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REVIEW ARTICLE

Imaging

What are the clinical effects of the different emergency department imaging options for suspected renal colic? A scoping review

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Abstract

Objectives: Clinicians have minimal guidance regarding the clinical consequences of each radiologic imaging option for suspected renal colic in the emergency department (ED), particularly in relation to patient-centered outcomes. In this scoping review, we sought to identify studies addressing the impact of imaging options on patient-centered aspects of ED renal colic care to help clinicians engage in informed shared decision making. Specifically, we sought to answer questions regarding the effect of obtaining computed tomography (CT; compared with an ultrasound or delayed imaging) on safety outcomes, accuracy, prognosis, and cost (financial and length of stay [LOS]).

Methods: We conducted a comprehensive search using Pubmed, EMBASE, Web of Science conference proceedings index, and Google Scholar, identifying studies pertaining to renal colic, urolithiasis, and ureterolithiasis. In a prior qualitative study, stakeholders identified 14 key questions regarding renal colic care in the domains of safety, accuracy, prognosis, and cost. We systematically screened studies and reviewed the full text of articles based on their ability to address the 14 key questions.

Results: Our search yielded 2570 titles, and 68 met the inclusion criteria. Substantial evidence informed questions regarding test accuracy and radiation exposure, but less evidence was available regarding the effect of imaging modality on patient-oriented outcomes such as cost and prognosis (admissions, ED revisits, and procedures). Reviewed studies demonstrated that both standard renal protocol CT and low-dose CT are highly accurate, with ultrasound having lower accuracy. Several studies found that ureterolithiasis diagnosed by ultrasound was associated with overall reduced radiation exposure. Existing studies did not suggest choice of imaging

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influences prognosis. Several studies found no substantial differences in monetary cost, but LOS was found to be shorter if a diagnosis was made with point-of-care ultrasound.

Conclusion: There is a plethora of data related to imaging accuracy. However, there is minimal data regarding the effect of CT on many patient-centered outcomes. Further research could improve the patient-centeredness of ED care.

KEYWORDS
computed tomography, kidney stones, patient-centered, renal colic, shared decision-making, ultrasound

1 | INTRODUCTION

1.1 | Background

Every year, 1.6–2.1 million patients get a computed tomography (CT) scan in US emergency departments (EDs) for suspected ureterolithiasis.[1] The majority of these patients do not see a change in management based on their CT scan, and this has led to a continuing discussion regarding how to decrease radiation exposure in this population.[2] Ultrasound, both ED point-of-care ultrasound (POCUS) and radiology performed, is considered an acceptable and safe alternative to CT despite lower accuracy.[3] Because the decision between these 2 diagnostic modalities involves trade-offs, this clinical situation has been identified by the emergency medicine community as appropriate for shared decision making (SDM).[4,5] However, to participate in SDM in this context, clinicians need to know evidence-based answers to patient-centered questions regarding the risks and benefits of obtaining versus delaying a CT. These may include prevalence of incidental findings, risks of alternative diagnoses, likelihood of urologic intervention, and questions about other consequences of this decision. Although a recent multispecialty systematic review and consensus paper made imaging recommendations for 29 different scenarios where ureterolithiasis is suspected, it did not answer the patient-centered questions that both patients and clinicians have when discussing imaging options.[6]

1.2 | Importance

Considerations beyond accuracy are relevant to both patients and clinicians in SDM conversations about the decision to undergo CT scan for suspected ureterolithiasis.[7,8] Many questions may arise in these conversations, with each question being of variable importance to different patients and clinicians. A scoping review, which examines a broader array of literature and outcomes, is appropriate for examining the evidence and assessing what evidence is appropriate to include in decision making in this context. A scoping review provides a broader view of a complex topic rather than focusing on a narrow question.

1.3 | Goals of this investigation

Drawing from a patient-centered and clinician-centered needs assessment,[8] we sought to examine the existing literature to explore what is known about the patient-centered consequences of the decision between ultrasound and CT scan.

2 | METHODS

We applied the scoping review methodology of Arksey and O'Malley.[9] Per Arksey and O'Malley, we chose a scoping review to "map the extent, range, and nature of research activity," "summarize and disseminate findings," and "identify research gaps." Because we were looking at a broader range of research, we did not feel a narrow systematic review would be appropriate.[10]

2.1 | Identifying the research questions

As described in a related qualitative study creating a decision aid, we engaged 102 stakeholders, both clinicians and patients, through 10 focus groups and 30 interviews, to determine decisional needs. This included an exploration of which questions are commonly asked, by both clinicians and patients, regarding the decision to use CT or ultrasound for the diagnosis of ureterolithiasis.[8] Questions fell into several domains: safety (including risk of an incidental findings), accuracy, prognosis (changes in admissions, ED revisits, or procedure rates), and the cost (including time and financial) (Table 1). Questions related to treatment (types of urologic procedures, the effects of α-blockers) were felt to be outside the scope of this review.

