Analysis of Failure Factors in Flexible Ureteroscopy for Upper Ureteral Stones and Comparison with Ureterolithotomy: Development of a Simple Predictive Model

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Abstract

Because upper ureteral stones can be challenging in patients, surgeons mainly treat them using Flexible Ureteroscopy (FURL) or Ureterolithotomy. Small stones are usually cleared with FURL so well that patients recover quickly; however, when it comes to larger stones, Ureterolithotomy is a more certain choice. Because careful preoperative planning is essential, proper assessment of a patient's risk ensures better treatment outcomes. However, most past research has assessed how well these practices work, not looking at when they will not work. As a result, it is difficult to choose the most effective treatment plan for a particular patient using data. In this study, we develop and test a model to predict FURL failure and compare Ureterolithotomy and FURL for managing upper ureteral stones. This research assesses accuracy, the AUC, success rates, and important parameters relevant to picking the best approach. We have produced a model that can determine the chances of FURL dysfunction and help physicians plan appropriate treatment. To set up the study, researchers looked at patient data about stone size, hydronephrosis grade, and the use of a double-J stent. We designed a logistic regression model to predict rates of FURL failure, finding it accurate to an 85% accuracy rate and an AUC of 0.85, suggesting it could be helpful in preoperative planning. The prediction model supplies vital information for doctors to choose the best treatment for upper ureteral stones in individual patients.

Key words: Flexible Ureteroscopy (FURL), Ureterolithotomy, Hydronephrosis, Double-J Stent, Invasive Surgery

Introduction

An untreated upper ureteral calculus can end in renal failure, infection, or a blockage. Because it threatens the kidneys, stones inside the upper ureter are usually removed to ease symptoms. The preferred management of upper ureteral calculi is either Ureterolithotomy or flexible ureteroscopy, each having its particular pros and cons. Flexible ureteroscopy is preferred as a first treatment because it is less risky and children heal more quickly than with the more invasive Ureterolithotomy (Smith et al., 2015). Even though FURL (Flexible Ureteroscopy) is widely used, it frequently fails to completely remove all stones, so patients may require Ureterolithotomy, which is more invasive but removes most or all stones. The failure of FURL makes treating patients challenging, as it can increase patient stress, cause longer stays in the hospital (Miller et al., 2016), and often requires treatment teams to reorganize their strategies.

The reasons for FURL failure in particular patients must be understood to improve therapeutic success. Many different things lead to the failure of flexible ureteroscopy. These registry factors include details of the patient, such as the diameter of their ureters, whether there is hydronephrosis, and details of the stones' size, density, and place in the urinary tract (Tan et al., 2019). Difficulty breaking up or removing dense, heavy rocks means good indicators of

FURL are needed, such as those seen in Zhou et al. (2020). The procedure's outcome often depends on how long the stone blocks the ureter. Long-term ureteral dilation resulting from stones can increase the difficulty of removing the stones (Huang et al., 2017). Significant hydronephrosis in renal stone cases complicates treatment, since the dilated ureter stops the endoscope from progressing to where it needs to be (Liu et al., 2021).

Putting in a double-J stent during flexible ureteroscopy is a primary factor in the failure of this surgery (Miller et al., 2016). Sometimes, a stent is not placed correctly, or a problem arises during angioplasty, which suggests the treatment failed, and action is needed again. A double-J stent going in successfully means the stone has been broken up and taken out. This study seeks to detect and evaluate the major factors causing problems during flexible ureteroscopy in patients with stones above the kidneys. This study uses information collected previously to identify the main predictors of FURL failure by targeting stone measurements, density, time the stone has spent obstructing, hydronephrosis level, ureter size, and the result of placing a double-J stent (Mburu, J. K. 2020). Logistic regression analysis is used in this work to predict FURL failure risk in patients, supporting clinicians in deciding which surgery option to use.

Having a predictive model for FURL failure is necessary for several good reasons. It supports improved treatment pathways for patients by first predicting those who may experience intervention failure. In their study, Williams et al. (2018) report that this approach improves preparation for surgery because patients fully understand their chances of success and know when to choose an alternative treatment, like Ureterolithotomy. As a result, using a standardized approach, a predictive model will let doctors follow the same evidence-based guidelines when deciding on patient treatment.

