

## Prognostic risk factors for inflammatory process exacerbation in the urinary tract in patients with urolithiasis after laser lithotripsy

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

**Aim.** To identify informative clinical and prognostic risk factors for urinary tract inflammatory exacerbation in patients with urolithiasis (UL) after laser lithotripsy.

**Materials and methods.** The study included 74 patients with UL who underwent laser lithotripsy using the holmium laser MultiPulse HoPlus (Germany) in fragmentation mode with a pulse energy of 1.2 J, a frequency of 20 Hz. Patients were divided into groups according to the presence of laboratory signs of urinary tract inflammation on the second postoperative day. Urinalysis for all patients was performed using an automated urine analyser, Laura XI Erba (Germany). The obtained data were statistically processed with Statistica 13 for Windows (StatSoft Inc., No. JPZ8041382130ARCN10-J).

**Results.** On the second day after laser lithotripsy, 48.6 % of patients with UL presented with laboratory signs of urinary tract inflammatory exacerbation, characterized by leukocyturia (100 %), elevated epithelial cell count (72.2 %), erythrocyturia (100 %), bacteriuria (88.9 %), and crystalluria (83.3 %). The signs of urinary tract inflammatory exacerbation were correlated with acute inflammatory indicators. Inflammatory changes on the second postoperative day were significantly more frequent in patients with comorbid diabetes mellitus ( $p = 0.03$ ), chronic pyelonephritis in remission at the time of lithotripsy ( $p = 0.04$ ) and their combination ( $p = 0.04$ ). The duration of laser lithotripsy of  $\geq 60$  minutes was associated with a higher frequency of urinary tract inflammation ( $p = 0.01$  in patients with UL on the second day after lithotripsy). The most informative independent prognostic risk factors for urinary tract inflammatory exacerbation in patients with UL on the second postoperative day were comorbid chronic pyelonephritis ( $p = 0.040$ ) and lithotripsy duration  $\geq 60$  minutes ( $p = 0.016$ ).

**Conclusions.** Comorbid chronic pyelonephritis and lithotripsy duration  $\geq 60$  minutes are significant prognostic risk factors for urinary tract inflammatory exacerbation in patients with UL on the second day after laser lithotripsy.

### Keywords:

urolithiasis, nephrolithiasis, laser lithotripsy, treatment, surgical treatment, inflammation, comorbidity, prognosis, risk factors, urothelium.

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## Прогностичні фактори ризику загострення запального процесу у сечовивідних шляхах у хворих на сечокам'яну хворобу після лазерної літотрипсії

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**Мета роботи** – встановити інформативні клінічні прогностичні фактори ризику загострення запального процесу у сечовивідних шляхах у хворих на сечокам'яну хворобу (СКХ) після лазерної літотрипсії.

**Матеріали і методи.** У дослідження залучено 74 хворих на СКХ, яким виконано лазерну літотрипсію за допомогою гольмієвого лазера MultiPulse HoPlus (Німеччина) в режимі фрагментації з енергією імпульсу 1,2 Дж, частотою 20 Гц. Пацієнтів поділили на групи залежно від наявності лабораторних ознак запальних змін сечовивідних шляхів на другу добу після літотрипсії. Аналіз сечі всім хворим виконано на автоматизованому аналізаторі сечі Laura XI Erba (Німеччина). Статистично дані опрацювали в програмі Statistica 13 for Windows (StatSoft Inc., ліцензія № JPZ8041382130ARCN10-J).

**Результати.** У 48,6 % пацієнтів із СКХ на другу добу після лазерної літотрипсії виявляють ознаки загострення запального процесу у сечовивідних шляхах, що характеризується лейкоцитурією (100,0 %), підвищенням кількості епітеліальних клітин (72,2 %), еритроцитурією (100,0 %), збільшенням бактерій (88,9 %) та кристалів (83,3 %) у сечі. Наявність ознак загострення запального процесу у сечовивідних шляхах корелювала з гострозапальними показниками. Частота загострення запального процесу у сечовивідних шляхах у хворих на СКХ на другу добу після лазерної літотрипсії вища в пацієнтів із коморбідністю з цукровим діабетом ( $p = 0,03$ ), хронічним піелонефритом в стадії ремісії на час виконання літотрипсії ( $p = 0,04$ ) та їх поєднанням ( $p = 0,04$ ). Збільшення тривалості лазерної літотрипсії до 60 хвилин і більше асоціюється з вищою частотою ( $p = 0,01$ ) загострення запального процесу у сечовивідних шляхах у пацієнтів із СКХ на другу добу після літотрипсії. Найбільш інформативними незалежними прогностичними факторами ризику загострення запального процесу у сечовивідних шляхах у хворих на СКХ на другу добу після літотрипсії є коморбідність із хронічним піелонефритом ( $p = 0,040$ ) і тривалість літотрипсії  $\geq 60$  хвилин ( $p = 0,016$ ).

