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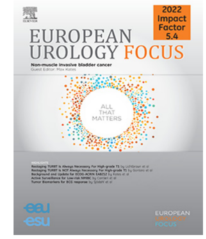

Stone Disease

Real-world Practice Stone-free Rates After Ureteroscopy: Variation and Outcomes in a Surgical Collaborative

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Article info

Article history:
Accepted March 16, 2023
Available online 6 April 2023
Associate Editor: Christian Gratzke

Keywords:
Urolithiasis
Outcomes
Quality improvement
Lithotripsy
Ureteroscopy

Abstract

Background: Studies assessing the stone-free rate (SFR) after ureteroscopy are limited to expert centers with varied definitions of stone free. Real-world data including community practices related to surgeon characteristics and outcomes are lacking.

Objective: To evaluate the SFR for ureteroscopy and its predictors across diverse surgeons in Michigan.

Design, setting, and participants: We assessed the Michigan Urological Surgery Improvement Collaborative (MUSIC) clinical registry for patients with renal or ureteral stones treated with ureteroscopy between 2016 and 2021 who had postoperative imaging.

Outcome measurements and statistical analysis: Stone free was defined as no fragments on imaging reports within 60 d entered by independent data abstractors. Factors associated with being stone free were examined using logistic regression, including annual surgeon volume. We then assessed variation in surgeon-level SFRs adjusted for risk factors.

Results and limitations: We identified 6487 ureteroscopies from 164 surgeons who treated 2091 (32.2%) renal and 4396 (67.8%) ureteral stones. The overall SFRs were 49.6% (renal) and 72.7% (ureteral). Increasing stone size, lower pole, proximal ureteral location, and multiplicity were associated with not being stone free. Female gender, positive urine culture, use of ureteral access sheath, and postoperative stenting were associated with residual fragments when treating ureteral stones. Adjusted surgeon-level SFRs varied for renal (26.1–72.4%; $p < 0.001$) and ureteral stones (52.2–90.2%; $p < 0.001$). Surgeon volume was not a predictor of being stone free for renal stones. Limitations include the lack of imaging in all patients and use of different imaging modalities.

Conclusions: The real-world complete SFR after ureteroscopy is suboptimal with substantial surgeon-level variation. Interventions focused on surgical technique refinement are needed to improve outcomes for patients undergoing ureteroscopy and stone intervention.

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https://doi.org/10.1016/j.euf.2023.03.010

Patient summary: Results from a diverse group of community practicing and academic center urologists show that for a large number of patients, it is not possible to be completely stone free after ureteroscopy. There is substantial variation in surgeon outcomes. Quality improvement efforts are needed to address this.

1. Introduction

Ureteroscopy is increasingly used worldwide as the primary treatment option for upper tract urinary stones [1–3]. One of the primary objectives of stone treatment is to obtain complete stone clearance. This is important because residual fragments may act as a source of stone recurrence and reintervention [4–8]. Early reports on the stone-free rate (SFR) after ureteroscopy demonstrated outcomes surpassing 90% [9,10], thus paving the way for its increasing utilization to treat renal stones over shockwave lithotripsy [11]. However, recent studies [12,13] and expert opinion [14] have suggested that the SFR after ureteroscopy may not be as high as reported previously.

A limitation with prior studies is the inconsistent definition of stone free, with investigators using varied residual fragment threshold definitions [5,13]. Most studies are based on a retrospective review using self-reported data without independent data abstraction [15,16]. Some even report the SFR based on surgeons' interpretation without imaging follow-up [9]. Another limitation is that virtually all SFR outcomes are from endourology specialist and select expert centers [10,15,16]. Since ureteroscopy is now one of the most common procedures in urology, we are concerned that published SFR outcomes may not reflect real-world practice. In particular, the impact of stone factors or surgeon characteristics on SFRs in community practice is not well understood.

