

Newly Developed Hydronephrosis in Patients Following Ureteroscopy: Who Is at Risk?

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Abstract

Introduction and Objective: Imaging rates are low after ureteroscopy in the United States. Detecting postoperative hydronephrosis is important to minimize patient morbidity, and predicting patients at greatest risk for new postoperative hydronephrosis could inform imaging guidelines. We used data from a clinical registry to understand new-onset postoperative hydronephrosis and associated risk factors after ureteroscopy and stone intervention.

Methods: Using the Michigan Urological Surgery Improvement Collaborative registry, we retrospectively identified all ureteroscopy for urolithiasis between July 2020 and June 2023. We included patients without hydronephrosis on preoperative CT or ultrasound. New postoperative hydronephrosis was defined as hydronephrosis seen between postoperative days 29 and 60 following ureteroscopy. We compared demographic and clinical variables from patients with new postoperative hydronephrosis with patients who did not develop hydronephrosis. Logistic regression was performed to evaluate risk factors for new postoperative hydronephrosis.

Results: Preoperative imaging was available for 4742 patients across 31 urology practices, of which 1066 also had postoperative imaging within 29 to 60 days of surgery. New postoperative hydronephrosis was seen in 87 (8.2%) patients. Among them, 51 patients (58.6%) had transient hydronephrosis, 6 (6.9%) strictures, 5 (5.7%) residual stones, 2 (2.3%) hematomas, and 23 (26.4%) did not have information available. Silent hydronephrosis was present in seven patients (0.66%). Factors associated with new postoperative hydronephrosis included location of the stone (kidney vs ureter), greater stone size, use of ureteral access sheath, ureteral stent placement after surgery, longer stent dwell time, and the presence of residual stones. After adjustment, renal location of the largest stone was found to be an independent predictor of developing postoperative hydronephrosis.

Conclusions: Postoperative hydronephrosis in patients without preoperative hydronephrosis occurs 1 in 13 patients who had both pre and postoperative studies after ureteroscopy. More than half of these cases are transient, and silent postoperative hydronephrosis is rare. These data support a goal-directed approach to imaging rather than routine imaging for all patients.

Keywords: ureteroscopy, lithotripsy, kidney stones, urolithiasis, postoperative hydronephrosis, silent hydronephrosis

Introduction

Postoperative complications following ureteroscopy are a critical area of investigation because of their potential impact on patient outcomes. Among these complications, the reported incidence of postoperative hydronephrosis varies widely, ranging from 3.1% to 32.1%.^{1–10} Asymptomatic or silent postoperative hydronephrosis, although relatively uncommon, has been documented in up to 2.9% of cases and carries clinically significant implications for long-term impairment in

renal function.³ Despite its clinical relevance, the understanding of this complication, particularly in patients without preoperative hydronephrosis, remains limited.

Although there is controversy around whether imaging should be performed for all patients after ureteroscopy,^{1–4} the fact remains that in the United States, low rates of imaging (<50%) are the norm.^{11–13} This potentially hinders timely detection and management of complications related to postoperative hydronephrosis. Identifying patients at increased risk for new postoperative hydronephrosis could guide the

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development of targeted imaging protocols, optimizing resource utilization while minimizing unnecessary imaging.

For these reasons, we evaluated the incidence of new postoperative hydronephrosis within a statewide surgical collaborative using a clinical registry for patients undergoing ureteroscopy in Michigan. We aimed to identify preoperative and perioperative risk factors associated with postoperative hydronephrosis in patients without preoperative hydronephrosis. Through this work, we seek to provide insights based on real-world data from a diverse clinical environment that could allow for more targeted imaging and follow-up strategies.