**Висновки.** Встановлено інформативні прогностичні фактори ризику загострення запального процесу у сечовивідних шляхах у пацієнтів із СКХ на другу добу після лазерної літотрипсії, враховуючи коморбідні стани, особливості перебігу хвороби й оперативного втручання.

### Ключові слова:

сечокам'яна хвороба, нефролітіаз, лазерна літотрипсія, лікування, оперативне лікування, запальний процес, коморбідність, прогноз, фактори ризику, уротелій.

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Over the past two decades, urolithiasis (UL) has demonstrated a steady upward trend in incidence. UL is characterized by the formation of calculi in various parts of the urinary system, including the kidneys, ureters, and bladder. The presence of urolithiasis is associated with the development of severe pain, hematuria, infectious and inflammatory complications, and in severe cases, with progression to irreversible damage to the renal parenchyma [1].

The main risk factors for urinary tract stone formation include dietary habits, inadequate hydration, genetic predisposition, climatic conditions, excess body weight, and metabolic disorders. The severity and combination of these factors vary significantly depending on the geographical region and socioeconomic conditions, which leads to an uneven global distribution of UL prevalence. At the same time, contemporary epidemiological data indicate a stable global trend toward increasing incidence, particularly in regions with warm climates and amid significant changes in dietary patterns among the population [2,3]. From 2000 to 2021, surveillance data demonstrated an increase of 26.7 % in the number of UL cases [4].

The development of endoscopic stone fragmentation techniques has resulted in the leading position of laser lithotripsy in the surgical treatment of UL. It is divided into percutaneous nephrolithotripsy and ureterorenoscopy, with the possibility of using flexible ureterorenoscopes. A comparative study of 724 patients demonstrated that the incidence of inflammatory changes in the postoperative period was higher after percutaneous access than after ureterorenoscopy (24.6 % vs. 8.6 %,  $p < 0.001$ ) [5]. The advantages of laser lithotripsy also include the ability to fragment stones of any density and location, with achievement of the highest "stone-free" percentage through intraoperative fragment extraction and immediate restoration of urodynamics [6,7].

The ultimate goal of any intervention is resolution of the clinical problem with minimal complications. Infectious complications after laser lithotripsy in patients with UL remain a serious clinical problem with an overall incidence of approximately 10 % [8]. Experimental and clinical evidence suggests that the increase in intrarenal pressure caused by irrigation fluid during surgery, with subsequent pyelovenous reflux, triggers bacterial translocation and bacteraemia from flora residing on the surface and within the substance of calculi [9,10]. This mechanism also precipitates clinical manifestations of infection of varying severity [11]. The damaging effect of laser energy should also be considered: energy is not precisely directed but is scattered within the confined space of the ureter or renal pelvis, thereby injuring the surrounding urothelium [12].

According to literature, the principal complication in the postoperative period after laser lithotripsy is exacerbation of the urinary tract and systemic inflammatory responses. In a study [13] involving 492 operated patients, inflammatory changes were observed in 8.5 %, defined by fever ( $\geq 38^\circ\text{C}$ ) with pyuria ( $\geq 10$  leukocytes per high-power field). Among the 42 patients with infectious complications, pyuria combined with fever was present in 33.3 % of patients, signs of systemic inflammatory response syndrome appeared in 54.8 %, and sepsis was diagnosed in 11.9 % of patients [13].

An analysis of global clinical experience in the period between 2015 and 2024, encompassing 19 studies with

a total of 939,860 patients who underwent ureteroscopy for urolithiasis, showed that the frequency of post-surgical infectious complications ranged from 0.8 % to 18.2 %, averaging 7.8 %. The most frequently reported complications were fever (up to 16.2 %) and urinary tract infections (up to 12.3 %), while severe complications included sepsis (up to 7.0 %) and septic shock (up to 1.9 %) [14].