For these reasons, we examined the SFR following ureteroscopy among diverse practices and surgeons in Michigan. We used a definition of complete stone free and assessed the data from the Michigan Urological Surgery Improvement Collaborative (MUSIC) clinical registry. This dataset is entered by independent abstractors at each practice and, unlike other registries, is not surgeon self-reported. We hypothesized that outcomes in community practice may not reflect published literature. The exploratory hypothesis was to assess factors associated with being stone free and the impact of the individual surgeon on the SFR. We explored surgeon-level variation in adjusted SFRs. The goal of this quality improvement (QI) study is to provide information for patient counseling and identify factors that can improve outcomes.

2. Patients and methods

2.1. Data source

MUSIC was established in 2011 in partnership with Blue Cross Blue Shield of Michigan. It consists of a diverse group of academic and private practice groups across the state of Michigan. More than 90% of practicing urologists in the state participate in MUSIC. The Reducing Operative Complications from Kidney Stones (ROCKS) initiative, started in 2016, comprises 29 community and academic urology practices in Michigan. ROCKS maintains a registry of unilateral ureteroscopy cases performed by each practice in hospitals or ambulatory surgery centers regardless of insurance type or status. By collecting data, the goal of ROCKS is to improve the overall quality of care for patients undergoing ureteroscopy for urinary stones. Trained abstractors prospectively record standardized data elements in a web-based registry by chart review. Patient data are entered into the registry 60 d after a ureteroscopy procedure, and data entry is guided by standard variable definitions and operating procedures. To ensure data quality, the coordinating center performs onsite data audits semiannually. The data collection strategy has been described previously [17–19]. Stone size is determined by the diameter of the largest treated stone on preoperative imaging. Each MUSIC practice has obtained an exemption or approval from the local institutional review board for participation in the collaborative.

2.2. Study population

All patients $\geq$18 yr old undergoing a primary ureteroscopy for urinary stones in the MUSIC ROCKS registry between June 2016 and October 2021 were included in this analysis. We excluded unilateral procedures where ureter and kidney stones were treated simultaneously in a single session. In addition, patients with missing stone-free or stone location data were omitted. Only patients with postoperative imaging taken within 60 d after ureteroscopy were included. Cases were stratified based on the location of the stone: (1) renal and (2) ureteral.

2.3. Outcome measures

The primary outcome of interest was to assess the surgeon-level SFR after ureteroscopy. We also assessed the predictors for being stone free for renal and ureter stones separately. Stone free was defined as no fragment reported on imaging within 60 d, confirmed by any modality (abdominal x-ray, renal ultrasound (US), or computed tomography [CT]). For stone location, renal stones were categorized as lower pole versus nonlower pole, while ureteral stones were grouped as proximal (upper and midureter) versus distal. To assess the surgeon volume effect on the SFR, the annual volume of ureteroscopy per surgeon was obtained and categorized according to quartiles based on the frequency of procedures per surgeon among the total surgeons performing ureteroscopy in MUSIC.

2.4. Statistical analysis

Clinical and demographic characteristics were reported for all eligible MUSIC ROCKS patients stratified by the location of the stone (kidney or ureter). For reliability purposes, urologists with five or more ureteroscopy cases in the registry were included in the surgeon-specific variation analysis and displayed on a bubble chart to incorporate surgical case volume. Demographics between renal and ureteral stones were compared using Wilcoxon rank-sum tests for continuous measures and χ^2 tests for categorical measures (Supplementary Table 1). Factors associated with the SFR were examined using multivariable logistic regression separately for renal and ureter stones. Fixed effects in the model included patient age, gender, insurance status, body mass index, Charlson comorbidity index, stone size (mm), preoperative urine culture result, use of an alpha-blocker, use of antiplatelet medication, stone location, stone multiplicity, intraoperative use of ureteral access sheath (UAS), preoperative stent, postoperative use of stenting, and annual surgeon ureteroscopy volume. Predicted probabilities from the model were reported for adjusted surgeon-level SFRs. All statistical tests were two tailed, performed using Statistical Analysis System software, version 9.4 (SAS Institute Inc., Cary, NC, USA), and $p < 0.05$ was considered statistically significant.