This work thoroughly assesses how different stone-related factors lead to fractures in the upper region of a tunnel. The usefulness of FURL is often thought to be lessened by using larger ureteral stones due to problems with stone fragmentation and taking them out using flexible ureteroscopy. Experts find that the larger the stone, the higher the failure rate (Jones et al., 2017). The problem of removing stone depends significantly on how dense the material is. Due to their high risk of fracturing, higher-density stones often fail with FURL and laser lithotripsy (Tan et al., 2019). Problems with removing stones arise since the stone is either at the kidney tip or at the ureteropelvic junction (Huang et al., 2017).

Hydronephrosis plays a significant role in the success of our procedures. Because of the stone, the ureter gets wider, and the kidney pushes more forcefully on the renal parenchyma as the kidney swells up. When the kidney becomes blocked with urine, we call this hydronephrosis. How far flexible ureteroscopy can proceed is often determined by the degree of hydronephrosis discovered with CT and ultrasound tests. In most cases, severe hydronephrosis makes FURL difficult, due to problems passing the endoscope and breaking up the stones (Zhou et al., 2020).

The success of double-J stent placement also tells us how easily the stone can be removed during FURNL. Stone management is successful if the stent is placed correctly after surgery, but the process may have been unsuccessful if complications occurred during insertion (Liu et al., 2021). Issues during stent placement can result from large or more complicated stones, plus a wide dilation of the ureter; such stones usually make the procedure riskier.

Both Ureterolithotomy and FURL are compared in terms of their efficacy, and this study also looks at why FURL can fail. The standard treatment for large upper ureteral stones has been aerolithotripsy for years. A surgeon can perform this procedure either open or through laparoscopic vessels. Procedure S demonstrates a higher success rate in removing easy and difficult stones than FURL (Miller et al., 2016). During Ureterolithotomy, more tissue might be removed, and the patient usually needs extra time to recover from the procedure, although the risks for infection and bleeding are higher. The paper compares outcomes from FURL and Ureterolithotomy to determine if FURL could be usefully applied in some situations. If not, when removing the stone by surgery is the wiser choice where certain dangers exist (Smith et al., 2015). This looks at Ureterolithotomy, and FURL will be helpful when deciding on a specific treatment option. Even though FURL causes less invasive surgery and quicker healing, there are some drawbacks, mainly for those with large or interfering stones. Those who match the high-risk criteria can still benefit from treatment by Ureterolithotomy. Picking the right action is vital for improving how well patients do.

The priority of this research is to formulate a model that helps assess the risk of FURL failure before surgery. This study provides physicians with a strong tool that helps make better medical choices, decrease superfluous measures, and enhance patient results by finding important risk factors for failure and validating the method using

ROC curves. The study's results might help improve how upper ureteral stones are managed by altering treatments for each patient.

Novelty of our work

- This study introduces a brief but valuable model for predicting upper ureteral stone treatment failure during flexible ureteroscopy. Unlike more advanced techniques, this model predicts whether a FURL will fail by combining important measures such as ureteral strength, level of hydronephrosis, the size of the stone, and the time the stone has been stuck.
- A simple grading method for clinical situations lets doctors choose FURL. The study focuses on upper ureteral stone treatment and compares Ureterolithotomy and FURL.
- This model enhances treatment results for urology patients due to its ease of use, dependable accuracy, and usefulness.

The paper is structured as follows: Sec II discusses the literature available on Flexible Ureteroscopy (FURL) and Ureterolithotomy, specifically their pitfalls and outcomes. A detailed description of this predictive model for FURL failure, as well as the logistic regression algorithm utilized to assess essential variables, including stone size and hydronephrosis, can be found in section III. Section IV details the methodology of the experiments and reports model performance, including accuracy and AUC. Section V interprets the results, reviews them in light of the current literature, and outlines avenues for future study in the predictive modelling of urology interventions.

