ORIGINAL ARTICLE

Clinical and epidemiological factors associated with residual lithiasis among patients who underwent laser lithotripsy

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ABSTRACT

Objective: To evaluate the clinical and epidemiological factors associated with residual lithiasis among patients who underwent flexible ureteroscopy with laser lithotripsy (FURSLL). **Materials and methods:** An observational, analytical, retrospective and cross-sectional study, using a non-probability sampling method through consecutive case series. Demographic and clinical variables were collected from the medical records of patients who underwent FURSLL. Descriptive statistics, including measures of central tendency and dispersion, were applied. Pearson's chi-square test and Fisher's exact test were used to assess the associations, with statistical significance set at $p \leq 0.05$. **Results:** A total of 24 medical records from patients with nephrolithiasis who underwent FURSLL were analyzed. The sample consisted of eight males (33.30 %) and 16 females (66.70 %), with a mean body mass index (BMI) of 30.8 ± 6.21 kg/m^2. Comorbidities included diabetes mellitus in five (20.83 %), systemic hypertension in eight (33.30 %), obesity in nine (37.50 %) and chronic kidney disease (CKD) in two (8.33 %) patients. The stones were located in the renal pelvis in 11 cases (45.80 %), followed by five cases (20.80 %) in the lower calyx, four cases (16.70 %) in multiple sites, three cases (12.50 %) in the middle calyx and one case (4.20 %) in the upper calyx. Fisher's exact test showed an association between renal surgery and residual lithiasis after FURSLL ($p = 0.038$) ($p \leq 0.05$). A similar association was observed when stone sizes were dichotomized into two categories (≤ 20 mm and ≥ 21 mm). Using Pearson's chi-square test, stone size was also found to be associated with residual lithiasis ($p = 0.017$) ($p \leq 0.05$). **Conclusions:** Stone size and a history of renal surgery are factors associated with residual lithiasis following FURSLL among patients diagnosed with nephrolithiasis.

Keywords: Nephrolithiasis; Laser Therapy; Lithotripsy; Lasers; Waste Products (Source: MeSH NLM).

INTRODUCTION

Urinary lithiasis, also known as urolithiasis, involves the formation of stones or calculi in the urinary tract and is a very common condition in urology.

The prevalence of this condition has significantly increased in recent decades and varies by geographical region: 7–13 % in North America, 5–9 % in Europe and 1–5 % in Asia [1]. In the United States, recent surveys estimated a prevalence of 8.80 % in 2010 [2,3]. In Mexico, epidemiological data from the state of Yucatán indicate a higher hospitalization rate for kidney stones compared to the national average, making it the region with the highest rate in the country. Between 2014 and 2016, a total of 1,078 first-time hospitalizations for urolithiasis were reported: 324 in 2014, 345 in 2015 and 409 in 2016 [3]. Hospitalizations due to urolithiasis accounted for 4.36 % of all general hospital admissions in the state. The hospitalization rate per 1,000 inhabitants was 1.2 points higher than in the other Mexican states, such as Sonora, and exceeded the national average [3].

Several studies have linked obesity to the development of lithiasis [4]. Given the high prevalence of obesity in Mexico, which is considered a major public health concern [5-8], this may represent a contributing factor to the country's burden of urinary lithiasis.

Urolithiasis is a public health issue due to its substantial economic burden. Costs are associated with diagnostic testing, medical and surgical treatment, productivity loss, and the need for retreatment in recurrent cases [9]. In the United States, the annual cost of managing this condition exceeds USD 10 billion [10].

The etiology and pathophysiology of urolithiasis involve a complex biochemical process, primarily driven by urinary supersaturation. Supersaturation occurs when urine contains

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solutes (e.g., calcium, phosphate, uric acid, oxalate, cystine, among others) in concentrations that exceed their solubility. This leads to solute precipitation, nucleation and the formation of crystals. These crystals then aggregate and grow, eventually forming stones [11].