3. Results

Of 16 765 ureteroscopy cases that met the inclusion criteria, we identified 6487 that underwent postoperative imaging from 29 urology practices and 164 surgeons. Of these, 2091 (32.2%) were renal and 4396 (67.8%) ureter stones. Table 1 compares demographic, preoperative, and stone factors between renal and ureteral stone groups. Procedures for renal stones had larger and more often multiple stones. The prestented rate was higher in the ureteral stone group (40.2% vs 27.3%, $p < 0.001$). In the renal stone group, UAS insertion (58.6% vs 34.9%, $p < 0.001$) and postureteroscopy stenting (81.0% vs 77.3%, $p < 0.001$) were performed more frequently. There were no significant differences in the annual surgeon volume thresholds or intraoperative complication rates between the two groups. For postoperative imaging, US (50.6%) was the most frequently used modality in the ureteral stone group. However, in the renal stone group, x-ray (41.3%) was used most frequently. CT was used in 19.4% and 15.7% of renal and ureteral stones cases, respectively (Table 1). The overall SFRs by imaging type were 71.4%, 68.4%, and 45.8% for kidney, ureter, and bladder (KUB) imaging only, US only, and CT only, respectively.

The unadjusted overall SFRs were 49.6% and 72.7% for renal and ureteral stone locations, respectively. There was significant variation in SFR outcomes across surgeons when treating renal stones (8.3–100%) and ureteral stones (28.6–100%, $p < 0.001$; Fig. 1).

Table 2 demonstrates a multivariable analysis assessing stone free after ureteroscopy for renal and ureteral stones. For renal stones, larger stone size, lower pole location, and multiplicity were significantly associated with residual fragments. For ureteral stones, female gender, larger stone size, proximal location, multiplicity, positive (vs negative) urine culture, use of UAS, and postureteroscopy stenting were associated with a lower SFR. There were no significant differences in SFRs regarding prestenting for either renal or ureteral stone groups. Surgeon volume was not associated with being stone free in the renal stone cohort. However, for patients with ureteral stones, the lowest ureteroscopy volume quartile had the highest SFR with odds of being stone free 2.2 (95% confidence interval 1.1–4.2) times greater than the highest volume quartile. Surgeon variation in the SFR when adjusted for risk factors was 26.1–72.4% ($p < 0.001$) for renal stones and 52.2–90.2% ($p < 0.001$) for ureteral stones (Fig. 2).

Table 3 compares the patient and stone characteristics in each quartile of annual surgeon ureteroscopy volume. Surgeons in the higher quartile group treated more morbid patients and renal stones than those in the lower volume group.

Table 1 – Demographic and stone characteristics of renal and ureteral stone groups

	Renal (n = 2091)	Ureteral (n = 4396)	p value
Age, median (IQR)	59.3 (47.1–68.9)	57.7 (45.6–68.5)	0.010
Male gender, n (%)	865 (41)	2163 (49)	<0.001
BMI, n (%)			0.2
<25	423 (21)	868 (20)	
25–<30	565 (28)	1282 (30)	
30–<35	468 (23)	1068 (25)	
35–<40	277 (14)	574 (13)	
≥40	291 (14)	467 (11)	
CCI, n (%)			<0.001
0	1361 (65)	3058 (70)	
1	400 (19)	785 (18)	
≥2	330 (16)	552 (13)	
Right side laterality, n (%)	978 (47)	2028 (46)	0.6
Stone size (mm), median (IQR)	9 (6–12)	6 (5–8)	<0.001
Multiple stones, n (%)	469 (22)	186 (4.2)	<0.001
Preoperative urine culture result, n (%)			0.004
Positive	342 (16)	690 (16)	
Negative	1393 (67)	3081 (70)	
Not performed	356 (17)	617 (14)	
Patients on preoperative alpha-blocker, n (%)	672 (33)	2322 (54)	<0.001
Patients on preoperative anticoagulant, n (%)	151(7.3)	219 (5.1)	<0.001
Lower pole (renal only), n (%)	1028 (49)	NA	NA
Distal (ureteral only), n (%)	NA	1894 (43)	NA
Preoperative hydronephrosis, n (%)			<0.001
No	1298 (62)	686 (16)	
Yes	545 (26)	3505 (80)	
Unknown	247 (12)	204 (4.6)	
Prestented, n (%)	573 (27)	1748 (40)	<0.001
Use of UAS during ureteroscopy, n (%)	1210 (59)	1503 (35)	<0.001
Postureteroscopy stenting, n (%)	1691 (81)	3391 (77)	<0.001
Postoperative imaging type, n (%)			<0.001
CT	406 (19)	691 (16)	
KUB	864 (41)	1482 (34)	
US	821 (39)	2223 (51)	
Stone free, n (%)	1036 (50)	3196 (73)	<0.001
Intraoperative complication, n (%)	24 (1.2)	38 (0.9)	0.3
Yearly surgeon volume, n (%)			0.036
5–12	24 (1.2)	87 (2.0)	
13–35	253 (12)	591 (14)	
35–67	534 (26)	1115 (26)	
≤68	1254 (61)	2559 (59)	

