Research Square

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External validation of the NUM-score for guiding imaging decisions after febrile urinary tract infection in children

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Research Article

Keywords: Urinary Tract Infections, Vesico-Ureteral Reflux, Child, Diagnostic Imaging, Risk Assessment, Predictive Value of Tests

Posted Date: July 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10449685/v1

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Abstract

Purpose

To validate the performance of the NUM-score for stratifying the risk of nephrourological malformations (NUM) in children with febrile urinary tract infection (fUTI), and to assess its ability to predict clinically relevant malformations requiring treatment (NUMRT) and guide imaging decisions.

Methods

We conducted a retrospective observational study including 235 pediatric patients under 16 years old with fUTI evaluated in a tertiary care emergency department. Patients were stratified into low-, moderate-, and high-risk groups according to the NUM-score. Diagnostic performance for predicting NUMRT and guiding imaging decisions was assessed at two predefined thresholds: indication for renal-bladder ultrasound (RBUS) and indication for voiding cystourethrography (VCUG).

Results

The prevalence of NUMRT was 5%, 21%, and 54% in the low-, moderate-, and high-risk groups, respectively. For RBUS indication (moderate/high vs. low risk), the NUM-score showed high sensitivity (90%) and negative predictive value (95%). For VCUG indication (high vs. moderate risk), specificity was 95%. Overall, 35% of RBUS examinations could have been avoided, with only four missed NUMRT cases, all diagnosed after a subsequent UTI episode. Notably, 33% of patients with normal RBUS had vesicoureteral reflux on VCUG.

Conclusion

The NUM-score accurately stratifies the risk of nephrourological malformations and identifies patients with clinically relevant disease. It may support a more selective and efficient use of imaging after fUTI, reducing unnecessary investigations while ensuring appropriate identification of patients requiring further evaluation.

BACKGROUND

Febrile urinary tract infection (fUTI) in the pediatric population often represents the first clinical manifestation of underlying nephrourological malformations (NUM), which are present in approximately 10–30% of patients [1–3]. Identifying these cases is essential, as some may benefit from specific medical or surgical interventions. However, most anomalies follow a benign course or resolve spontaneously, as occurs in approximately 80% of low-grade vesicoureteral reflux (VUR), raising questions about the need for systematic investigation in all patients [4–6].

Imaging studies play a central role in this context. Renal-bladder ultrasound (RBUS) is an accessible, non-invasive, and radiation-free technique that allows evaluation of renal and urinary tract anatomy. In contrast, voiding cystourethrography (VCUG) is an invasive procedure requiring bladder catheterization and exposure to ionizing radiation, and remains the gold standard for diagnosing VUR and lower urinary tract obstruction [7]. Nevertheless, both modalities have limitations. Routine ultrasound after a first episode of fUTI yields a high proportion of normal findings, exceeding 80% in some series, which questions its universal use [2, 8, 9]. Furthermore, VCUG involves radiation exposure and should therefore be reserved for selected cases [7].

In this setting, there is no clear consensus regarding the diagnostic approach following fUTI. Recommendations from different clinical guidelines are heterogeneous and largely based on expert opinion. While some societies advocate routine RBUS after the first episode [10–12], others support a more selective approach [13–16]. Similarly, the indication for VCUG varies widely, depending on factors such as patient age, recurrence of infection, causative microorganism, or ultrasound findings [11, 13–16], with some guidelines even recommending systematic use in specific age groups [10]. This variability reflects the ongoing uncertainty and highlights the need for tools that allow individualized decision-making regarding imaging studies.

In addition, the relatively low proportion of clinically significant malformations, estimated at around 3% [2], underscores the importance of avoiding unnecessary investigations. The indiscriminate use of imaging not only increases healthcare costs and workload but also exposes patients to potential adverse effects [6, 8, 9].

In this context, a clinical-analytical predictive model (NUM-score) has recently been developed to stratify patients with fUTI according to their risk of NUM [1]. The score incorporates readily available clinical and laboratory variables, including age, history of previous UTI, causative microorganism, inflammatory markers such as procalcitonin, and the presence of acute kidney injury. It classifies patients into low-, moderate-, and high-risk groups, with reported malformation prevalences of 10%, 35%, and 93%, respectively. Based on this stratification, a targeted diagnostic algorithm has been proposed to optimize the use of imaging studies by avoiding unnecessary investigations in low-risk patients while prioritizing more comprehensive evaluation in higher-risk patients.

