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# External Validation and Calibration of a Novel and Practical RIRS-FUTI Predictive Scoring System for Febrile Urinary Tract Infection After Retrograde Intrarenal Surgery

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# Abstract

**Aim:** The preoperative identification of individuals at elevated risk for infectious complications after retrograde intrarenal surgery (RIRS) is a significant therapeutic problem. In this context, we aimed to validate and evaluate the calibration efficacy of the RIRS-febrile urinary tract infection (fUTI) score, a previously established predictive model for fUTI subsequent to RIRS.

**Methods:** In this external validation study, consecutive adult patients who underwent RIRS for upper urinary tract stones at a tertiary referral center were included. Following the application of the inclusion and exclusion criteria, the remaining patients formed the final study cohort and were categorized into two groups according to the incidence of postoperative fUTI for comparison of demographic, clinical, and perioperative characteristics. The RIRS-FUTI score was calculated for each patient according to the original model without modification. Model performance was evaluated in terms of discrimination using the area under the receiver operating characteristic curve (AUC) and calibration using calibration plots and the Brier score. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated at predefined cut-off values.

**Results:** A total of 525 patients were included, of whom 44 (8.4%) developed postoperative fUTI. Patients with postoperative fUTI had significantly higher platelet-to-lymphocyte ratios; larger stone sizes; higher rates of preoperative nephrostomy, hydronephrosis, and positive preoperative urine cultures; urine leukocyte counts >10/high-power field; and a history of post-ureterorenoscopy urinary tract infections (all $p<0.05$). On multivariable logistic regression analysis, a history of post-ureterorenoscopy urinary tract infection (OR: 114.826, 95% CI: 37.803–348.787; $p < 0.001$) and preoperative urine leukocyte count >10/high-power field (OR: 2.940, 95% CI: 1.253–6.898; $p = 0.013$) remained independent predictors of postoperative fUTI. Calibration analysis of the logistic regression model demonstrated good agreement between the predicted probabilities and observed postoperative fUTI outcomes (Brier score: 0.0573). The incidence of postoperative fUTI increased progressively with higher RIRS-FUTI scores. The scoring system demonstrated good discriminatory performance for predicting postoperative fUTI, with an AUC of 0.809.

**Conclusion:** The novel and practical RIRS-FUTI score demonstrated good discrimination in predicting postoperative fUTI in an independent external cohort. This simple preoperative scoring system may serve as a practical tool for risk stratification before RIRS, although further prospective multicenter validation is warranted.


# Introduction

In recent years, remarkable advances in laser technology, most notably the refinement of Holmium:YAG systems and the emergence of Thulium fiber lasers, together with the development of ureteral access sheaths and the widespread adoption of flexible ureterorenoscopes, have profoundly reshaped the landscape of minimally invasive stone surgery (1). Within this evolving paradigm, retrograde intrarenal surgery (RIRS) has emerged as a cornerstone modality for the management of upper urinary tract calculi, offering high stone-free rates with a favorable morbidity profile. Nevertheless, despite its increasing utilization, the prediction and prevention of perioperative complications remain a significant clinical challenge, particularly with respect to infectious complications.

According to the EAU Guidelines on Urolithiasis, ureteroscopy, including RIRS, is associated with an overall complication rate of 4–25%, with most complications being minor; however, infectious complications remain

among the most clinically relevant adverse events (2). A total of 559 complications following ureterorenoscopy/RIRS were reported in a systematic review, with 474 being minor (Clavien–Dindo grade I–II), mostly fever and febrile urinary tract infection (fUTI) requiring medical treatment (3). In contrast, serious infectious complications such as sepsis and multiorgan failure were less frequent but clinically important. Despite these findings, preoperative risk stratification is still limited by variability in reporting and lack of standardized predictive tools. We hypothesized that the RIRS-FUTI scoring system would provide a reliable and generalizable tool for predicting fUTI following RIRS in an independent patient cohort.

In this context, the present study was conducted to externally validate the new RIRS-FUTI scoring system developed by Senel et al. in 2024 (4), a predictive model for fUTI following RIRS, in an independent patient cohort. By evaluating the performance of this model in a different clinical setting, we aimed to assess its generalizability and potential role in routine clinical practice for preoperative risk stratification and clinical decision-making, leading to improved patient outcomes.

# Material and Methods

### *Ethical standards*

Ethical approval for this study was obtained from the Ethics Committee of our institution, Başakşehir Çam and Sakura City Hospital, prior to study initiation (approval number: KAEK/19.03.2025.101; date: 24.03.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective nature of the study, the requirement for obtaining informed consent was waived by the ethics committee. All data were anonymized before analysis to maintain patient confidentiality.