BMI = body mass index; CCI = Charlson comorbidity index; CT = computed tomography; IQR = interquartile range; KUB = kidney, ureter, and bladder imaging; NA = not available; UAS = ureteral access sheath; US = ultrasound.

4. Discussion

We conducted a QI study assessing real-world practice complete SFR outcomes for patients undergoing ureteroscopy to treat renal and ureteral stones in Michigan. Our work has several key findings. The SFR was higher for ureteral stones than for renal stones. Nevertheless, complete SFRs using a zero-fragment definition were not as high as in published reports from expert centers, and there was significant variation in risk-adjusted SFRs across surgeons.

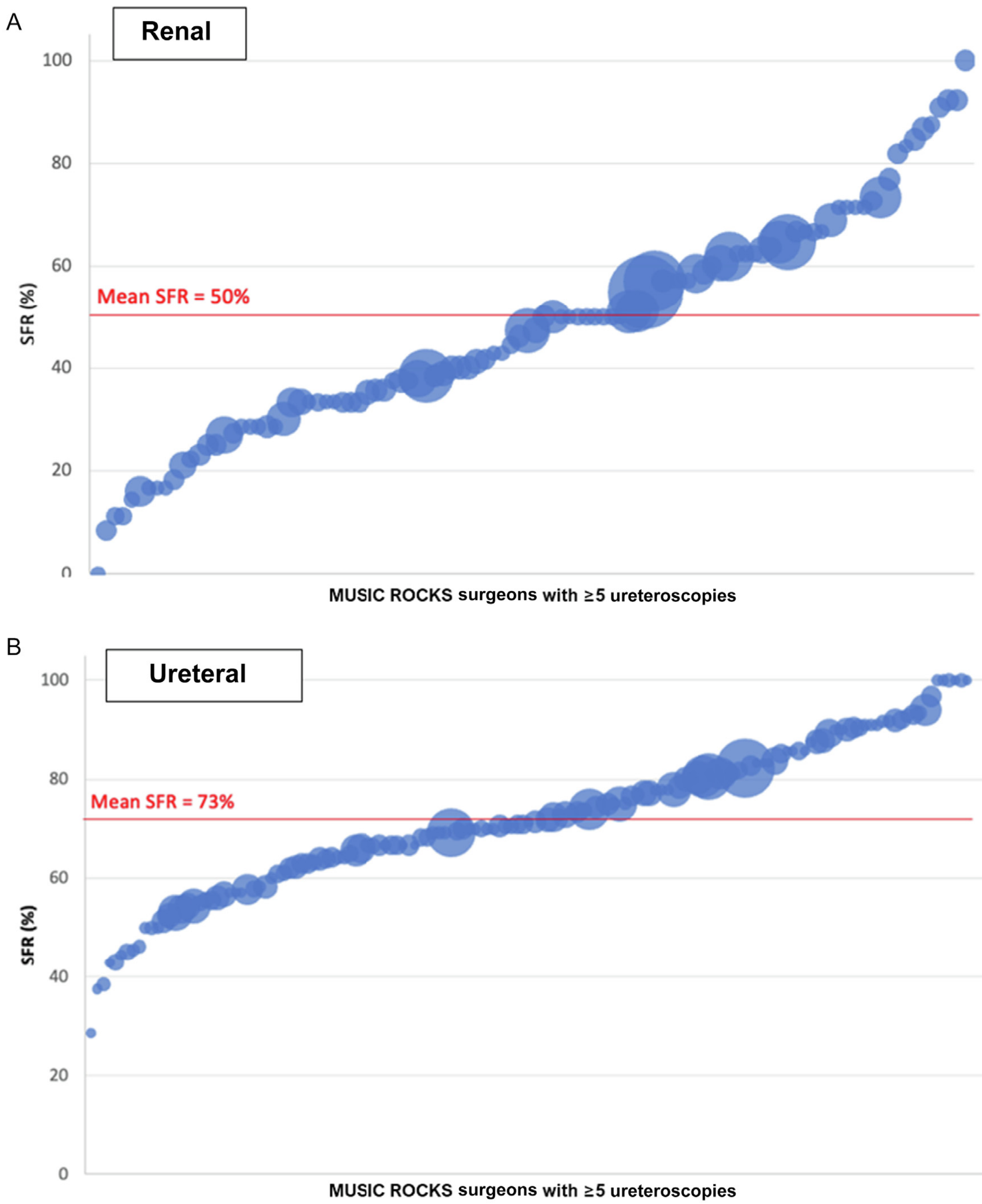

Fig. 1 – Nonadjusted surgeon-level SFR for (A) renal and (b) ureteral stones, treated with ureteroscopy in the Michigan Urological Surgery Improvement Collaborative. MUSIC = Michigan Urological Surgery Improvement Collaborative; ROCKS = Reducing Operative Complications from Kidney Stones; SFR = stone-free rate.

Stone size, location, and multiplicity were associated with stone-free status. There was no relation between annual surgeon volume and SFR outcomes for renal stones.

In earlier studies, the SFR after ureteroscopy for renal stones was noted to be 87–96.7% [9,20]. De la Rosette et al [15], using the Clinical Research Office of the Endourological Society (CROES) database of 114 expert stone centers from 34 countries, found that the overall SFR for ureteroscopy was 85.6%, when applying a 1 mm threshold. The majority in this series were ureteral stones (73.0%), while renal stones constituted a minority (15.6%) among 11 885 patients. They did not provide data on the SFR for renal or ureteral stones specifically. In a separate study from Traxer et al [16], the SFR (fragment