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RESEARCH ARTICLE

Association Between Stone Mucosal Contact and Postoperative Fever or Systemic Inflammatory Response Syndrome After Retrograde Intrarenal Surgery

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Abstract

Objective: To evaluate the association between the Mucosal Contact Index (MCI), a novel imaging-based parameter reflecting stone-mucosa interaction, and postoperative fever/SIRS after retrograde intrarenal surgery, and to compare its predictive performance with systemic inflammatory markers.

Methods: This retrospective study included 666 patients undergoing RIRS for upper urinary tract stones. Patients with preoperative infection, malignancy, or missing CT data were excluded. Mucosal Contact Index was calculated on non-contrast CT using a 2-dimensional planimetric method on the axial slice with the largest stone cross-section, defined as the ratio of mucosal contact length to total stone circumference. The primary outcome was postoperative fever/SIRS. Logistic regression analyses were performed, and predictive performance was evaluated using ROC analysis. Internal validation was conducted with bootstrap resampling.

Results: Postoperative fever/SIRS occurred in 53 patients (8.0%). MCI was significantly higher in patients who developed postoperative fever/SIRS ($p < 0.001$). In univariate analysis, age, multiple stones, stone volume, preoperative double-J stent, and MCI were associated with postoperative fever/SIRS. MCI demonstrated the highest discriminative performance, with an area under the curve (AUC)=0.811, outperforming inflammatory markers (NLR, PLR, LMR). The optimal cutoff was 0.157. In multivariable analysis, age (adjusted OR=1.06, $p < 0.001$), multiple stones (OR=3.95, $p = 0.001$), stone volume (OR=1.04 per 100 mm^3, $p = 0.029$), preoperative DJ stent (OR=2.64, $p = 0.026$), and MCI as a continuous variable (OR=1.087 per 0.01-unit increase, $p < 0.001$) remained independent predictors. The model showed good discrimination (AUC=0.874), with an optimism-corrected AUC of 0.863 on internal validation.

Conclusion: MCI is a strong and independent predictor of postoperative fever/SIRS in patients with negative preoperative urine cultures undergoing RIRS, outperforming systemic inflammatory markers. As a preoperative imaging-based parameter, it may improve risk stratification in this selected population. External validation in broader patient cohorts is warranted.

Keywords: retrograde intrarenal surgery, mucosal contact index, urolithiasis, postoperative fever, systemic inflammatory response syndrome, risk prediction

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INTRODUCTION

Retrograde intrarenal surgery (RIRS) has been widely adopted in recent years as a minimally invasive treatment modality with high success rates for upper urinary tract stones (1,2). Advances in flexible ureteroscope technology, improvements in laser systems, and the increasing use of ureteral access sheaths have enabled the safe management of larger and more complex stones (3,4). Despite these technical advancements, postoperative infectious complications remain one of the most significant causes of morbidity following RIRS (5,6). The incidence of postoperative fever, systemic inflammatory response syndrome (SIRS), and sepsis after RIRS has been reported to range between 5% and 15% in the literature. These complications prolong hospital stay, increase healthcare costs, and may rarely result in life-threatening clinical conditions (5,7,8). Therefore, accurate preoperative prediction of postoperative fever/SIRS risk is of critical importance for clinical decision making.

Previous studies have identified several risk factors, including advanced age, higher comorbidity burden, positive urine culture, larger stone volume, prolonged operative time, and the presence of a preoperative double-J (DJ) stent. In addition, certain systemic inflammatory markers derived from complete blood count have been reported to predict postoperative infectious complications (9). However, these parameters primarily reflect systemic inflammatory status and do not directly provide information regarding the local anatomical characteristics of the stone or its interaction with the urothelial mucosa.

The extent of stone contact with the urothelial mucosa may be clinically relevant in terms of local inflammation, increased intrarenal pressure, and potential bacterial biofilm formation. Stones with a larger mucosal contact surface area may theoretically cause greater mucosal irritation and facilitate bacterial translocation during surgery. Nevertheless, no standardized parameter has been defined in the literature to objectively and quantitatively assess stone–mucosa interaction.

The primary aim of this study was to evaluate the association between stone mucosal contact and the development of postoperative fever/SIRS in patients undergoing RIRS. As a secondary objective, we sought to compare the predictive performance of mucosal contact with systemic inflammatory markers and to determine its independent contribution within a multivariable model.

MATERIALS AND METHODS

Study Design and Patient Population

This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline for observational studies.

For this retrospective study, consecutive patients who underwent RIRS for upper urinary tract stones between January 2020 and April 2025 were screened. A total of 782 patients were assessed for eligibility. Inclusion criteria were availability of complete clinical and laboratory data, negative preoperative urinalysis and urine culture, and availability of preoperative CT imaging suitable for MCI assessment. Patients with evidence of preoperative infection, urinary tract malignancy, unavailable CT imaging for MCI assessment, or incomplete clinical or laboratory data were excluded.

Of the 782 patients screened, 116 were excluded: 27 because of evidence of preoperative infection, 34 because preoperative CT images obtained at external institutions were not accessible in a format suitable for MCI measurement, and 55 because of incomplete clinical or laboratory data. Among the 27 patients excluded because of preoperative infection, 21 had a positive preoperative urine culture and 6 additional patients had preoperative fever despite a negative urine culture; 5 of the 21 patients with a positive urine culture also had fever. No patients were excluded because of urinary tract malignancy. Consequently, 666 patients fulfilled the eligibility criteria and were included in the final analysis (Figure 1).