### *Study Design and Patient Population*

This retrospective external validation study was performed in a tertiary referral institution, Başakşehir Çam and Sakura City Hospital, Department of Urology. The study encompassed all consecutive adult patients who underwent RIRS for upper urinary tract calculi between January 2024 and March 2025. Data on patients were retrospectively collected from electronic medical records and hospital records. Patents aged ≥18 years who underwent RIRS for renal or proximal ureteral calculi were eligible for inclusion. Exclusion criteria were insufficient clinical or laboratory data, bilateral surgeries, patients on antiplatelet therapy and patients with known immunological or hematological diseases that could potentially affect the assessment of the risk of infection. Based on the inclusion and exclusion criteria, the remaining patients defined the final study group and were divided into two groups according to the incidence of postoperative fUTI for comparison of demographic, clinical, and perioperative characteristics (Figure 1).

All patients underwent a standardized preoperative evaluation, including detailed medical history, physical examination, urinalysis, urine culture, and radiological imaging. In accordance with current guideline recommendations, patients with positive preoperative urine cultures received targeted antibiotic therapy, and surgical intervention was deferred until urine sterilization was achieved. Surgical indications and perioperative management were conducted in line with institutional protocols and the 2026 European Association of Urology (EAU) Guidelines on Urolithiasis (2), with particular adherence to recommendations regarding preoperative infection control, imaging-based stone evaluation, and personalized treatment selection based on stone characteristics and patient-related risk factors.

***Definition of Febrile Urinary Tract Infection***

Febrile UTI was defined in accordance with the EAU Guidelines on Urological Infections as the presence of all of the following clinical, microbiological, and systemic criteria (5):

1. Fever ≥38.0°C and,
2. Urinary symptoms, including dysuria, urgency, or increased frequency and
3. Microbiological confirmation, defined as a positive urine culture with bacterial growth of $\geq 10^5$ colony-forming units per milliliter (CFU/mL) and
4. Systemic manifestations of infection, such as chills, malaise, or elevated inflammatory markers (e.g., C-reactive protein or leukocytosis) and
5. Exclusion of alternative sources of infection, ensuring that the febrile episode is attributable to the urinary tract.

Urosepsis is defined according to the Sepsis-3 criteria as sepsis originating from a UTI, characterized by infection associated with an acute increase of ≥2 points in the Sequential Organ Failure Assessment (SOFA) score (6).

***Application of the RIRS-FUTI Score***

The RIRS-FUTI score was calculated for each patient based on the model described by Senel et al. (4) The scoring system was developed using feature selection followed by multivariable logistic regression to identify independent predictors of postoperative fUTI after RIRS. The final model included three variables: hydronephrosis (10 points), history of post-ureterorenoscopy (URS) urinary tract infection (18 points), and preoperative urine leukocyte count >10 per high-power field (18 points). The total score ranged from 0 to 46 and was calculated by summing the individual component scores. Higher scores indicate an increased risk of postoperative fUTI. The model demonstrated good discriminative performance, with an area under the receiver operating characteristic curve of 0.837.

***Sample size***

Due to the retrospective design of the study, all consecutive patients who satisfied the established inclusion and exclusion criteria during the study period were incorporated into the analysis to reduce selection bias and enhance statistical power. Consequently, no formal a priori sample size determination was conducted. The sample size's appropriateness was evaluated according to the number of result occurrences, deemed sufficient for external validation and accurate estimation of model performance indicators, such as discrimination and calibration.

***Statistical analysis***

Statistical analyses were performed in Python (Version 3.15; Python Software Foundation, Wilmington, DE, USA). Normality of continuous variables was assessed using the Shapiro–Wilk test and visual methods such as histograms and Q–Q graphs. Continuous data were reported as mean ± standard deviation or median (interquartile range) where appropriate, and categorical variables were reported as frequencies and percentages.

Comparisons between patients with and without postoperative F-UTI were conducted utilizing the independent samples t-test or Mann–Whitney U test for continuous data and the chi-square or Fisher's exact test for categorical variables, as applicable.

The RIRS-FUTI score was computed for each patient based on the original model without modification. The model's predictive performance was assessed for discrimination and calibration. Discrimination was evaluated using the area under the receiver operating characteristic curve (AUC) accompanied by 95% confidence intervals. Calibration was assessed by calibration plots and the Brier score. The concordance between expected and observed results was evaluated.

The diagnostic efficacy of established cut-off values was assessed by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The ideal cut-off value was evaluated utilizing the Youden index.

A two-tailed p-value of <0.05 was deemed statistically significant.