size ≤1 mm) for 2239 patients with renal stones treated with ureteroscopy was 78.0%. Our mean SFRs of renal and ureteral stones using a zero-fragment definition are low compared with these previous reports that used self-reported data. However, comparing with some of the smaller studies assessing complete SFRs after ureteroscopy for renal stones using CT, a rate of

Table 2 – Multivariable model assessing the odds of being stone free after ureteroscopy for renal and ureteral stones treated in the Michigan Urological Surgery Improvement Collaborative

	Renal stone			Ureteral stone		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Age (vs mean)	0.97	0.94–1.01	0.2	0.99	0.96–1.02	0.5
Female (vs male)	1.16	0.91–1.37	0.30	0.86	0.73–1.00	0.049
BMI			0.8			0.2
25–29 (vs <25)	1.16	0.87–1.54		0.98	0.79–1.21	
30–34 (vs <25)	1.15	0.85–1.55		1.05	0.84–1.32	
35–39 (vs <25)	1.18	0.83–1.66		1.21	0.92–1.58	
≤40 (vs <25)	1.00	0.71–1.42		1.27	0.95–1.70	
CCI			0.9			0.5
1 (vs 0)	0.95	0.72–1.22		0.98	0.80–1.20	
≥2 (vs 0)	1.12	0.84–1.50		0.87	0.69–1.09	
Stone size	0.93	0.91–0.95	**<0.001**	0.93	0.91–0.95	<0.001
Proximal stone (vs distal)	NA		NA	0.78	0.66–0.93	0.005
Lower pole (vs nonlower pole)	0.68	0.55–0.83	**<0.001**	NA		NA
Multiple stones (vs single stone)	0.70	0.54–0.90	0.005	0.52	0.36–0.73	<0.001
Urine culture			0.4			0.004
Positive (vs negative)	1.21	0.90–1.61		0.73	0.59–0.89	
Not performed (vs negative)	1.00	0.75–1.32		0.80	0.64–1.01	
Preoperative stenting (vs no stent)	1.09	0.85–1.39	0.5	0.89	0.75–1.06	0.18
Use of UAS	0.81	0.64–1.03	0.091	0.79	0.66–0.94	0.009
Postoperative stenting (vs no stent)	0.87	0.66–1.15	0.3	0.72	0.58–0.88	0.002
Annual surgeon volume			0.6			0.021
5–12 (vs ≤68)	1.08	0.39–2.97		2.15	1.09–4.24	
13–35 (vs ≤68)	1.31	0.88–1.94		1.35	0.99–1.83	
36–67 (vs ≤68)	1.16	0.84–1.61		1.34	1.04–1.73	