The primary endpoint was postoperative fever or systemic inflammatory response syndrome (SIRS), analyzed as a composite binary outcome (0 = no event, 1 = event). This endpoint was intended to capture clinically relevant postoperative inflammatory events. Microbiological confirmation was not required; therefore, fever/SIRS was not considered synonymous with microbiologically confirmed postoperative infection.

This study was approved by the Adıyaman University Non-Interventional Clinical Research Ethics Committee (Decision No: 2025/10–10; Date: December 16, 2025).

Data Collection and Variables

Demographic characteristics, stone-related variables, preoperative laboratory parameters, and perioperative data were obtained from patient records.

The Mucosal Contact Index was calculated using a 2-dimensional (2D) analysis method based on non-contrast CT images. The axial slice demonstrating the largest cross-sectional area of the stone was selected. This slice was chosen because it best reflects stone morphology, allows measurement of the maximum circumference, and represents the plane where mucosal contact is most prominent. Additionally, this approach was adopted to reduce partial volume effects, improve measurement standardization, and minimize interobserver variability. For assessment of interobserver reliability, two urology residents independently evaluated the preoperative CT images of all 666 patients and calculated MCI at separate time points, without access to each other's measurements. Interobserver agreement was assessed using the intraclass correlation coefficient (ICC) based exclusively on these independent measurements. After completion of the independent assessments, discrepant measurements were jointly reviewed and resolved by consensus for use in the final analyses. Consensus measurements were not used for the calculation of the ICC.

On the selected slice, the total stone circumference (perimeter) was determined using manual planimetric measurement. The length of the stone surface directly contacting the urothelial mucosa was measured on the same section. The MCI was defined as the ratio of the mucosa-contacting length to the total stone circumference (Figure 2).

In patients with multiple stones, MCI was calculated separately for each stone, and the values were summed to obtain a patient-based total MCI. MCI measurements were independently performed by two observers for interobserver agreement analysis. Discrepant cases were subsequently reviewed jointly to obtain the final consensus measurement used in the analyses.

Stone localization was categorized based on preoperative CT findings as ureter (0), renal pelvis (1), lower calyx (2), middle calyx (3), and upper calyx (4).

Maximum stone diameter was defined as the largest measured stone dimension on preoperative non-contrast CT. Stone volume was calculated using the ellipsoid formula: volume = $(\pi/6) \times$ length $\times$ width $\times$ depth, with all dimensions measured in millimeters.

A negative urine culture obtained within 14 days before RIRS was required before surgery. If the most recent negative urine culture had been obtained more than 14 days before the scheduled procedure, urine culture was repeated, and only patients with a negative repeat culture proceeded to RIRS.

The following inflammatory indices were derived from preoperative complete blood count parameters: Neutrophil-to-Lymphocyte Ratio (NLR), Platelet-to-Lymphocyte Ratio (PLR), and Lymphocyte-to-Monocyte Ratio (LMR).

Statistical Analysis

All statistical analyses were performed using Python version 3.12 (Python Software Foundation, Wilmington, DE, USA). Statistical computations and data analysis were conducted using the pandas, NumPy, SciPy, statsmodels, and scikit-learn libraries. Receiver operating characteristic analyses and bootstrap validation procedures were performed using scikit-learn–based implementations. Continuous variables were presented as mean ± standard deviation or median (interquartile range), depending on distribution. Normality was assessed using the Kolmogorov–Smirnov test. Given the relatively large sample size, the Kolmogorov–Smirnov test was preferred because the Shapiro–Wilk test may detect trivial departures from normality in large datasets. Visual inspection of distributional characteristics was also considered during data evaluation. Univariate logistic regression analysis was performed to identify factors associated with postoperative fever/SIRS. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs).

Because the Mucosal Contact Index, when analyzed as a continuous variable, resulted in quasi-complete separation in conventional logistic regression, Firth's penalized logistic regression method was applied to obtain bias-reduced estimates. For clinical interpretability, the OR for MCI was reported per 0.01-unit increase. The relationship between maximum stone diameter and MCI was assessed using Spearman's rank correlation coefficient.

The discriminative performance of MCI and inflammatory indices was evaluated using receiver operating characteristic (ROC) curve analysis. The area under the curve (AUC) and corresponding 95% confidence intervals (CIs) were calculated using a bootstrap method with 1.000 resamples. Pairwise comparisons of correlated ROC curves were performed using the DeLong test, and *p*-values were calculated to assess differences in AUC values between predictors.

Optimal cutoff values were determined using the Youden index. Variables were then dichotomized according to ROC-derived optimal cutoff values, and univariate logistic regression analyses were repeated.

The final multivariable logistic regression model included age, multiple stones, stone volume, preoperative DJ stent placement, continuous MCI, and operation time. These variables were selected a priori based on their clinical relevance and potential association with postoperative fever/SIRS. Operation time was modeled per 10-minute increase to facilitate clinical interpretation. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Model discrimination was assessed using the area under the receiver operating characteristic curve (AUC), and calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Multicollinearity among independent variables was assessed using the variance inflation factor (VIF), with VIF <5 considered acceptable.