## Results

A total of 525 patients were included in the study, and 44 (8.4%) of them developed postoperative fUTI. Table 1 compares the baseline and perioperative characteristics of patients who developed and did not develop postoperative fUTI. No significant differences were found between the groups in terms of age, modified Charlson Comorbidity Index, operation time, NLR, presence of diabetes mellitus, history of preoperative double-J stent, history of shock wave lithotripsy, stone localization, urinary system anomaly, and stone-free rate. However, patients who developed postoperative fUTI had a higher PLR (p=0.009), a larger stone size (p=0.050), and a higher proportion of females (p=0.004). Additionally, in this group, the presence of preoperative nephrostomy (p=0.047), hydronephrosis (p=0.047), a positive preoperative urine culture (p<0.001), the presence of >10 leukocytes in urine (p<0.001), and a history of post-ureterorenoscopy UTI (p<0.001) were found to be significantly higher.

**Table 1.** Baseline and perioperative characteristics according to postoperative UTI status

| Variable | No UTI, n=481 | Postoperative UTI, n=44 | p value |
|---|---|---|---|
| Age, years, **mean** ± SD | 48.31 ± 14.32 | 48.52 ± 12.14 | 0.913* |
| Modified CCI score, **median [IQR]** | 1.00 [0.00–2.00] | 1.00 [0.00–2.00] | 0.531‡ |
| Surgery time, min, **median [IQR]** | 55.00 [45.00–62.00] | 49.00 [37.50–60.00] | 0.064‡ |
| NLR, **median [IQR]** | 2.22 [1.62–3.00] | 2.05 [1.99–3.00] | 0.661‡ |
| PLR, **median [IQR]** | 134.00 [101.65–178.50] | 152.48 [126.91–226.50] | **0.009‡** |
| Stone size, mm, **median [IQR]** | 14.00 [10.00–20.00] | 19.00 [12.00–26.25] | 0.050‡ |
| Sex**, n (%)** | | | **0.004§** |
| -Male | 334 (68.9%) | 20 (45.5%) | |
| -Female | 147 (30.6%) | 24 (54.5%) | |
| Diabetes mellitus**, n (%)** | 84 (17.5%) | 9 (20.5%) | 0.771§ |
| Preoperative nephrostomy**, n (%)** | 54 (11.2%) | 10 (22.7%) | **0.047§** |
| Preoperative double-J stent**, n (%)** | 162 (33.7%) | 14 (31.8%) | 0.933§ |
| Preoperative SWL**, n (%)** | 162 (33.7%) | 15 (34.1%) | 1.000§ |
| Hydronephrosis**, n (%)** | 317 (65.9%) | 36 (81.8%) | **0.047§** |
| Positive urine culture**, n (%)** | 106 (22.0%) | 26 (59.1%) | **<0.001§** |
| Urine leukocyte count >10**, n (%)** | 167 (34.7%) | 27 (61.4%) | **<0.001§** |
| Stone location**, n (%)** | | | 0.450§ |
| - Ureter | 125 (26.0%) | 9 (20.5%) | |
| - Renal pelvis | 120 (24.9%) | 13 (29.5%) | |
| - Calyx | 161 (33.5%) | 12 (27.3%) | |
| - Multiple | 74 (15.4%) | 10 (22.7%) | |
| Lower calyx**, n (%)** | 135 (28.1%) | 14 (31.8%) | 0.724§ |
| Middle calyx**, n (%)** | 120 (24.9%) | 11 (25.0%) | 0.955§ |
| Upper calyx**, n (%)** | 27 (5.6%) | 2 (4.5%) | 1.000§ |
| Multiple locations**, n (%)** | 90 (18.7%) | 10 (22.7%) | 0.777§ |
| Urinary anomaly**, n (%)** | 45 (9.4%) | 3 (6.8%) | 0.907§ |
| Postop UTI history**, n (%)** | 6 (1.2%) | 24 (54.5%) | **<0.001ᵖ** |

| | | | |
|---|---|---|---|
| Stone-free status**, n (%)** | 251 (52.2%) | 28 (63.6%) | 0.194§ |

**CCI,** Charlson Comorbidity Index; **IQR,** interquartile range; **NLR,** neutrophil-to-lymphocyte ratio; **PLR,** platelet-to-lymphocyte ratio; **SD,** standard deviation; **SWL,** shock wave lithotripsy; **UTI,** urinary tract infection.

*****: *Student's t-test,* **‡**: *Mann–Whitney U test,* ***§***: *Chi Square test* ***p****:Fischer exact test*

In univariate logistic regression analysis, hydronephrosis (OR: 2.328; 95% CI: 1.058–5.124; p = 0.036), a history of post-ureterorenoscopy urinary tract infection (OR: 95.000; 95% CI: 34.940–258.297; p < 0.001), and the presence of >10 leukocytes in preoperative urine (OR: 2.986; 95% CI: 1.582–5.636; p < 0.001) were found to be significantly associated with the development of postoperative fUTI. In multivariate logistic regression analysis, only a history of post-ureterorenoscopy urinary tract infection (OR: 114.826; 95% CI: 37.803–348.787; p<0.001) and the presence of >10 leukocytes in preoperative urine (OR: 2.940; 95% CI: 1.253–6.898; p=0.013) were identified as independent predictors. Hydronephrosis lost its statistical significance in multivariate analysis (OR: 2.513; 95% CI: 0.887–7.125; p=0.083) (Table 2).