Several well-established risk factors are associated with stone formation in the urinary tract: 1) Age: Most frequent in individuals between the fourth and sixth decades of life. 2) Sex: Historically more prevalent in men, with a male-to-female ratio of 2–3:1; however, this gap is narrowing. 3) Geographical region: Higher prevalence in arid or dry climates such as deserts or tropical areas. 4) Climate: Elevated risk in regions with higher average temperatures and during sunnier months, due to increased vitamin D synthesis induced by sunlight, which may contribute to urinary stone formation. 5) Diet: Excessive intake of animal protein increases risk of urolithiasis; intake should be limited to 0.8–1.0 g/kg/day. High consumption of sodium, calcium, oxalate and vitamin C also contributes to stone formation. 6) Fluid intake: Low fluid intake is strongly associated with an increased risk of stone formation, whereas adequate hydration offers a protective effect by reducing urinary supersaturation. A daily intake of at least 2 to 2.5 liters is therefore recommended. 7) Occupation: Workers in environments with high heat and humidity (e.g., steel, glass and machining industries) are at increased risk. 8) Genetics: Family history is a significant risk factor, with 15–65 % of patients having a first-degree relative with urolithiasis. 9) Associated comorbidities: Obesity (BMI > 30) has been associated with increased urinary excretion of oxalate, uric acid, sodium and phosphate, all of which contribute to a higher risk of developing urolithiasis. Type 2 diabetes mellitus contributes to lower urinary pH due to insulin resistance and renal ammonium production, favoring uric acid stone formation. Metabolic syndrome—defined by the presence of at least three of the following: central obesity, hypertension, fasting hyperglycemia, hypertriglyceridemia and low HDL cholesterol—increases the risk of urolithiasis. The risk is doubled in individuals with four or more of these conditions [1].

The clinical presentation of patients with urolithiasis falls into two categories: those with symptoms—such as recurrent urinary tract infections and acute pain secondary to urinary tract obstruction—and those who are completely asymptomatic. An accurate diagnosis requires imaging studies. Plain abdominal X-ray is the most widely used technique to detect urinary stones; however, it is only effective for radiopaque stones (if they are dense enough to be visible), with a reported sensitivity of 54 %. Renal ultrasound is commonly used as the initial diagnostic tool in emergency settings due to its rapid application, safety profile and lack of radiation exposure. It allows the identification of stones and pyelocaliceal system dilation due to obstructive uropathy. Nonetheless, non-contrast abdominopelvic computed tomography (CT) is considered the gold standard for the evaluation of urolithiasis according to international guidelines. It provides detailed information on stone size, number, location and density, as well as any complications related to urinary tract obstructions or anatomical abnormalities; it has a sensitivity of 100 % and a specificity exceeding 90 % [12].

Once the diagnosis is confirmed, the choice of treatment primarily depends on the size and location of the stone [13]. For kidney stones, treatment options include conservative medical management, extracorporeal shock wave lithotripsy (ESWL) or surgical intervention. Surgical approaches may be open, laparoscopic, robotic or endourological. Global trends indicate a growing preference for endourological techniques, given their minimally invasive nature and favorable outcomes [9].

Endourological treatment of kidney stones typically involves three main procedures: 1) percutaneous nephrolithotomy (PCNL), 2) retrograde intrarenal surgery (RIRS) and 3) endoscopic combined intrarenal surgery (ECIRS). The selection among these depends on individual patient characteristics. Current legislation and international guidelines recommend PCNL for kidney stones ≥ 2 cm and RIRS for stones ≤ 2 cm. ECIRS, a hybrid approach combining PCNL and RIRS, is indicated for large kidney stones and anatomically complex cases. This approach minimizes the required number of PCNL passageways and reduces the risk of bleeding-related complications [9,14-16].

Technological advancements have enabled the safe performance of RIRS using flexible ureteroscopy with laser lithotripsy (FURSLL). The procedure involves the insertion of a flexible endoscopic instrument capable of ascending through the ureter to the kidney and navigating within the collecting system. It is equipped with high-resolution imaging and a working channel that accommodates the laser fiber used in lithotripsy (i.e., stone fragmentation and/or dusting). FURSLL has shown favorable outcomes in the treatment of stones < 2 cm, with stone-free rates (SFRs) ranging from 55 % to 95 %, depending on stone size and location, as well as anatomical factors and surgeon experience [10,17].