However, before its implementation in clinical practice, external validation in independent populations is essential to confirm its diagnostic performance and generalizability across different clinical settings.

Therefore, the aim of this study was to externally validate the NUM-score and assess its diagnostic performance in an independent cohort of pediatric patients with fUTI, evaluating its ability to predict nephrourological malformations requiring medical or surgical treatment (NUMRT) and to guide imaging decisions.

METHODS

Study design

We conducted a retrospective observational study including all patients younger than 16 years diagnosed with febrile urinary tract infection (fUTI) in the Emergency Department (ED) of a tertiary care hospital between December 1st, 2020, and December 31st, 2023.

Population

Inclusion criteria were: (1) diagnosis of fUTI, (2) age < 16 years, (3) availability of blood tests at ED admission, and (4) performance of RBUS with a minimum follow-up of 2 years.

Exclusion criteria included: (1) previously known urinary tract malformations, (2) previous impaired renal function, (3) chronic conditions requiring treatment with drugs affecting electrolyte balance (e.g., diuretics or angiotensin-converting enzyme inhibitors), (4) kidney transplant recipients, (5) immunodeficiency, and (6) patients already receiving treatment for fUTI.

For patients with more than one fUTI episode during the study period, only the first episode was included. In some cases, this episode was not the first patient's UTI in their lifetime.

Variables

The primary outcome was the presence of nephrourological malformations requiring treatment (NUMRT). A secondary outcome was the presence of any nephrourological malformation (NUM).

Clinical variables included sex, age at the current episode, age at first UTI, history of recurrent UTIs, fever duration, and maximum temperature (reported by caregivers or recorded in the ED). Laboratory and microbiological variables included serum C-reactive protein (CRP), procalcitonin (PCT), creatinine levels, isolated microorganisms, and blood culture results. Imaging findings (RBUS and VCUG) and treatment were also recorded.

Definitions

- **fUTI**: temperature ≥ 38°C with compatible urinalysis (leukocyturia and/or nitrituria) and culture-confirmed bacteriuria (> 1,000 CFU/mL in suprapubic aspiration, > 10,000 CFU/mL in catheterized samples, or > 100,000 CFU/mL in clean-catch samples).
- **Nephrourological malformation (NUM)**: defined as significant urinary tract dilatation, vesicoureteral reflux (VUR), duplex system with pyelectasis, neurogenic bladder with VUR, posterior urethral valves, parenchymal malformations (e.g., horseshoe kidney), and polycystic kidney disease. Urinary tract dilatation was classified according to the Urinary Tract Dilatation Classification System, considering abnormalities >P1. VUR was graded according to the International Reflux Grading System.

- **Nephrourological malformation requiring treatment (NUMRT)**: nephrourological malformations requiring either surgical correction or long-term antibiotic prophylaxis (defined as ≥ 2 years), based on clinical decision during follow-up.
- **Moderate acute kidney injury (AKI)**: serum creatinine > 2 times the age-specific median, using reference values described by Pottel et al. [17], given the lack of baseline creatinine in most pediatric patients.
- **Recurrent UTI**: ≥1 previous UTI episode.

Study protocol

According to institutional protocol, all patients with suspected fUTI undergo blood testing in the ED and RBUS after microbiological confirmation. VCUG is performed in cases of urinary tract dilatation, imaging findings suggestive of pyelonephritis, or recurrent UTI. Additional imaging is performed at the clinician´s discretion. All imaging studies are conducted by experienced pediatric radiologists.

Statistical analysis

Data were analyzed using Microsoft Excel and SAS version 9.4. Quantitative variables are presented as mean and standard deviation (SD) or median and interquartile range (IQR), and qualitative variables as absolute and relative frequencies.

Statistical significance was set at $p < 0.05$. Patients were grouped into NUMRT and non-NUMRT categories. Continuous variables were compared using Student's t-test or Mann–Whitney U test, and categorical variables using the chi-square test with Yates' correction. A complete case analysis was performed.

Patients were also stratified into low-, moderate-, and high-risk groups according to the NUM-score [1]. The diagnostic performance of the NUM-score for predicting NUM was evaluated at two predefined decision thresholds reflecting clinical decision-making: (1) indication for RBUS, comparing low-risk versus moderate/high-risk groups, and (2) indication for VCUG, comparing high-risk versus moderate-risk groups. Sensitivity, specificity, positive and negative predictive values (PPV, NPV), and likelihood ratios (LR + and LR–) were calculated for each threshold.

