Regional Variation in Shock Wave Lithotripsy Utilization Among Medicare Patients with Nephrolithiasis

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OBJECTIVE To characterize shock wave lithotripsy (SWL) utilization and assess for regional variation in the use of this procedure across the United States.

MATERIALS AND METHODS We examined SWL and URS utilization among Medicare Beneficiaries with a diagnosis of nephrolithiasis for the years 2006, 2009, and 2014. Adjusted utilization rates were calculated per 1000 beneficiaries accounting for age, sex, and race. Utilization rates were examined nationally and by hospital referral region (HRR).

RESULTS A total of 511,495, 604,493, and 806,652 Medicare beneficiaries had a diagnosis of nephrolithiasis in 2006, 2009, and 2014, respectively. The adjusted rate of SWL per 1000 beneficiaries with nephrolithiasis decreased from 59.4/1000 in 2006 to 52.2/1000 and 45.5/1000 in 2009 and 2014 (13.9% decrease, $P < .001$). Variation was observed in SWL utilization; up to a 12-fold difference between HRRs (9.2/1000 in Winchester, VA to 105.8/1000 in Lincoln, NE). The adjusted rate of URS per 1000 beneficiaries increased by 10.2% ($P < .001$) between 2006 and 2014. However, the percent decrease in SWL utilization did not correlate with the percent increase in URS utilization when examined by HRR ($P = .66$).

CONCLUSION Variation exists in the utilization of SWL among Medicare beneficiaries (12-fold difference). This variation is likely secondary to a series of supply, urologist, and patient-specific factors. SWL utilization decreased between 2006 and 2014, while URS increased. Stone procedure type is likely highly dependent on where patients receive their urologic care. UROLOGY 133: 103–108, 2019. © 2019 Elsevier Inc.

Since its introduction in the early 1980's shock wave lithotripsy (SWL) has remained the primary noninvasive approach for the treatment of nephrolithiasis in the United States.[1] The procedure is technically easy to perform and is associated with low morbidity and few complications for patients.[2] However, compared to ureteroscopy (URS), SWL is known to result in lower stone-free rates and a greater likelihood for repeat intervention.[3] Consequently, over the last 15 years, utilization of URS has increased by more than 12%, proposed by some to be at the expense of SWL.[4]

Both SWL and URS are offered as effective treatment modalities for renal and proximal ureteral calculi <2 cm in size.[5] Patients must therefore be educated on the risks and benefits of each procedure type and make an informed-decision regarding how to proceed. With multiple treatment options available, preference-sensitive care can become a factor in patient choice, especially among patients prioritizing minimally invasive techniques. In addition, SWL is highly dependent on lithotripter availability, which has the potential to influence care solely based on supply.[6] Healthcare that is predominantly dictated by patient preference and supply can result in local and regional practice patterns that inappropriately utilize healthcare services.[7] As a result, SWL may be particularly susceptible to misuse, overuse, and under use, potentially resulting in variation in the utilization of this procedure around the country. Such variation would raise concerns for adherence to societal guidelines, delivery of evidence-based care and the quality of care provided to patients with nephrolithiasis.

To date, limited research has been conducted to understand how procedures for nephrolithiasis are utilized across the Unites States' regional variation in the use of SWL is suspected, but has not been thoroughly evaluated.[8] Therefore, the primary purpose of this study was to characterize

Financial Disclosure: *None.*
Conflicts of Interest: *The authors of this manuscript have no financial disclosures or conflicts of interest to report.*

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Submitted: April 22, 2019, accepted (with revisions): July 22, 2019

SWL utilization and assess for regional variation in the use of this procedure across the United States.

MATERIALS & METHODS

Data Sources

We used the Dartmouth Atlas Rate Generator to analyze the 100% Medicare Physician/Supplier and Medicare Denominator files of beneficiaries with full part A or B coverage for the years 2006, 2009, and 2014 (www.dartmouthatlas.org).[9-11] The Dartmouth Atlas Rate Generator is a data processing tool that can be used to examine region specific data and perform comparisons and analysis of the United States health care system using Medicare claims data.[9] The Physician/Supplier file contains all Medicare Part B claims submitted by physicians, including information regarding *Current Procedural Terminology* codes, *International Classification of Diseases, Ninth Revision* diagnosis codes, procedure date, and patient demographics. The Medicare denominator file includes information about beneficiary eligibility by year for Part B as well as beneficiary age, gender, and race. Beneficiaries aged 65 and older were included in the analysis. Claims with missing values for region, gender, age, or race were omitted. The analysis was performed under the data use agreement and institutional approval of the Dartmouth Atlas of Healthcare and in accordance with the Declaration of Helsinki.[12]

Creating a Cohort of Medicare Beneficiaries

Our population of interest was Medicare beneficiaries who underwent SWL for the treatment of nephrolithiasis. Patients with nephrolithiasis were identified using International Classification of Diseases, Ninth Revision code 592, *calculus of the kidney and ureter*. Current Procedural Terminology codes were also used to determine if stone patients underwent SWL, URS, or any other type of procedure (Table 1).

