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SYSTEMATIC REVIEW-META-ANALYSIS

Evidence-Based Emergency Medicine

A systematic review and meta-analysis of clinical signs, symptoms, and imaging findings in patients with suspected renal colic

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Abstract

Study Objective: The objective of this study was to conduct a systematic review and meta-analysis of the diagnostic accuracy of the clinical signs, symptoms, laboratory investigations, and imaging modalities commonly used in patients with clinically suspected renal colic.

Methods: We conducted this systematic review and meta-analysis according to an a priori, registered protocol (PROSPERO CRD42017055153). A literature search was performed using MEDLINE and EMBASE from inception to July 2, 2020. We assessed the risk of bias using Quality Assessment of Diagnostic Accuracy Studies–2, calculated likelihood ratios (LRs), and applied a random-effects model for meta-analysis.

Results: Among 7641 references screened, 76 were included in the systematic review and 53 were included in the meta-analyis. The overall pooled prevalence for ureteral stones was 63% (95% confidence interval [CI], 58%–67%). No individual demographic feature, symptom, or sign when present had an LR+ ≥2.0 for identifying ureterolithiasis. A (Sex, Timing and Origin of pain, race, presence or absence of Nausea, and Erythrocytes) STONE score ≥10 increased (sensitivity 0.49, specificity 0.91, LR 5.3 [95% CI, 4.1–6.7]) and a STONE score <6 reduced the likelihood of ureteral stones (sensitivity 0.94, specificity 0.43, LR 0.15 [95% CI, 0.10–0.22]). Standard-dose (sensitivity 0.96, specificity 0.94, LR+ 16 [95% CI, 11–23], LR– 0.05 [95% CI, 0.03–0.07]) and low-dose computed tomography (CT) scanning (sensitivity 0.93, specificity 0.94, LR+ 17 [95% CI, 8.8–31], LR– 0.08 [95% CI, 0.03–0.19]) were the most useful imaging techniques for identifying patients with or without ureteral stones.

Conclusions: Individual signs, symptoms, or the presence of microscopic hematuria do not substantially impact the likelihood of ureteral stones in patients with clinically suspected renal colic. The STONE score at high and low thresholds and a modified STONE score at a high threshold may sufficiently guide physicians' decisions to obtain imaging. Low-dose, non-contrast CT imaging provides superior diagnostic accuracy compared with all other imaging index tests that are comparable with standard CT imaging. Limitations of the evidence include methodological shortcomings and considerable heterogeneity of the included studies.

KEYWORDS
diagnostic accuracy, evidence-based clinical practice, meta-analysis, physical examination findings, renal colic, systematic review

1 | INTRODUCTION

1.1 | Background

In the United States, ≈1 in 11 adults self-report a history of urolithiasis.[1] Risk factors include age, geographic location, comorbidities such as obesity and diabetes, and dietary factors such as fluid intake.[2,3] Stones are most commonly calcium-based (calcium oxalate, calcium phosphate, and mixed calcium oxalate with phosphate); the remainder are formed from uric acid, cystine, or struvite.[2,3] Although most patients with nephrolithiasis are asymptomatic, renal colic is a frequent clinical presentation secondary to ureteral obstruction caused by the passage of a stone into the ureter. Renal colic is acute, severe, intermittent abdominal pain (often located between the ribs and the hip) that comes and goes in waves.[4] The severity of the pain is mostly related to the acuteness of the obstruction rather than its degree.[5] Common sites of stone retention in the ureter are the ureteropelvic junction and the ureterovesical junction.[6] Proximal and mid ureteral stones causing acute obstruction may cause referred pain radiating to the ipsilateral testicle, scrotal skin, or labia because of their common innervation. Suspected renal colic is a common reason for seeking urgent or emergent medical care.[7,8] Based on a study of emergency department (ED) visits from 1992 to 2009 with the diagnosis code of urolithiasis, this would account for 700,000 visits annually. During this time period, the use of computed tomography (CT) imaging tripled from 21% to 71%, resulting in radiation exposure and major healthcare expenditures.[9] Most patients with an uncomplicated presentation (no fever or other signs of systemic infection, normal renal function, recent trauma, surgery or active malignancy) can be managed conservatively with pain control, observation, and medical expulsive therapy with α-blockers because about half of the patients pass their stone spontaneously.[10] Patients who go on to pass their stone spontaneously do not require any further treatment, although they may be offered urology consultation for stone analysis and metabolic workup. In patients with suspected renal colic, 10% have an alternative etiology and 3% have acutely important findings, such as acute appendicitis, testicular torsion, ectopic pregnancy, ruptured ovarian cyst, or abdominal aortic aneurysm dissection.[11] In addition, a missed diagnosis of a ureteral stone with obstruction may lead to long-term loss of kidney function.

