Variation and Correlation in Postoperative Imaging After Shockwave Lithotripsy and Ureteroscopy by Treatment Modality: Results of a Statewide Clinical Registry

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OBJECTIVE To understand how patient, practice/urologist-level factors impact imaging after ureteroscopy (URS) and shockwave lithotripsy (SWL).

METHODS Using the Reducing Operative Complications from Kidney Stones (ROCKS) clinical registry from the Michigan Urological Surgery Improvement Collaborative (MUSIC), we identified patients undergoing URS and SWL between 2016-2019. Frequency and modality of 60-day postoperative imaging was assessed. We made bivariate comparisons across demographic/clinical data and assessed provider/practice-level imaging rate variation. We assessed correlation between imaging use within practices by treatment modality. Multivariable logistic regression controlling for practice/urologist variation was used to adjust for group differences.

RESULTS 14,894 cases were identified (9621 URS, 5273 SWL) from 33 practices and 205 urologists. Overall postoperative imaging rate was 49.1% and was significantly different following URS and SWL (36.3% vs 72.4%, $P<0.01$). Substantial practice variation was seen in rates following URS (range 0-93.1%) and SWL (range 36-95.2%). Odds of postoperative imaging by practice varied significantly (range 0.02-1.96). Moderate postoperative imaging correlation for URS and SWL (0.7, $P<0.001$) was seen. No practice had significantly higher odds of post-URS imaging. There was increased odds of postoperative imaging for SWL modality, larger stones and renal stones.

CONCLUSION Imaging rates after URS are almost half the rate for SWL with wide variation, underscoring uncertainty with how postoperative imaging is approached. However, practices who have higher post-URS imaging rates also image highly after SWL. Increased patient complexity and renal stone location drive imaging following URS. UROLOGY 168: 79−85, 2022.

Postoperative imaging assessment after ureteroscopy (URS) and shockwave lithotripsy (SWL) is important to determine treatment efficacy and diagnose potential asymptomatic postoperative complications.[1] Despite this, there remains disagreement from professional societies regarding an optimal approach to postoperative imaging. The European Association Urology (EAU) urolithiasis guidelines recommend imaging after all stone procedures, including URS and SWL, at approximately 4 weeks postoperatively.[2] In contrast, the American Urological Association (AUA) surgical stone management guidelines do not provide guidance on post-URS or post-SWL imaging.[3] AUA guidance is currently provided by a clinical effectiveness protocol directed at ureteral stone management, which provides no guidance for renal stones.[1]

Perhaps due to this lack of consensus, prior studies have shown low rates of imaging after URS and higher rates following SWL.[4,5] National claims data demonstrate approximately 55% and 20% of patients fail to receive postoperative imaging within 3 months after URS and SWL, respectively.[4] Further, there is significant variation

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in post-URS imaging within 60-days of surgery.[5] Few would argue that such imaging rates are acceptable given our growing knowledge about prevailing stone-free rates (SFR) after URS and SWL.[3,6] Yet, tangible quality improvement on this front is challenging due to the heterogeneity of postoperative imaging timing and techniques, and because the aforementioned studies lack clinical rationale for the observed differences in imaging rates.

We thus used data from the Michigan Urological Surgery Improvement Collaborative's (MUSIC) Reducing Operative Complications from Kidney Stones (ROCKS) registry to understand differences in the use of postoperative imaging after both URS and SWL. We hypothesized that patient and clinical factors may impact imaging use. Moreover, understanding that practice characteristics such as facilities, processes, size, location, may contribute to the choice and feasibility of obtaining imaging after stone treatment, we hypothesized that practices and urologists with higher postoperative imaging rates (those that image routinely after SWL) would likely perform postoperative imaging at similar rates following URS and vice versa. It is our hope that the findings presented herein will support efforts to optimize postoperative care after stone surgery and provide real-world data to inform future guideline recommendations.