Outcomes

The primary aim of our analysis was to determine the rate of SWL utilization among Medicare beneficiaries with nephrolithiasis for the years 2006, 2009, and 2014 and to assess for regional variation in SWL across the Unites States. Second, we also sought to examine utilization and regional variation in the use of URS as well as any type of procedure for nephrolithiasis. Utilization rates for other stone treatment options, particularly URS, were examined to allow for comparisons between procedure types.

Statistical Analysis

We first calculated the unadjusted rate of SWL for each study year. The numerator consisted of the number beneficiaries undergoing SWL for nephrolithiasis, while the denominator was comprised of all beneficiaries with nephrolithiasis. Adjusted rates were then calculated accounting for beneficiary age, sex, and race similar to comparable analyses.[13] Rate adjustment was performed using an indirect method beginning with determining the national event rate for each age, sex, and race category and then applying these rates to the hospital referral regions (HRR) population to produce the expected number of events by HRR. Additional details regarding the rate adjustment methodology are available from the Dartmouth Atlas for Healthcare Project.[11] All rates were expressed per 1000 Medicare beneficiaries. To examine regional variation, we examined rates of SWL utilization within each of the 306 HRRs in the United States for all study dates. HRRs are distinct tertiary medical care networks that have been repeatedly used to study variation in healthcare utilization.[9] Similar analysis steps were then employed to examine utilization and variation in URS as well as any type of procedure for stone disease as described above. We then used descriptive statistics (t test) to calculate the percent change in SWL, URS, and any type of stone procedure utilization between 2006 and 2014. Finally, to assess whether SWL was being replaced with URS, we examined the association between the percent change in SWL and URS utilization between 2006 and 2014 at the HRR level using Pearson correlation. We also examined the correlation between SWL and URS utilization for the year 2014 only. The P value used for statistical significance for all analyses was <.05. The statistical software STATA 11.2 (StataCorp, College Station, TX) was used for all analyses.

RESULTS

A total of 511,495, 604,493, and 806,652 Medicare beneficiaries had a diagnosis of nephrolithiasis in 2006, 2009, and 2014, respectively (Table 2). The adjusted rate of SWL utilization

Table 1. CPT codes for shock wave lithotripsy, ureteroscopy, and other stone procedure

CPT code	Description
	Shock wave lithotripsy
50590	Lithotripsy, extracorporeal shock wave
	Ureteroscopy
52352	Cystourethroscopy with ureteroscopy and/or pyeloscopy with removal or manipulation of calculus
52353	Cystourethroscopy with ureteroscopy and/or pyeloscopy with lithotripsy
52356	Cystourethroscopy with ureteroscopy and/or pyeloscopy with lithotripsy including insertion of ureteral stent
	Other stone procedures
50080	Percutaneous nephrostolithotomy or pyelostolithotomy, with/without dilation, endoscopy, lithotripsy, stenting of basket extraction; up to 2 cm
50081	Percutaneous nephrostolithotomy or pyelostolithotomy, with/without dilation, endoscopy, lithotripsy, stenting of basket extraction; over 2 cm
50060	Nephrolithotomy with removal of calculus
50065	Nephrolithotomy, secondary surgical operation for calculus
50070	Nephrolithotomy complicated by congenital kidney abnormality
50075	Nephrolithotomy with removal of large staghorn calculus
50130	Pyelotomy with removal of calculus

Abbreviations: CPT; Current Procedural Terminology

Table 2. Utilization of SWL, URS and all stone procedure types per 1000 medicare beneficiaries by year and highest/lowest hospital referral regions