Materials and Methods

Data source: Reducing Operative Complications from Kidney Stones Registry

The Michigan Urological Surgery Improvement Collaborative (MUSIC), established in 2011, is a physician-led quality improvement collaborative comprised of more than 90% of practicing urologists across the state of Michigan and three centers outside Michigan.¹⁴ Support for MUSIC is provided by Blue Cross Blue Shield of Michigan. Reducing Operative Complications from Kidney Stones Registry (ROCKS) is a MUSIC's initiative launched as a pilot in August 2016 with the aim to reduce emergency department visits following ambulatory stone surgery. The prospectively maintained ROCKS clinical registry includes 46 diverse academic and community urology practices. Ureteroscopy cases performed in hospitals and ambulatory surgery centers, regardless of insurance type or status included. Detailed demographic, clinical, operative, and postoperative data for patients undergoing ureteroscopy are entered into a web-based clinical registry by trained abstractors at each practice location using standardized definitions. To ensure data quality, the coordinating center performs on-site data audits on a regular basis. Additional details on the ROCKS registry have been described previously.^{12,15} Each practice has obtained an exemption or approval by the local institutional review board for participation in MUSIC.

Study population

All patients over the age of 18 who underwent ureteroscopy for urolithiasis between July 2020 and June 2023 were included. Patients with preoperative imaging without hydronephrosis diagnosed by CT or ultrasound (US) and a postoperative imaging with newly developed hydronephrosis in the first postoperative image (CT or US) between 29 and 60 days were selected. We excluded staged procedures, defined as ipsilateral surgery performed within 4 weeks from initial ureteroscopy and also those ones with the first image beyond postoperative day 60, since the registry only collects data to day 60.

Outcome measures

The primary outcome of this study was the incidence of new postoperative hydronephrosis identified on postoperative imaging. New postoperative hydronephrosis was defined as the presence of hydronephrosis in a patient without hydronephrosis on preoperative imaging on the first postoperative

imaging study (CT or US) performed no earlier than the day of stent removal and between postoperative days 29 and 60 following ureteroscopy. This time frame was selected to exclude cases of transient hydronephrosis and ended on the final day of the registry data collection (day 60 after the procedure). As a secondary outcome, we evaluated the incidence of silent postoperative hydronephrosis, defined as new postoperative hydronephrosis occurring in an asymptomatic patient.

In the initial phase of analysis, patients were categorized based on demographic, clinical, and perioperative data obtained from medical records. New postoperative hydronephrosis was determined by a data abstractor and independently verified by a physician (G.F.M.) to assess symptomatology and etiology. If subsequent imaging demonstrated resolution of postoperative hydronephrosis without surgical intervention, the case was classified as transient even if it occurred within the 29- to 60-day window.

Stone size was measured based on the maximum diameter. Largest stone location was classified as either renal or ureteral based on the location of the stone with the maximum diameter. If a patient had stones in both the kidney and ureter, the location was assigned to the site of the larger stone. Stones in multiple locations were defined as stones present in multiple of the eight locations collected in the registry (Table 1). Additional perioperative variables, including ureteral dilation, use of a ureteral access sheath, type of procedure, stent placement at the surgery, and intraoperative complications, were recorded. Stone-free status was defined as the absence of visible residual stone fragments on postoperative imaging.

Statistical analyses

Descriptive statistics were used to summarize patient characteristics, stratified by the presence or absence of new postoperative hydronephrosis within the 29- to 60-day window. Continuous variables, such as age, body mass index (BMI), maximum stone diameter, and stent dwell time, were reported as medians with interquartile ranges. The Wilcoxon rank sum test was used to compare continuous variables between groups. Categorical variables, including gender, Charlson comorbidity index (CCI) categories (0, 1, and ≥ 2), stone location (kidney, ureter, and both), procedure type (basket only, laser with/without basket), and use of alpha-blockers, were reported as counts and percentages. Group comparisons for categorical variables were conducted using Pearson's chi-squared test. For categorical variables with low expected frequencies in a 2×2 table, such as intraoperative complications, Fisher's exact test was applied to ensure appropriate statistical inference. To analyze the association between stone size categories and new postoperative hydronephrosis within the 29- to 60-day window, maximum stone diameter was stratified into four predefined groups (≤ 5 , >5 –10, >10 –15, and >15 mm). Comparisons between these groups were made using the Pearson's chi-squared test.