**Table 2.** Logistic regression analyses for predictors of postoperative UTI

| Variable | Univariate OR (95% CI) | p value | Multivariate OR (95% CI) | p value |
|---|---|---|---|---|
| Diabetes mellitus | 1.215 (0.563–2.623) | 0.619 | - | - |
| Hydronephrosis | 2.328 (1.058–5.124) | 0.036 | 2.513 (0.887–7.125) | 0.083 |
| History of post-URS UTI | 95.000 (34.940–258.297) | <0.001 | 114.826 (37.803–348.787) | <0.001 |
| Urine leukocyte count >10 | 2.986 (1.582–5.636) | <0.001 | 2.940 (1.253–6.898) | 0.013 |

**Abbreviations:** CI, confidence interval; hpf, high-power field; OR, odds ratio; URS, ureterorenoscopy; UTI, urinary tract infection.

Calibration analysis of the logistic regression model demonstrated excellent agreement between the predicted probabilities of postoperative fUTI generated by the RIRS-fUTI score and the observed event rates, while the low Brier score (0.0573) indicated good model calibration and overall predictive accuracy (Figure 2).

When postoperative fUTI development rates were evaluated according to the RIRS-FUTI score, it was observed that the risk of infection increased significantly as the score increased. The postoperative fUTI rate was 1.7% in patients scoring 0, 2.5% at 10 points, 8.9% at 18 points, 13.2% at 28 points, 100% at 36 points, and 86.7% at 46 points. The postoperative fUTI rate in the general patient population was 8.4% (44/525) (Table-3).

**Table 3.** Postoperative UTI rate according to original study score

| Score | Total, n | No UTI, n | Postoperative UTI, n | UTI rate |
|---|---|---|---|---|
| 0 | 115 | 113 | 2 | 1.7% |
| 10 | 202 | 197 | 5 | 2.5% |
| 18 | 56 | 51 | 5 | 8.9% |
| 28 | 136 | 118 | 18 | 13.2% |
| 36 | 1 | 0 | 1 | 100.0% |
| 46 | 15 | 2 | 13 | 86.7% |
| **Total** | **525** | **481** | **44** | **8.4%** |

The diagnostic performance of the RIRS-FUTI score was evaluated at different threshold values. A threshold of ≥10 points provided high sensitivity (95.5%) and negative predictive value (98.3%), while sensitivity decreased and specificity gradually increased as the threshold value increased. A threshold of ≥28 points showed a balanced performance between sensitivity (72.7%) and specificity (75.1%). In contrast, threshold values of ≥36 and ≥46 points provided very high specificity (99.6%) and positive predictive value, while sensitivity decreased to 31.8% and 29.5%, respectively (Table-4).

**Table 4.** Diagnostic performance of score cut-offs for predicting postoperative UTI

| Cut-off | TP | FP | TN | FN | Sensitivity | Specificity | PPV | NPV | Accuracy | LR+ | LR− |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ≥10 | 42 | 368 | 113 | 2 | 95.5% | 23.5% | 10.2% | 98.3% | 29.5% | 1.25 | 0.19 |
| ≥18 | 37 | 171 | 310 | 7 | 84.1% | 64.4% | 17.8% | 97.8% | 66.1% | 2.37 | 0.25 |
| ≥28 | 32 | 120 | 361 | 12 | 72.7% | 75.1% | 21.1% | 96.8% | 74.9% | 2.92 | 0.36 |
| ≥36 | 14 | 2 | 479 | 30 | 31.8% | 99.6% | 87.5% | 94.1% | 93.9% | 76.52 | 0.69 |
| ≥46 | 13 | 2 | 479 | 31 | 29.5% | 99.6% | 86.7% | 93.9% | 93.7% | 71.06 | 0.71 |

**FN,** false negative; **FP,** false positive; **LR+,** positive likelihood ratio; **LR−,** negative likelihood ratio; **NPV,** negative predictive value; **PPV,** positive predictive value; **TN,** true negative; **TP,** true positive.

In ROC analysis, the RIRS-FUTI score was found to have good discriminatory performance in predicting postoperative fUTI (AUC=0.809) (Figure 3).

Postoperative urosepsis developed in 1 patient (0.2%). No urosepsis-related mortality was observed during the study period.