RESULTS

A total of 881 patients were diagnosed with fUTI during the study period, of whom 235 met the inclusion criteria (Fig. 1).

Sixty-four percent were male (150/235), with a median age of 7 months (IQR: 3–15). Mean temperature was 39.1°C (SD 0.8), and median fever duration at presentation was 24 hours (IQR: 12–72). Most patients (91.5%) had no prior UTI.

The most frequently isolated pathogen was *Escherichia coli* (92%), followed by *Enterococcus spp.* (3%), *Klebsiella spp.* (3%), *Proteus spp.* (1.3%), *Pseudomonas spp.* (0.8%), and *Citrobacter spp.* (0.4%). Of 219 blood cultures obtained, 8 (3.7%) were positive, all yielding *E. coli*. Coagulase-negative *Staphylococcus* was detected in 8 cultures (3.7%) and considered contamination.

Median CRP was 82 (IQR: 37–144), and median PCT was 0.82 (IQR: 0.27–3.95). Acute kidney injury was observed in 4.7% of patients, with moderate AKI in 0.9%.

According to the NUM-score, 83 patients (35%) were classified as low risk, 139 (59%) as moderate risk, and 13 (6%) as high risk.

All patients underwent RBUS at a median of 8 days after diagnosis (IQR: 1–74), and 84 (36%) underwent VCUG. RBUS was normal in 60% of cases, while 9% showed significant urinary tract dilatation (UTD >P1). The remaining 31% presented mild pyelectasis or findings suggestive of pyelonephritis. Among VCUG studies, 64% were normal, and the remainder showed VUR. Notably, 33% of patients with VUR had a normal RBUS.

Overall, 51 patients (22%) were diagnosed with a NUM. Table 1 summarizes the types of malformations and their distribution according to the NUM-score.

Table 1
Distribution of nephrourological malformations according to NUM-score risk categories

NUM-score classification		**Low-Risk**	**Moderate-Risk**	**High-Risk**	**p Value**
		N = 9/83 (11)	**N = 32/139 (23)**	**N = 10/13 (77)**	
Urinary tract dilatation	**UTD >P1**	6 (7)	11 (8)	4 (31)	0.018
Vesicoureteral reflux	**grade I**	3 (4)	21 (15)	6 (46)	0.011
	grade II	0	0	0	
		1	10	1	
	grade III	0	8	1	
	grade IV	2	1	3	
	grade V	0	2	1	

Data are presented as absolute frequencies with the percentage in parentheses. Urinary tract dilatation was classified according to the Urinary Tract Dilatation Classification System, including children with a grade greater than P1, which encompasses abnormalities such as anterior-posterior renal pelvic diameter ≥ 15 mm or peripheral calyceal dilation, additional ureteral dilation, abnormal renal echogenicity or cysts, or bladder abnormalities, regardless of anterior-posterior renal pelvic diameter measurement. Vesicoureteral reflux was classified according to the International Grading System.

The diagnostic performance of the NUM-score for predicting NUM at the predefined decision thresholds is shown in Table 2. For the indication of renal-bladder ultrasound (moderate/high vs. low risk),

sensitivity was 90% (95% CI: 76.3–97.2) and specificity 40.5% (95% CI: 33.6–47.8). For the indication of VCUG (high vs. moderate risk), sensitivity was 19.4% (95% CI: 8.8–36) and specificity 94.8% (95% CI: 89.1–98.1). Positive and negative predictive values and likelihood ratios for both thresholds are detailed in Table 2.

Table 2
Diagnostic performance of the NUM-score for guiding imaging decisions after febrile urinary tract infection

Decision Threshold	Sensitivity	Specificity	PPV	NPV	LR+	LR−
VCUG (High vs. Moderate risk)	19.4% (8.8–36)	94.8% (89.1–98.1)	0.538 (0.251–0.808)	0.791 (0.714–0.856)	3.759 (1.350–10.470)	0.849 (0.720–1.003)
Ultrasound (High/Moderate vs. Low risk)	90% (76.3–97.2)	40.5% (33.6–47.8)	0.237 (0.172–0.313)	0.952 (0.881–0.987)	1.513 (1.295–1.767)	0.247 (0.096–0.635)

Diagnostic performance of the NUM-score for predicting nephrourological malformations (NUM) at two decision thresholds: (1) indication for renal-bladder ultrasound (moderate/high vs. low risk) and (2) indication for voiding cystourethrography (VCUG) regardless of ultrasound findings (high vs. moderate risk). Data are presented as point estimates with 95% confidence intervals in parentheses. PPV: positive predictive value; NPV: negative predictive value; LR+: positive likelihood ratio; LR−: negative likelihood ratio.