1.2 | Importance

The historical features, physical examination findings, and laboratory test results have varying abilities to predict ureteral stones when renal colic is suspected. To balance concerns of unnecessary radiation exposure and excessive resource use against the risk of incomplete or missed diagnosis, it is important to establish the test characteristics of patient history, physical examination, laboratory studies, clinical decision support tools, and imaging modalities when determining the diagnostic strategy for possible renal colic.

1.3 | Goals of this investigation

We conducted a systematic review and meta-analysis of the existing literature on patients' historical features, physical examination findings, laboratory test results, and imaging findings to determine their diagnostic accuracy either alone or when combined into a prediction rule for correctly establishing the diagnosis of renal colic.

2 | METHODS

2.1 | Study protocol

All aspects of this study were governed by an a priori, written protocol registered in the PROSPERO database (CRD42017055153).

2.2 | Search strategy and study selection

We undertook a comprehensive search using MEDLINE and EMBASE from inception through July 2, 2020, to identify published English-language studies evaluating the diagnostic accuracy of clinical signs, symptoms, components of the clinical examination, laboratory tests, and imaging tests for the diagnosis of renal colic. Search terms and strategy details are provided in the Appendix. We limited studies to those of adult patients presenting with acute pain of unknown etiology in whom renal colic was considered. Data had to be presented such that 2 × 2 contingency tables could be created. We excluded studies that only included patients with an established diagnosis of renal or ureteral calculi. If there were insufficient data to calculate likelihood ratios (LRs), the study was excluded from the analysis. We did not consider unpublished studies or search registries for ongoing studies.

Working in pairs of 2, the authors (P.D., A.S.R., D.K.N., C.J.G., A.K., S.B.) independently identified potentially eligible studies based on title and abstract. Pairs of review authors (P.D., A.S.R., D.K.N., C.J.G., A.K., S.B.) also independently evaluated the full texts for inclusion or exclusion according to the selection criteria. Disagreements were resolved by discussion and consensus. We documented the study selection process in a Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram (Figure 1).

2.3 | Data extraction

A standardized data extraction form was developed and piloted on 2 of the included studies based on the principles outlined by the Standards for Reporting of Diagnostic Accuracy (STARD).[12] We extracted the key baseline characteristics of the included studies such as age, sex of participants, type of study, study setting, geographic location where the study was performed, index tests, and reference tests.

The reference standard test for risk factors, symptoms, signs, or laboratory tests was imaging (intravenous urography, retrograde pyelograms, ureteroscopy, or CT) and clinical follow-up if a stone was spontaneously passed or recovered during ureteroscopy. For CT, the reference standard was clinical follow-up.

We cross-tabulated the numerical information from the index test results (positive or negative) in 2 × 2 tables against the target disorder (positive or negative) to calculate sensitivity, specificity, LRs, and diagnostic odds ratios (DORs).

2.4 | Assessment of study quality

We assessed the risk of bias for each study included in the meta-analysis using the Quality Assessment of Diagnostic Accuracy Studies–2 instrument and assigned a level of evidence according to a system previously developed for the Rational Clinical Examination series.[13,14] In brief, level 1 studies were those that included a large number of consecutive patients suspected to have renal colic who underwent independent, blind comparisons of sign or symptom results with the reference standard. Level 2 studies were similar but enrolled a smaller number of consecutive patients. Level 3 studies enrolled non-consecutive patients, and level 4 studies lacked an independent comparison. The review authors, working in pairs, extracted the relevant methodological details from each included study and used the information to assess the study quality. Any disagreements were resolved by discussion and consensus.