The SFR is the primary outcome measure used to evaluate the success of FURSLL. To date, there is no universally accepted definition for “stone-free,” and thresholds vary slightly across studies. Most reports define “stone-free” as the absence of residual fragments < 4 mm. However, recent advances in flexible ureteroscopes and laser fiber technology have prompted some authors to propose a cutoff point of < 2 mm for residual fragments [18,19].

Imaging studies are essential for assessing the SFR. The most frequently used modalities include plain abdominal X-ray, kidney ultrasound and non-contrast abdominopelvic CT. Among these, abdominopelvic CT offers the highest sensitivity, allowing detection of residual fragments ≤ 1 mm. Nevertheless, concerns about healthcare costs and cumulative radiation exposure have led to reduced postoperative use of abdominopelvic CT [12,20,21]. Some researchers argue against routine follow-up imaging in order to minimize radiation risks; however, imaging remains the only reliable method to confirm a stone-free status [22].

Several predictive factors help estimate the likelihood of achieving an SFR following FURSLL, based on studies conducted in Europe, Asia and the United States. The Resorlu-Unsal Stone Score (RUSS) incorporates four variables associated with residual lithiasis: stone size > 20 mm, multiple stones, a narrow lower pole infundibulopelvic angle, and renal anatomical abnormalities [23-25]. Other studies have also identified stone size and lower pole location as predictors of residual lithiasis [10,26]. In Mexico, research on this topic remains limited. Only one study, published in 2019, has examined predictive factors for stone-free status in a population of central Mexico who underwent FURSLL, assessed at a single postoperative time point [27].

Although FURSLL is considered a highly safe procedure, certain risks may still affect clinical outcomes, length of hospital stay, duration of sick leave and healthcare costs. The Clavien-Dindo classification is an internationally accepted tool for assessing the severity of postoperative complications [28-30].

MATERIALS AND METHODS

Study design and population

This was an observational, analytical, retrospective and cross-sectional study, using a non-probability sampling method through consecutive case series. Medical records of patients diagnosed with kidney stones who underwent FURSLL between January 1, 2020, and December 31, 2022, were reviewed. The procedures were performed at the Department of Urology of Hospital de Especialidades No. 2, a tertiary referral center of the Instituto Mexicano del Seguro Social (IMSS – Mexican Social Security Institute) located in the northwestern region of the country, which provides this specialized care to insured patients in the area.

Variables and measurements

The study included demographic variables (age and sex), along with clinical variables such as comorbidities, stone characteristics (size, number and location), stone density (measured in Hounsfield units [HU] on CT), operative time, history of ipsilateral JJ stent placement, use of a ureteral access sheath, lithotripsy technique, residual lithiasis, intraoperative bleeding, postoperative complications (graded by severity) and treatment outcomes (categorized as successful vs. unsuccessful).

Statistical analysis

A data collection form was used to record both quantitative and qualitative variables, which were subsequently transferred to a Microsoft Excel 2019 spreadsheet for Windows. The variables were then coded and analyzed using IBM SPSS Statistics 24 for Windows (in Spanish). Descriptive statistics, including measures of central tendency and dispersion, were applied. Pearson's chi-square test and Fisher's exact test were used to assess the associations between variables, with statistical significance set at $p \leq 0.05$. Results were presented using tables and graphs for interpretation.

Ethical considerations

This study was reviewed, revised and approved by both the Research Ethics Committee and the Health Research Committee of our hospital. The study was registered under number 2023-2602-033.

RESULTS

A total of 40 cases involving patients diagnosed with kidney stones who underwent FURSLL between January 1, 2020, and December 31, 2022, were evaluated. Sixteen cases were excluded for the following reasons: five due to incomplete paper medical records; seven because the patients underwent a procedure other than kidney laser lithotripsy; three in which no stones were identified during the procedure; and one in which the patient underwent litholapaxy only. Ultimately, 24 cases were included, accounting for 60 % of the study population.