Internal validation of the final multivariable model was performed using a Harrell-type bootstrap optimism-correction procedure with 1.000 resamples. In each bootstrap replicate, the entire modelling strategy was repeated and model performance was evaluated in both the bootstrap and original samples. The optimism-corrected AUC and calibration slope were calculated to assess model stability and potential overfitting.

RESULTS

A total of 666 patients were included in the analysis, of whom 53 (8.0%) developed postoperative fever or SIRS. Among these 53 patients, 35 (66.0%) developed postoperative fever and 18 (34.0%) met the criteria for SIRS. Of the 18 patients with SIRS, 8 (44.4%) required admission to the intensive care unit (ICU), and one of these patients died due to urosepsis. Patients who developed postoperative fever/SIRS were older and more frequently had multiple stones, a larger stone burden, and preoperative DJ stent placement. Hospital stay was statistically longer in patients with postoperative fever/SIRS, although the absolute difference between groups was modest. In addition, MCI was significantly higher in patients who developed postoperative fever/SIRS (Table 1).

In univariate analysis, age was significantly associated with postoperative fever or SIRS (OR=1.05 per year; 95% CI: 1.03–1.07; $p < 0.001$). Multiple stones were also associated with a higher odds of postoperative fever/SIRS (OR=5.17; 95% CI: 2.83–9.47; $p < 0.001$), as were greater stone length, stone width, stone perimeter, contact length, stone surface area, and stone volume. Preoperative DJ stent placement was another significant predictor (OR=3.01; 95% CI: 1.46–6.23; $p = 0.003$). Operation time was comparable between patients without and with postoperative fever/SIRS (45 [38–55] vs. 45 [40–60] min, respectively; $p = 0.405$). In univariable logistic regression, operation time was not significantly associated with postoperative fever/SIRS (OR=1.010 per 1-minute increase; 95% CI: 0.987–1.033; $p = 0.405$). MCI remained strongly associated with postoperative fever/SIRS in univariate analysis (OR=1.07 per 0.01-unit increase; 95% CI: 1.04–1.10; $p < 0.001$) (Table 1).

Maximum stone diameter was significantly greater in patients who developed postoperative fever/SIRS than in those who did not (17 [13–19] mm vs. 11 [8–15] mm, $p < 0.001$). In univariable logistic regression, each 1-mm increase in maximum stone diameter was associated with higher odds of postoperative fever/SIRS (OR=1.223; 95% CI: 1.147–1.303; $p < 0.001$). Maximum stone diameter showed only a very weak correlation with MCI (Spearman's $\rho=0.089$, $p = 0.022$), indicating limited correlation between the two measures (Table 1).

Interobserver agreement for MCI was excellent (ICC=0.993; 95% CI: 0.988–0.997; n = 666).

When preoperative hematologic and inflammatory markers were evaluated, patients who developed postoperative fever or SIRS had significantly higher neutrophil and monocyte counts, as well as higher NLR and PLR values, whereas lymphocyte count and LMR were significantly lower.

Table 1. Comparison of demographic, clinical, and stone-related characteristics between patients with and without postoperative fever/SIRS

Variable	Group A (No fever/SIRS)	Group B (Fever/SIRS)	OR	95% CI	p value
Age (year)	42 (33–54)	60 (49–69)	1.053	1.034–1.072	<0.001
Male sex, n (%)	372 (60.7%)	31 (58.5%)	0.91	0.52–1.59	0.742
BMI (kg/m^2)	24.97 (23.51–27.41)	24.97 (24.00–27.68)	1.038	0.954–1.130	0.382
Maximum stone diameter (mm)	11 (8–15)	17 (13–19)	1.223	1.147–1.303	<0.001
Stone volume (per 100 mm^3)	900 (554–1.542)	1.524 (849–2.139)	1.10	1.06–1.14	<0.001
Hounsfield unit	857 (625–1.150)	945 (635–1.238)	1.000	0.999–1.001	0.447
Stone localization, n (%)			-	-	0.266
Ureter	21 (3.4%)	5 (9.4%)			
Pelvis	324 (52.9%)	27 (50.9%)			
Lower Pole	80 (13.1%)	5 (9.4%)			
Middle Pole	161 (26.3%)	13 (24.5%)			
Upper Pole	27 (4.4%)	2 (3.8%)			
Multiple stones, n (%)	132 (21.5%)	29 (54.7%)	5.174	2.826–9.472	<0.001
Preop hydronephrosis	2 (1–3)	2 (2–3)	1.215	0.883–1.672	0.231
Preoperative double-J stent	49 (8%)	11 (20.8%)	3.015	1.460–6.226	0.003
Access sheath use	528	46	1.058	0.462–2.420	0.894
FANS use	293	21	0.717	0.404–1.271	0.254
Intraoperative double-J stent	554	46	0.700	0.302–1.620	0.405
Hospital stay (hours)	24 (21–26)	28 (24–49)	1.030	1.019–1.041	<0.001
Operation time	45 (38–55)	45 (40–60)	1.010	0.987–1.033	0.404
Mucosal Contact Index (per 0.01)	0.11 (0.08–0.14)	0.20 (0.15–0.24)	1.069	1.044–1.096	<0.001

Statistical Notes: Continuous variables are presented as median (Q1–Q3), and categorical variables as number (n, %). Between-group comparisons were performed using the Mann-Whitney *U* test for continuous variables and the chi-square test for categorical variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were obtained from univariate logistic regression analyses. A 2-sided *p*-value <0.05 was considered statistically significant.