2.5 | Data analysis

Meta-analysis excluded Rational Clinical Examination Quality level 4 studies.[15] A random-effects model was used to estimate the prevalence of ureteral stones. When ≥4 studies were available for sensitivity, specificity, and LRs, a random-effects bivariate model with 95% credible confidence intervals (CIs) was constructed using a Monte Carlo Markov chain.[16] The unit of analysis was individual patients. When 3 studies were available, univariate analysis was performed using a random-effects model. When 2 studies were available, diagnostic test accuracy parameters were summarized with a range. When 1 study was available, diagnostic test accuracy parameters were summarized as point estimates with 95% CI. The test characteristics for the clinical prediction rules were calculated according to various thresholds. We highlighted findings where either the LR+ ≥2.0 or the LR− ≤0.5. In our setting, LRs compare the likelihood of a given index test result (positive or negative) in patients with an obstructing ureteral stone to the likelihood of the same results in patients without an obstructing ureteral stone.[13,14]

Meta-regression was performed with the bivariate model to examine the effect of ureteral stone prevalence on sensitivity and specificity. Statistical analyses were performed using R version 3.6.2 (R Foundation for Statistical Computing) using the *mada* and *meta* packages and Stata version 16.1 (StataCorp) using the *midas* module.[17]

2.6 | Subgroup and sensitivity analyses

We planned subgroup analyses for sex (male vs female) and reference standard (non-contrast CT scan vs intravenous urography) to assess for heterogeneity. We also examined the robustness of the meta-analyses by conducting a sensitivity analysis including only level 1 and 2 studies.

3 | RESULTS

After removal of duplicate studies, our search initially retrieved 7641 studies of which 250 were assessed as full-text documents (Figure 1). Of these, 76 studies[18–90] were included, but only 53 could be used in the quantitative meta-analysis (see Table S1). Additional information about these studies is provided in Tables S1–S3.