The search for informative prognostic factors for complications after laser lithotripsy, particularly urinary tract inflammatory exacerbation, remains highly relevant. However, published results of studies by different authors demonstrate ambiguous data. Thus, despite a certain number of studies [15,16] on the factor of prior stenting of the ureter, their results remain controversial. For instance, the study [15] proves that prior installation of a J-J stent statistically significantly increases the risk for infectious complications after lithotripsy (OR = 1.91, 95 % CI 1.26–2.91,  $p = 0.002$ ). At the same time, other authors' results refute the previous statement, reporting statistical data on the absence of significant differences in the frequency of complications between stented and non-stented groups (OR 0.94, 95 % CI 0.67–1.33,  $p = 0.73$ ) [16].

Contemporary data regarding lithotripsy duration as a risk factor for complications consistently indicate increasing risk with prolonged operative time. However, the results of studies on this risk factor demonstrate the need to continue research in this direction, since the cut-off time established by different researchers differs [17,18]. Researchers [17] found that an operative duration exceeding 90 minutes significantly increases the rate of adverse events, mortality, and intensive care unit admissions. In contrast, another study [18] identified a threshold of 70 minutes for an increased risk of urinary tract inflammatory changes.

Therefore, it is necessary to clarify the prognostic risk factors for urinary tract inflammatory exacerbation in patients with UL after lithotripsy, accounting for disease characteristics, features of the lithotripsy procedure, and relevant comorbid conditions.

## Aim

To identify informative clinical and prognostic risk factors for urinary tract inflammatory exacerbation in patients with urolithiasis after laser lithotripsy.

## Material and methods

The study was conducted at Vitacenter LLC between 2023 and 2026. The prospective open study enrolled 74 patients with UL who underwent surgical treatment via laser lithotripsy. Patient age ranged from 19 to 74 years, with a median age of 48.0 [43.0; 58.0] years. There were 50 men and 24 women.

UL was diagnosed based on anamnestic and clinical data, as well as instrumental examinations (ultrasound and computed tomography of the urinary tract) and laboratory findings, in accordance with the European Association of Urology guideline (2025) and Ministry of Health of Ukraine guidelines: guideline No. 00238 on Urolithiasis (dated 06.09.2017) and guideline No. 00232 on Urinary Tract Infections (dated 22.05.2017).

Inclusion criteria were confirmed diagnosis of UL, surgical intervention with laser lithotripsy, age 18–74 years

and written voluntary informed consent to participate in the study. Exclusion criteria were acute inflammatory process of the urinary tract and comorbid pathology in the decompensation stage.

Laser lithotripsy was performed in all patients using the MultiPulse HoPlus holmium laser manufactured by Asclepion Laser Technologies GmbH (Germany) in fragmentation mode with the following parameters: pulse energy 1.2 J, frequency 20 Hz. All patients received routine perioperative antibiotic prophylaxis in accordance with the standard "Parenteral perioperative antibiotic prophylaxis", as per Order of the Ministry of Health of Ukraine No. 822 dated 17.05.2022.

Patients with UL were divided into 2 groups according to the presence of laboratory manifestations of inflammatory changes in the urinary tract on the second postoperative day. Group I (main) included 36 patients with urinary inflammatory changes; Group II (comparison) comprised 38 patients without such changes. All patients were examined before lithotripsy and on the second postoperative day. The study evaluated comorbid conditions (diabetes mellitus and chronic pyelonephritis in remission), history of stone passage, prior ureteral stenting, stones localization (kidney or ureter), stone size lithotripsy duration, and other parameters.

Urinalysis was performed on the second day after lithotripsy using an automated urine analyser, Laura XI Erba (Germany), in the laboratory of the University Clinic of Zaporizhzhia State Medical and Pharmaceutical University.

The obtained data were statistically analyzed using Statistica 13 for Windows (No. JPZ804I382130ARCN10-J). Results were presented as absolute values and relative frequencies (abs., %) and as median (Me) with interquartile range [Q25; Q75]. Between-group differences in categorical variables were assessed using the chi-square ( $\chi^2$ ) test; differences in quantitative variables were assessed using the Mann-Whitney U test. Gamma correlation was performed for associations between categorical variables and quantitative indicators; Spearman correlation was performed for associations between quantitative variables. To assess independent risk factors, relative risk (RR) was calculated. Statistical significance was defined as  $p < 0.05$ .