Hemoglobin, total leukocyte count, and platelet count were not significantly associated with postoperative fever/SIRS (Table 2).

ROC analysis showed that MCI had the highest discriminative performance among the evaluated inflammatory and composite markers, with an AUC of 0.811. The optimal cutoff value for MCI was 0.157, corresponding to a sensitivity of 73.6% and a specificity of 81.6%. Among the inflammatory indices, LMR demonstrated an AUC of 0.731, followed by NLR (0.717) and PLR (0.711) (Table 3). The ROC-derived cutoff value was subsequently used in secondary exploratory analyses and was not incorporated into the primary multivariable model.

As a secondary exploratory analysis, ROC-derived cutoff values were applied to evaluate the association between dichotomized inflammatory markers and postoperative fever or SIRS. All evaluated markers remained significantly associated with postoperative fever/SIRS. The strongest association was observed for MCI. Patients with MCI >0.157 had an approximately 11-fold higher risk of postoperative fever/SIRS (OR=11.21; 95% CI: 5.96–21.08; $p < 0.001$). NLR, PLR, and LMR were also significantly associated with postoperative fever/SIRS, although their discriminative performance was lower than that of MCI (Table 4). Because the cutoff value was derived and evaluated within the same cohort, these results should be interpreted as exploratory and may overestimate the true effect size.

Table 2. Preoperative Hematologic and Inflammatory Markers Associated with Postoperative Fever or SIRS

Variable	Group A (No fever/SIRS)	Group B (Fever/SIRS)	OR	95% CI	p value
Hemoglobin	14.3 (12.8–15.4)	13.6 (12.1–15.2)	0.866	0.744–1.008	0.064
Leukocyte	8.6 (7.5–9.6)	8.2 (7.3–9.2)	0.924	0.779–1.095	0.361
Neutrophil	4.5 (3.8–5.4)	4.7 (4.3–6.0)	1.224	1.013–1.479	0.036
Lymphocyte	2.57 (2.10–3.00)	2.00 (1.60–2.72)	0.358	0.220–0.583	<0.001
Monocyte	0.75 (0.68–0.82)	0.82 (0.74–0.86)	1.042	1.017–1.068	<0.001
Platelet	253 (210–301)	264 (213–315)	1.001	0.997–1.005	0.627
NLR	1.80 (1.46–2.21)	2.71 (1.61–3.41)	5,181	3,308–8,115	<0.001
PLR	102 (82–123)	128 (107–152)	1.029	1.018–1.039	<0.001
LMR	3.42 (2.76–4.20)	2.52 (2.08–3.28)	0.404	0.282–0.578	<0.001

Statistical Notes: Continuous variables are presented as median (Q1–Q3). Univariate logistic regression analysis was performed to evaluate the association between each variable and postoperative fever/SIRS. Results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). A 2-sided *p*-value <0.05 was considered statistically significant.

Table 3. ROC Analysis of Inflammatory Markers and MCI for Predicting Postoperative Fever/SIRS

Marker	AUC	95% CI	Optimal Cut-off	Sensitivity	Specificity
NLR	0.717	0.625–0.803	2,783	0.491	0.945
PLR	0.711	0.628–0.791	122,500	0.604	0.749
LMR	0.731	0.651–0.803	2,798	0.642	0.741
MCI	0.811	0.747–0.863	0.157	0.736	0.816

In the multivariable logistic regression model, age (aOR=1.059; 95% CI: 1.037–1.081; $p < 0.001$), multiple stones (aOR=3,865; 95% CI: 1.661–8,996; $p = 0.002$), stone volume (aOR=1.038 per 100 mm^3; 95% CI: 1.004–1.074; $p = 0.030$), preoperative DJ stent placement (aOR=2,609; 95% CI: 1.108–6,146; $p = 0.028$), and MCI (aOR=1.087 per 0.01 increase; 95% CI: 1.056–1.120; $p < 0.001$) remained independently associated with postoperative fever/SIRS. Operation time was not independently associated with the outcome (aOR=1.062 per 10-minute increase; 95% CI: 0.793–1.422; $p = 0.687$) (Table 5).

The multivariable model demonstrated good discriminative ability, with an apparent AUC of 0.874. Calibration analysis showed no evidence of poor fit (Hosmer-Lemeshow $p = 0.242$). Internal validation using a Harrell-type bootstrap optimism-correction procedure yielded an optimism-corrected AUC of 0.862 and a calibration slope of 0.926, indicating limited overfitting. Overall, model performance remained stable after the inclusion of operation time as a clinically relevant perioperative covariate.

Receiver operating characteristic (ROC) curve analysis was also performed to evaluate the discriminative performance of individual predictors. Among these, MCI showed the highest discriminative ability (AUC=0.811). Pairwise comparison of ROC curves using the DeLong test demonstrated that the AUC of MCI was significantly higher than that of PLR ($p = 0.045$), whereas the differences between MCI and NLR ($p = 0.080$) and between MCI and LMR ($p = 0.074$) did not reach statistical significance (Figure 3).