The study included eight males (33.30 %) and 16 females (66.70 %). The mean age was 46.7 ± 12.1 years (range: 20–67). The mean body mass index (BMI) was 30.8 ± 6.21 kg/m². Comorbidities were identified in some patients, including diabetes mellitus in five (20.80 %), systemic hypertension in eight (33.30 %), obesity in nine (37.50 %) and chronic kidney disease (CKD) in two (8.30 %). Regarding urine cultures, 18 patients (75 %) had negative results prior to surgery, while in the remaining six cases (25 %), the most frequently isolated microorganism was extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli* in three patients (12.50 %) (Table 1).

Table 1. Association between demographic and clinical characteristics and residual lithiasis in the study population

		Residual lithiasis		
	No. of patients	Yes	No	*p* value
No. of patients	24	7 (29.20 %)	17 (70.80 %)	
Sex				1
Male	8 (33.30 %)	2 (25.00 %)	6 (75.00 %)	
Female	16 (66.70 %)	5 (31.30 %)	11 (68.70 %)	
Age (years)				0.18
≤ 49	13 (54.20 %)	2 (15.40 %)	11 (84.60 %)	
≥ 50	11 (45.80 %)	5 (45.50 %)	6 (54.50 %)	

		Residual lithiasis		
	No. of patients	Yes	No	*p* value
BMI (kg/m²)				1
≤ 29.9	12 (50.00 %)	4 (33.33 %)	8 (66.67 %)	
≥ 30	12 (50.00 %)	3 (25.00 %)	9 (75.00 %)	
Comorbidities				
Diabetes mellitus	5	0	5 (100.00 %)	0.27
Hypertension	8	3 (37.50 %)	5 (62.50 %)	0.64
Obesity	9	3 (25.00 %)	6 (75.00 %)	1
CKD	2	1 (50.00 %)	1 (50.00 %)	0.50

Abbreviations: BMI, body mass index; CKD, chronic kidney disease.
Source: Department of Urology, Hospital de Especialidades No. 2, Unidad Médica de Alta Especialidad (UMAE – Tertiary Care Center), Ciudad Obregón, Sonora.

Regarding laterality, 15 patients (62.50 %) underwent surgery on the right kidney, while nine (37.50 %) underwent surgery on the left. A history of renal surgery was documented in six patients (25 %), whereas 18 (75 %) had no prior kidney surgery. Only one patient (4.20 %) had an anatomical abnormality, specifically a right incomplete duplex collecting system. Stone size was categorized into three groups: ≤ 10 mm (*n* = 3; 12.50 %), 11–20 mm (*n* = 18; 75 %) and ≥ 21 mm (*n* = 3; 12.50 %). Seventeen patients (70.80 %) had a single kidney stone, while the remaining seven (29.20 %) presented with multiple stones (Table 2).

Table 2. Association between preoperative clinical characteristics and residual lithiasis in the study population

		Residual lithiasis		
	No. of patients	Yes	No	*p* value
Laterality of the operated kidney				1
Right	15 (62.50 %)	4 (26.70 %)	11 (73.30 %)	
Left	9 (37.50 %)	3 (33.33 %)	6 (66.67 %)	
History of renal surgery				0.038*
Yes	6 (25.00 %)	4 (66.67 %)	2 (33.33 %)	
No	18 (75.00 %)	2 (11.10 %)	16 (88.90 %)	
Anatomical abnormality				0.29
Yes	1 (4.20 %)	1 (100.00 %)	0	
No	23 (95.80 %)	6 (26.00 %)	17 (74.00 %)	
Stone size				0.017*
≤ 20 mm	21 (87.50 %)	4 (19.00 %)	17 (81.00 %)	
≥ 21 mm	3 (12.50 %)	3 (100.00 %)	0	
Number of stones				0.13
Single	17 (70.80 %)	3 (17.60 %)	14 (82.40 %)	
Multiple	7 (29.20 %)	4 (57.00 %)	3 (43.00 %)	
Stone location				1
Renal pelvis	11 (45.80 %)	3 (27.30 %)	8 (72.70 %)	
Upper calyx	1 (4.20 %)	0	1 (100.00 %)	
Middle calyx	3 (12.50 %)	2 (66.70 %)	1 (33.30 %)	
Lower calyx	5 (20.80 %)	0	5 (100.00 %)	
Multiple sites	4 (16.70 %)	2 (50.00 %)	2 (50.00 %)	