BMI = body mass index; CCI = Charlson comorbidity index; CI = confidence interval; NA = not available; OR = odds ratio; UAS = ureteral access sheath.

55–60% has been observed, which is similar to our result [13]. Our SFR data are collected by independent abstractors at each practice using the imaging report. This minimizes the bias that self-reporting may pose. Compared with a single-center or multicentric group of stone experts, our community-based SFR may reflect the real-world situation better.

Studies have demonstrated that increasing stone size, number, and presence of lower pole calculi are predictive of residual fragments after ureteroscopy [21–23]. Wong [23] reported that a renal stone size of >15 mm was associated with single-session stone-free failure after flexible ureteroscopy. Lim et al [22] showed that lower pole calculus was significantly associated with ureteroscopy failure. Our findings are consistent with these prior reports. Perioperative use of ureteral stents and UAS was not associated with stone-free status in our study, which was consistent with the literature [16,24].

A multicenter study from CROES had shown that high-volume centers have better SFRs after ureteroscopy [15]. However, in our study, the surgeon's expertise, as assessed by the annual volume of ureteroscopy, was not associated with being stone free for renal stones. Our community-based outcomes reflect the possibility of more challenging cases being referred to and performed by higher-volume surgeons. Higher-volume surgeons treated patients with greater comorbidity and stones in renal location. Interestingly, for ureteral stones, higher-volume surgeons were associated with a lower SFR. This could be because higher-volume surgeons tackle more complex ureteral stones, or also that these were the type of cases that underwent imaging.

The MUSIC registry includes a variety of practices across Michigan. Nevertheless, there are limitations to our study. First, approximately 40% of patients underwent imaging within 60 d. Administrative-claims data from the USA have demonstrated that only 45% of patients undergo imaging within 3 mo after ureteroscopy [25]. It is possible that the SFRs could be higher if all patients were imaged. In the real-world setting, it is feasible that complex cases are the ones that undergo imaging. MUSIC uses a 60-d period for postoperative imaging, and there is a chance of having residual fragments in patients who get imaged earlier. Second, there is no agreement on the follow-up imaging modality. Most patients underwent KUB imaging or US. Studies have shown that the SFR is lower when CT is used [13]. However, our findings reflect real-world follow-up, and it could be postulated that the SFR would be lower if CT was used routinely. High compliance rates of imaging can be obtained only through a prospective clinical trial. Even in this manner, in a recent clinical trial where 93% of patients underwent pragmatic imaging of KUB, US, or CT (similar to our dataset) after ureteroscopy and holmium laser lithotripsy, the complete SFR for kidney stones was only 52% [26]. CT was used in 13% of patients with a complete SFR of 50%, while in our registry, it was used in 20% of cases with a complete SFR of 45.8%. Lastly, the complexity of the stone may have an impact on the SFR. This cannot be evaluated thoroughly in our study because certain operative variables are difficult to collect in a systematic manner via real-world registries. Another limitation is that our findings are from one region of the USA, and may not be generalizable to other states or other countries.