METHODS

Data Source

MUSIC was established in 2011 in partnership with Blue Cross Blue Shield of Michigan. The ROCKS initiative was started in 2016 and currently comprises 36 community and academic urology practices in the state. ROCKS maintains a clinical registry of all URS, both rigid and flexible ureteroscopies, and SWL procedures for the treatment of nephrolithiasis performed by these practices and urologists in hospitals and ambulatory surgery centers, regardless of insurance type or status. Trained abstractors prospectively and independently record standardized data elements including patient, stone, procedural and postoperative care up to 60-days after the procedure in a web-based registry by chart review, as described previously.[7,8] Stone size is determined by the maximum diameter of the treated stone(s) based on preoperative imaging. Intraoperative complications, unplanned healthcare encounters within 30-days and imaging results within 60-days of the procedure are recorded. Each MUSIC practice has obtained an exemption or approval by the local institutional review board for participation in the collaborative.

Study Population

All URS and SWL cases performed on patients ≥ 18 years of age by participating practices between June 2016 and December 2019 were identified. Patients who have an ipsilateral nephrostomy tube, undergo URS as a second-stage procedure, had synchronous bilateral procedures, or have concomitant non-stone related surgery are excluded from the ROCKS registry.

Outcomes and Statistical Analysis

The primary outcome of this study was the frequency of postoperative imaging, defined as receipt of any imaging modality in the 60-days following URS or SWL. The frequency and modality, including abdominal X-Ray (KUB), ultrasound, computed tomography (CT), or any combination, of postoperative imaging was assessed and compared between surgery type with a chi-square test.

Demographic, clinical, and operative data were compared between groups using bivariate analyses to understand factors associated with postoperative imaging by treatment modality. Bivariate comparisons were made between those who did and did not have imaging across a range of sociodemographic, clinical, and perioperative factors. Continuous factors were tested with a t-test or rank test and categorical factors with a chi-square. Comparisons of the factor associations with imaging between surgery types were conducted using the joint test for the interaction of the factor with surgery type from a logistic model or the Breslow-Day test for categorical factors.

Variation in imaging was evaluated at the practice and provider level. For reliability purposes, we only included those practices who performed >10 URS and SWL and those providers who performed >5 URS and SWL. To understand how urology practice infrastructure may impact the choice to image a patient, the correlation was examined between URS and SWL imaging use within each practice with the Pearson correlation coefficient.

We performed multivariable logistic regression to understand factors associated with post-operative imaging. Independent variables in the model included surgery type (URS or SWL), practice, the interaction of surgery type and practice, age, gender, body mass index, comorbidity (Charlson comorbidity index),[9] insurance status, stone size, stone location, presented status, urinalysis/culture result, intraoperative stent placement and ED visit within 30 days.

We performed 2-sided significance testing and set a type-I error rate at 0.05. All the statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

We identified 14,894 cases (9621 URS and 5273 SWL) performed across 33 urology practices by 205 urologists. The postoperative imaging rate was 36.3% after URS and 72.4% after SWL (P<0.001). This led to an overall imaging rate of 49.1%. Imaging modalities differed between treatment type. The most common imaging modalities for patients following URS were ultrasound (35.5%), KUB (34.7%), CT (13.7%), and KUB plus ultrasound (9.6%), while after SWL it was KUB (63.9%), KUB plus ultrasound (17.2%), and ultrasound (11.1%).

Bivariate analysis comparing patients who did and did not receive postoperative imaging are demonstrated in Table 1. Factors associated with postoperative imaging for both URS and SWL included: older age, higher comorbidity, larger stone size, renal stone location, non-prestented patients, intraoperative stent omission, and postoperative emergency department (ED) visit within 30 days of their procedure. Additional associated factors for post-URS imaging included intraoperative stent placement. Interaction testing revealed significant differing effect on postoperative imaging by treatment modality due to patient age, and postoperative ED visit.