	2006	2009	2014
Medicare beneficiaries with nephrolithiasis (n)	511,495	604,493	806,652
	SWL utilization per 1000 beneficiaries		
No. of beneficiaries	30,392	31,577	36,684
National adjusted rate	59.4	52.2	45.5
Top 3 HRRs	Hattiesburg, MS (126.7)	Flint, MI (121.4)	Lincoln, NE (105.8)
	Flint, MI (115.8)	Muskegon, MI (117.2)	Salinas, CA (104.9)
	Salinas, CA (112.8)	Lincoln, NE (107.5)	Provo, UT (103.9)
Bottom 3 HRRs	Rochester, MN (20.9)	Winchester, VA (16.8)	Winchester, VA (9.2)
	St Paul, MN (21.1)	Greenville, NC (17.7)	Bronx, NY (13.5)
	Jonesboro, RA (21.7)	Bronx, NY (20.8)	Greenville, NC (16.1)
	URS utilization per 1000 beneficiaries		
No. of beneficiaries	8890	11,549	21,967
National adjusted rate	17.4	18.0	27.2
Top 3 HRRs	Portland, OR (44.1)	Omaha, NE (40.8)	Boise, ID (63.1)
	Kansas City, MO (42.7)	Kansas City, MO (40.5)	Portland, OR (59.0)
	Omaha, NE (37.8)	Madison, WI (38.9)	Peoria, IL (58.1)
Bottom 3 HRRs	Toledo, OH (6.4)	Pensacola, FL (6.0)	Hattiesburg, MS (7.9)
	Buffalo, NY (6.8)	Tampa, FL (6.4)	Jackson, MS (9.3)
	Jackson, MS (6.8)	Baton Rouge, LA (7.5)	Columbus, GA (10.5)
	All stone procedures utilization per 1000 beneficiaries		
No. of beneficiaries	38,615	42,465	57,550
National adjusted rate	75.5	70.3	71.3
Top 3 HRRs	Florence, SC (144.2)	Muskegon, MI (132.6)	Lincoln, NE (131.0)
	Green Bay, WI (133.9)	Flint, MI (124.3)	Provo, UT (126.9)
	Hattiesburg, MS (133.7)	Lincoln, NE (124.1)	Pueblo, CO (126.1)
Bottom 3 HRRs	Scranton, PA (35.3)	Greenville, NC (34.5)	Corpus Christi, TX (31.4)
	Miami, FL (41.0)	Corpus Christi, TX (35.6)	Bronx, NY (31.7)
	Jonesboro, AR (41.6)	Meridian, MS (38.4)	Harlingen, TX (37.9)

Abbreviations: HRR, hospital referral region; SWL, shock wave lithotripsy.

per 1000 beneficiaries to treat nephrolithiasis decreased from 59.4/1000 in 2006 to 52.2/1000 and 45.5/1000 in 2009 and 2014. Focusing on 2014 data, variation was observed in SWL utilization across HRRs (Figs. 1 and 2). The HRR with the lowest adjusted SWL utilization rate was Winchester, VA (9.2/1000) and the highest was Lincoln, NE (105.8/1000). This represents a more than 12-fold difference in SWL utilization across the United States.

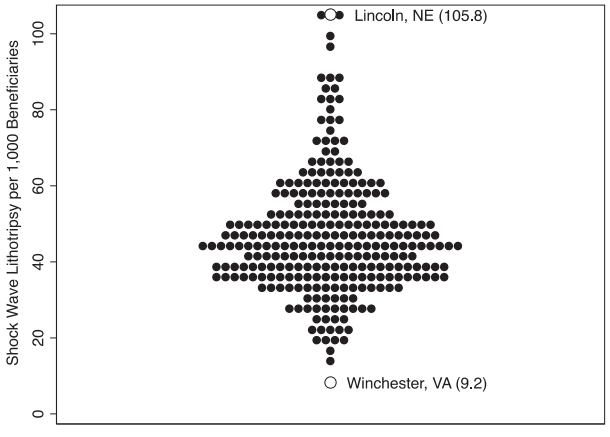

Figure 1. Turnip plot displaying variation in SWL utilization per 1000 Medicare Beneficiaries in 2014. Lincoln, NE has the highest utilization, while Winchester, VA as the lowest.

The adjusted rate of URS utilization per 1000 beneficiaries increased from 17.4/1000 in 2006 to 18/1000 and 27.2/1000 in 2009 and 2014. Variation was observed in URS utilization across HRRs in 2014 (Supplementary Figure 3). The highest rate of utilization was found in Boise, ID (63.1/1000) while Hattiesburg, MS (7.9/1000) was the HRR with the lowest rate; an 8-fold difference in URS utilization. Nationally, utilization of any type of stone procedure was relatively stable over the study period. However, four-fold variation was observed in the use of any type of stone procedure when examining utilization by HRR. When examining trends between 2006 and 2014, the percent change in utilization was −13.9% for SWL ($P < .001$), +10.2% for URS ($P < .001$), and −4.2% for any type of stone procedure ($P = .06$, Supplementary Figure 4). There was no correlation observed between the percent change in SWL and URS utilization by HRR between 2006 and 2014 ($P = .66$). Similarly, there was no correlation observed between SWL and URS utilization by HRR looking solely at the year 2014 ($P = .90$).