Limitations notwithstanding, our work has several implications. First, we show that in the real-world setting, postoperative imaging in the USA is not used in the majority of patients after ureteroscopy. While this has been shown previously [17,25], and the issue with imaging is not the focus of our study, as a community it reflects the need to better address this problem, especially on whether patients

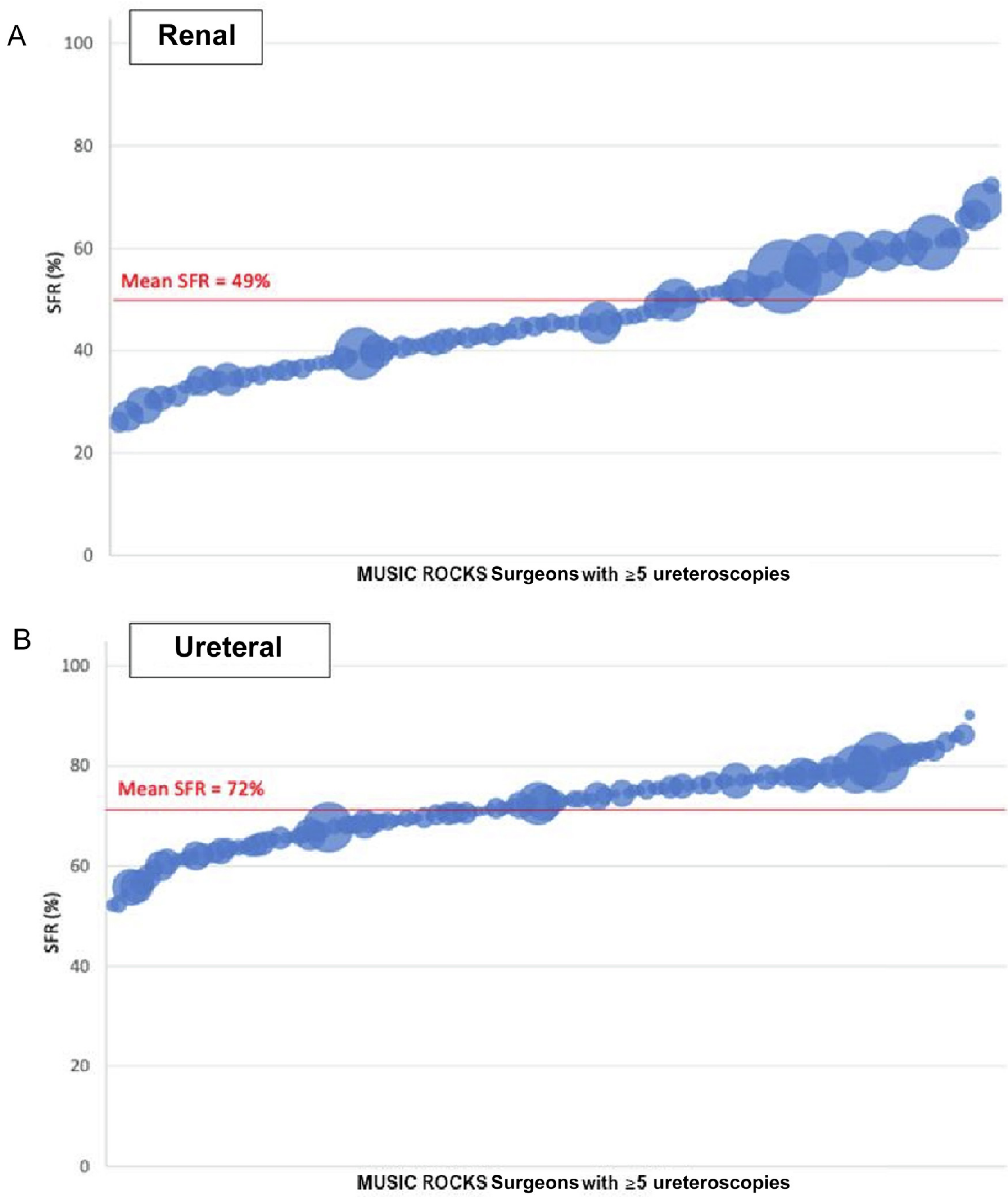

Fig. 2 – Adjusted surgeon-level SFR for (A) renal and (b) ureteral stones, treated with ureteroscopy in the Michigan Urological Surgery Improvement Collaborative. MUSIC = Michigan Urological Surgery Improvement Collaborative; ROCKS = Reducing Operative Complications from Kidney Stones; SFR = stone-free rate.