Substantial variation in postoperative imaging rates for both treatment modalities was identified. Figure 1a demonstrates practice variation in postoperative imaging following URS (range 0-93.1%) and SWL (range 36-95.2%). Urologist variation in postoperative imaging following URS (range 0-100%) and SWL (range 23.1-100%) is represented in Figure 1b. Moderate

Table 1. Patient characteristics associated with receipt of postoperative imaging following stone treatment in MUSIC ROCKS

	URS			SWL			
	Postoperative Imaging			Postoperative Imaging			
	Yes	No	p	Yes	No	p	IT P
Cases	3494	6127		3819	1454		
Age, median (IQR)	58 (46-68)	57 (44-67)	*<0.001*	59 (48-67)	55 (43-64)	*<0.001*	*<0.001*
Largest stone size (mm), median (IQR)	7 (5-9.8)	6 (5-9)	*<0.001*	8 (6-10)	7 (6-10)	*<0.001*	0.82
Gender			*<0.001*			0.69	0.083
Male	1624 (34.5%)	3084 (65.5%)		2057 (72.2%)	792 (27.8%)		
Female	1870 (38.1%)	3043 (61.9%)		1762 (72.7%)	662 (27.3%)		
BMI			0.049			0.77	0.66
<25	670 (37.8%)	1103 (62.2%)		725 (73%)	268 (27%)		
>25-30	992 (35.9%)	1775 (64.1%)		1190 (73.6%)	426 (26.4%)		
>30-35	818 (38.8%)	1289 (61.2%)		895 (75.1%)	296 (24.9%)		
>35-40	477 (40.4%)	704 (59.6%)		464 (74.7%)	157 (25.3%)		
>40	387 (39.2%)	600 (60.8%)		267 (73%)	99 (27%)		
CCI			*<0.001*			*<0.001*	0.13
0	2404 (35%)	4465 (65%)		2848 (70.8%)	1174 (29.2%)		
1	605 (39.6%)	923 (60.4%)		614 (76.7%)	187 (23.3%)		
>2	485 (39.7%)	736 (60.3%)		357 (79.3%)	93 (20.7%)		
Insurance type			*<0.001*			*0.004*	0.32
None	49 (22.4%)	170 (77.6%)		51 (67.1%)	25 (32.9%)		
Private	1974 (34.5%)	3747 (65.5%)		2352 (70.9%)	963 (29.1%)		
Public	1452 (40.1%)	2171 (59.9%)		1385 (75.1%)	460 (24.9%)		
Stone Size			*<0.001*			*<0.001*	0.21
<5 mm	1028 (33.8%)	2011 (66.2%)		652 (67.5%)	314 (32.5%)		
>5-10 mm	1712 (36.4%)	2993 (63.6%)		2266 (73.3%)	825 (26.7%)		
>10-15mm	452 (42.3%)	617 (57.7%)		615 (74.7%)	208 (25.3%)		
>15mm	170 (43.8%)	218 (56.2%)		181 (78.3%)	50 (21.7%)		
Stone location			*<0.001*			0.42	0.022
Renal	876 (41.9%)	1216 (58.1%)		2500 (72.8%)	933 (27.2%)		
Ureter	1833 (33.5%)	3639 (66.5%)		720 (70.9%)	296 (29.1%)		
Both	659 (39.2%)	1023 (60.8%)		296 (73.4%)	107 (26.6%)		
UA/UCx			*<0.001*			*<0.001*	0.83
Pos	448 (42.3%)	610 (57.7%)		174 (78.7%)	47 (21.3%)		
Neg	2463 (37.2%)	4158 (62.8%)		2814 (74.2%)	980 (25.8%)		
Not performed	551 (29.2%)	1336 (70.8%)		797 (65.5%)	419 (34.5%)		
Pre-op Hydronephrosis			*<0.001*			*<0.001*	0.22
No	975 (42.8%)	1301 (57.2%)		2335 (74.2%)	810 (25.8%)		
Yes	2271 (34.2%)	4361 (65.8%)		939 (69%)	421 (31%)		
Stent prior to surgery			0.37			0.15	0.09
No	2067 (36.7%)	3572 (63.3%)		3245 (72.2%)	1251 (27.8%)		
Yes	1414 (35.8%)	2541 (64.2%)		566 (74.7%)	192 (25.3%)		
Intraoperative stenting			*<0.001*			0.052	0.82
No	759 (29.9%)	1779 (70.1%)		3653 (72.2%)	1403 (27.8%)		
Yes	2731 (38.6%)	4338 (61.4%)		151 (78.7%)	41 (21.3%)		
Intraoperative complication			0.15			0.26	0.13
No	3439 (36.3%)	6046 (63.7%)		3808 (72.5%)	1446 (27.5%)		
Yes	50 (42.7%)	67 (57.3%)		5 (55.6%)	4 (44.4%)		
ED visit (30 days)			*<0.001*			*<0.001*	*<0.001*
No	2919 (32.9%)	5962 (67.1%)		3661 (72%)	1427 (28%)		
Yes	536 (80.6%)	129 (19.4%)		138 (89%)	17 (11%)		