DISCUSSION

Wide regional variation has been observed in the use of common surgical procedures in the US procedures with lower variation profiles include hip fracture (1.9-fold) and colorectal (2.5-fold) surgeries, while procedures with higher variation include radical prostatectomy (7.8-fold) and carotid endarterectomy (10.1-fold).[14] In our national

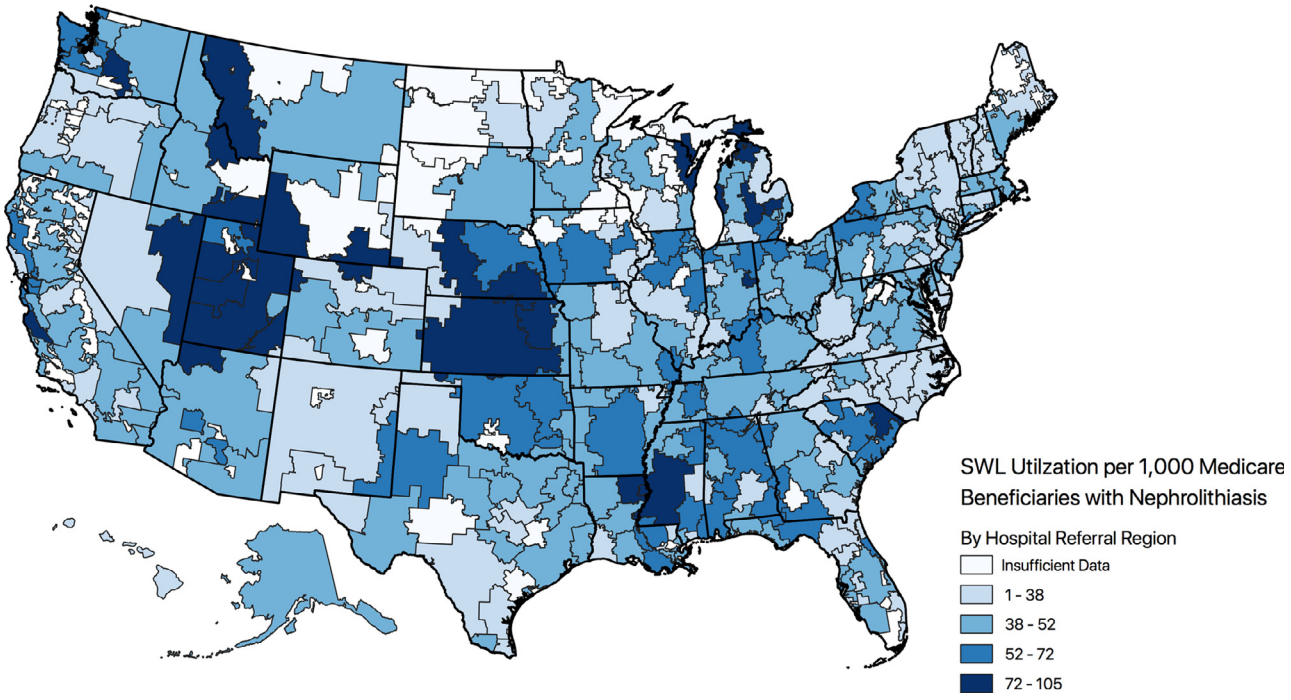

Figure 2. United States shock wave lithotripsy utilization heat map by hospital referral region. (Color version available online.)

study, we found an impressive 12-fold difference in the rate of SWL utilization among Medicare Beneficiaries with nephrolithiasis. Lincoln, NE (105.8/1000) had the highest utilization of SWL, while Winchester, VA had the lowest (9.2/1000). Such marked differences in SWL utilization demonstrate the degree of variation that can be observed for a sub-specialty procedure that is only 1 of many treatment options available for nephrolithiasis.

In the Unites States, variation in SWL utilization has previously been reported on a small scale amongst counties in California for younger adults and between individual hospitals treating pediatrics patients with nephrolithiasis.[8,15] Internationally, SWL utilization has been found to vary approximately 5-fold amongst the states of Australia.[16] Our study of Medicare beneficiaries confirms the findings of these prior investigations and provides a stronger estimate of the degree of variation in SWL utilization for the United States. The primary factors influencing such marked variation in SWL utilization are not well known, but can be hypothesized.