A multivariable mixed logistic regression model was performed to assess the association between clinical variables and postoperative hydronephrosis. The model included as fixed effects gender, age, BMI, CCI (0, 1, and ≥ 2), prior stone surgery, prior stent placement, largest stone location (ureter or renal), maximum stone diameter, stones in multiple

TABLE 1. COMPARISON OF PATIENTS WITH NEW POSTOPERATIVE HYDRONEPHROSIS WITH PATIENTS WHO DID NOT DEVELOP POSTOPERATIVE HYDRONEPHROSIS

Characteristics	New postoperative hydronephrosis		p-Value ^b
	No N = 979 ^a	Yes N = 87 ^a	
Gender			0.6
Male	468 (48%)	39 (45%)	
Female	511 (52%)	48 (55%)	
Age (years)	62 (50, 71)	63 (53, 74)	0.12
BMI	30 (26, 35)	29 (26, 34)	0.2
Charlson score	0.00 (0.00, 1.00)	0.00 (0.00, 1.00)	0.6
Charlson score category			0.8
0	643 (66%)	60 (69%)	
1	176 (18%)	13 (15%)	
≥2	160 (16%)	14 (16%)	
Any prior stone surgery	262 (41%)	27 (48%)	0.3
Prior stent	262 (27%)	29 (33%)	0.2
Location of stones			0.068
Ureter	226 (23%)	11 (13%)	
Renal	638 (66%)	66 (78%)	
Both	98 (10%)	8 (9.4%)	
Location of largest stone			0.009
Ureter	285 (30%)	14 (16%)	
Renal	671 (70%)	71 (84%)	
Location of largest stone			
Interpolar calyx	83 (9.7%)	4 (5.7%)	
Lower/distal pole calyx	270 (32%)	28 (40%)	
Lower/distal ureter	99 (12%)	6 (8.6%)	
Renal pelvis	137 (16%)	17 (24%)	
Upper/proximal pole calyx	88 (10%)	7 (10%)	
Upper/proximal/mid ureter	99 (12%)	4 (5.7%)	
Ureteropelvic junction	35 (4.1%)	3 (4.3%)	
Ureterovesical junction	43 (5.0%)	1 (1.4%)	
Maximum stone diameter (mm)	7.6 (5.0, 11.0)	8.0 (6.0, 13.0)	0.10
Maximum stone diameter (mm)			<0.001
≤5	248 (26%)	18 (21%)	
>5–10	452 (48%)	36 (42%)	
>10–15	180 (19%)	14 (16%)	
>15	68 (7.2%)	17 (20%)	
Stones in multiple locations	267 (27%)	31 (36%)	0.10
Ureteral dilation performed	208 (21%)	15 (17%)	0.4
Ureteral access sheath used	532 (55%)	59 (69%)	0.009
Basket extraction only (no laser)	87 (8.9%)	7 (8.0%)	0.8
Ureteral stent placed at the time of surgery	791 (81%)	78 (90%)	0.045
Stent dwell time (days)	7 (5, 12)	9 (6, 16)	0.010
Stone-free	561 (58%)	30 (36%)	<0.001
Intraoperative complications?	5 (0.5%)	1 (1.1%)	0.4
Postop CT scan	98 (10%)	18 (21%)	0.002
Postop ultrasound	896 (92%)	76 (87%)	0.2
Patient discharged with alpha-blockers	619 (63%)	53 (61%)	0.7

Bold values indicate statistically significant differences ($p < 0.05$).

^an (%); Median (Q1, Q3).

^bPearson's chi-squared test; Wilcoxon rank sum test; Fisher's exact test.

BMI = body mass index; CT = computed tomography.

locations, ureteral dilation, ureteral access sheath usage, basket extraction only, and ureteral stent placement. Intraoperative complications were excluded from the analysis because of their low frequency, which prevented appropriate balancing. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are provided for each covariate. To account for

potential variability in surgical technique, decision-making, and preoperative care, urological practice and surgeon were included as a nested random intercepts with an unstructured covariance matrix in the model, inflating model standard errors to properly account for clustering of patients within the same practice or surgeon.

Additionally, a sensitivity analysis was performed including only patients with preoperative CT imaging, excluding those assessed by US. Multivariable logistic regression was repeated in this subgroup.

Analyses were performed using R statistical software, version 4.4.1 (R-Foundation for Statistical Computing, Vienna, Austria).