2.2 | Identifying relevant studies

To identify all possibly relevant research articles, we developed a search strategy in consultation with a health research librarian (B.G.). An exhaustive search for all articles published before September 2018 was done using the following databases: Pubmed, EMBASE, Web of Science conference proceedings index, and Google Scholar. The following

TABLE 1 Patient-centered and clinician-centered questions developed by patients, community members, clinicians, and other stakeholders

Domain	Question	Evidence compilation (Supplement B)
Safety	Patient oriented:[a] How much radiation do patients receive as a result of the workup for nephrolithiasis? (During this episode of renal colic and lifetime exposure, both diagnosis and treatment)	Table 1 in Supplement B
	What is the risk of missing a dangerous alternative diagnosis if CT is not performed at the index visit? (And does a risk stratification score help decrease this risk?)	Table 2 in Supplement B
	Patient oriented: What are my chances of having an incidental finding picked up?	Table 3 in Supplement B
Accuracy	How accurate is a (standard dose) renal protocol CT scan? How accurate is a low-dose CT scan?	Table 4 in Supplement B
	How accurate is ultrasound for the diagnosis of renal colic?	Table 5 in Supplement B
	Can a stone be predicted by other factors without using CT?	Table 6 in Supplement B
Plan of care/prognosis	Patient oriented: Will a CT change my chance of admission?	Table 7 in Supplement B
	Will a CT change my chance of ED revisit?	Table 8 in Supplement B
	Clinician centered: What is the chance the patient will need a procedure (and therefore should have a CT)? Patient oriented: Will getting a CT change my chance of needing a procedure?	Table 9a in Supplement B
	Patient oriented: Can ultrasound predict the likelihood of needing a procedure?	Table 9b in Supplement B
Cost (time and money)	Patient oriented: What will I be charged for each option?	Table 10 in Supplement B
	Patient oriented: How long will each option keep me in the ED?	Table 11 in Supplement B

CT, computed tomography; ED, emergency department.
[a]Many questions were asked by both patients and clinicians. Labeled questions were more frequently asked by the labeled group.

keywords were included in the search: emergency, kidney stones, renal colic, urolithiasis, and ureterolithiasis (see Supplement A for full search terms). The search was updated on February 29, 2020.

2.3 | Selecting studies included in review

2.3.1 | Eligibility criteria

Studies were included if either the primary or secondary outcomes addressed any of our a priori determined questions (Table 1). Exclusion criteria included duplicates, editorials, case studies/series, and articles not available in English. Upon discussion, we decided to exclude articles published before 2000, as the diagnosis of ureterolithiasis has evolved considerably during the past 20 years, and we did not feel earlier articles were as relevant to current questions. Because much of the literature regarding diagnostic accuracy (of CT, low-dose CT, and ultrasound) has been summarized and analyzed in systematic reviews and meta-analyses, we chose to exclude individual articles if they were included in a later systematic review or meta-analysis, but include the systematic reviews and meta-analyses for the questions of diagnostic accuracy. If those studies answered questions in other domains, they were included. We excluded articles in which the content focused on pediatrics, geriatrics, pain management, urologic/surgical treatment strategies, preventive strategies, epidemiologic data, stone formation, and basic science. We excluded abstracts if there was no associated article as we decided these abstracts did not contain sufficient information for inclusion or quality rating.

2.3.2 | Screening

Two levels of screening took place using dedicated online article screening software (Center for treatment comparison and integrative analysis (CTCIA); Tufts Medical Center, Boston, MA). First, E.D. and E.S. independently screened all titles and abstracts to evaluate for relevancy and exclusion criteria. Studies were included in the next stage of screening if either author considered inclusion. Each full-text article was independently evaluated by 2 authors (E.D., E.S., or S.D.) for final inclusion. Disagreements were resolved through team discussions involving a third author.