Lithotripter availability, location, and portability as well as urologist presence are logical drivers of SWL utilization. If there is no machine or urologist (ie supply) then SWL cannot be used. If a machine is only available certain days of the month or located geographically further away from another type of stone procedure, then it is less likely to be offered to patients.[6,16] If a machine were available, then healthcare facilities or providers who own or contract with a company who leases out a lithotripter could deliver more SWL to their patient base. However, as evident in Figure 2, there are definite "hot spots" around the United States where SWL is highly utilized. Such drastic differences in SWL utilization between HRRs, raises concern of possible overuse and misuse of SWL in high utilization areas. Oppositely, chronic limited use of SWL in locations such as Winchester, VA (2009 and 2014 lowest area of utilization) may represent underutilization or that disparities in access to comprehensive stone management exist in such regions. As such, the 12-fold variation of SWL utilization observed in the study raises concerns about adherence to societal guidelines, delivery of evidenced-base care, and access to and availability of urologic care for patients with nephrolithiasis across the United States.

In addition to supply, there are urologist characteristics that can drive stone treatment practices. In a 2009 survey of urologists, SWL was found to be associated with community urologists, increased time from completion of residency, and fear of creating stent pain.[17] In addition, urologists who owned a lithotripter were found to be 4 times more likely to select SWL for their patients compared to those without immediate access to and financial ties to a machine (Supplementary Table 3).[17]

Patient preference likely plays an important part in driving SWL utilization. However, it's unclear how such preferences could exacerbate the degree of variation observed in our study. Prior research has found that despite lower stone free rates, SWL is preferred amongst many patients because it is noninvasive, does not require urinary tract instrumentation, and is relatively safe.[18-20] Increased geographic distance to SWL may also decrease utilization secondary to patient unwillingness to travel.[16,21]

Over the study period, we found that the rate of SWL utilization decreased by 13.9% while the use of URS

increased by 10.2% (Supplementary Figure 4). This is a trend observed in similar investigations and has been attributed to the growing role of URS in the treatment of nephrolithiasis, particularly as it relates to obtaining higher stone free rates.[3,4,22] Declining accessibility to lithotripters and possibly a growing patient population with obesity and on anticoagulation may also contribute to this decline, but this has not been studied to date. Interestingly, we did not observe a correlation between the percent change in SWL and URS utilization at the HRR level over the study period. This may suggest that the simple substitution of SWL for URS does not completely explain the general decrease in SWL utilization and increase in URS utilization observed at the HRR level. Although only speculative, greater availability of endourologists may be resulting in more URS at the expense of SWL at academic medical centers, but this trend may not be occurring amongst community urologists. Thus, investigating this relationship between SWL and URS at a more granular level is warranted and would likely be beneficial. In addition, we found an 8-fold difference in the use of URS (Supplementary Figure 3). Although additional research is needed, this degree of variation may reflect unequal uptake and adoption of URS secondary to physician comfort, availability of fellowship trained endourologists, and a growing awareness that URS may be more cost-effective than SWL.[23] Lastly, the rate of use of any type of stone procedure was greater in 2006 (75.5/1000) compared to 2014 (71.3/1000), although not statistically different. This finding may be explained by the rising incidence of stone disease among Medicare beneficiaries that is outpacing availability of urologists to provide treatment.

Our analysis is limited by our use of administrative data. We were unable to account for patient (eg, severity of disease, obesity, and disability), clinical (eg, stone size and location, number of prior procedures), and provider characteristics (eg years in practice, urologist density, and lithotripter availability) that are known to influence treatment choice. We could also not determine who had failed SWL and progressed to URS or who had multiple treatments in any given year. Claims data is also susceptible to inaccuracies in miscoding that can impact results. Lastly, our results may only be applicable to those patients greater than or equal to 65 years of age with Medicare insurance. However, prior work would suggest that similar patterns may be observed in other stone disease populations.

CONCLUSIONS

In conclusion, more than 12-fold variation exists in the use of SWL across the United States. This variation is likely secondary to a series of supply, urologist, and patient-specific factors. SWL utilization decreased between 2006 and 2014, while URS increased. Variation was also observed in URS utilization. Stone procedure type is highly dependent on where patients receive their urologic care. Future research should be conducted to better understand and intervene upon factors responsible for such impressive variation in stone procedure utilization and ensure the care is being delivered in alignment with AUA guidelines.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2019.07.024.

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