Results

Out of 18,785 patients who underwent ureteroscopy between July 2020 and June 2023, 4742 did not have preoperative hydronephrosis. CT was the dominant preoperative imaging modality representing 88% of cases, whereas US was performed in 12%. Among these, after excluding cases of postoperative hydronephrosis observed before the 29- to 60-day window after the procedure, 1066 patients (23%) underwent postoperative imaging (CT or US) with available data on postoperative hydronephrosis status. These patients were included in the final analysis (Fig. 1). The predominant imaging modality used in the postoperative setting was US (91%), whereas CT was performed in 9.5%.

New postoperative hydronephrosis occurring within the 29- to 60-day window was identified in 87 patients (8.2%). Among these, the following causes were identified: transient hydronephrosis in 51 patients (58.6%), ureteral stricture in 6

patients (6.9%), residual stone in 5 patients (5.7%), and hematoma in 2 patients (2.3%); the remaining 23 (26.4%) patients did not have follow-up information available in chart review. Locations of strictures with postoperative hydronephrosis are presented in Supplementary Table S3. Because of the small number of stricture cases, we were underpowered to identify predictive factors through regression analysis. As such, we did not perform a separate risk factor analysis specific to ureteral stricture development. Among the five patients with residual stones causing hydronephrosis, stone locations are presented in Supplementary Table S1. Complications occurred in six patients (0.56%; Supplementary Table S2). In this cohort, silent postoperative hydronephrosis was identified in seven patients (0.66% of patients with no preoperative hydronephrosis; 8.2% of patients with new postoperative hydronephrosis), including four with a ureteral stricture, two with residual stones, and one with a hematoma (Fig. 1). Two patients (0.18%), one with a residual stone fragment and one with a ureteral stricture, needed additional surgical treatment. Supplementary Table S4 presents extended follow-up data for the five patients with ureteral strictures who did not require surgical intervention.

There were no significant differences in gender ($p = 0.6$), age ($p = 0.12$), BMI ($p = 0.2$), or CCI ($p = 0.8$) between patients with and without postoperative hydronephrosis. Prior history of stone surgery and prior stent placement were