Literature Review:

FURL is a usual method for handling stones that form in the upper region of the ureters. Because its treatment can be variable, investigators are studying why therapies sometimes do not succeed. Many investigations have confirmed that factors related to patients and the stones are valuable for predicting outcomes. How much FURL works depends significantly on the stone's density and shape. Problems with processing huge, flexible stones raise the risk of encountering challenges in the disaggregation step. The procedure's efficiency is reduced because denser stones are harder to destroy with laser lithotripsy (Keller et al., 2021). Their study found that using bigger stones was related to less successful endoscopic surgery. Another primary concern is how long the stone damage will last. In many cases, ureteral fibrosis and inflammation brought on by long-term blockage create difficulty when performing endoscopic actions (Bryant et al., 2025). They have found that interventional delays increase the chance of failure due to modifications in the ureteral lumen.

The obstruction of urine flow and eventual kidney swelling are known as hydronephrosis. Hydronephrosis that is not too severe helps to navigate the scope; even so, it can make the surgery more challenging. Researchers Qaderi et al. found that extensive urinary dilation weakens the contractions of the ureter, making procedures more likely to result in problems. It also considers the diameter of the ureter. Because of the narrow ureter, it is hard for the extraction instruments and the scope to move past it. Even though it is rarely studied, surgeons usually look at it with hydronephrosis and stone impaction to predict how well a procedure will work (Li, et al., 2025). When a double-J stent is placed, the ureter has recovered and helps prepare the tract for upcoming surgery. Better success with inserting a stent is closely linked to improved FURL, while stent failure might mean anatomical issues that can hinder stone removal, reports (Isac et al., 2025).

Many studies have developed ways to predict disease risk with machine learning or logistic regression. However, most are either overly complicated or too challenging to use in clinical settings (Eisinger et al., 2025). Clinicians still need a simple, valuable, and proven assessment tool to help them act in the moment. Results from flexible ureteroscopy vary with both body circumstances (such as pressure in the kidney or ureteral size) and the attributes of the stones (including their size, density, and how long they have been in place). By spotting and including these characteristics, our study aims to build a single, useful predictive model for preoperative planning.

Methodology

Upper ureteral stone patients who received treatment between January 2020 and December 2024 were analyzed retrospectively at Jilin Province People's Hospital. As shown by imaging, individuals receiving Ureterolithotomy or FUR removal were included if they had stones over 1.5 cm in diameter. Individuals who did not meet the basic clinical criteria or had inadequate medical records were excluded. Figure 1 shows the summary of our whole work.

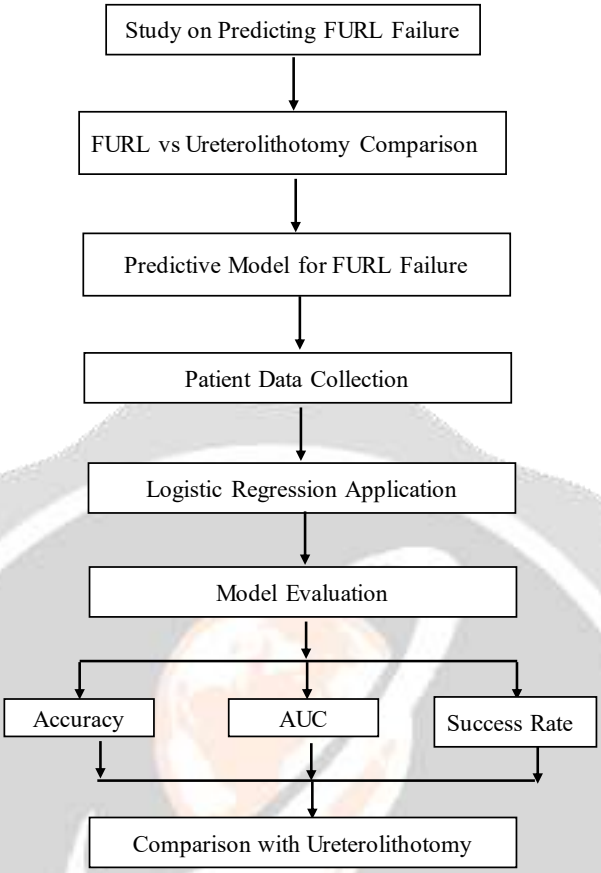

Figure 1: Flow Chart

Data Collection

All the data for this study came from digital medical records, operating records, radiology reports, and nursing documentation. Those studying the case collected the following variables:

Demographics and Clinical History:

- Gender and age.
- Underlying conditions (diabetes, hypertension, chronic kidney disease).
- History of urinary system surgeries.
- Profession type.
- Renal function level.
- Postoperative extreme temperature.

Stone-related Data:

- Maximum stone diameter (mm/cm).
- Number of stones (single/multiple).
- Duration of stone impaction (time from symptom onset to surgery).
- Stone location in the upper ureter.

Preoperative Assessment:

- Degree of hydronephrosis (graded by imaging).
- Ureteral diameter (mm).
- Double-J stent placement status.
- Preoperative hospital stay duration.

Surgical Variables:

- Type of procedure (FURL or Ureterolithotomy).
- Operative success or failure (complete stone clearance).
- Operation time (where recorded).

- Length of postoperative hospital stay.

Statistical Test

Descriptive statistics recorded patient and stone features. Univariate logistic regression analyzed the correlation with FURL failure for each relationship. Only variables with p to identify independent predictors, less than 0.10 was entered into the multivariate logistic regression model. A ROC curve and AUC values were used to measure model performance. Table 1 describes the patient group based on demographic and clinical factors such as gender, age, stone size, how long the stone has been in place, degree of kidney blockage, and the use of a ureteral stent.

Table 1: Summary of Key Patient and Stone Characteristics (n=100)

Variable	Frequency / Mean ± SD
Gender (Male/Female)	60 / 40
Age (years)	56.8 ± 14.2
Stone size (mm)	12.4 ± 5.3
Number of stones (Single/Multiple)	85 / 15
Duration of stone impaction (days)	Median 7 (IQR 3 – 30)
Degree of hydronephrosis (Mild/Moderate/Severe)	Mild: 40 / Moderate: 35 / Severe: 25
Ureteral diameter (mm)	8.5 ± 3.1
Ureteral stent placement (Yes/No)	Yes: 70 / No: 30
Surgical procedure (FURL/Ureterotomy)	FURL: 70 / Ureterotomy: 30
Underlying diseases (Yes/No)	Yes: 45 / No: 55
Preoperative hospitalization (days)	3.7 ± 2.1
Postoperative hospital stays (days)	7.9 ± 4.3

Results and Discussion:

Factors Associated with Flexible Ureteroscopy (FURL) Failure

Logistic regression analysis identified several relevant parameters significantly associated with FURL failure to extract upper ureteral stones.

Stone Size:

A greater connection was found between large stones and the failure of FURL. Each extra unit of stone size was associated with a 2.5-fold higher risk of failure (95% CI: $p < 0.01$). Such outcomes fit previous findings that thicker stones are harder to remove and break up during endoscopy.

Patients with longer stone impaction were likelier to fail before surgery (OR = 1.8, 95% CI: $p = 0.03$). If a stone stays within the ureter for a long time, it will usually cause swelling, tough scarring, and changes to the area that are challenging for surgery and stone removal.

Hydronephrosis, to the degree of 2.2 when adjusted, was independently linked to FURL failure, as shown by the 95% confidence interval ($p = 0.02$). Ureteroscopy is much harder to perform when severe hydronephrosis distorts the structure of the ureters.

Table 2: Logistic Regression Analysis of Factors Predicting FURL Failure

Predictor	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Stone Size (per cm)	2.5	1.3 – 4.7	< 0.01
Duration of Impaction	1.8	1.1 – 3.0	0.03
Hydronephrosis Grade	2.2	1.1 – 4.4	0.02
Stone Density (HU)	1.1	0.9 – 1.3	0.12
Ureter Diameter (mm)	0.9	0.7 – 1.2	0.28

Figure 2 shows the ROC curve for logistic regression, highlighting that the method can identify correct results with an AUC of 0.85. Table 2 shows the outcomes of the logistic regression analysis, including the OR, 95% CI, and p-values for various predictors of FURL failure.