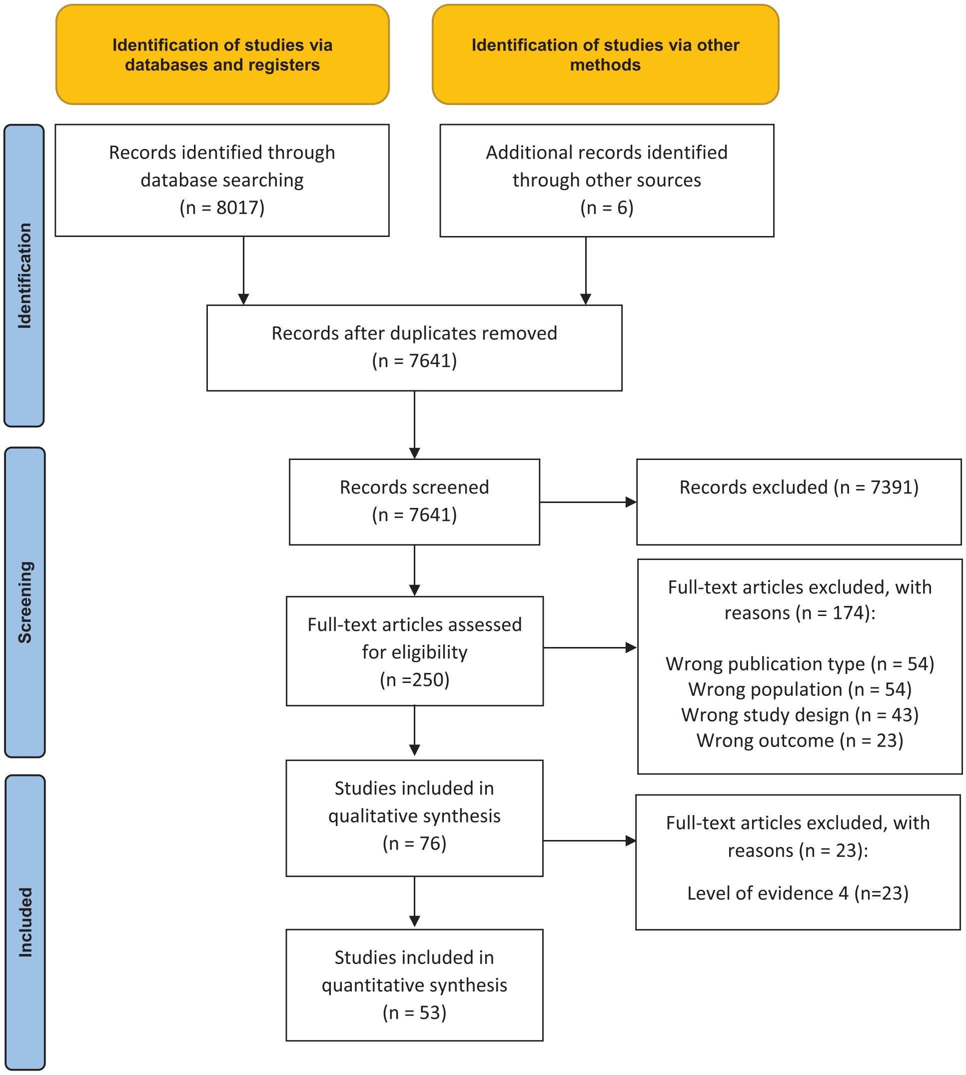

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flow diagram for new systematic reviews, which included searches of databases, registers, and other sources

3.1 | Prevalence of renal colic

The pooled prevalence of a ureteral stone in these studies of patients presenting with suspected renal colic was 63% (95% CI, 58%–67%). There was variability in the reported prevalence in studies included in the meta-analysis, ranging from 16%[26] to 88%.[27,59]

3.2 | Risk factors and demographics

No risk factors or demographic features had an LR+ ≥2.0 (see Table S2). A family history of nephrolithiasis might have an LR+ ≥2.0, as the LR range in 2 studies was 1.5–3.2. A personal history of nephrolithiasis had a point estimate close to 2.0, but also had a broad CI (LR 1.9 [95% CI, 0.83–3.6]). Patients making repeat visits to the ED with a clinical suspicion of renal colic had a lower likelihood of ureteral stones than patients making their initial visit for renal colic (LR 0.48 [95% CI, 0.41–0.56]).

3.3 | Symptoms

No individual symptom when present had an LR ≥2.0 (see Table S2). The absence of flank pain (LR 0.28 [95% CI, 0.17–0.48]), pain that was rated <5 on a scale of 10 (LR 0.44 [95% CI, 0.27–0.72]), or pain that occurred gradually rather than suddenly (LR 0.47 [95% CI, 0.40–0.55]) were the findings that were most useful for identifying patients less likely to have a ureteral stone (Table 1).

3.4 | Physical examination findings

No individual physical examination finding had an LR+ ≥2.0 or an LR– ≤0.5 (see Table S2).

3.5 | Laboratory findings

Studies used different definitions of a positive urine analysis (UA) that ranged from >5 RBC/high powered field (HPF),[47] >3 RBC/HPF,[39,52]

TABLE 1 Summary of diagnostic test accuracy of individual signs and symptoms where LR+ ≥2.0 or LR− ≤0.5 (see Table S2 for findings with LR+ <2.0 and LR > 0.5)

Index test	Prevalence n/N, %	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR− (95% CI)	DOR (95% CI)
First ED visit with renal colic suspected[68]	568/1040, 55%	0.71 (0.67–0.75)	0.60 (0.56–0.64)	1.8 (1.6–2.0)	0.48 (0.41–0.56)	3.7 (2.9–4.8)
Pain onset sudden[68]	568/1040, 55%	0.74 (0.70–0.77)	0.56 (0.51–0.60)	1.7 (1.5–1.9)	0.47 (0.40–0.55)	3.5 (2.7–4.6)
Flank pain[68]	568/1040, 55%	0.97 (0.95–0.98)	0.11 (0.81–0.14)	1.1 (1.1–1.1)	0.28 (0.17–0.48)	3.8 (2.2–6.8)
Pain ≥5/10[68]	388/516, 75%	0.92 (0.89–0.94)	0.19 (0.13–0.26)	1.1 (1.0–1.2)	0.44 (0.27–0.72)	2.6 (1.5–4.6)

Abbreviations: CI, confidence interval; DOR, diagnostic odds ratio; ED, emergency department; LR, likelihood ratio.

to any RBC/HPF (Table 2).[45,68,91] The threshold of any RBC/HPF to define a positive UA had the most favorable accuracy as defined by the DOR and indicated the greatest shift in pretest probability both for any RBC/HPF (LR 2.2 [95% CI, 1.3–3.6]) or for no RBC seen (LR 0.29 [95% CI, 0.21–0.39]).