Among patients with NUM, 40 (77%) required treatment (NUMRT), including surgical intervention in 14 cases (27%). The proportion of patients requiring treatment increased across NUM-score risk categories. Table 3 compares patients with and without NUMRT according to NUM-score risk categories.

Table 3
Distribution of patients with nephrourological malformations requiring treatment (NUMRT) according to NUM-score risk categories

NUM-score classification	Non-NUMRT N = 195	NUMRT N = 40
Low risk (< 2 points)	75 (95)	4 (5)
Moderate risk (2–6 points)	110 (79)	29 (21)
High risk (> 6 points)	6 (46)	7 (54)

Non-NUMRT includes patients without nephrourological malformations or with mild abnormalities not requiring treatment. NUMRT includes patients with nephrourological malformations requiring medical or surgical treatment. Data are presented as absolute frequencies with the percentage in parentheses (%). Differences between groups were statistically significant (chi-square test, $p < 0.001$).

DISCUSSION

The present study validates the ability of the NUM-score to stratify pediatric patients with fUTI according to their risk of NUM and to guide the indication of imaging studies. In our cohort, the prevalence of malformations requiring treatment (NUMRT) was 5% in low-risk patients, compared with 21% in the moderate-risk group and 54% in the high-risk group. Furthermore, a high-risk NUM-score showed high specificity (95%) for identifying patients who should undergo VCUG, regardless of RBUS findings, whereas a low-risk score demonstrated a high negative predictive value (95%) for ruling out the need for imaging studies.

The diagnostic approach following an episode of fUTI remains controversial, with considerable variability among clinical guidelines. While some scientific societies recommend routine ultrasound after the first episode [10, 11], others, such as NICE [14] or KHA-CARI [16], advocate a more selective strategy. Similarly, the indication for VCUG varies widely depending on factors such as age, recurrence of infection, causative microorganism, or ultrasound findings [11, 13–16], with some guidelines recommending its systematic use in specific age groups [10]. This heterogeneity reflects the lack of standardized, evidence-based criteria that are easily applicable in clinical practice, which may lead to both overuse and underuse of imaging studies [9, 18].

In this context, several predictive models have been developed combining clinical, laboratory, microbiological, and even radiological variables to identify patients at higher risk of nephrourological malformations [19–22]. However, most of these models have shown limited predictive performance, with areas under the curve below 0.8. The NUM-score [1] is, to date, the only clinical-analytical model demonstrating adequate predictive performance (AUC ≥ 0.8), with the additional advantage of not including radiological variables, making it particularly useful for guiding imaging decisions at the initial clinical evaluation.

The NUM-score is based on readily available clinical and laboratory parameters and classifies patients into three risk categories (low, moderate, and high), proposing a management algorithm according to this stratification (Fig. 2). In low-risk patients, clinical follow-up without initial imaging is suggested; in moderate-risk patients, RBUS is recommended, with VCUG reserved for those with abnormal ultrasound findings; and in high-risk patients, both RBUS and VCUG are recommended regardless of ultrasound results. Our findings support these recommendations. For RBUS indication, the score showed high sensitivity (90%) and a high negative predictive value (95%), reinforcing its utility as a rule-out tool in low-risk patients. In contrast, for VCUG indication, the high-risk threshold showed high specificity (95%) and a positive likelihood ratio of 3.76, indicating good ability to identify patients with a higher probability of underlying malformations.

Beyond confirming the predictive capacity of the NUM-score, our study provides additional insight into the clinical relevance of these malformations by specifically analyzing those requiring treatment. In the general pediatric population with fUTI, the prevalence of NUMRT has been estimated at around 3% [2]. In our cohort, this prevalence was 5% in the low-risk group, similar to that reported in the general population, 21% in the moderate-risk group, and over 50% in the high-risk group.