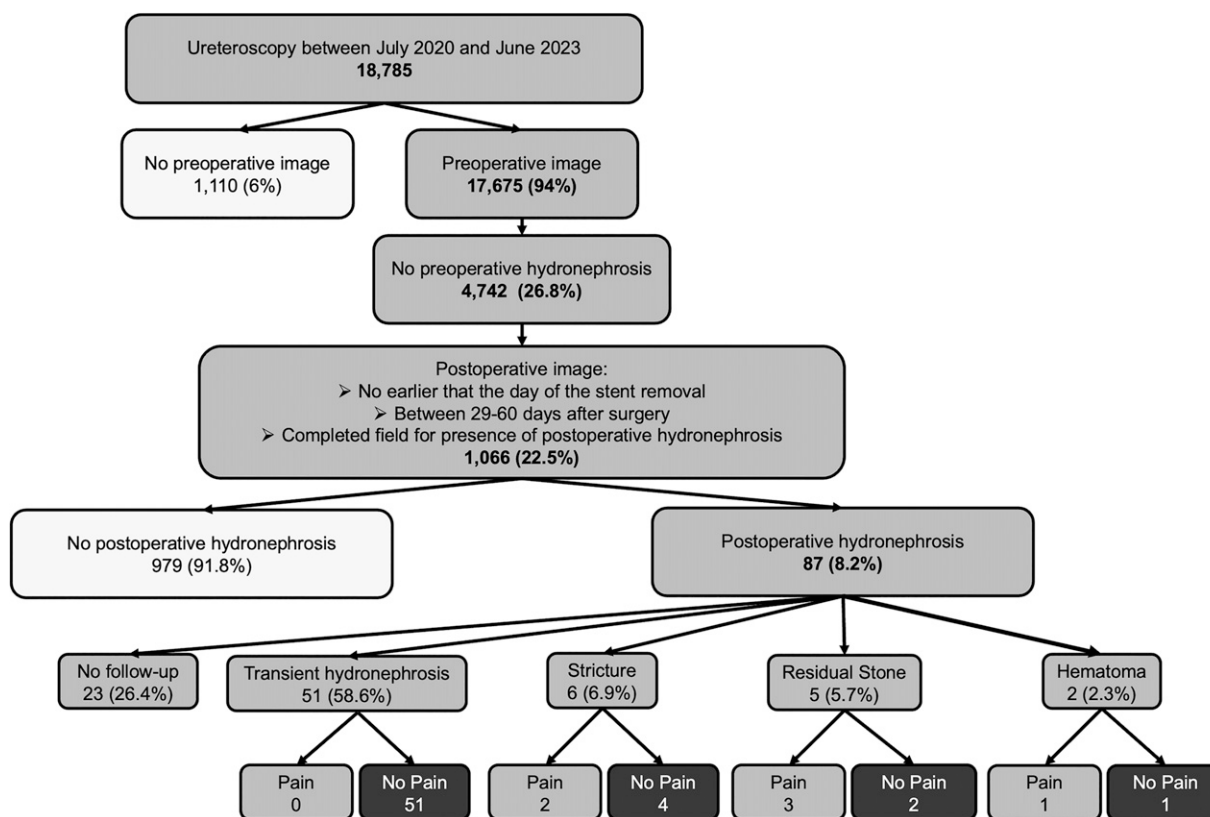


FIG. 1. Patient inclusion flowchart for analysis of postoperative hydronephrosis after ureteroscopy in patients without preoperative hydronephrosis. Among 18,785 ureteroscopy cases, 94% had a preoperative image, and 26.8% of those showed no preoperative hydronephrosis. Of these, 1066 (22.5%) had postoperative imaging performed 29 to 60 days after surgery, including a completed field for hydronephrosis presence. Postoperative hydronephrosis was identified in 87 patients (8.2%), with etiologies including transient hydronephrosis, ureteral stricture, residual stone, and hematoma. Associated pain outcomes are also reported.

also not significantly associated with postoperative hydronephrosis ($p = 0.6$ and 0.3 , respectively).

Regarding stone characteristics, patients with postoperative hydronephrosis were more likely to have the largest stone in a renal location as opposed to ureteral location (84% vs 70%, $p = 0.009$). Maximum stone diameter was larger in the hydronephrosis group (median 8.0 mm vs 7.6 mm), with a significantly higher proportion of patients having stones >15 mm (20% vs 7.2%, $p < 0.001$).

Procedural factors also demonstrated several significant associations (Table 1). Patients who underwent ureteral access sheath placement had a higher incidence of postoperative hydronephrosis (69% vs 55%, $p = 0.009$). Ureteral stent placement at the time of surgery was more frequent in the hydronephrosis group (90% vs 81%, $p = 0.045$), and stent dwell time was significantly longer in this group (median 9 days vs 7 days, $p = 0.010$). Additionally, patients with new postoperative hydronephrosis were less likely to achieve a stone-free status (36% vs 58%, $p < 0.001$).

Results of the logistic regression model found that renal location of the largest stone (relative to ureteral stone) was the only factor significantly associated with new postoperative hydronephrosis (OR: 2.41, 95% CI: 1.05–5.55, $p = 0.039$). Although not reaching statistical significance, the presence of stones in multiple locations (OR: 1.66, 95% CI: 0.92–3.00, $p = 0.091$) and ureteral access sheath usage (OR: 1.76, 95% CI: 0.89–3.50, $p = 0.10$) were close to significance (Table 2).

A sensitivity analysis limited to patients with preoperative CT imaging showed similar findings to the primary model. Renal stone location was no longer statistically significant, likely because of reduced power. However, stones in

multiple locations became significant (OR: 1.98; $p = 0.037$). Full results are shown in Supplementary Table S4.

Discussion

In 1066 patients without preoperative hydronephrosis who had postoperative imaging, 8.2% developed new postoperative hydronephrosis. Reasons for new postoperative hydronephrosis were transient hydronephrosis, ureteral stricture, residual stone, and hematoma. Postoperative silent hydronephrosis was present in 0.66% of patients. After accounting for measured differences between groups, renal stone location was associated with over twice the odds of developing new postoperative hydronephrosis.

To our knowledge, this is the largest study to assess the underlying causes of postoperative hydronephrosis and whether it was symptomatic. In our cohort, the incidence of new postoperative hydronephrosis was 8.2%, within the reported 1.1% to 32.1% range.^{1–10,16,17} This highlights the considerable variability in reported incidences across studies. Differences in these findings may be attributed to variations in study methodologies, including the measurement window—our study assessed hydronephrosis between 29- and 60-day postoperatively—or distinctions in definitions, as we specifically report new-onset hydronephrosis, whereas prior studies may not have made this distinction.