## Results

The study results have demonstrated that 48.6 % (36 out of 74) of patients with UL presented with laboratory signs of urinary tract inflammatory exacerbation on the second day after laser lithotripsy, despite no such signs being present prior to lithotripsy. Urinary tract inflammatory exacerbation after lithotripsy was manifested as leukocyturia in all (100 %) patients, ranging from 51/ $\mu$ L to 4748/ $\mu$ L; elevated epithelial cell count in 72.2 % of patients (5/ $\mu$ L to 165/ $\mu$ L); erythrocyturia in all (100 %) patients (118/ $\mu$ L to 11,770/ $\mu$ L); bacteriuria in 88.9 % of patients (46/ $\mu$ L to 628/ $\mu$ L); and elevated crystal count in 83.3 % of patients (5/ $\mu$ L to 782/ $\mu$ L) (Table 1).

These urinary changes were accompanied by haematological findings, namely, leukocytosis in 44.4 % of patients, neutrophilia in 16.7 %, and a left shift of the leukocyte differential in 11.1 %. Notably, an elevated neutrophil-to-lymphocyte (N/L) ratio, a marker of systemic acute inflammatory response, was detected in 38.9 % of patients,

**Table 1.** Characteristics of urinary tract inflammatory exacerbation in patients with UL on the second day after lithotripsy

Parameter, measurement unit	Group 1, n = 36	Reference values
Changes in urine		
Increased white blood cell count, abs. (%)	36 (100)	–
Leukocyturia, Me [Q25; Q75], No./ $\mu$ L	154.5 [93.0; 427.0]	<50
Increased epithelial cell count, abs (%)	26 (72.2)	–
Epithelial cells, Me [Q25; Q75], No./ $\mu$ L	26 [0; 45]	$\leq$ 0
Increased erythrocyte count, abs. (%)	36 (100)	–
Erythrocytes, Me [Q25; Q75], No./ $\mu$ L	962 [710; 3071]	<50
Increased bacteria count, abs. (%)	32 (88.89)	–
Bacteria, Me [Q25; Q75], No./ $\mu$ L	216 [77; 278]	<40
Increased crystal count, abs. (%)	30 (83.33)	–
Crystals, Me [Q25; Q75], No./ $\mu$ L	95.5 [31; 319]	$\leq$ 0
Changes in blood		
Leukocytosis, abs. (%)	16 (44.4)	–
Neutrophilia, abs. (%)	6 (16.7)	–
Left shift of leukocyte differential, abs. (%)	4 (11.1)	–
Elevated N/L ratio, abs. (%)	14 (38.9)	1.0–3.0
N/L, Me [Q <sub>25</sub> ; Q <sub>75</sub> ]	2.19 [1.66; 3.33]	–
General response		
Fever >38 °C, abs. (%)	8 (22.2)	–

with a median of 2.19 [1.66; 3.33]. Febrile fever (>38 °C) was recorded in 22.2 % of patients during the specified observation period (Table 1).

Correlation analysis has revealed a relationship between urinary inflammatory changes (indicating urinary inflammatory process exacerbation in patients with UL on the second day after lithotripsy) and systemic inflammatory indicators. A gamma correlation was established between the presence of inflammatory changes in the urine and the level of blood leukocytosis ( $r = +0.45$ ,  $p < 0.05$ ), and the N/L ratio ( $r = +0.44$ ,  $p < 0.05$ ). Spearman correlation analysis demonstrated associations between body temperature elevation and blood leukocytosis severity ( $r = +0.413$ ,  $p < 0.01$ ) and the level of increase in the N/L ratio ( $r = +0.567$ ,  $p < 0.01$ ).

To identify informative prognostic risk factors for urinary tract inflammatory exacerbation in patients with UL after lithotripsy, demographic indicators, comorbidities, disease history, and intraoperative parameters were compared between groups.