3.6 | Clinical decision rules

Combinations of findings have been evaluated because individual risk factors, demographic features, symptoms, and signs have low diagnostic accuracy (Table 3). The STONE score, the most frequently studied combination of findings, is a clinical prediction rule for ureteral stones based on 5 factors (patient sex, timing and origin of pain, race, presence or absence of nausea, and erythrocytes) with a score range of 0–13.[44,51,53,67,69,77,78,86,92] Scores of 10–13 (defined as "high," see Table 4) were associated with an LR of 5.3 (95% CI, 4.1–6.7). A score of <10 (0–9) yielded an LR of 0.56 (95% CI, 0.52–0.61). At a lower threshold <6 (evaluated in 7 studies), the STONE score is more efficient at identifying patients less likely to have ureteral stones with an LR of 0.15 (95% CI, 0.10–0.22). The modified STONE score[92] drops the race variable, effectively treating all patients as not White (see Table 3). The modified STONE score was evaluated at a threshold of 8 with an LR+ similar to that of the original STONE score at a threshold of 10 ($LR_{\text{modified STONE} \geq 8}$ 4.2 [95% CI, 3.2–5.7] vs $LR_{\text{modified STONE} <8}$ 0.64 [95% CI, 0.59–0.71]). For comparison, at a pretest probability of 63%, a STONE score >10 increases the probability of ureteral stones to 90%, whereas a $STONE_{\text{modified}}$ ≥8 that eliminated race increases the probability to an almost identical 88%. The CHOKAI[51] prediction score has a highly efficient LR−, but it requires imaging to complete the score.

3.7 | Plain film radiographs

A suspected ureteral stone based on plain x-ray imaging increased the likelihood of renal colic (LR 2.7 [95% CI, 1.9–3.7]). Similarly, the absence of a ureteral stone on plain x-ray decreased the probability of a ureteral stone (LR 0.57 [95% CI, 0.46–0.68]).

3.8 | Intravenous urogram

The presence of a ureteral stone on an intravenous urogram (IVU) increases the likelihood of renal colic (LR 9.5 [95% CI, 3.6–21]) at range above the CI for plain film radiographs. Similarly, a negative IVU reduces the likelihood (LR 0.34 [95% CI, 0.24–0.45]).

3.9 | Renal ultrasound

A positive renal ultrasound increased the probability of renal colic (LR 7.0 [95% CI, 3.4–14]). Meanwhile, a negative renal ultrasound decreased the likelihood of renal colic to a lesser degree (LR 0.31 [95% CI, 0.16–0.49]).

3.10 | Computed tomography

Based on a large number of studies, both positive and negative findings on low-dose and standard-dose CT imaging substantially changed the likelihood of renal colic as assessed by clinical follow-up (passing a stone or finding a stone on ureteroscopy). Findings were similar for standard-dose CT imaging (LR+ 16 [95% CI, 11–23], LR− 0.05 [95% CI, 0.03–0.07]) and low-dose CT imaging (LR+ 17 [95% CI, 8.8–31], LR− 0.08 [95% CI, 0.03–0.19]).

3.11 | Secondary analyses

There were no substantial changes compared with the summary measures when the quality level 1–2 studies were compared to quality level 1–3 studies. We were unable to perform planned subgroup analyses for population sex or reference standard given the lack of the necessary data. We were also unable to perform a meaningful meta-regression analyses for the studies of ultrasound or IVU comparing clinical follow-up to CT imaging because the number of studies that could be included was <10.