2.4 | Charting the data

A standardized abstraction form was created to abstract relevant data. E.S. created the form, which was then reviewed with all data abstractors and revised as needed. The 3 authors abstracting the data (E.D., E.S., and S.D.) together piloted and modified the data abstraction form, discussing issues as they arose. Two authors (E.D., E.S., or S.D.) independently abstracted the data from each study. If the researcher felt the study met the inclusion criteria, the standardized data abstraction form was used to record relevant data, including author, title, journal, date, type of study, hypothesis, sample size, results of the study as they related to scoping review questions (Table 1), relevance to clinical scenario, and population comparability. If the tested hypothesis was a secondary outcome or secondary analysis, this was also noted. The two authors abstracting the data also rated the studies using the

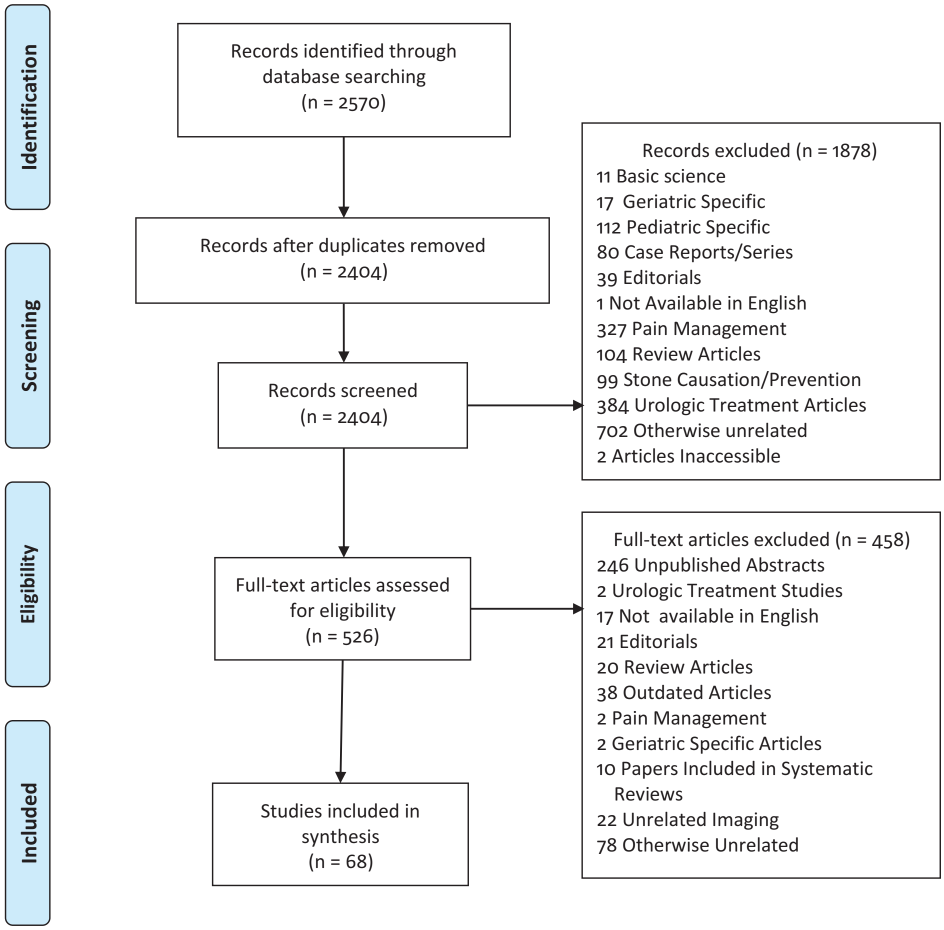

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow diagram of included studies[77]

National Heart, Lung, and Blood Institute quality assessment tools.[11] The 2 entries were then compared, discussed, and combined. At this point, studies rated poor quality by both reviewers were excluded. Disagreements were discussed with a third reviewer, who re-reviewed the article, until consensus was reached.

2.5 | Collating and summarizing results

Studies were grouped by domains and questions. We discussed all domains of the relevant studies, returning to the abstraction file or original articles as needed, and summarized the data. Individual studies were included under multiple domains if they answered multiple study questions.

3 | RESULTS

The initial search yielded 2570 citations (Figure 1). After removing duplicates, we had 2404 citations. After dual screening and full-text review, we were left with 68 articles that met the inclusion criteria. We included 7 (10.3%) systematic reviews, 3 (4.4%) meta-analyses, 3 (4.4%) randomized control trials, 5 (7.4%) secondary analyses of the "STONE" randomized controlled trial (RCT) by Smith-Bindman et al,[12,13] 17 (25.0%) prospective studies, 30 (44.1%) retrospective studies, 1 (1.5%) combined prospective and retrospective study, 1 (1.5%) cross-sectional study, and 1 (1.5%) quasi-experimental study. Our articles included 6 analyses of a single RCT and 2 analyses of a retrospective cohort, leaving us with 62 unique studies. Regarding quality, 36.8% were rated as "good," 20.6% as "good/fair," 36.8% as "fair," and 5.9% as "fair/poor." Data are summarized in Table 2, and complete data from all included studies are presented in Supplement B.