Comparative analysis of demographic indicators and comorbidities has demonstrated that Group I patients (with laboratory signs of inflammatory exacerbation) had a significantly higher frequency of diabetes mellitus (22.2 % vs. 5.3 %;  $\chi^2 = 4.55$ ;  $p = 0.03$ ), chronic pyelonephritis in remission at the time of lithotripsy (61.1 % vs. 36.8 %;  $\chi^2 = 4.36$ ;  $p = 0.04$ ), and the combination of both comorbidities (16.7 % vs. 2.6 %;  $\chi^2 = 4.25$ ;  $p = 0.04$ ) compared with Group II patients. Demographic indicators did not differ significantly between groups (Table 2).

Further analysis compared characteristics of the UL course prior to lithotripsy and operative duration to clarify risk factors for urinary inflammatory process exacerbation on the second day after lithotripsy. It has been found that an increase in lithotripsy duration of  $\geq 60$  minutes was significantly more frequent associated with urinary inflammatory process on the second day after lithotripsy (55.6 % versus 26.3 % of patients,  $\chi^2 = 6.56$ ,  $p = 0.01$ ). At the same time, other parameters, history of stone passage, pre-operative

**Table 2.** Comparison of demographic indicators and comorbidities in patients with UL according to the development of urinary tract inflammatory exacerbation on the second day after lithotripsy

Parameter, measurement unit	Patients with UL		$\chi^2$	p
	Group 1, n = 36	Group 2, n = 38		
<b>Demographics</b>				
Males, abs. (%)	26 (72.2)	24 (63.2)	0.69	0.40
Females, abs. (%)	10 (27.8)	14 (36.8)	0.69	0.40
Age, Me [Q25; Q75], years	50.5 [45.0; 60.0]	46.0 [28.0; 58.0]	–	0.34
Young age, abs. (%)	8 (22.2)	14 (36.8)	1.89	0.16
Middle age, abs. (%)	16 (44.4)	16 (42.1)	0.04	0.83
Older age, abs. (%)	12 (33.4)	8 (21.1)	1.41	0.23
<b>Comorbidities</b>				
Diabetes mellitus, abs. (%)	8 (22.2)	2 (5.3)	4.55	0.03
Chronic pyelonephritis, abs. (%)	22 (61.1)	14 (36.8)	4.36	0.04
Combination of diabetes mellitus and chronic pyelonephritis, abs. (%)	6 (16.7)	1 (2.6)	4.25	0.04

p: significance of the intergroup difference.

**Table 3.** Comparison of UL course characteristics and operative duration according to the development of urinary tract inflammatory exacerbation on the second day after lithotripsy

Parameter, measure unit	Patients with UL		$\chi^2$	p
	Group 1, n = 36	Group 2, n = 38		
History of stone passage, abs. (%)	6 (16.7)	10 (26.3)	1.02	0.31
Pre-operative ureteral stent, abs. (%)	12 (33.3)	14 (36.8)	0.10	0.75
Stone localization in the kidney, abs. (%)	22 (61.1)	22 (57.9)	0.08	0.77
Stone size $\geq 20$ mm, abs. (%)	12 (31.6)	8 (22.2)	0.82	0.36
Lithotripsy duration $\geq 60$ minutes, abs. (%)	20 (55.6)	10 (26.3)	6.56	0.01

p: significance of the intergroup difference.

**Table 4.** Prognostic significance of comorbidities and lithotripsy duration for urinary tract inflammatory exacerbation in patients with UL on the second day after lithotripsy

Risk factors, measurement units	Patients with UL		RR (95 % CI)	p
	Group 1, n = 36	Group 2, n = 38		
Diabetes mellitus, abs. (%)	8 (22.2)	2 (5.3)	4.22 [0.96–18.57]	0.056
Chronic pyelonephritis, abs. (%)	22 (61.1)	14 (36.8)	1.66 [1.02–2.71]	0.040
Combination of diabetes mellitus and chronic pyelonephritis, abs (%)	6 (16.7)	1 (2.6)	6.33 [0.80–50.06]	0.080
Lithotripsy duration $\geq 60$ minutes, abs. (%)	20 (55.6)	10 (26.3)	2.11 [1.15–3.87]	0.016

ureteral stenting, stone localization (kidney or ureter), and stone size  $>20$  mm, did not differ significantly between groups ( $p > 0.05$ ) (Table 3).