TABLE 2 Pooled results of laboratory and imaging tests for renal colic with LR+ ≥2.0 or LR− ≤0.5 (see Table S3 for results from individual studies)

Index test	Prevalence n/N, %[a] (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR− (95% CI)	DOR (95% CI)
Urine findings						
Microscopic urine examination						
>0 RBC/HPF[46,69,92]	912/1483, 68% (48%–85%)	0.83 (0.81–0.85)	0.59 (0.42–0.85)	2.2 (1.3–3.6)	0.29 (0.21–0.39)	7.9 (3.2–19)
>3 RBC/HPF[40,53]	189/248, 76% (69%–83%)	0.84–0.87	0.32–0.60	1.2–2.2	0.22–0.51	2.4–9.8
Leukocyte esterase present[92]	62/93, 67% (57%–76%)	0.84 (0.73–0.91)	0.55 (0.38–0.71)	1.9 (1.2–2.8)	0.29 (0.15–0.56)	6.3 (2.4–17)
Hematuria on dipstick[77,81]	374/555, 67% (63%–71%)	0.59–0.93	0.41–0.88	1.6–4.8	0.18–0.47	8.8–10
Imaging						
CT Low dose[28,51,63,64,69–71,74]	621/944, 68% (57%–77%)	0.93 (0.82–0.98)	0.94 (0.89–0.97)	17 (8.8–31)	0.08 (0.03–0.19)	257 (88–594)
CT Standard dose[26,28,41,42,44,48,50,55,60,65,66,71–73,75,80,81,83,85,88–91]	1357/2274, 62% (55%–69%)	0.96 (0.93–0.97)	0.94 (0.91–0.96)	16 (11–23)	0.05 (0.03–0.07)	341 (175–604)
IVU[73,84–86,90,91]	302/424, 71% (63%–78%)	0.70 (0.59–0.79)	0.92 (0.80–0.97)	9.5 (3.6–21)	0.34 (0.24–0.45)	29 (9.6–70)
Ultrasound[26,28,39,45,49,55,59,61,67,72,75,76,80,83,84,86,87,91]	1625/2878, 63% (53%–72%)	0.74 (0.55–0.86)	0.89 (0.78–0.95)	7.0 (3.4–14)	0.31 (0.16–0.49)	25 (8.9–57)
Plain film[26,43,47,48,62,77,82,86]	891/1316, 68% (59%–76%)	0.55 (0.43–0.66)	0.79 (0.68–0.87)	2.7 (1.9–3.7)	0.57 (0.46–0.68)	4.7 (3.1–6.8)

Abbreviations: CI, confidence interval; CT, computed tomography; DOR, diagnostic odds ratio; HPF, high powered field; IVU, intravenous urogram; LR, likelihood ratio.

[a]Pooled prevalence calculated using random-effects meta-analysis with inverse variance weighting.

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TABLE 3 Criteria of clinical prediction rule scores included

Score	Factors	Points
STONE score*[68]	Sex	0
	Female	2
	Male	
	Timing	0
	>24 hours	1
	6–24 hours	3
	<6 hours	
	RaceNon-Caucasian	0
	Caucasian	3
	Nausea	0
	None	1
	Nausea alone	2
	Nausea with vomiting	
	Hematuria (on dipstick)	0
	Absent	3
	Present	
CHOKAI score[58]	Nausea or vomiting	0
	None	1
	Nausea or vomiting	
	Hydronephrosis	0
	Absent	4
	Present	
	Occult blood in urine	0
	Present	3
	Absent	
	History of kidney stone	0
	No	1
	Yes	
	Sex	0
	Female	1
	Male	
	Age	0
	≥60 years	1
	60 years	
	Timing of pain	0
	≥6 hours	2
	<6 hours	
Osmangazi score[40]	Stone history	0
	No	2
	Yes	
	Nausea	0
	No	1
	Yes	
	Hematuria	0
	No	3
	Yes	
	Creatinine >1.2 mg/dl	0
	No	3
	Yes	

*A modified (Sex, Timing and Origin of pain, race, presence or absence of Nausea, and Erythrocytes) STONE score exists in which race is excluded and the maximum score is 10 points.[93.]