Among patients with new postoperative hydronephrosis, 58.6% had transient hydronephrosis, a rate comparable to previously reported findings.^{8,16} Silent postoperative hydronephrosis was observed in 0.66% of patients, which is lower than reported rates (0.37%–8%).^{3,5,6,11,17} Differences in these rates may stem from variations in study populations or follow-up duration.

In our cohort, the multivariable analysis showed that only largest stone in a renal location was found to be an independent prognostic marker of developing postoperative hydronephrosis. In contrast to our findings, Kim et al. reported in their multivariable analysis that increased preoperative hydronephrosis and impacted stones were independent predictors of postoperative hydronephrosis.⁷ Likewise, Barbour et al. identified increasing stone diameter, prior ipsilateral ureteroscopy, and longer operative duration as independent predictors of postoperative hydronephrosis.¹⁷ In a specific pediatric population, predictors for the development of postoperative hydronephrosis were history of ureteroscopy, ureteral injury during the procedure, and the presence of impacted stones.¹⁸ All these factors mentioned previously are crucial for determining the need for postoperative imaging to optimize patient outcomes.

Our overall postoperative imaging rate after ureteroscopy ($N = 18,785$) is relatively low, with 8230 cases (44%) undergoing CT or US and 10,092 cases (54%) receiving CT, US, or kidney ureter bladder X-ray. This aligns with national claims data, which indicate that approximately 55% of patients do not undergo imaging within 3 months after ureteroscopy, and 39% remain without imaging at 12 months.¹³ Although preoperative imaging was more often performed with CT and postoperative imaging predominantly with US, this variation mirrors real-world practice and underscores the absence of standardized postoperative surveillance protocols.

TABLE 2. ADJUSTED MODEL FOR FACTORS ASSOCIATED WITH NEW POSTOPERATIVE HYDRONEPHROSIS, AMONG THOSE WITHOUT PREOPERATIVE HYDRONEPHROSIS

Characteristics	OR	95% CI	p-Value
Female gender	1.20	0.67–2.13	0.5
Age (per 5 years)	1.05	0.95–1.17	0.3
BMI (per 5 kg/mm ²)	0.94	0.76–1.16	0.5
Charlson score category			0.8
0	(ref)	(ref)	
1	0.81	0.36–1.82	
≥2	0.81	0.36–1.84	
Any prior stone surgery	1.08	0.60–1.92	0.8
Prior stent	0.92	0.45–1.87	0.8
Location of largest stone			
Ureter	(ref)	(ref)	
Renal	2.41	1.05–5.55	0.039
Maximum stone diameter (per 5 mm)	1.10	0.79–1.52	0.6
Stones in multiple locations	1.66	0.92–3.00	0.091
Ureteral dilation performed	0.77	0.36–1.61	0.5
Ureteral access sheath used	1.76	0.89–3.50	0.10
Basket extraction only (no laser)	0.95	0.26–3.48	>0.9
Ureteral stent placed at the time of surgery	1.13	0.42–3.04	0.8

Bold values indicate statistically significant differences ($p < 0.05$).

Model controls for correlation within practices and procedures done by the same surgeon through nested random effects.

BMI = body mass index; CI = confidence interval; OR = odds ratio.

The American Urological Association bases the decision for postoperative imaging on the extent of stone removal (intact vs partial) and the presence of symptoms, specifically for ureteral stones.^{19,20} Many urologists perform imaging after ureteroscopy specifically to avoid missing silent hydronephrosis, reported in up to 3% of patients.³ Our study intentionally included a highly selected group of patients without preoperative hydronephrosis in an effort to understand the rate of newly developed postoperative hydronephrosis. Our reported rate of silent postoperative hydronephrosis is significantly lower than many reported in the literature challenging the dogma of “imaging for all.” Results of our multivariable model indicate that renal stone location of the largest stone is associated with a substantial risk of development of new postoperative hydronephrosis. Taken together, our data support a goal-directed approach to imaging rather than routine imaging for all patients. For instance, treatment of a ureteral stone without clinical suspicion for ureteral injury may not require routine imaging. However, symptomatic patients, those with renal stones, or stones in multiple locations may be best served by CT postoperatively both to assess for postoperative hydronephrosis and stone-free status.