DISCUSSION

In this study, we demonstrated that MCI, which quantitatively reflects the extent of stone–mucosa interaction, is a significant and independent predictor of postoperative fever/SIRS

Table 4. Univariate Analysis According to ROC-Derived Cut-off Values

Marker	Cut-off Definition	Group A (n above cutoff)	Group B (n above cutoff)	OR	95% CI	p value
NLR	>2,783	34	25	15,205	8,012–28,856	<0.001
PLR	>122,500	154	31	4,200	2,361–7,472	<0.001
LMR	≤2,798	159	34	5,110	2,833–9,215	<0.001
MCI	>0.157	113	39	11.209	5,961–21.080	<0.001

Statistical Notes: Variables were dichotomized according to optimal cutoff values derived from receiver operating characteristic (ROC) analysis. Univariate logistic regression analysis was performed to assess the association between each variable and postoperative fever/SIRS, and results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Since lymphocyte-to-monocyte ratio (LMR) is inversely associated with infection risk, values below the cutoff were considered indicative of high risk. A 2-sided p value <0.05 was considered statistically significant.

Table 5. Multivariable Logistic Regression Analysis and Model Performance

Variable	Adjusted OR	95% CI	p	VIF
Age	1.059	1.037–1.081	<0.001	1.01
Multiple stones	3.865	1.661–8.996	0.002	1.24
Stone volume (per 100 mm^3)	1.038	1.004–1.074	0.030	1.24
Preop DJ stent	2.609	1.108–6.146	0.028	1.01
MCI (per 0.01 increase)	1.087	1.056–1.120	<0.001	1.02
Operation time per 10 min	1.062	0.793–1.422	0.687	1.02

Statistical Notes: Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were obtained from the multivariable logistic regression model. MCI was analyzed as a continuous variable and reported per 0.01-unit increase. The model demonstrated good discrimination (AUC=0.874) and adequate calibration (Hosmer-Lemeshow $p = 0.242$). Internal validation yielded an optimism-corrected AUC of 0.862 and a calibration slope of 0.926. No significant multicollinearity was observed (all VIFs <1.3).

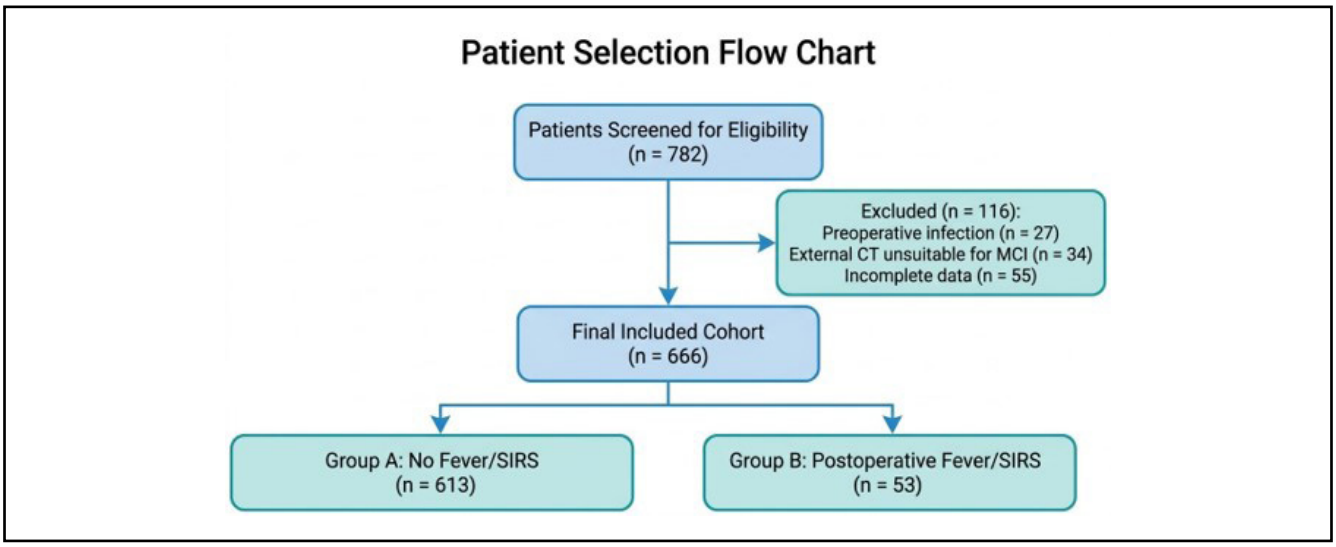


Figure 1. STROBE-compliant flowchart of patient selection and study enrollment process.