## Discussion

In the original derivation study, the RIRS-FUTI score, despite being based on only three routinely available preoperative variables, demonstrated good discriminatory performance (AUC = 0.837). In the present external validation study, the model maintained good discrimination and satisfactory calibration, with postoperative fUTI rates increasing stepwise from 1.7% in patients with a score of 0 to 86.7% in those with a score of 46. Lower score thresholds provided excellent sensitivity and negative predictive value, whereas higher thresholds identified a smaller subgroup of patients at substantially increased risk with high specificity. Collectively, these findings support the RIRS-FUTI score as a simple and clinically applicable tool for preoperative risk stratification before RIRS. The apparent 100% event rate in the 36-point category should be interpreted cautiously because it was based on a single patient. Larger validation cohorts including more high-risk patients are needed to more precisely estimate the true risk associated with this score category.

The predictive performance of the RIRS-FUTI score is biologically plausible because it is based on three clinically relevant preoperative variables: hydronephrosis, a history of post-ureterorenoscopy UTI, and a preoperative urine leukocyte count >10/high-power field. Hydronephrosis may increase the risk of postoperative infectious complications by causing urinary stasis, impaired drainage, and subsequent bacterial proliferation. Similarly, a history of post-ureterorenoscopy UTI may indicate persistent bacterial colonization or an individual susceptibility to recurrent infections following endourological intervention. Likewise, preoperative leukocyturia may reflect subclinical urinary tract inflammation or occult infection, even in the absence of overt clinical symptoms. Consistent with our findings, Kim et al. identified preoperative pyuria as the only independent predictor of fUTI after RIRS, underscoring the importance of preoperative inflammatory findings in identifying patients at increased risk (7). Furthermore, a systematic review and meta-analysis by Bhojani et al. showed that postoperative urosepsis following ureteroscopy is a multifactorial complication, emphasizing the need for careful preoperative risk assessment before endourological surgery (8). The successful confirmation of these predictors in our independent external validation cohort further supports the biological basis of the original RIRS-FUTI model and its potential value in routine clinical practice.

In addition to its predictive performance, the RIRS-FUTI score has important clinical implications in preoperative risk stratification. Since all three variables are routinely assessed as part of standard preoperative evaluation, the score can be easily calculated without the need for additional laboratory tests, imaging, or increased healthcare costs. In our external validation cohort, the ≥10-point threshold showed excellent sensitivity (95.5%) and a high negative predictive value (98.3%), suggesting that the score may be especially useful for identifying patients at low risk for postoperative fUTI. By contrast, higher thresholds (≥36 and ≥46 points) had excellent specificity (99.6%) and positive predictive values of 87.5% and 86.7%, respectively, enabling the identification of a small subgroup of patients at substantially increased risk. Such risk stratification may allow for individualized perioperative management, including optimization of infection control strategies, more intensive postoperative surveillance and more informed clinical decision-making. Moreover, good discrimination and satisfactory

calibration (Brier score = 0.0573) further highlight the RIRS-FUTI score as a simple, practical, and easy-to-apply tool for routine preoperative risk assessment before RIRS.

Our results are consistent with the original derivation study of Senel et al., where the RIRS-FUTI score showed good discriminatory performance (AUC = 0.837) using only three routinely available preoperative variables (4). In our external validation cohort, good discrimination and calibration were observed, indicating the predictive performance was maintained in an independent patient population. Similarly, Qi et al. constructed a nomogram to predict postoperative fever after RIRS with similar discrimination (AUC = 0.807), further emphasizing the importance of preoperative risk prediction models for infectious complications (9). Moreover, a systematic review by the EAU Section of Urolithiasis emphasized that infectious complications after ureteroscopy are multifactorial and highlighted the importance of identifying high-risk patients before surgery to optimize perioperative management (10). These findings together contribute to the evidence regarding the clinical use of the RIRS-FUTI score for routine preoperative risk stratification in diverse patient populations.

The increasing interest in predictive models for infection complications after RIRS reflects the growing emphasis on individualized perioperative management in endourology. Recent studies have proposed both traditional statistical models and machine learning-based nomograms to predict the risk of postoperative infection events, demonstrating encouraging discriminative performance (11, 12). However, most published models have undergone only internal validation, and independent external validation has been limited. Furthermore, a recent systematic review highlighted that calibration, external validation, and assessment of clinical utility are still inconsistently reported, limiting the widespread application of these models in routine practice (12). In this context, our findings provide additional evidence supporting the reproducibility and potential clinical applicability of the RIRS-FUTI score in an independent patient population.

This study has several limitations that should be considered when interpreting the findings. First, its retrospective single-center design may have introduced selection bias and may limit the generalizability of the results to other clinical settings. Second, although the overall cohort was relatively large, the number of postoperative fUTI events remained limited, particularly in the highest-risk score categories, which may have reduced the precision of subgroup estimates. In particular, the apparent 100% event rate observed in the 36-point category should be interpreted cautiously because it was based on a single patient. Residual confounding inherent to retrospective studies also cannot be completely excluded.