4 | LIMITATIONS

Limitations of this study are related to the available evidence included. First, we found only 5 eligible studies that assessed the diagnostic accuracy of readily accessible clinical features to rule in or rule out the diagnosis of renal colic. Most studies instead examined the role of imaging tests. Second, for studies assessing diagnostic imaging modalities, there were several studies in which the test of interest was a component of the reference standard, suggesting incorporation bias.[26,35,43,54] However, only 2 of these studies were included in the meta-analysis on the grounds of being of adequate methodological quality (level 1–3 evidence).[43,54] Third, index tests that included few studies produced wide CIs, resulting in imprecision of the point estimates. Fourth, many studies were not transparently reported according to STARD criteria,[12] compounding our concern of low study quality. Fifth, we acknowledge that our search included studies published only in full-text English journals. Accordingly, we did not consider abstract proceedings because they were considered unlikely to provide the necessary information for meta-analyses of index tests. Sixth, most included studies were performed in an ED setting; therefore, our findings may not translate directly into practice settings where general practitioners have a larger role in triaging and managing patients with renal colic.[94] Finally, the included studies reflect major methodological heterogeneity (eg, prospective and retrospective studies reflecting different levels of evidence), studies with varying baseline prevalence of renal colic, and studies from both resource-rich and resource-poor settings with different practice patterns; all of these issues lower our confidence in the study findings.

5 | DISCUSSION

In this review, we found 76 studies addressing the diagnostic accuracy of clinical findings and imaging tests for renal colic. Of these, 5 studies[39,51,67,77,86] addressed aspects of the patient history, clinical presentation, and physical examination findings for the development and validation of the STONE score clinical prediction rule. Two additional studies described performance on the CHOKAI[51] and Osmangazi[39] scores. A total of 8 studies[39,45,47,52,67,77,81,91] addressed the diagnostic accuracy of RBCs in a UA. We found that individual aspects of a presenting patient's history, physical examination findings, and laboratory results alone were mostly insufficient to either establish or discount a diagnosis of a ureteral stone. This represents an important finding that should discourage overreliance on individual findings, for example, the incorrect assumption that the absence of RBCs on a UA rules out renal colic.

Recognition of these limitations has prompted the development the STONE score and a modified version thereof, the CHOKAI score, and the Osmangazi score that include information from several signs and symptoms. The purpose of these clinical prediction rules is 3-fold: determine if the patient is so unlikely to have renal colic that diagnostic testing directed at this diagnosis is unwarranted, determine that

TABLE 4 Pooled results of clinical prediction rule scores for renal colic (see Table S2 for results from individual studies)

Index test	Prevalence n/N, %, (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR− (95% CI)	DOR (95% CI)
STONE score						
Cutoff ≥4[79]	70/134, 52% (44%–61%)	0.97 (0.90–0.99)	0.25 (0.16–0.37)	1.3 (1.1–1.5)	0.11 (0.03–0.48)	11 (2.5–52)
Cutoff ≥5[93]	331/845, 39% (36%–42%)	0.96 (0.93–0.98)	0.23 (0.20–0.27)	1.2 (1.2–1.3)	0.17 (0.10–0.30)	7.3 (4.0–13)
Cutoff ≥6[45,54,68,70,78,79,93]	1970/3891, 52% (46%–58%)	0.94 (0.91–0.96)	0.43 (0.36–0.49)	1.6 (1.5–1.8)	0.15 (0.10–0.22)	11 (7.3–17)
Cutoff ≥7[79]	70/134, 52% (44%–61%)	0.87 (0.77–0.93)	0.73 (0.62–0.83)	3.3 (2.2–5.0)	0.18 (0.09–0.33)	18 (7.7–46)
Cutoff ≥8[78,79]	226/371, 59% (46%–72%)	0.75–0.79	0.70–0.84	2.5–5.0	0.25–0.36	7.1–20
Cutoff ≥9[52,79]	154/258, 60% (45%–75%)	0.63–0.68	0.89–0.90	5.7–6.8	0.36–0.42	14–19
Cutoff ≥10[45,54,68,70,78,79,93]	1970/3891, 52% (46%–58%)	0.49 (0.45–0.53)	0.91 (0.88–0.93)	5.3 (4.1–6.7)	0.56 (0.52–0.61)	9.4 (6.8–13)
Cutoff ≥11[79,93]	401/979, 45% (33%–58%)	0.31–0.37	0.92–0.97	4.5–10	0.69–0.71	6.6–14
Cutoff ≥12[79]	70/134, 52% (44%–61%)	0.14 (0.08–0.24)	1.0 (0.94–1.0)	18 (1.1–309)	0.86 (0.78–0.94)	21 (1.2–373)
Modified STONE score*						
Cutoff ≥8[93]	331/845, 39% (36%–43%)	0.42 (0.37–0.47)	0.90 (0.87–0.92)	4.2 (3.2–5.7)	0.64 (0.59–0.71)	6.6 (4.6–9.4)
CHOKAI score						
Cutoff ≥6[52]	84/124, 68% (59%–76%)	0.93 (0.85–0.97)	0.90 (0.77–0.96)	9.3 (3.7–24)	0.08 (0.04–0.17)	117 (31–440)
Osmangazi score						
Cutoff ≥4[40]	98/123, 80% (71%–86%)	0.68 (0.60–0.78)	0.84 (0.65–0.94)	4.3 (1.8–11)	0.36 (0.26–0.51)	12 (3.8–38)