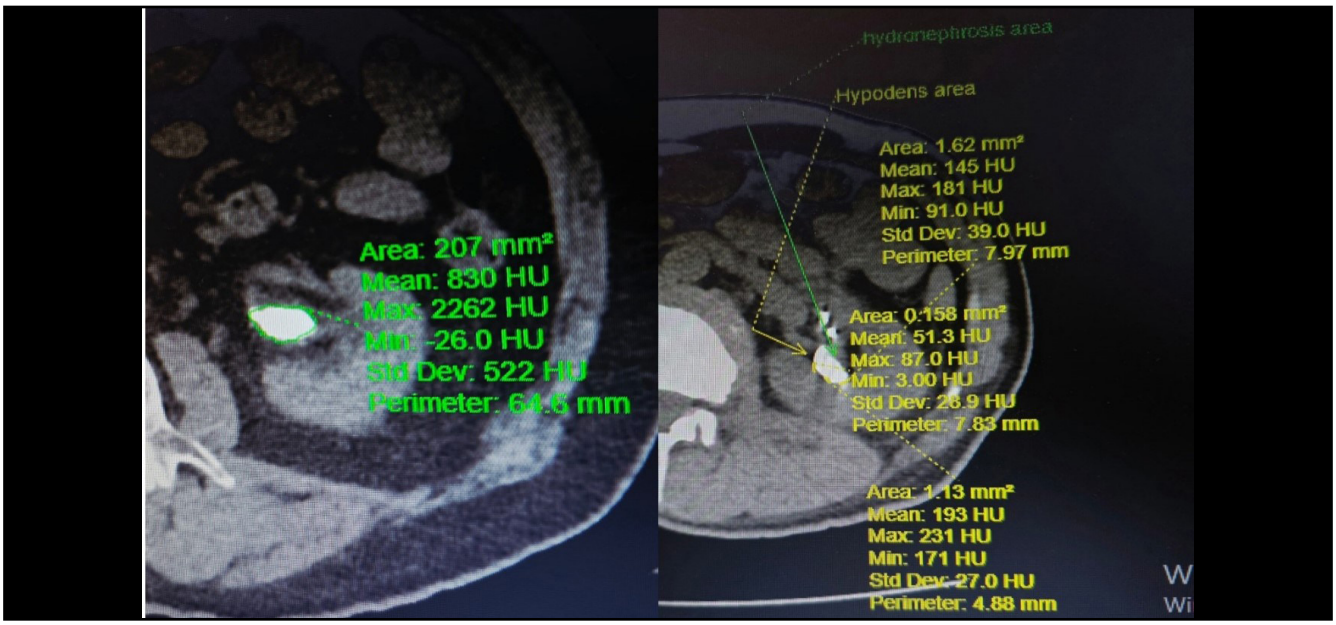


Figure 2. Measurement method of the Mucosal Contact Index.

(Panel 1) Measurement of the total stone circumference on the widest axial section using a 2D planimetric method. (Panel 2) Measurement of the segments of the stone directly contacting the renal pelvis or calyceal mucosa. Areas of hydronephrosis indicated by the green were excluded from the mucosal contact surface. Hypodense regions surrounding the stone, indicated by the yellow arrow, were considered non-contact areas and were excluded from measurement.

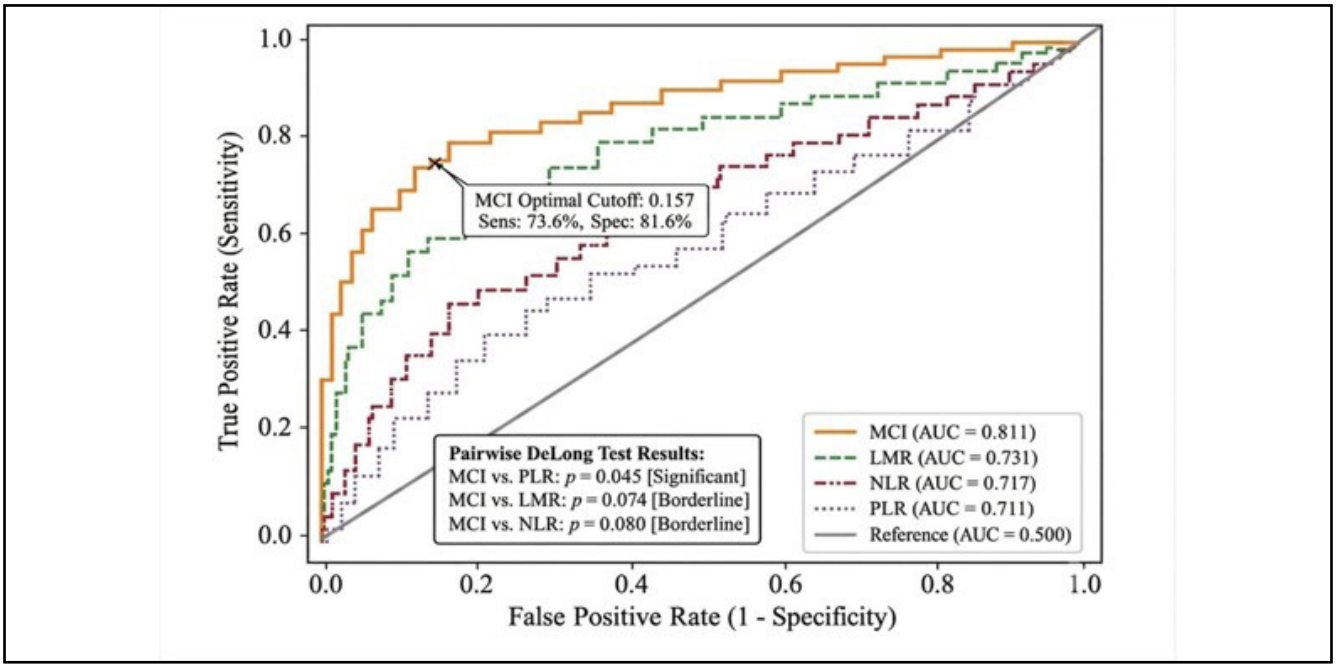


Figure 3. ROC curves of MCI and inflammatory markers for predicting postoperative fever or SIRS after RIRS. MCI demonstrated the highest discriminative performance (AUC=0.811), followed by LMR (AUC=0.731), NLR (AUC=0.717), and PLR (AUC=0.711). Pairwise comparisons of correlated ROC curves were performed using the DeLong test. The AUC of MCI was significantly higher than that of PLR ($p = 0.045$), whereas the differences between MCI and NLR ($p = 0.080$) and between MCI and LMR ($p = 0.074$) did not reach statistical significance. The optimal cutoff value for MCI was 0.157, corresponding to a sensitivity of 73.6% and a specificity of 81.6%.

following RIRS. Our findings indicate that MCI showed higher discriminative performance compared with systemic inflammatory markers and remained independently associated with postoperative fever/SIRS in multivariable analysis.