4 | SAFETY

4.1 | Stakeholder-derived question: How much radiation do patients receive as a result of the workup for ureterolithiasis?

4.1.1 | Summary of current evidence

A total of 9 studies published between 2009 and 2019 addressed radiation exposure (Table 1 in Supplement B).[12–20] The mean radiation dose of a single CT scan may be as high as 12.9 mSv for standard CT,

TABLE 2 Summary of answers based on included articles (summary of each article found in Supplement B)

Domain	Question	Patient/ clinician	Answers
Safety	How much radiation do patients receive as a result of the workup for nephrolithiasis? (During this episode of renal colic and lifetime exposure, both diagnosis and treatment)	Patient	One renal protocol CT exposes patients to ≈ 13 mSv of radiation (equivalent to 2–3 years of background radiation exposure). Low-dose and ultrasound low-dose CTs cause much smaller exposures. The use of CT, including repeat CT scans, may result in substantial cumulative radiation. The use of ultrasound first or low-dose CT decreases radiation exposure.
	What is the risk of missing a dangerous alternative diagnosis if CT is not performed at the index visit? Does a risk stratification score help decrease this risk?	Both	Studies show significant heterogeneity. Higher quality studies suggest that with a low-risk patient population (younger, higher likelihood of kidney stone, lack of concerning symptoms), the risk of a dangerous alternative diagnosis is low (<2%) and is not necessarily affected by the use of CT.
	What is my chance of having an incidental finding detected on CT?	Patient	Limited data suggest incidental findings found on CT range from 7% to 29%, but no quantification of economic or emotional burden is suggested.
Accuracy	How accurate is the CT? What is the role of low-dose CT?	Both	CT scan is the gold standard for the diagnosis of ureterolithiasis. Low-dose CT scan has high sensitivity and specificity for the diagnosis of ureterolithiasis.
	How accurate is ultrasound?	Both	Ultrasound has moderate sensitivity and specificity. Moderate or greater hydronephrosis has high specificity.
	Can a stone be predicted by other factors (prediction scores) without using CT?	Both	The most frequently evaluated scoring system for predicting ureterolithiasis is the STONE score. It risk stratifies patients regarding their likelihood of having a stone. External validation studies have had variable results, but the score may be useful for risk stratification. The accuracy of the score is improved with the addition of ultrasound.
Plan of care/prognosis	What is my chance of admission and will a CT change my chance of admission?	Patient	Admission rates ranged from 4% to 19%, and limited evidence suggests admission rates are not affected by the use of CT.
	What is the ED revisit rate and is it higher if a patient does not get a CT?	Both	ED revisits ranged from 12% to 30% and limited evidence suggests this rate is not affected by imaging modality.
	Clinician centered: what is the chance the patient will need a procedure (and therefore should have a CT)? Patient oriented: Will getting a CT change my chance of needing a procedure?	Both	The intervention rate varied from 6% to 33%, with the only population-level study having a 60-day intervention rate of 13% for patients initially discharged from the ED. Several studies suggested that imaging modality did not affect the procedure rate. Ultrasound results can risk stratify patients regarding the likelihood of needing a procedure.
	Can ultrasound predict the likelihood of needing a procedure?	Both	Ultrasound can risk stratify patients: patients with moderate or greater hydronephrosis had an 18%–33% likelihood of having an intervention. Those with no or mild hydronephrosis had an intervention rate of 0%–10%.
Cost (time and money)	What will I be charged for each option?	Patient	Patients in the United States will be charged between $2300 and $6000 for an ED visit for ureterolithiasis. These costs generally reflect the use of a CT scan.
	How long will each option keep me in the ED?	Patient	Minimal evidence exists, but one study directly comparing imaging reported a shorter length of stay for patients receiving POCUS as compared to CT or radiology-performed ultrasound.

CT, computed tomography; ED, emergency department; POCUS, point-of-care ultrasound; STONE, Sex, Timing, Origin, Nausea, Erythrocytes.

and lower, between 0.5 and 2.8 mSv, for a low-dose CT. Multiple studies demonstrated that a number of patients receive a higher amount of total radiation due to multiple CT scans and therapeutic procedures that involve radiation (fluoroscopy), with exposures as high as 50 mSv for 1 episode of renal colic. The 2 studies that evaluated an "ultrasound first" algorithm reported reduced mean total radiation exposure throughout their clinical course for patients who initially received an ultrasound for diagnosis. The RCT of Smith-Bindman et al found that the mean 6-month cumulative radiation exposure was significantly lower in the ultrasonography groups than in the CT group. They found that those who first had an ED POCUS or radiology-performed ultrasound had a cumulative radiation exposure of 10 and 9 mSv, respectively, whereas those who initially had a CT had a cumulative exposure of 17 mSv ($P < 0.001$).