Table 3 – Stone and patient characteristics according to quartile of annual surgeon volume based on the frequency of ureteroscopy cases among the total surgeons in the Michigan Urological Surgery Improvement Collaborative

Annual surgeon volume Number of patients	5–12 111	13–35 844	36–67 3813	≥68 1649	*p* value
CCI, *n* (%)					0.002
0	78 (70)	593 (70)	1129 (69)	2587 (68)	
1	22 (20)	160 (19)	336 (20)	645 (17)	
≥2	11 (10)	90 (11)	184 (11)	581 (15)	
Stone location, *n* (%)					0.036
Renal	24 (22)	253 (30)	534 (32)	1254 (33)	
Ureter	87 (78)	591 (70)	1115 (68)	2559 (67)	

CCI = Charlson comorbidity index.

should undergo CT and its timing [27]. Nevertheless, our study is the first to evaluate the SFR variation following ureteroscopy in a large group of surgeons with a relationship with volume. It may present a more realistic expectation of the outcomes after ureteroscopy. Substantial variation among surgeons was observed; the surgeon you see will have an impact on your outcome. To reduce this quality gap, collaborative QI methods such as technical skills workshops, video review, and coaching are interventions that could help teach strategies in the operating room to improve patient outcomes.

Future work is needed to understand surgeon factors other than ureteroscopy volume that may drive the SFR variation, such as fellowship training or access to equipment and techniques. It would also be informative to follow patients who are not stone free to determine the rate of reintervention. MUSIC does not collect longitudinal follow-up data, but our work has highlighted the importance of this. Potential next steps include leveraging the collaborative nature of MUSIC to do a qualitative analysis of operative technique in surgeons with the highest SFRs. This would facilitate acquiring skills and exposure to technology and devices that could improve stone-free outcomes, especially for renal stones that are most problematic. Previously MUSIC has tackled decision-making in ureteroscopy through a video-based technical skills webinar [28].

5. Conclusions

Real-world practice data from Michigan demonstrate substantial surgeon-level variation in the SFR for ureteroscopy. Residual fragments after ureteroscopy are especially high when treating renal stones. Interventions focused on surgical technique refinement are needed to improve outcomes.

***Author contributions*:** Hyung Joon Kim had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Kim, Dauw, Ghani.
Acquisition of data: Conrado, Daignault-Newton.
Analysis and interpretation of data: Kim, Daignault-Newton, Dauw, Ghani.
Drafting of the manuscript: Kim.
Critical revision of the manuscript for important intellectual content: DiBianco, Dauw, Ghani, Jafri, Seifman, Konheim.
Statistical analysis: Daignault-Newton.
Obtaining funding: Ghani.
Administrative, technical, or material support: Ghani, Dauw, Conrado.
Supervision: Ghani.
Other: None.

***Financial disclosures*:** Hyung Joon Kim certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding,
consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending) are the following: John Michael DiBianco is a consultant for Boston Scientific. Khurshid R. Ghani is a consultant for Boston Scientific, Olympus, Storz, Coloplast, and Ambu, and received investigator funding from Boston Scientific, Coloplast, and Blue Cross Blue Shield of Michigan. Casey A. Dauw is a consultant for Boston Scientific and Cook Medical, and received investigator funding from Blue Cross Blue Shield of Michigan.

***Funding/Support and role of the sponsor*:** The Michigan Urological Surgery Improvement Collaborative (MUSIC) is funded by Blue Cross Blue Shield of Michigan, which was involved in data collection.

***Acknowledgments*:** The authors would like to acknowledge the significant contribution of the clinical champions, urologists, and data abstractors in each participating MUSIC practice (details about specific participating urologists and practices are available at http://www.musicurology.com). They would like to acknowledge the support provided by the Value Partnerships program at Blue Cross Blue Shield of Michigan.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.euf.2023.03.010.

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