Despite these limitations, the study has several important strengths. To our knowledge, this is the first independent external validation of the RIRS-FUTI score in a high-volume tertiary referral center. In addition to confirming the model's discriminatory performance, we performed a comprehensive evaluation of calibration using both calibration plots and the Brier score, providing a more robust assessment of model performance. These findings strengthen the evidence supporting the RIRS-FUTI score as a simple and clinically applicable tool for preoperative risk stratification before RIRS, although further prospective multicenter validation remains warranted.

## Conclusion

In this external validation study, the RIRS-FUTI score demonstrated good discriminative performance for predicting postoperative fUTI. Specifically, a history of post-ureterorenoscopy urinary tract infection and the

presence of >10 leukocytes in the preoperative urine were confirmed as independent predictors. Owing to its simple and readily applicable structure, the RIRS-FUTI score may serve as a practical tool for preoperative risk stratification and individualized perioperative management in patients undergoing RIRS. Nevertheless, further prospective, multicenter studies involving diverse populations are warranted to validate its generalizability and clinical applicability.

## Abbreviations

CI
confidence interval
hpf
high-power field
OR
odds ratio
URS
ureterorenoscopy
UTI
urinary tract infection.

## Declarations

# Ethical approval

for this study was obtained from the Ethics Committee of our institution, Başakşehir Çam and Sakura City Hospital, prior to study initiation (approval number: KAEK/19.03.2025.101; date: 24.03.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki. Due to the retrospective nature of the study, the requirement for obtaining informed consent was waived by the ethics committee. All data were anonymized before analysis to maintain patient confidentiality.

# Author Contribution

T.O., A.E., and H.L.C. conceived and designed the study. T.O., B.D., E.Y., E.O.O., and B.A. were responsible for data acquisition. T.O., A.E. and B.A. performed the statistical analyses, interpreted the findings, and drafted the manuscript. H.L.C. supervised the study and critically revised the manuscript for important intellectual content. All authors contributed to the interpretation of the data, critically reviewed the manuscript for important intellectual content, approved the final version, and agree to be accountable for all aspects of the work.

# Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to institutional and ethical restrictions regarding patient confidentiality but are available from the corresponding author on reasonable request and with permission of the relevant institutional authorities.