		Residual lithiasis		
	No. of patients	Yes	No	*p* value
Stone density (HU)				0.19
≤ 999	9 (37.50 %)	1 (11.10 %)	8 (88.90 %)	
≥ 1000	15 (62.50 %)	6 (40.00 %)	9 (60.00 %)	
History of JJ stent placement				0.64
Yes	16 (66.70 %)	4 (25.00 %)	12 (75.00 %)	
No	8 (33.30 %)	3 (37.50 %)	5 (62.50 %)	
Lithotripsy technique				1
Fragmentation	2 (8.30 %)	1 (50.00 %)	1 (50.00 %)	
Dusting	21 (87.50 %)	6 (28.60 %)	15 (71.40 %)	
Combined	1 (4.20 %)	0	1 (100.00 %)	

* Statistically significant ($p \leq 0.05$).
Source: Department of Urology, Hospital de Especialidades No. 2, UMAE, Ciudad Obregón, Sonora.

The most common stone location was the renal pelvis, observed in 11 cases (45.80 %), followed by the lower calyx in five cases (20.80 %), multiple sites in four cases (16.70 %), the middle calyx in three cases (12.50 %) and the upper calyx in one case (4.20 %) (Table 2).

With regard to JJ stent placement prior to FURSLL, 16 patients (66.70 %) had the stent in place, while eight (33.30 %) did not. The most frequently used lithotripsy technique was dusting, performed in 21 cases (87.50 %), followed by fragmentation in two cases (8.30 %) and a combined technique in 1 case (4.20 %) (Table 2).

All postoperative complications were rated as grade I according to the Clavien-Dindo classification. Of these, two patients (8.33 %) experienced postoperative pain and one (4.20 %) developed a fever (Table 2). Among the 24 patients included in the final sample, 17 (70.80 %) achieved stone-free status, while seven (29.20 %) presented with residual lithiasis (Table 2).

To evaluate the association between study variables and residual lithiasis following FURSLL, inferential analyses were performed using Fisher's exact test. No statistically significant associations were found between residual lithiasis and demographic or clinical factors such as sex ($p = 1.00$), age ($p = 0.18$), BMI ($p = 1.00$), diabetes mellitus ($p = 0.27$), hypertension ($p = 0.64$), obesity ($p = 1.00$) or CKD ($p = 0.50$) (Table 1). Similarly, no associations were observed between residual lithiasis and clinical characteristics such as laterality of the operated kidney ($p = 1.00$), anatomical abnormalities ($p = 0.29$), number of stones ($p = 0.13$), stone density ($p = 0.19$) or history of JJ stent placement ($p = 0.64$). No statistically significant associations were observed between residual lithiasis and either stone location or lithotripsy technique (both $p = 1.00$), as determined by Pearson's chi-square test with Yates' correction for continuity (Table 2).

However, a statistically significant association was found between a history of renal surgery and residual lithiasis following FURSLL ($p = 0.038$) ($p \leq 0.05$) using Fisher's exact test. In addition, when stone size was dichotomized into two categories (≤ 20 mm and ≥ 21 mm), a statistically significant association was observed between stone size and residual lithiasis ($p = 0.017$) ($p \leq 0.05$), as determined by Pearson's chi-square test (Table 2).

DISCUSSION

According to current international urology guidelines, FURSLL is considered the gold standard for the treatment of kidney stones measuring ≤ 20 mm. The SFR remains the primary indicator of surgical success, as residual fragments after endoscopic procedures are a major risk factor for disease recurrence [22].