The incidence of postoperative infectious complications after RIRS has been reported to range between 5% and 15% in previous studies (5,10). In our cohort, postoperative fever/SIRS was 8.0%, which is consistent with the existing literature. Several clinical risk factors have been identified, including advanced age, larger stone burden, multiple stones, and preoperative DJ stent placement (7,11,12). In line with these findings, age, multiple stones, stone volume, and preoperative DJ stent placement were significantly associated with postoperative fever/SIRS in both univariate and multivariable analyses in our study. Preoperative DJ stent placement also remained independently associated with postoperative fever/SIRS after adjustment; however, the confidence interval approached the null value and the statistical significance was borderline. Similarly, the association observed for stone volume should be interpreted with some caution despite reaching statistical significance. Operation time was additionally evaluated as a clinically relevant perioperative covariate. However, it was not independently associated with postoperative fever/SIRS in the multivariable analysis (aOR=1.062 per 10-minute increase; 95% CI: 0.793–1.422; p = 0.687). Importantly, adjustment for operation time did not materially alter the association between MCI and postoperative fever/SIRS, with the effect estimate for MCI remaining essentially unchanged. No significant multicollinearity was observed between DJ stenting and MCI (VIF <1.3), suggesting that these variables represent distinct aspects of the underlying risk. While DJ stenting may be associated with bacterial colonization or prior obstruction, MCI appears to capture local anatomical interaction between the stone and the urothelial surface. Importantly, MCI remained independently associated with postoperative fever/SIRS when analyzed as a continuous variable, supporting a dose-response relationship between increasing mucosal contact and postoperative fever/SIRS. Although hospital stay was statistically longer in patients with postoperative fever/SIRS, the absolute difference between groups was relatively small, suggesting that this finding may reflect institutional discharge practices or early management rather than a clinically substantial prolongation of hospitalization.

Although stone burden has consistently been identified as a key determinant of postoperative fever/SIRS, our findings suggest that MCI may capture an additional anatomical dimension that is not fully reflected by conventional measures of stone size alone. While larger stones generally present a greater overall surface area, MCI specifically quantifies the extent of direct contact between the stone and the urothelial mucosa, thereby reflecting local epithelial exposure rather than absolute stone volume. In the present study, both stone volume and MCI remained independently associated with postoperative fever/SIRS in multivariable analysis, despite the inclusion of both variables in the same model. Furthermore, multicollinearity analysis demonstrated low VIF values, suggesting that substantial overlap between these parameters is unlikely. From a pathophysiological perspective, this distinction may be clinically relevant, as increased stone–mucosa contact could facilitate local inflammation, bacterial biofilm persistence, and subsequent bacterial translocation during endoscopic manipulation and periods of elevated intrarenal pressure (13,14). Therefore, MCI may provide complementary information beyond traditional stone burden metrics when assessing the risk of postoperative fever/SIRS.

The independent association between MCI and postoperative fever/SIRS suggests that local anatomical interaction between the stone and the collecting system may represent an important contributing factor to the development of postoperative fever/SIRS. While systemic inflammatory markers have been associated with infection risk in previous studies, our findings indicate that MCI may provide additional predictive information beyond these parameters. Infectious complications during RIRS are thought to be primarily related to increased intrarenal pressure, which facilitates bacterial translocation through pyelovenous and pyelolymphatic backflow (14,15). In addition, mucosal microtrauma caused by stone fragmentation and endoscopic manipulation may further promote bacterial dissemination (5,16,17). In this context, greater stone–mucosa contact may reflect not only a geometric characteristic but also a clinically relevant indicator of epithelial disruption and potential bacterial burden. The observed dose–response relationship between increasing MCI values and postoperative fever/SIRS further supports the biological plausibility of this association.

Previous studies have consistently demonstrated that systemic inflammatory markers are associated with postoperative infectious complications in endourological procedures. For instance, Sen et al. (18) reported that an elevated preoperative NLR was an independent predictor of postoperative sepsis following percutaneous nephrolithotomy. Similarly, Bai et al. (19) showed that NLR was significantly associated with the development of SIRS after flexible ureteroscopy, while Yahşi et al. (20) demonstrated that SII is a significant predictor of postoperative SIRS after ureteroscopy. However, in our cohort, although inflammatory indices such as NLR, PLR, and LMR were significantly associated with postoperative fever/SIRS in univariate analysis, their discriminative performance remained limited, and none retained independent significance in multivariable analysis. In contrast, MCI demonstrated superior discriminative performance (AUC=0.811), while the multivariable model achieved good overall discrimination with an apparent AUC of 0.874. Internal validation using Harrell-type bootstrap optimism correction yielded an optimism-corrected AUC of 0.862 and a calibration slope of 0.926, supporting the stability of the model and suggesting only modest overfitting. Pairwise ROC comparison further showed that the discriminative ability of MCI was significantly higher than that of PLR, whereas the differences between MCI and NLR and between MCI and LMR did not reach statistical significance.