BMI, body mass index; CCI, Charlson comorbidity index; ED, emergency department; IQR, interquartile range; IT, interaction test. SWL, shockwave lithotripsy; UA, urinalysis; UCx, urine culture; URS, ureteroscopy;

correlation of practice imaging rate by treatment modality was observed (r = 0.70, p = 0.0002) (Fig. 2). In other words, practices that imaged at higher rates after URS predicted similarly high rates for SWL, and vice versa.

Adjusting for practice and urologist variation revealed receipt of SWL therapy, female gender, increasing age, public insurance, increasing stone size, renal stone location, positive preoperative urinalysis/culture result and intraoperative stent placement increase the odds of postoperative imaging. Adjusting for gender, age, BMI, comorbidity, insurance status, stone size, stone location, prestented status, urinalysis/culture result and intraoperative stent placement, the odds of postoperative imaging after URS compared to SWL were significantly different by practice with the odds by practice ranging from 0.02 to 1.96 (P<0.001)

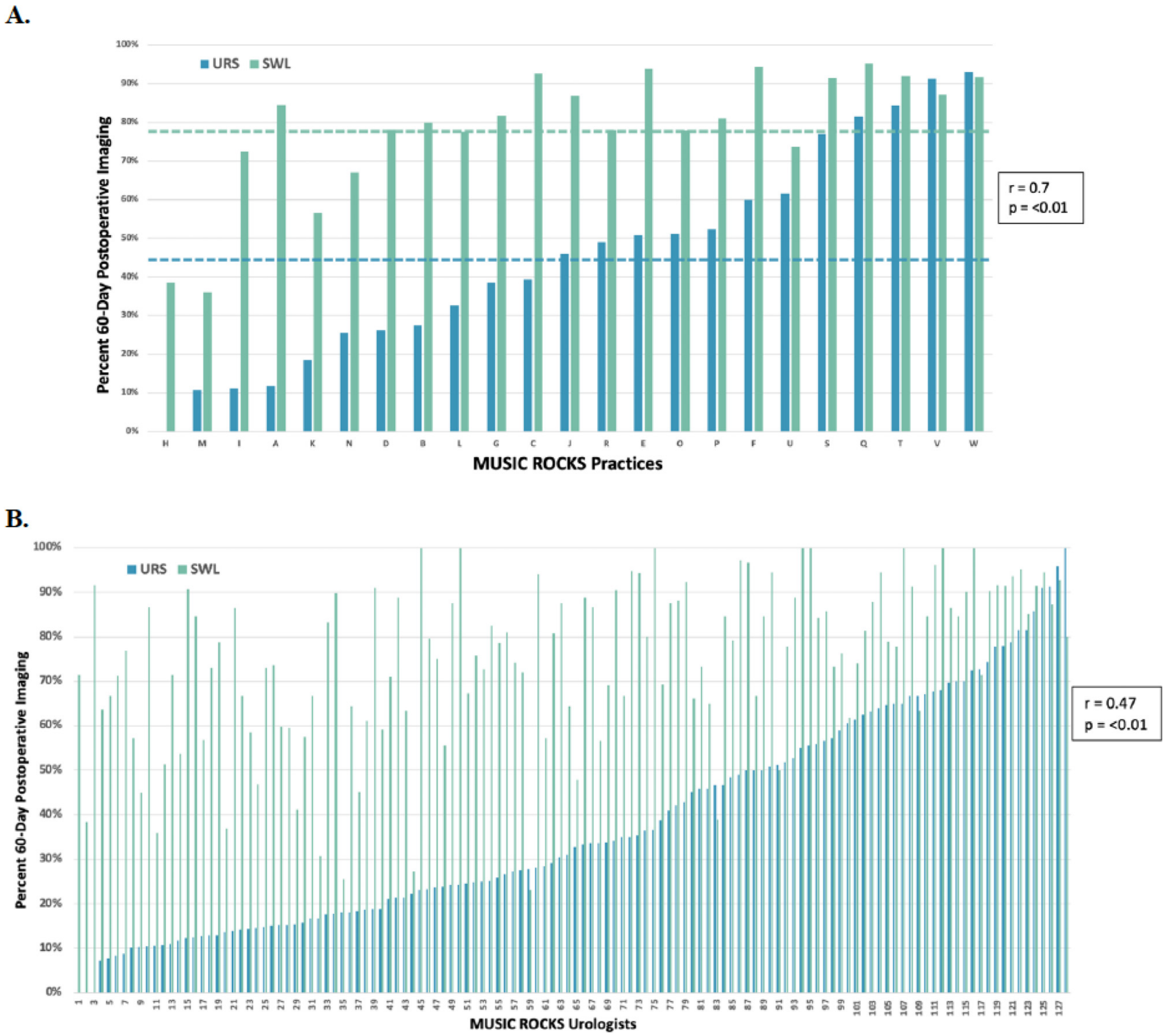

Figure 1. A) Variation in 60-day post-operative imaging rates for URS and SWL cases by practice in MUSIC ROCKS with ≥10 URS and ≥10 SWL cases (dashed lines indicating mean imaging rate). B) Variation in 60-day post-operative imaging rates for URS and SWL cases by urologist in MUSIC ROCKS with ≥5 URS and ≥5 SWL cases.
URS — ureteroscopy; SWL — shockwave lithotripsy; r — Pearson correlation coefficient. (Color version available online.)

(Fig. 3). After adjustment, 18 practices (54.5%) had significantly lower odds of imaging post-URS than post-SWL. No practice had significantly higher odds of post-URS imaging.

DISCUSSION

We examined postoperative imaging patterns after URS and SWL in the state of Michigan. We assessed predictors of imaging receipt as well as how practice and urologist influence the choice to pursue postoperative imaging. Our work has several principal findings. First, in evaluating our entire cohort, less than 50% of patients undergo imaging following URS/SWL. When examined by treatment type, rates of postoperative SWL imaging far outpace postoperative URS imaging. Secondly, substantial variation in imaging use exists at both a practice and urologist level. Additionally, moderate correlation was seen at a practice-level with regard to imaging, such that practices that image well tend to do the same across surgery type, however, no practice, even adjusting for case factors, has a higher odds of post-URS imaging relative to post-SWL imaging. Lastly, renal stone location cases are more likely to undergo postoperative imaging even after adjusting for practice and urologist variability.