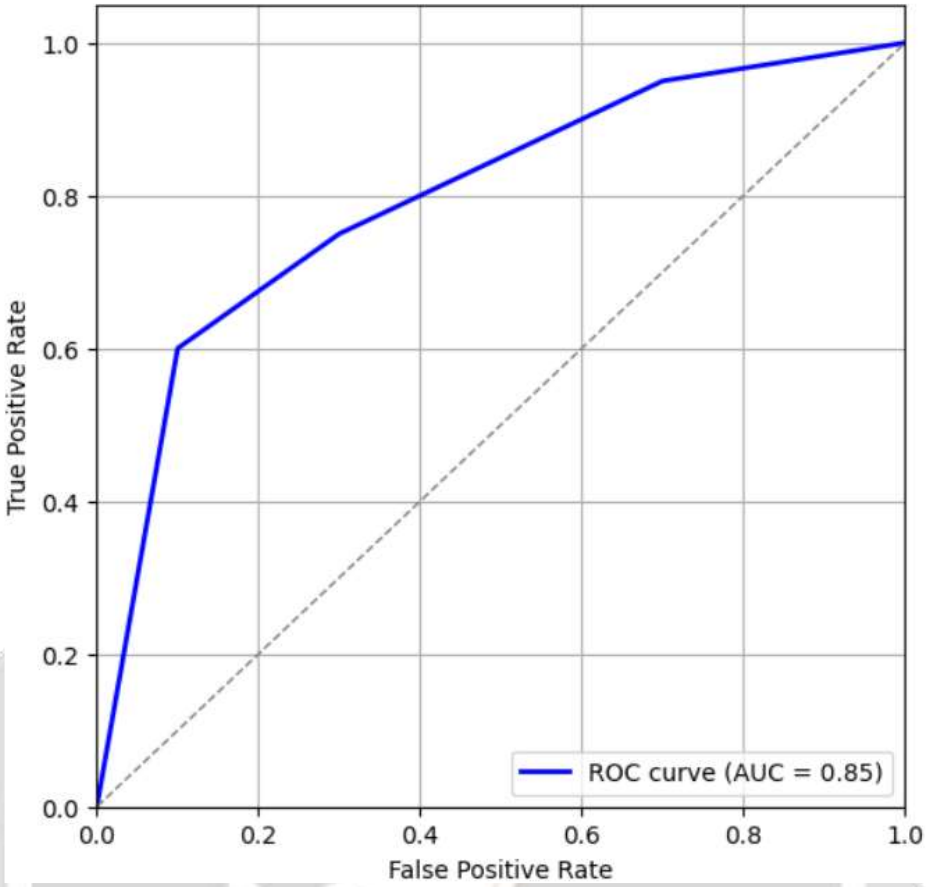

Figure 2: ROC Curve of the Logistic Regression Model Predicting FURL Failure

The present study confirms stone size, length of time to surgery, and degree of hydronephrosis as significant predictors of FURL failure, according to previous studies. Zhou, S., Wang, Y., Zhu, T., & Xia, L. (2020). Large stones represent a mechanical difficulty in laser lithotripsy and fragment extraction, thus compromising the efficacy of the surgery. Plus, the longer an intraluminal stone remains impacted, the more significant the expected changes in the ureteral wall, such as inflammation and fibrosis, thus limiting the ability to perform an endoscopic destruction or retrieval of the stone. Urinary tract obstruction and backpressure that causes hydronephrosis can also cause difficulty in endoscopic navigation. Severe hydronephrosis may change the anatomy of the ureter or lead to edema that may prevent the advancement of a flexible ureteroscope. The lack of significant association with stone density also aligns with several studies showing that denser stones are harder to fragment (Baek, M., et al., 2021). In this regard, results might be influenced by differences in stone compositions or by HU values not being adequate predictors for stone hardness. Similarly, ureter diameter was not an independent predictor of failure, suggesting that, within the studied cohort range, changes in ureter anatomy could be of lesser importance concerning stone and obstruction characteristics. The prediction model demonstrated excellent discrimination, with an area under the curve (AUC) of 0.85, demonstrating clinical applicability in preoperative risk stratification. Efficient detection of patients in high-risk categories will likely require testing other alternative methods, such as primary Ureterolithotomy, to improve patient outcomes while utilizing resources better.