Several mechanisms may potentially explain the observed association between MCI and postoperative fever/SIRS:

- increased mucosal surface contact may amplify local inflammatory response;
- larger contact areas may be associated with higher bacterial colonization and biofilm formation;
- irrigation under elevated intrarenal pressure may facilitate bacterial translocation in cases with extensive mucosal exposure
- greater contact may indicate a more complex stone configuration, requiring prolonged manipulation and increasing the likelihood of mucosal injury.

It should be noted that MCI is derived from preoperative imaging and reflects a static anatomical relationship between the stone and the urothelial surface. Intraoperative factors such as stone relocation, repositioning, and fragment migration may alter this relationship during the procedure. However, the primary objective of MCI is to provide a preoperative risk assessment based on baseline anatomical characteristics. Therefore, while intraoperative dynamics may influence infection risk, MCI is intended to capture the initial stone–mucosa interaction present before surgery. This baseline anatomical relationship may be relevant to the risk of postoperative fever/SIRS by reflecting the extent of mucosal exposure and the potential for local inflammatory and bacterial processes.

From a clinical perspective, increasing MCI values were associated with progressively higher risk of postoperative fever/SIRS. Therefore, MCI may help identify patients who could benefit from closer postoperative monitoring and more individualized perioperative management. Although a cutoff value of 0.157 demonstrated good discriminatory performance in this cohort, it was derived and evaluated within the same dataset and should therefore be considered exploratory until externally validated. The potential impact of MCI-guided management strategies on clinical outcomes requires further investigation in prospective studies.

Previous predictive models for infectious complications after RIRS have incorporated clinical variables such as operative time, stone burden, and comorbidities (21–23). However, to our knowledge, no prior study has introduced a quantitative parameter directly reflecting stone–mucosa interaction. In this regard, MCI represents a novel, anatomically grounded metric that can be objectively derived from preoperative CT imaging. The strong association between MCI and postoperative fever/SIRS, together with its superior discriminative performance compared with conventional inflammatory markers, highlights the potential clinical relevance of local anatomical factors in postoperative risk assessment. Furthermore, interobserver agreement for MCI measurements was excellent (ICC=0.993; 95% CI: 0.988–0.997), supporting the reproducibility of the measurement approach. Nevertheless, because the measurements were performed within the context of a single study cohort, further validation in independent external cohorts and by independent observers is warranted before widespread clinical implementation.

This study has several limitations. First, its retrospective and single-center design may limit the generalizability of the findings and introduce potential selection bias. Second, MCI was calculated using 2-dimensional measurements on axial CT images rather than 3-dimensional volumetric analysis, which may not fully capture the spatial complexity of stone-mucosa interaction. Third, microbiological data such as stone cultures or renal pelvic urine cultures were not available. Although all patients had negative preoperative bladder urine cultures, it is well established that these do not exclude bacterial colonization within the collecting system or stone matrix. Therefore, the absence of microbiological confirmation limits our ability to determine whether individual postoperative fever/SIRS events were truly infectious in origin.

Additionally, the duration of preoperative DJ stenting was not available and could not be analyzed, which may represent an unmeasured confounder. Certain intraoperative parameters, including irrigation pressure and intrarenal pressure control, were also not recorded and therefore could not be incorporated into the model, despite their known association with infectious complications. Furthermore, intraoperative factors such as stone relocation, repositioning, and fragment migration were not evaluated and may influence the dynamic interaction between the stone and the urothelium. Although external validation was not performed, internal validation using a Harrell-type bootstrap optimism-correction procedure yielded an optimism-corrected AUC of 0.862 and a calibration slope of 0.926, suggesting acceptable model stability and only modest overfitting. In addition, the optimal MCI cutoff value was derived and evaluated within the same cohort. Therefore, the performance of the dichotomized MCI should be interpreted with caution, as data-driven threshold selection may lead to optimistic estimates of discrimination and effect size. Consequently, the cutoff-based analyses should be considered exploratory until externally validated. Future prospective multicenter studies incorporating 3-dimensional imaging, standardized microbiological assessment, independent reproducibility analyses, and external validation are warranted to further refine and validate the clinical applicability of MCI.

CONCLUSION

In conclusion, the occurrence of postoperative fever/SIRS after RIRS appears to be associated not only with established clinical factors such as age, stone burden, and preoperative DJ stent placement, but also with local anatomical stone–mucosa interaction. MCI remained independently associated with postoperative fever/SIRS when analyzed as a continuous variable and demonstrated superior discriminative performance compared with conventional inflammatory markers. Internal validation supported the stability of the proposed model, although external validation remains necessary. Therefore, MCI may represent a useful imaging-based parameter for preoperative risk stratification for postoperative fever/SIRS in patients with negative preoperative urine cultures undergoing RIRS. However, further prospective multicenter studies and external validation in broader patient populations are required before routine clinical implementation.

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Ethics Approval: This study was approved by the Adıyaman University Non-Interventional Clinical Research Ethics Committee (Decision No: 2025/10–10; Date: December 16, 2025). The study was conducted in accordance with the Declaration of Helsinki. Due to the retrospective design, informed consent was waived by the ethics committee.

Availability of Data and Materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

FÇ, BK: Study conception and design, data analysis, manuscript drafting.
FÇ, BK: Data collection and interpretation.
FÇ, BK: Critical revision and supervision.
All authors read and approved the final manuscript.

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