Our findings that imaging is performed following URS and SWL in 36% and 72% of patients respectively, are consistent with previously published studies. Ahn and colleagues reported that approximately 45% and 80%% of patients receive post-URS and post-SWL imaging within 3 months.[4] Insurance claims data found a similar pattern when examining postoperative imaging after URS and SWL in the pediatric population.[10] Potential reasons for the low observed rates of postoperative imaging are multifactorial and may include confidence in surgical success,

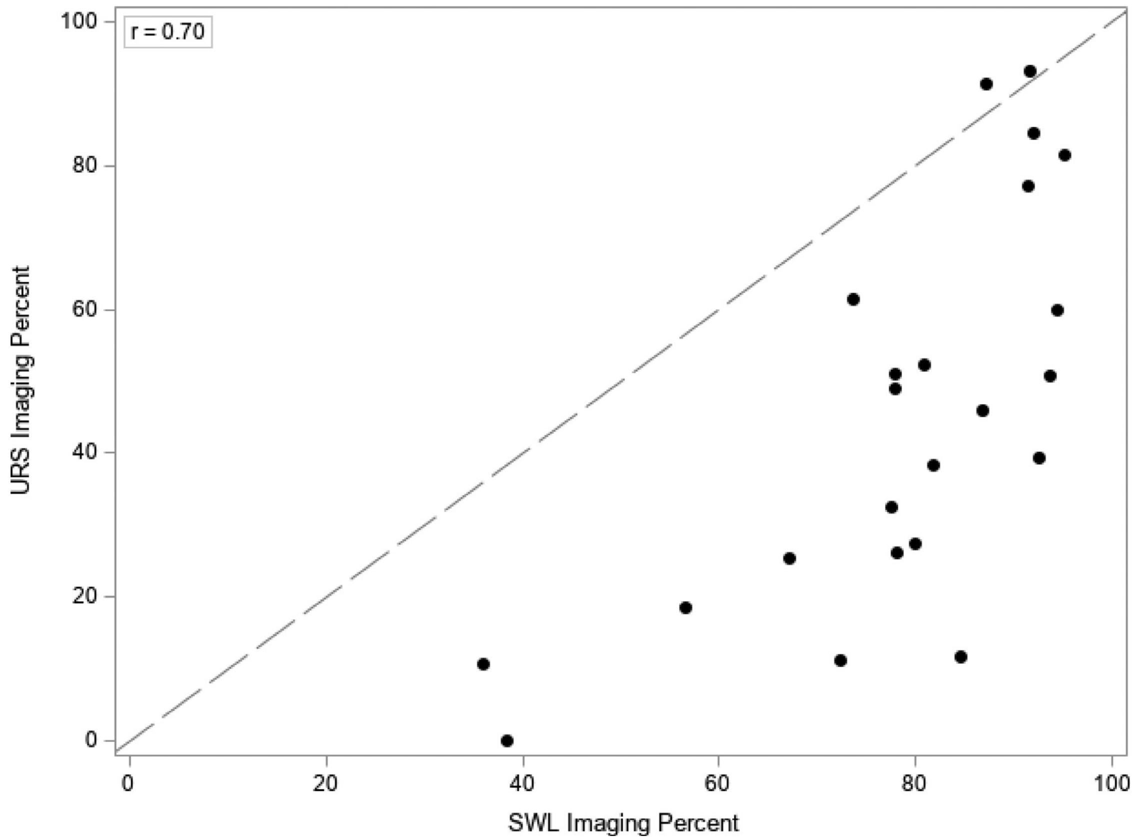

Figure 2. Rates of 60-day post-operative imaging after URS versus SWL by practices with ≥5 URS and ≥5 SWL procedures
URS — ureteroscopy; SWL — shockwave lithotripsy; r — Pearson correlation coefficient

low rates of complications, cost, patient compliance and a lack of strong guidelines. The striking difference in rates of post-URS imaging versus post-SWL imaging is less understood but may be due to perceived surgical efficacy. While SFRs following URS have been repeatedly shown to be superior to those following SWL,[3] more recent studies using strict imaging criteria dispel the notion that URS is uniformly successful.[11] Indeed, prior data from the MUSIC ROCKS registry shows a relatively modest SFR difference between URS and SWL when treating renal stones.[8] Taken together, these data suggest that the choice to image a URS patient less frequently than a similar SWL patient based on perceived efficacy alone may be misguided.