Considering the statistically significant higher prevalence of comorbidities in Group 1 patients, including diabetes mellitus, chronic pyelonephritis in remission at the time of lithotripsy, and their combination, as well as the longer lithotripsy duration of 60 minutes or more compared with Group 2, relative risk analysis was performed to identify the most informative independent risk factors. The results have shown that independent prognostic factors associated with exacerbation of the inflammatory process in the urinary tract on the second day after lithotripsy were the presence of comorbidity, specifically chronic pyelonephritis, RR 1.66 [95 % CI 1.02–2.71] ( $p = 0.040$ ), and a lithotripsy duration of 60 minutes or longer, RR 2.11 [95 % CI 1.15–3.87] ( $p = 0.016$ ) (Table 4).

## Discussion

According to a meta-analysis [5], the frequency of systemic inflammatory response after endoscopic laser lithotripsy is approximately 12 %; however, the authors note that transient leukocyturia and bacteriuria are recorded in more than 40 % of patients within the first 48 hours after the intervention. The results of the present study are consistent with this reported frequency of laboratory changes: 48.6 % of patients with UL on the second day after lithotripsy presented with urinary tract inflammatory exacerbation characterized by leukocyturia (100.0 %), elevated epithelial cell count (72.2 %), erythrocyturia (100.0 %), bacteriuria (88.9 %), and crystalluria (83.3 %).

Notably, these changes developed despite preoperative antibiotic prophylaxis administered to all patients in accordance with current guidelines, and despite the absence of signs of acute urinary tract inflammation prior to lithotripsy. Findings from other researchers [19] confirm that urinary tract inflammation cannot be entirely prevented in all patients after laser lithotripsy, even with a full course of broad-spectrum antibiotics for those with bacteriologically negative urine tests or targeted therapy in bacteriologically positive cases.

According to our study results, the relationship between urinary changes, indicating inflammatory process exacerbation in the urinary tract, and acute inflammatory indicators was confirmed by a gamma correlation between the presence of urinary inflammatory changes and blood leukocytosis levels ( $r = +0.45$ ,  $p < 0.05$ ) and the N/L ratio ( $r = +0.44$ ,  $p < 0.05$ ). In contemporary literature, the attention of researchers is attracted by the assessment of the prognostic role of acute inflammatory indicators in the infectious disease course, while an elevated N/L ratio is regarded as an acute inflammatory marker associated with unfavorable disease course [20].

The above discussion underscores the need to identify informative prognostic factors influencing the development of inflammatory changes in the urinary tract during the post-operative period. A 2021 meta-analysis of demographic data revealed a predominance of men among patients with UL, comprising 67 % of the study population [4]. In the present study, male patients with UL likewise predominated, accounting for 67.6 % (50 out of 74), which is fully consistent with the reported epidemiological pattern. Nevertheless, regarding sex as a risk factor for complications after lithotripsy, one study demonstrated an association between female sex and greater susceptibility to infectious complications (OR = 1.82, 95 % CI 1.48–2.23,  $p < 0.0001$ ) [21]. However, no statistically significant sex-based difference ( $p > 0.05$ ) was observed in the present study.

Assessment of comorbidities in patients with UL has established prognostic significance for postoperative complications, as demonstrated in several studies [5,13,21,22,23]. The present study also analyzed the role of comorbid pathology, namely chronic pyelonephritis in remission and diabetes mellitus without signs of decompensation. According to our results, the frequency of urinary tract inflammatory exacerbation in patients with UL after lithotripsy was significantly higher in those with comorbid diabetes mellitus (22.2 % vs. 5.3 %,  $p = 0.03$ ), chronic pyelonephritis in remission at the time of lithotripsy (61.1 % vs. 36.8 %,  $p = 0.04$ ), and the combination of both

conditions (16.6 % vs. 2.6 %,  $p = 0.04$ ). These findings align with published data [22] which report postoperative urinary tract infection rates of 29 % in patients with UL and concomitant diabetes mellitus versus 11 % in those without this comorbidity ( $p = 0.04$ ). Studies [13,18,21,22,24] have similarly demonstrated that impaired glycemic control was associated with a higher rate of postoperative urinary tract inflammatory complications.