These differences in prevalence are likely explained by differences in study design. For instance, in the original NUM-score study, which included patients with previously known nephrourological malformations, the reported prevalence of NUM was 10%, 35%, and 93% in the low-, moderate-, and high-risk groups, respectively. In contrast, our cohort consisted of previously undiagnosed patients, resulting in lower prevalence rates across all categories (11%, 23%, and 77%), which more accurately reflects routine clinical practice. Notably, when we restricted the analysis to malformations requiring treatment (NUMRT), the gradient between risk groups became even more clinically meaningful (5%, 21%, and 54%, respectively). This suggests that the NUM-score not only identifies structural abnormalities but also effectively stratifies clinically relevant disease.

The NUM-score is based on readily available parameters, even in limited-resource settings and without access to pediatric radiologists. Its application provides a more standardized and evidence-based approach that may help optimize healthcare resources by reducing unnecessary imaging studies. It has been estimated that approximately 80% of ultrasounds performed routinely after fUTI are normal. In our series, up to 35% of RBUS examinations could have been avoided, with only four cases of NUMRT initially missed. Importantly, all these cases presented a subsequent episode of UTI during follow-up, allowing diagnosis at a later stage.

Moreover, the NUM-score improves the selection of patients undergoing VCUG, potentially reducing the number of invasive studies with normal findings, which may account for a substantial proportion of cases, reaching up to 80% in some series [23, 24]. In our cohort, nearly one in two high-risk patients had high-grade VUR on VCUG. It is also important to note that many clinical guidelines rely on RBUS as the main screening tool to decide whether to perform VCUG. However, RBUS has limited sensitivity for detecting VUR, reported at approximately 0.44 (95% CI 0.34–0.54) [3]. In our series, 33% of patients with a normal RBUS had VUR on VCUG. These findings highlight the limitations of ultrasound as a sole screening tool and support the incorporation of predictive models to improve diagnostic efficiency.

This study has several limitations. First, the application of the NUM-score requires blood testing, which may be considered a limitation; however, it is a widely available test and, in many settings, more accessible than imaging studies requiring specialized personnel. Second, not all patients underwent VCUG, which may have led to underestimation of certain malformations, although the minimum follow-up of two years reduces the likelihood of missing clinically relevant cases. In addition, this is a single-center study, and further validation in multicenter cohorts and prospective studies is warranted. Future research should also evaluate the cost-effectiveness of this approach and its impact on clinical practice.

In conclusion, the NUM-score demonstrated good ability to stratify the risk of NUM in children with fUTI, allowing accurate identification of low-risk patients in whom imaging studies could be avoided, as well as high-risk patients who may benefit from more comprehensive evaluation. These findings suggest that the NUM-score may be a useful tool guiding clinical decision-making and optimizing patient management. However, as with any predictive tool, it is not infallible. In our cohort, some low-risk patients had clinically relevant malformations, highlighting the need for cautious interpretation and

integration of the score within a comprehensive clinical assessment, including appropriate follow-up when indicated.

Abbreviations

AKI — Acute kidney injury
CRP — C-reactive protein
ED — Emergency department
fUTI — Febrile urinary tract infection
IQR — Interquartile range
LR — Likelihood ratio
NPV — Negative predictive value
NUM — Nephrourological malformation
NUMRT — Nephrourological malformation requiring treatment
PCT — Procalcitonin
PPV — Positive predictive value
RBUS — Renal-bladder ultrasound
SD — Standard deviation
UTD — Urinary tract dilatation

Declarations

Funding: This work has been financed with the Research grant 2021 of the Spanish Society of Pediatric Emergencies (SEUP).

Competing interest: The authors have no relevant financial or non-financial interest to disclose.

Author contributions: Isabel González-Bertolín: Conception and design, analysis and interpretation of data, drafting of the manuscript, statistical analysis, and obtaining funding. Guillermo Barbas Bernardos: Conception and design and drafting of the manuscript. Alejandro Zarauza Santoveña: conception and design. Rosario López López: Acquisition of data and obtaining funding. Belén González-Bertolín: drafting of the manuscript. Cristina Calvo Rey: Critical revision of the manuscript for important intellectual content and supervision.

Ethics approval: This study protocol was reviewed and approved by Hospital Universitario La Paz Ethics Committee, approval number HULP: PI-4495. The study has been granted an exemption from requiring written informed consent by Hospital Universitario La Paz Ethics Committee.