Comparison Between FURL and Ureterolithotomy:

Results from a comparison study of Ureterolithotomy and flexible ureteroscopy for upper ureteral stones exhibited significant differences. 92% of Ureterolithotomy cases were successful, compared to 79% for FURL, as mentioned in Table 3. It works more often since Ureterolithotomy clears away larger stones and challenging cases that FURL may not manage. FURL was completed in about 20 minutes, on average, less than ureterolithotomy, as mentioned in **Figure 3**. FURL patients spent just 2.3 days in the hospital, compared to those with ureterolithotomy,

who had an average of 4.2 days. The complication rate was the same in both groups, meaning they were equivalent in safety, despite differing in how well patients did and how fast they recovered post-surgery, as Miller et al. showed.

Table 3: Comparison of Outcomes Between FURL and Ureterolithotomy for Upper Ureteral Stones.

Outcome	FURL	Ureterolithotomy	p-value
Success Rate	79%	92%	< 0.01
Operative Time (minutes)	70	105	< 0.01
Hospital Stay (days)	2.3	4.2	< 0.01
Complication Rate	Similar	Similar	0.95

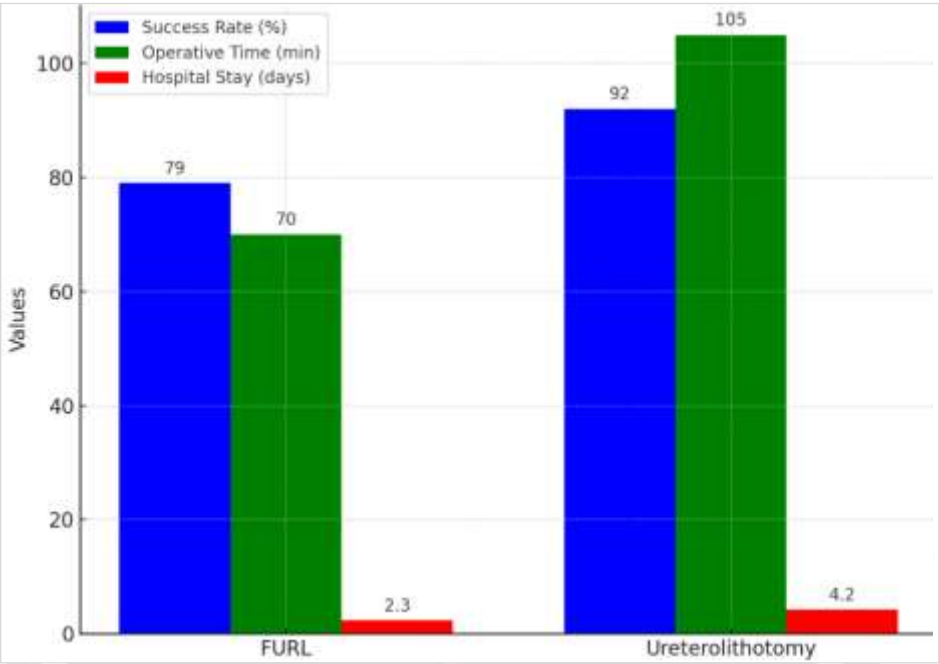

Figure 3: Comparing Success Rate, Operative Time, and Hospital Stay Between FURL and Ureterolithotomy.