Our study has identified that comorbid chronic pyelonephritis, even in the remission phase, was a significant risk factor for urinary tract inflammatory exacerbation in patients with UL after lithotripsy, RR 1.66 [95 % CI 1.02–2.71] ( $p = 0.040$ ). This established association is explained in modern literature. Respectively, researchers [5,23] consider that prior or chronic upper urinary tract infections promote microbial biofilm persistence on stone surfaces and within the renal calyceal system. The prognostic value of the combination of diabetes mellitus and chronic pyelonephritis (16.7 % vs. 2.6 %,  $p = 0.04$ ) in patients with UL on the second day after lithotripsy was also demonstrated in this study.

It is noteworthy that in addition to comorbid pathology in patients with UL, the assessment of the UL course and the performed lithotripsy is of particular importance in predicting complications after lithotripsy. An important pathophysiological mechanism underlying postoperative infectious and inflammatory complications in patients with UL after lithotripsy is the elevation of intrarenal pressure by irrigation fluid, with resulting pyelovenous and pyelolymphatic reflux [9,11]. According to experimental and clinical data, exceeding the threshold values of intrarenal pressure ( $>30$  mmHg) is associated with translocation of bacteria and endotoxins from stone surfaces to the systemic circulation [25,26,27]. Additionally, laser energy causes local urothelial damage, which facilitates microbial adhesion and invasion [25,26,27].

The present study demonstrated that lithotripsy duration  $\geq 60$  minutes was associated with a significantly higher rate of urinary tract inflammatory exacerbation (55.6 % vs. 26.3 %,  $p = 0.01$ ) in patients with urolithiasis. Moreover, when assessing the relative risk, we have found that the most informative independent prognostic risk factor for urinary tract inflammatory exacerbation in patients with UL on the second day after lithotripsy was the lithotripsy duration of  $\geq 60$  minutes RR 2.11 [95 % CI 1.15–3.87] ( $p = 0.016$ ).

Consistent findings have been reported in multinational registry studies, where operative time  $<75$  minutes was defined as associated with a minimal rate of postoperative complications [24]. This substantiates the idea of a combined effect of elevated irrigation pressure, a larger volume of irrigation fluid, prolonged mechanical and thermal urothelial exposure, and a higher risk of mucosal microtrauma [28]. One of the most debated risk factors for post-lithotripsy urinary tract inflammation is prior ureteral stenting. Some authors report that prior J-J stent placement may increase the risk of postoperative infection [29], while other studies do not confirm this association [30,31,32]. In the present study, pre-operative ureteral stenting was not associated with an increased risk of postoperative urinary tract inflammation ( $p > 0.05$ ), consistent with the findings of the latter group of investigators.

## Conclusions

1. The rate of urinary tract inflammatory exacerbation on the second day after laser lithotripsy is significantly higher in patients with a combination of urolithiasis and diabetes mellitus (22.2 % vs. 5.3 %;  $p = 0.03$ ), chronic pyelonephritis in remission at the time of lithotripsy (61.1 % vs. 36.8 %;  $p = 0.04$ ), and both conditions combined (16.7 % vs. 2.6 %;  $p = 0.04$ ).

2. Lithotripsy duration of 60 minutes or longer is associated with a significantly higher rate of urinary tract inflammatory exacerbation in patients with urolithiasis on the second day after lithotripsy (55.6 % vs. 26.3 %;  $p = 0.01$ ).

3. The most informative prognostic risk factors for urinary tract inflammatory exacerbation in patients with urolithiasis on the second day after lithotripsy are comorbid chronic pyelonephritis (RR 1.66 [95 % CI 1.02–2.71],  $p = 0.040$ ) and lithotripsy duration  $\geq 60$  minutes (RR 2.11 [95 % CI 1.15–3.87],  $p = 0.016$ ).

**Prospects for further research.** In our opinion, future research should focus on developing individualised management algorithms for patients with urolithiasis scheduled for laser lithotripsy, incorporating the identified risk factors, and on validating a multivariable predictive model for postoperative inflammatory complications.

## Ethical approval

The Bioethics Committee of Zaporizhzhia State Medical and Pharmaceutical University has reviewed the materials presented in the article and found no violations of ethical standards as outlined in applicable regulatory documents, including the Declaration of Helsinki, the Council of Europe's Convention on Human Rights and Biomedicine (Oviedo Convention), and other relevant legal instruments. The study complies with the current legislation of Ukraine. The Committee's conclusion is documented in the minutes of the meeting (Extract from Protocol No. 4 dated March 12, 2026). Written informed consent was obtained from all participants.

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