We identified substantial practice and urologist variation in postoperative imaging following URS and SWL. There was significantly decreased odds of imaging post-URS compared to post-SWL by practice, even on multivariable analysis. Given varied patient populations, potential infrastructure required for routine postoperative imaging, the lack of professional consensus and the absence of guidance for treated renal stones, we suspected that practices and urologists would be either high or low imaging utilizers in general. Moderate correlation between practice level postoperative imaging rates were observed between higher utilizers. Interestingly, practices with high rates of post-URS imaging also had high post-SWL rates, while high post-SWL rates were not predictive of post-URS imaging rates. Further evaluation of practice level correlation with imaging may prove useful to identify high performing practices to understand what makes them successful.

Our results did indicate that more complicated (older, larger stone, positive urinalysis/culture, stented patients) and renal stone location cases are significantly more likely to receive postoperative imaging. These remained significant even after adjusting for practice and urologist variability. These findings underscore the importance of unified imaging guidance from professional societies as we found that renal stone location is predictive of higher imaging rates. Interestingly, intraoperative complications were not significantly associated with post-URS imaging. Prior work has advocated for selective postoperative imaging in leu of routine practice for complicated URS as this strategy would identify the patients with asymptomatic pathology.[12] Our results indicate that even selective postoperative imaging, in the absence of strong guidance, may be difficult to obtain in diverse clinical practice.

Our registry includes a variety of practices which enables better representation of real-world practice patterns. Nevertheless, there are several limitations. It may be argued that analyzing the performance of imaging in a 60-day postoperative window is too limiting and may underestimate its true rate. Although, these rates are consistent with national data allowing for 3 months of follow up time, moreover, for this specific group of practices within MUSIC ROCKS, unpublished collaborative survey data suggests that the majority of urologists perform postoperative imaging within