The primary objective of this study was to identify factors associated with residual lithiasis following FURSLL among patients diagnosed with kidney stones. While several studies have previously addressed this issue, to date there are no reports from the northwestern region of Mexico. The present study included most of the variables explored in earlier research, in addition to introducing some context-specific factors.

This study analyzed a population of 24 patients. By comparison, the sample sizes in similar studies were as follows: Resorlu et al. (2012), 207 patients; Ito et al. (2015), 546 patients; Maldonado-Alcaraz et al. (2019), 158 patients; Pattarawongpaiboon, Usawachintachit (2021), 75 patients; and Elbakary (2022), 47 patients. The small sample size in the present study limits the generalizability of the findings.

The SFR observed in our analysis accounted for 70.80 %, which is comparable to previously published rates: 86.00 % (Resorlu et al., 2012), 85.20 % (Ito et al., 2015), 73.60 %

(Maldonado-Alcaraz, 2019), 53.00 % (Pattarawongpaiboon, Usawachintachit, 2021) and 61.70 % (Elbakary, 2022). Despite the limited sample size, the wide international variability in residual lithiasis supports the consistency of our findings with those reported by other researchers.

In this study, the cutoff point for defining stone-free status was residual fragments ≤ 2 mm, consistent with the definition used by Pattarawongpaiboon, Usawachintachit (2021). In contrast, Resorlu et al. (2012) defined stone-free status as fragments ≤ 1 mm, while Ito et al. (2015), Maldonado-Alcaraz (2019) and Elbakary (2022) used a cutoff point ≤ 4 mm [18,19,23,26,27]. These inconsistencies in estimating stone size in relation to residual fragments limit the ability to draw firm conclusions regarding the association between stone size ≥ 21 mm and residual lithiasis.

Resorlu et al. (2012) identified several factors associated with residual lithiasis, including stone size, location, composition and number, as well as renal malformations and lower pole infundibulopelvic angle [23]. In our cohort, residual lithiasis was not significantly associated with stone location or density, nor with anatomical abnormalities.

In the study by Maldonado et al. (2019), predictive factors were analyzed by sex. In male patients, age—along with stone size, density and multiplicity—was associated with residual lithiasis. In contrast, among female patients, BMI and stone multiplicity were significant predictors of residual lithiasis [27]. In the present study, no associations were found with sex or stone multiplicity; however, as in Maldonado et al., a statistically significant association was found between stone size ≥ 21 mm and residual lithiasis following FURSLL [27]. A history of renal surgery (p = 0.038) was also significantly associated with residual lithiasis among patients who subsequently underwent FURSLL—an association not previously reported in the literature. However, it should be noted that this association was identified using a less robust statistical test, which limits the generalizability of these findings to a broader population.

These findings are preliminary and may be strengthened by increasing the sample size and applying more robust statistical analyses to yield more accurate and generalizable results.

In conclusion, this study identified stone size and a history of renal surgery as potential factors associated with residual lithiasis following FURSLL. Despite its limitations, the study offers preliminary insights that may help identify patients who are more likely to require multiple procedures to achieve complete stone clearance. These findings also suggest possible strategies for increasing the likelihood of achieving a stone-free status in a single procedure, thereby reducing the need for additional surgical interventions and their associated risks and costs.

The main limitation of the study was the sample size, as the procedure is performed during scheduled sessions at our institution. This is largely due to the limited availability of laser lithotripsy equipment, which is managed on an itinerant basis. Additionally, underreporting in medical records contributed to case exclusion. Another potential source of bias is that most patients were re-evaluated using plain abdominal X-rays, which are associated with a high false-negative rate for detecting residual lithiasis.

It should be noted that the small sample size limits the generalizability of the findings. However, the study is expected to continue with a larger cohort in order to obtain more robust results with fewer limitations. Furthermore, the use of low-dose non-contrast abdominopelvic CT scans for postoperative assessment could improve the accuracy of stone-free status [22].

A prospective study with a larger cohort and additional variables may help identify further predictors of residual lithiasis among patients who underwent FURSLL.

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