Abbreviations: CI, confidence interval; DOR, diagnostic odds ratio; LR, likelihood ratio; STONE (Sex, Timing and Origin of pain, race, presence or absence of Nausea, and Erythrocytes)
*Pooled prevalence calculated using random-effects meta-analysis with inverse variance weighting.
*Excludes race and has total score of 10.

renal colic cannot be adequately ruled in or ruled out and further diagnostic testing is required, or determine if the patient is so likely to have renal colic that no additional testing is necessary to care for the patient. Based on our meta-analysis, a STONE score of <6 decreases the likelihood of renal colic and may allow the healthcare professional to forego additional imaging. STONE scores between 6 and 9 do not have adequate diagnostic performance to prevent further evaluation such as CT imaging, whereas a score of ≥ 10 increases the likelihood and may allow for the presumptive management of renal colic to prevent unnecessary CT imaging. A modified STONE score that omits race as a criterion appears to perform similarly well. Given the challenges of defining race, the risk of its biased interpretation, and the lack of a plausible pathophysiological explanation for any difference, this finding makes sense.[93]

The STONE score approaches are predicated on the assumption that there is an acceptable threshold of diagnostic error for a missed alternative diagnosis. Unfortunately, the acceptable threshold of error has not been determined. Consequently, the authors recommend using these rules when an important alternative diagnosis is not being considered, allowing for their safe application. Once a CT scan has been obtained, clinical prediction rules are unlikely to help further refine the diagnosis.

The Choosing Wisely recommendations by the American College of Emergency Physicians published in 2014 stated that CT imaging should be avoided in young (age <50 years), otherwise healthy ED patients with known histories of nephrolithiasis presenting with symptoms consistent with uncomplicated renal colic.[95] Of note, in our meta-analysis, the presence or absence of a prior history of nephrolithiasis did not confidently change the likelihood of renal colic. The underlying rationale of the Choosing Wisely recommendations is that in those patients in whom a ureteral stone is confirmed, information by the CT scan is unlikely to change immediate therapeutic management in the ED. Nevertheless, a subset of patients who fail medical management and do not pass the stone may ultimately still require subsequent imaging to further treatment. Our meta-analysis also supports the approach that there is an identifiable population of ED patients presenting with renal colic who do not require imaging, may be well served with an ultrasound, or could undergo a low-dose CT scan. Nevertheless, a recent study suggests that >80% of patients presenting with suspicion of renal colic underwent an abdominal CT scan demonstrating a gap between recommendations and clinical practice.[96]

Our review further found that both standard-dose and low-dose CT scan have a high sensitivity and specificity, which correspond to high probabilities of ruling in and ruling out stones. Therefore, in otherwise healthy patients presenting with possible renal colic, a low-dose CT scan provides an alternative imaging modality with similar diagnostic accuracy to a standard-dose CT scan. Further studies may clarify whether using a low-dose CT scan as an alternative to a standard-dose CT scan leads to similar long-term outcomes in patient morbidity.

In conclusion, individual clinical signs and symptoms alone do not have sufficient diagnostic performance to effectively rule in or rule out renal colic in patients presenting with a suspected ureteral stone. However, a combination of clinical signs, symptoms, and the STONE score clinical prediction rule may identify a subset of patients in whom the post-test probability is sufficient to adequately rule in or rule out renal colic and therefore limit the need for additional imaging. This is particularly true if the probability of competing causes of a patient's symptoms is low. In all other patients, especially those in whom the differential diagnosis includes other severe and potentially life-threatening etiologies, CT imaging will continue to play a major role.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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