ACKNOWLEDGMENTS

To the Biostatistics Department, Clinical Epidemiology section, Hospital Universitario La Paz for their support.

This work has been financed with the SEUP Research grant 2021 of the Spanish Society of Pediatric Emergencies.

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Figures

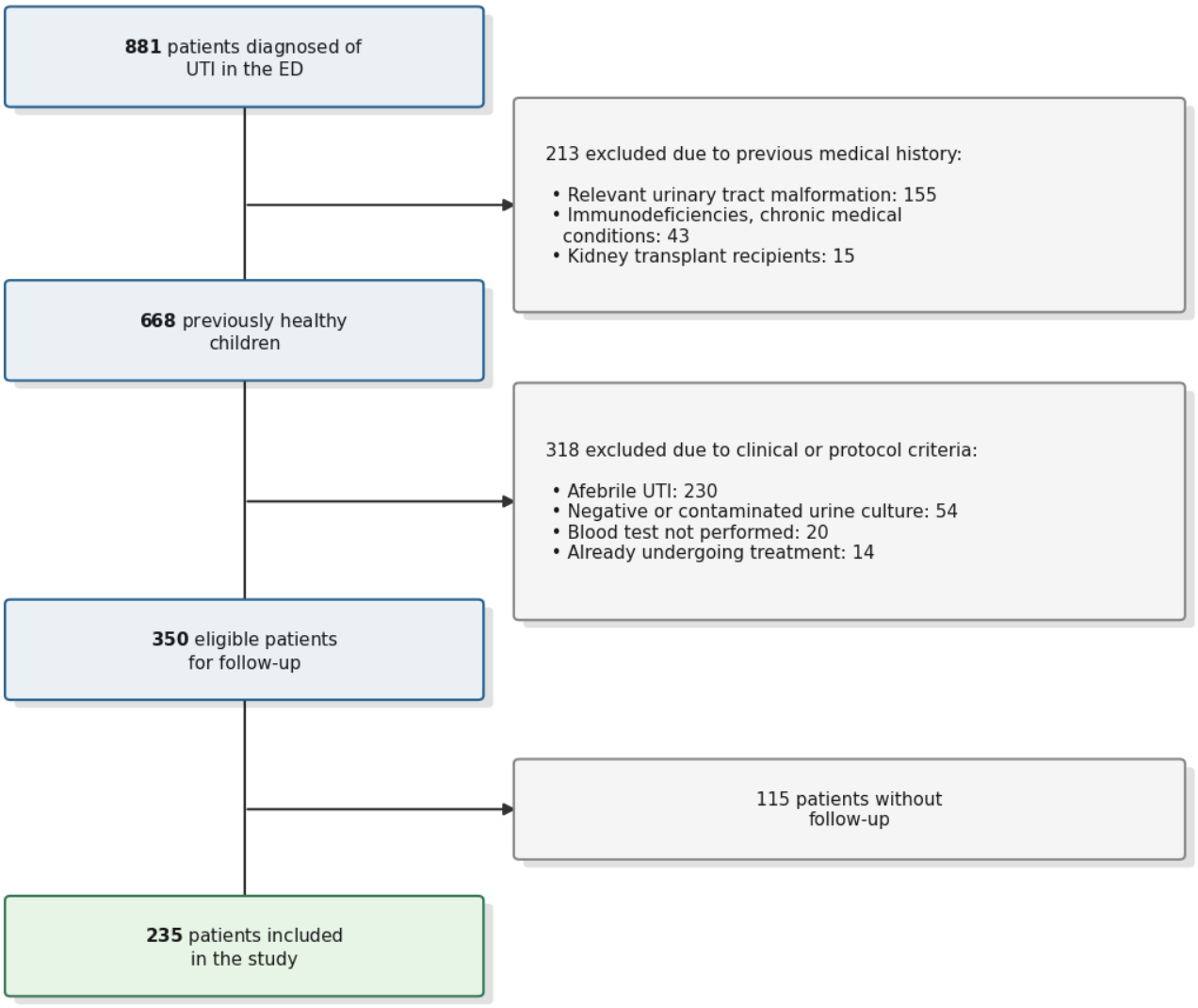


Figure 1

Flow diagram to indicate the included and excluded patients.