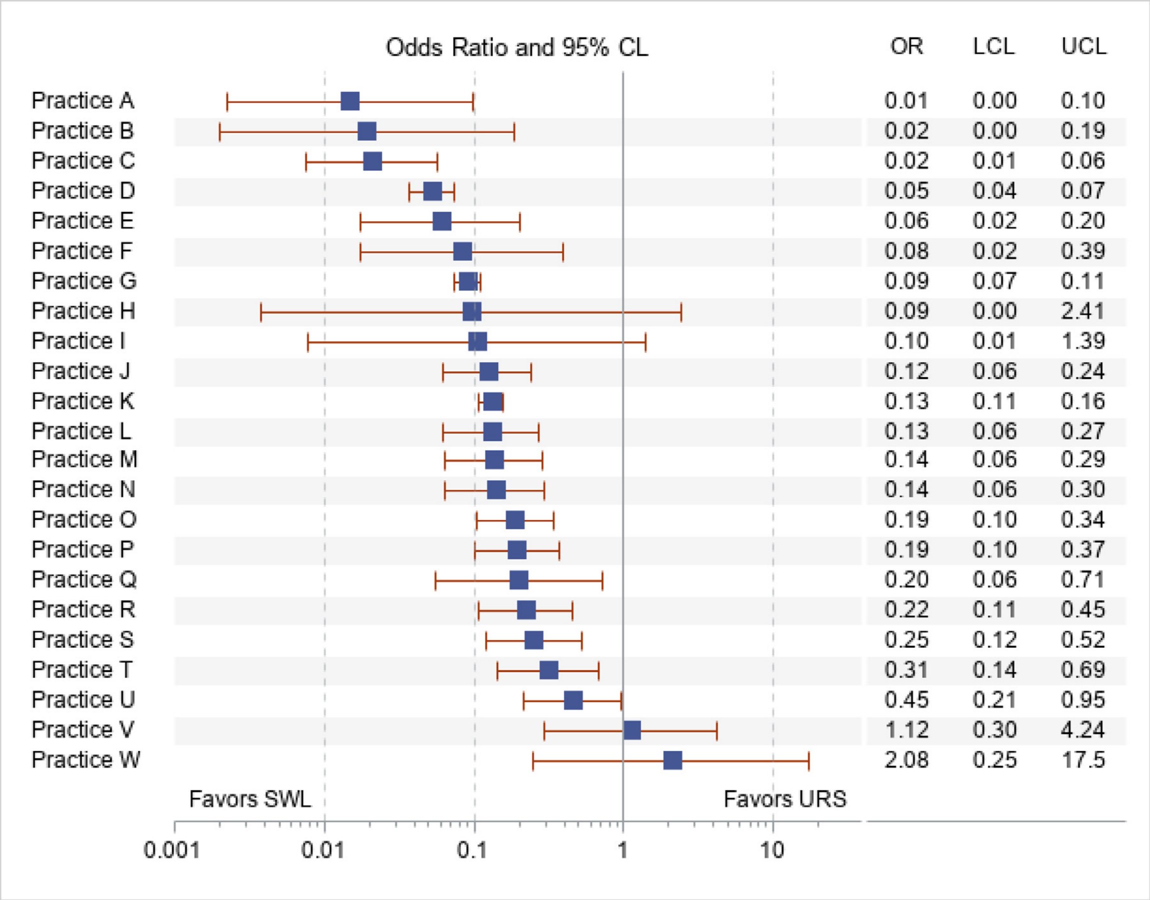

Figure 3. Variation in odds of 60-day post-operative imaging after URS versus SWL by practices with ≥5 URS and ≥5 SWL procedures, adjusting for age, gender, BMI, CCI, insurance status, stone size, stone location, presented status, UA/UCx result, intraoperative stent placement and ED visit within 30 days.

SWL – shockwave lithotripsy; URS – ureteroscopy; BMI – body mass index; CCI – Charlson comorbidity index; UA – urinalysis; UCx – urine culture; OR – Odds Ratio; CL – Confidence Limit; LCL – 95% Lower Confidence Limit; UCL – 95% Upper Confidence Limit. (Color version available online.)

this period. In contrast, potentially augmenting the amount of postoperative imaging performed, are those studies obtained secondary to symptoms, emergency evaluations or hospital admission. Additionally, the design does not allow for distinction between, routine versus selective postoperative imaging, that may occur in an unplanned setting. Importantly, we do not distinguish between imaging ordered versus imaging obtained. Nor do we capture imaging done by the urologist in clinic without official radiological interpretation. Therefore, we cannot differentiate between physician or patient factors for a lack of imaging especially in the setting where a patient has had the stone successfully treated and is subsequently lost to follow up or the urologist performs a bedside clinic US of the renal unit.

Limitations notwithstanding, our work has several implications. We corroborate prior work demonstrating low overall rates of postoperative imaging with decreased odds after URS compared to SWL. Further study may provide insight into justification for this omission or yield an opportunity to further inform guideline recommendations. As a quality improvement initiative, the goal of ROCKS is not simply to observe and report, but to improve care. To this end, ROCKS has developed and made freely available the "*Imaging After Kidney Stone Surgery*" education pamphlet to inform patients of the importance of postoperative imaging (https://musicurology.com/wp-content/uploads/2020/11/PT-Resource-Post-Op-Imaging-V12.pdf). We have also recently made imaging after URS a statewide quality improvement priority which is tied to a payor-based incentive. Findings from this study, in particular, that high performing practices tend to image well for both URS and SWL, confirms that targeting the urology practice with focused outreach may be sufficient to increase statewide imaging.

CONCLUSION

Less than 50% of patients receive imaging after URS or SWL in Michigan with wide variation in imaging use at a provider and practice level. There is correlation between practices that image at a high rate for URS and SWL which suggests that targeted interventions at the practice level may improve statewide imaging rates. Increased patient complexity and renal stone location seem to drive imaging following URS despite the absence of guidelines for these patients. Results from this study show tremendous heterogeneity in imaging practices after stone surgery highlighting the need for clinical guidelines on this topic.

CONFLICT OF INTEREST

None.

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