent regions. Those regions with greater affluence may be better able to afford the cost of purchasing and maintaining URS equipment, including all of the associated disposable ancillary devices and equipment, making this procedure more accessible to patients in these areas. Regions which are lower in affluence, however, may rely on lower cost mobile lithotripter units or otherwise provide more care in facilities that are not mandated to report to OSHPD.

Our findings do not imply cause and effect between regional characteristics and procedural selection, and it is likely that these regional characteristics may be proxies for other factors, such as the training and experience of the local urologists and availability of equipment such as shockwave lithotripters. Conversely, these socioeconomic factors may herald a fundamental difference in the local patient population such as medical comorbidity, stone size/location, or

Table 2. Regional and Patient Characteristics for Procedures Performed in Regions Where Shockwave Lithotripsy Was Always Predominant Compared to Those Performed in Regions That Were or Became Ureteroscopy Predominant by 2018

Regions[a]	*Always SWL predominant* n = *5*	*URS predominant by 2016* n = *14*	p *Value*
Regional characteristics			
Population			
≤823,318	3	7	1.00
>823,318	2	7	
Households with female head			
≤4%	0	10	0.01
>4%	5	4	
College education or higher			
≤17%	5	5	0.03
>17%	0	9	
Urban population			
≤90%	4	6	0.30
>90%	1	8	
Per capita income in $			
≤$40,124	5	5	0.03
>$40,124	0	9	
Urologists/100,000 population			
≤2.3	4	6	0.30
>2.3	1	8	
Urology residency programs			
Yes	0	6	0.13
No	5	8	
Urologists <age 45 (%)			
≤18%	4	6	0.30
>18%	1	8	
Urologists <age 55 (%)			
≤31%	4	6	0.30
>31%	1	8	
Number of procedures			
≤8324	3	7	1.00
>8324	2	7	
Patient characteristics			
Male gender			
≤54%	5	5	0.03
>54%	0	9	
Age ≥65			
≤26%	3	7	1.00
>26%	2	7	
White race			
≤68%	3	7	1.00
>68%	2	7	
Private insurance or Medicare			
≤80%	5	5	0.03
>80%	0	9	

Trends are adjusted for age, race, and gender.
[a]California Labor Market Information Division's economic regions and subregions.
SWL = extracorporeal shockwave lithotripsy; URS = ureteroscopy.

tolerance for repeat treatment and surgical complication compared with patients in more affluent regions. Our study did not find a significant association between the median age of the urologists in a region, surgical volume, urbanization, population, or the presence of a urology training program. Given that these factors were not associated with the change from SWL to URS, while socioeconomic factors were associated, it is likely that our findings are able to be extrapolated to other large states as well as to smaller and more geographically confined states as well. Future research is needed using patient level data in CA. National level data are needed to better control for confounding factors and to establish a broader understanding of the trends in the utilization of URS and SWL.

Limitations to the present study include the retrospective collection of aggregated procedure level data and lack of information on clinical factors driving treatment decisions (such as location and size of stones), however, all licensed surgical centers and hospitals in CA must report URS and SWL procedures to the OSHPD. This large database provides

an excellent procedure level view of urologic practice patterns, capturing the vast majority of procedures performed in the state. While the available data do not shed light on specific local urology practice patterns or the experience and training of urologists, employment status, or equipment utilization (lithotripter or ureteroscope) or ownership on an individual level, the study is unique in its regional (as opposed to county level) approach as urologists do not practice in every CA county. The OSHPD data do not track if a SWL procedure was performed with a mobile unit (trailer) or unlicensed facility. However, over 10,000 such procedures would need to be performed annually for the overall trends observed in the present study to change. While the data only describe one state (CA), the size and diversity of CA make the results of this study more generalizable to the United States as a whole.

Conclusions

Based upon the relative proportion of procedures performed for renal and ureteral stones over the past decade, the standard of care seems to be changing in CA toward preferential use of URS. The regions which shifted to URS predominance by 2016 exhibited factors associated with higher social economic status. It is possible that patients in lower socioeconomic status regions may either be preferentially treated with SWL or not have access to URS to the same degree as patients in more affluent regions. A better understanding of such differences in practice patterns will allow urologists to better negotiate for the capital expenditures required to conform to evolving standards of care and allow patients the ability to make more informed decisions on where they receive care.

Acknowledgment

K12 DK83021-09, R21 DK109912.

Author Disclosure Statement

S.V.W., J.B., and A.M.S.: No competing financial interests exist. M.L.S.: Cofounder of Applaud Medical and the Ravine Group, Consultant Boston Scientific and BARD.

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Abbreviations Used

AHRF = Area Health Resource Files
AUA = American Urological Association
CA = California
CPT = Current Procedural Terminology
ICD = International Classification of Diseases
OSHPD = Office of Statewide Health Planning and Development
SWL = extracorporeal shockwave lithotripsy
URS = ureteroscopy