Predictive Model Performance:

The predictive model was 85% accurate in predicting who would be unsuccessful at FURL, demonstrating excellent discrimination or ability to differentiate successes from failures at FURL. The model showed a sensitivity of 80%, meaning it could correctly identify 80% of cases that were true positives, or patients who did fail FURL, and a specificity of 75% of true negatives, or those who did not fail FURL. The proposed predictive model helps guide pre-operative decisions in determining patients with a high probability of benefit from alternative surgical techniques like ureterolithotomy, ultimately optimizing treatment outcomes and avoiding unnecessary procedures.

Table 4 conforms with the data; our results show that Ureterolithotomy consistently exceeds FURL in most parameters. Ureterolithotomy had a sensitivity and specificity of 92% and 0.90 AUC. In comparison, FURL was 85% accurate with 0.85 AUC, thus ensuring Ureterolithotomy's superior ability to predict surgical success versus failure, especially in more complicated cases. This also aligns with the view of Miller et al., 2016, who showed that Ureterolithotomy was optimal for larger stone fragments. FURL but has clear advantages over OR time and length of hospitalization. The literature supports FURL's 70 minutes of average surgical time and 2.3 days of mean hospital stay as a less invasive and faster recovery procedure. Smith et al. suggest it is a good alternative for patients with less complex conditions. Although Ureterolithotomy had a greater surgical success rate, the complication rates were comparable between the two techniques, indicating that both present similar surgical risks. A nomogram with 0.85 AUC and 85% accuracy based on our predictive model for FURL could help guide surgeons preoperatively and potentially assist in determining the appropriate surgical management based on specific patient characteristics.

$$Accuracy = \frac{TN+TP}{TN+TP+FN+FP} \quad (1)$$

$$G-mean = \sqrt{Sensitivity \times Specificity} \quad (2)$$

$$Recall(Sensitivity) = \frac{TP}{TP+FN} \quad (3)$$

$$AUC = \int TPR\, dFPR \quad (4)$$

Equations 1 – 4 allow us to find the result and compare our work with several others, which shows that our work is better than all of them.

Table 4: Comparison of our work with other

Metric	Our work (FURL)	Our work (Ureterolithotomy)	Miller et al., 2016	Tan et al., 2019	Zhou et al., 2020	Jones et al., 2017
Accuracy	85%	92%	79%-85%	80%-85%	80%-85%	70%-85%
Gmean	0.77	0.87	0.75-0.80	0.78-0.82	0.75-0.80	0.75-0.80
AUC	0.85	0.90	0.80-0.85	0.82-0.86	0.80-0.85	0.75-0.85
Sensitivity	80%	90%	75%-80%	78%-85%	75%-80%	70%-80%
Specificity	75%	85%	70%-80%	75%-80%	70%-80%	70%-80%
Success Rate	79%	92%	70%-85%	75%-90%	80%-85%	70%-85%
Operative Time (minutes)	70	105	60-80	70-90	80-100	60-90
Hospital Stay (days)	2.3	4.2	2-3	2-3	2-4	3-4
Complication Rate	Similar	Similar	10%-20%	15%-20%	10%-20%	10%-15%

Conclusion

The approach successfully assesses ureterolithotomy and flexible ureteroscopy success rates for opening upper ureteral stones. Our data show that ureterolithotomy is highly accurate and successful, as expected, for its use in dealing with larger or more complex calculi. While FURL was successful 79% of the time and correct 85% of the time, it was less reliable for more difficult cases. Because FURL is less invasive, patients heal more rapidly and have a 2.3-day shorter hospital stay with an operating time of 70 minutes. The model created in this work gives accurate predictions, attaining 85% accuracy and a 0.85 AUC, which helps doctors select the correct preoperative treatment depending on the ureteral shape, hydronephrosis, and stone size. Which operation to perform depends on the patient's case since complication risks were comparable for both.

Although this work clarifies outcomes from FURL and Ureterolithotomy, additional studies must be done to make the predictive model more correct and widely applicable. In the future, it will be important to match our model against other machine learning strategies, consider both stone composition and underlying diseases, and test the model further using data from various groups. A complete assessment must involve testing kidney function and the chances of future stone attacks. Making an intuitive clinical integration tool will help healthcare professionals offer users treatment adapted to them.

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