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# Figures

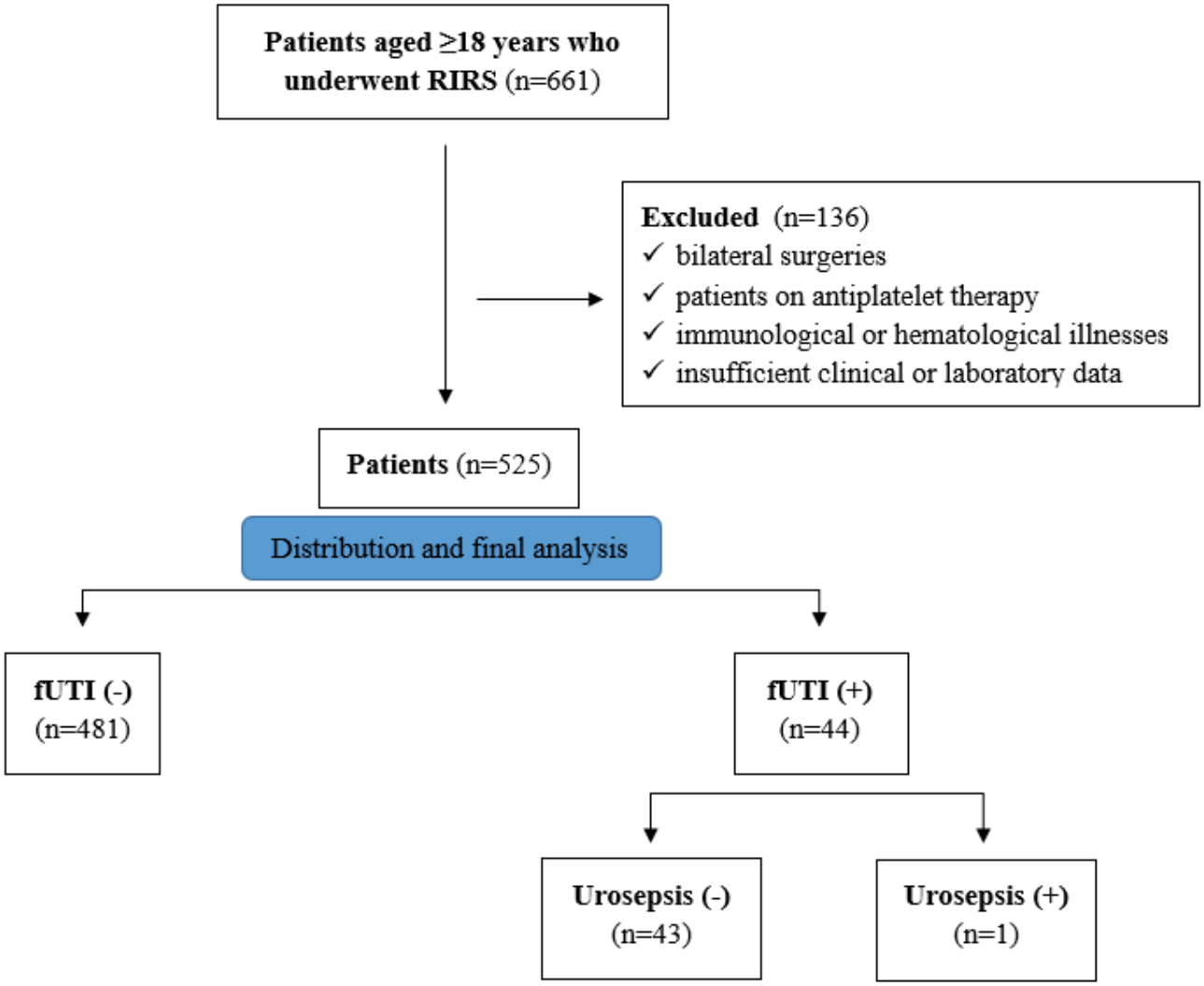



**Figure 1**

Flowchart of the study

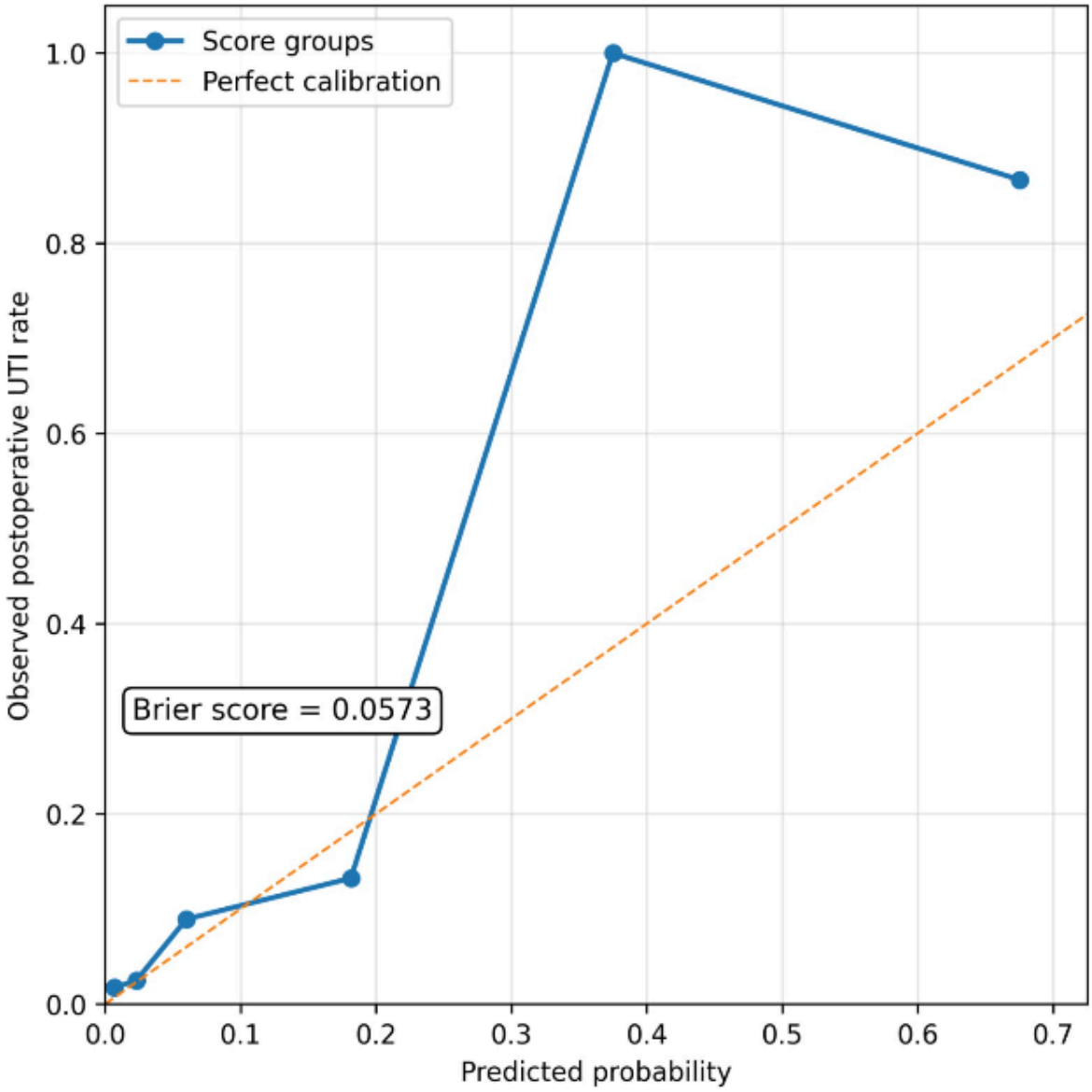



**Figure 2**

Calibration plot of the logistic regression-based RIRS-FUTI model for predicting postoperative fUTI. Calibration plot showing good