Our findings must be viewed within the context of several limitations. We acknowledge that because of the retrospective design characteristics of the study, the ability to establish causality is limited and increases the potential for selection bias. Another limitation is the variability in imaging protocols, as postoperative imaging modalities were determined at the discretion of individual urologists rather than following a standardized protocol, and the MUSIC registry only collects the first image up to 60 days after surgery, which may exclude subsequent imaging. However, this variability is a common issue in similar studies and is particularly relevant to our statewide registry, which includes a diverse group of urologists with varying practice patterns. We understand that postoperative US is less sensitive than CT for identifying residual stone fragments. However, postoperative CT imaging is not routinely performed in clinical practice, and our study reflects real-world imaging utilization. A standardized grading system for hydronephrosis was not applied, as this information was not routinely included in clinical radiology reports. Hydronephrosis was identified based on explicit terminology or descriptive phrases noted in imaging reports, as abstracted by trained reviewers. This approach may introduce variability in detection and reporting. Because of our study design, we did not include patients who may be at higher risk of postoperative ureteral strictures such as those with obstructing ureteral stones causing preoperative hydronephrosis. Therefore, we are not reporting global rates of postoperative hydronephrosis, rather the development of new hydronephrosis following ureteroscopy. Additionally, postoperative imaging was performed in only 23.3% of patients, which could lead to an underestimation of the true incidence of postoperative hydronephrosis in Michigan. Finally, although we collect a multitude of clinical variables, there is a potential for unmeasured confounding given that operative characteristics such as surgeon experience, type of ureteroscope used, laser type and settings, operative time, the condition of the ureter, or the presence of impaction, which may impact postoperative hydronephrosis, are not collected in the registry.

This study seeks to provide an accurate representation of postoperative hydronephrosis by including a highly selected

cohort of patients without preoperative hydronephrosis and excluding imaging in the early postoperative period when hydronephrosis may be transient. In this study, the presence of new postoperative hydronephrosis was relatively uncommon, and many cases were transient. Future implications of a directed imaging approach across ROCKS practices in Michigan (Supplementary Fig. S1) are currently being explored. We acknowledge that any postoperative image approach should avoid unintended consequences such as missed hydronephrosis that could negatively impact patient outcomes.

Conclusion

New postoperative hydronephrosis occurs in approximately 1 out of 13 patients who had both pre and postoperative studies after ureteroscopy in Michigan with 0.66% presenting as silent or asymptomatic postoperative hydronephrosis. Renal location of the largest stone was identified as a significant risk factor, associated with over twice the odds of developing postoperative hydronephrosis compared with ureteral stones. Given multiple barriers to widespread adoption of routine postoperative imaging after ureteroscopy, we are exploring a goal-directed approach to postoperative imaging.

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Authors' Contributions

G.F.M., S.M., and C.D. conceptualized the study and led the methodology design. G.F.M. and S.M. collected and curated the data. S.M. performed the statistical analysis. G.F.M. drafted the article, with critical revisions from S.K., A.J., J.R., E.S., S.D., R.S., D.W., B.S., W.S., K.G., and C.D. All authors reviewed and approved the final version of the article.

Disclaimer

Although Blue Cross Blue Shield of Michigan and MUSIC work collaboratively, the opinions, beliefs, and viewpoints expressed by the authors do not necessarily reflect the opinions, beliefs, and viewpoints of BCBSM or any of its employees.

Author Disclosure Statement

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Supplementary Material

Supplementary Figure S1
 Supplementary Table S1
 Supplementary Table S2
 Supplementary Table S3
 Supplementary Table S4

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Abbreviations Used

BMI = body mass index
 CCI = Charlson comorbidity index
 CIs = confidence intervals
 CT = computed tomography
 MUSIC = Michigan Urological Surgery Improvement Collaborative
 ORs = odds ratios
 ROCKS = Reducing Operative Complications from Kidney Stones Registry
 US = ultrasound