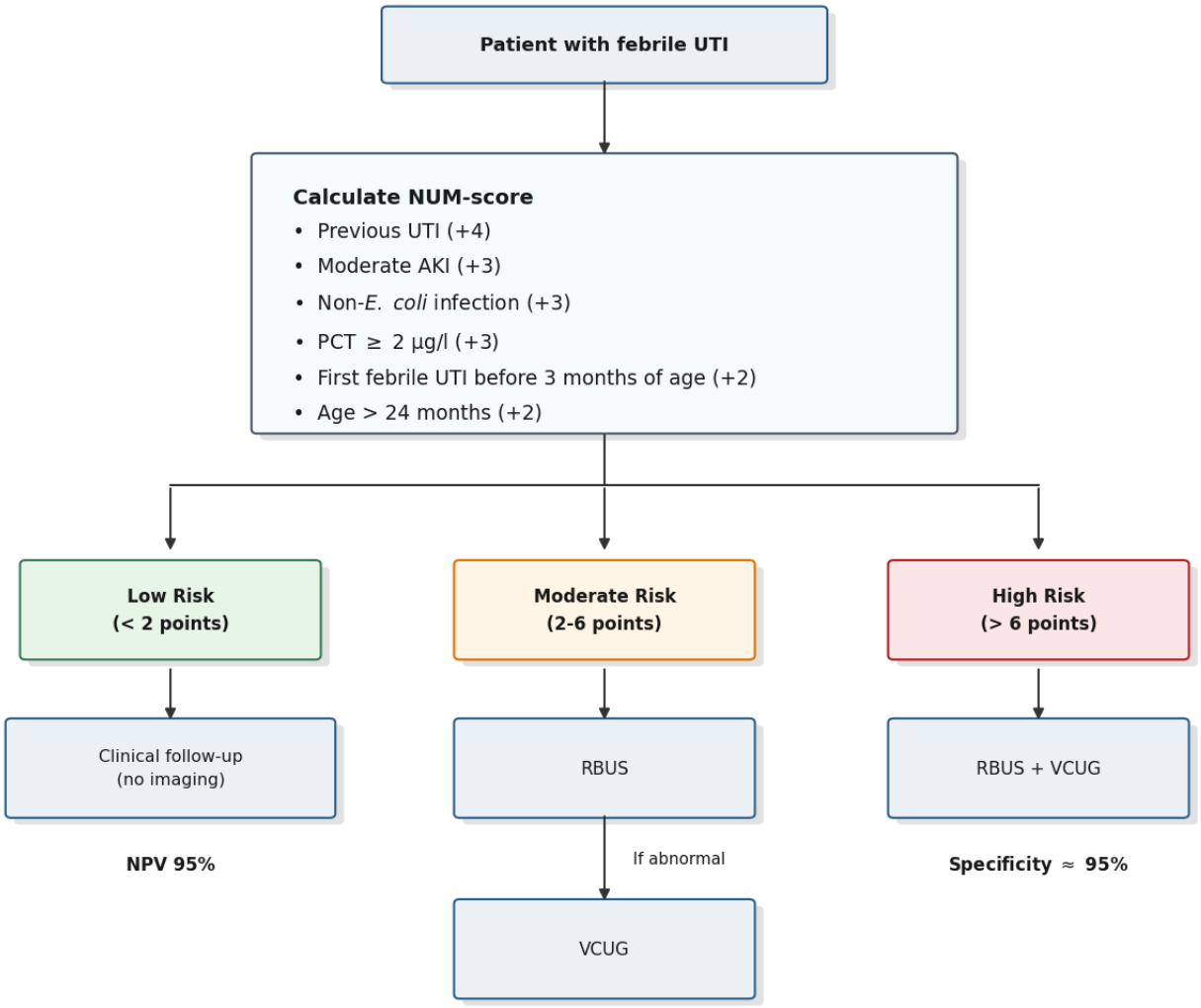


Figure 2

NUM-score–based imaging algorithm after febrile urinary tract infection.

Footnote: UTI, urinary tract infection; AKI, acute kidney injury; *E. coli, Escherichia coli*; PCT, procalcitonin; RBUS, renal-bladder ultrasound; VCUG, voiding cystourethrography; VUR, vesicoureteral reflux; NPV, negative predictive value. The figure illustrates risk stratification according to the NUM-score and the corresponding recommended imaging strategy. This algorithm is based on the diagnostic approach proposed by González-Bertolín et al. [1] and adapted to incorporate the findings of the present study.