agreement between predicted and observed probabilities across the spectrum of postoperative fUTI risk.

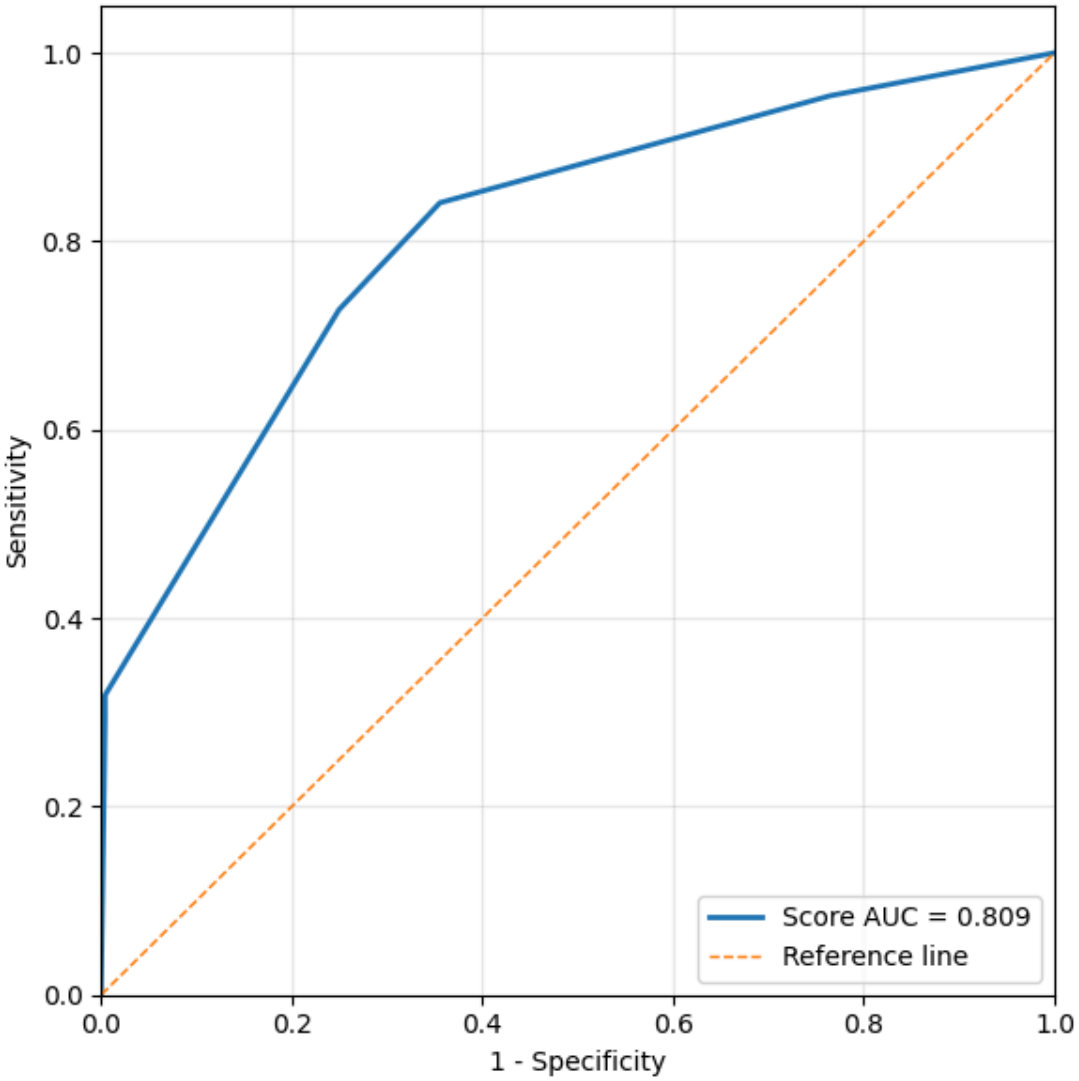



**Figure 3**

ROC curve of the scoring system for predicting postoperative UTI. ROC curve demonstrating good discriminatory performance of the RIRS-FUTI score for predicting postoperative fUTI.