4.2 | Stakeholder-derived question: What is the risk of missing a dangerous alternative diagnosis if CT is not performed at the index visit? (And does a risk stratification score help decrease this risk?)

4.2.1 | Summary of current evidence

A total of 21 publications addressed this question via different methods, including 8 retrospective studies, 7 prospective observational studies, 4 systematic reviews, and 2 RCTs (Table 2 in Supplement B).[2,6,12,15,21-37] Only 1 study directly compared immediate CT to delayed CT in patients who were clinically improving in the ED—and neither group had any alternative diagnoses considered life-threatening.[28] "Alternative diagnoses" were not standardized and were not always clearly defined as dangerous, emergent, or urgent. The rate of dangerous alternative diagnosis (defined by several articles as "clinically important alternate pathology") ranged from 0% to 9%. In studies that used risk stratification methods such as age or the Sex, Timing, Origin, Nausea, Erythrocytes (STONE) score, the rate of dangerous alternative diagnoses was 0%–1.8% for those with a high likelihood of ureterolithiasis.[32,36] Of the studies, 2 defined young patients as those aged 18–50 years, and found no dangerous alternative diagnoses when clinicians suspected uncomplicated renal colic (95% CI 0-1.5% and 0-3%).[25,36] The range of 0%–9% reflects the heterogeneity of clinical contexts and patient characteristics: cohorts with older patients or less-strict inclusion criteria—such as in retrospective studies—had higher rates of dangerous alternative diagnoses.

Risk stratification scores may help decrease the risk of missing an alternative diagnosis. The risk of missing a dangerous alternative diagnosis if a CT is not obtained may be higher with increasing age, female sex, higher WATUR (white blood count, abdominal pain, temperature, urine red blood count) score (WBC, fever, lack of hematuria, abdominal tenderness), and lower STONE score. For young, healthy, afebrile patients with high STONE scores and/or signs of ureterolithiasis on ultrasound, the risk appears to be <2%.

4.3 | Stakeholder-derived question: What is my chance of having an incidental finding detected on CT?

4.3.1 | Summary of current evidence

A total of 3 retrospective studies addressed the question of the prevalence of incidental findings (Table 3 in Supplement B).[2,38,39] Samim et al. defined "important" incidental findings as those for which "further radiologic characterization or additional evaluation including surgical or medical intervention is recommended."[39] These studies identified that incidental findings were not uncommon: The rate of incidental findings ranged from 12.4% to 18%; however, not all of them required follow-up.[2,38] The rate of incidental findings requiring some type of follow-up ranged from 7% in young patients aged 18–30 years and incrementally increased by decade of life to 29% in patients aged older than 80 years.[39]

Based on the available studies, it is unclear what proportion of patients benefited from the detection of these findings. Kelly et al found that 2% of the incidental findings were confirmed to be occult neoplasms on follow-up care.[38] No studies gave a patient-centered estimate of the burden (economic or emotional) related to incidental findings.

5 | ACCURACY

5.1 | Stakeholder-derived question: How accurate is a (standard dose) renal protocol CT scan?

5.1.1 | Summary of current evidence

CT is well regarded as the gold standard to diagnose ureterolithiasis, having replaced intravenous urography. Many studies addressing the accuracy of CT were published before 2000. Two additional recent studies, including 1 meta-analysis, showed CT to have a high level of accuracy in the diagnosis of ureterolithiasis.[34,40] One study found pooled positive likelihood ratios for non-contrast helical CT was 23.15 (95% confidence interval [CI], 11.53–47.23), and the pooled negative likelihood ratios for non-contrast helical CT was 0.05 (95% CI, 0.02–0.15).[40] These likely represent 64-slice scanners.

5.2 | Stakeholder-derived question: How accurate is the low-dose CT scan?

5.2.1 | Summary of current evidence

A total of 4 systematic reviews and 1 meta-analysis report that the accuracy of the low-dose CT is comparable with the standard-dose CT in the diagnosis of ureterolithiasis (Table 4 in Supplement B).[14,15,41-43] Sensitivities ranged from 90% to 100%, and specificities ranged from 86% to 100%. The lowest levels of accuracy were found in the studies that included ultra-low-dose CT.

5.3 | Stakeholder-derived question: How accurate is ultrasound for the diagnosis of renal colic?

5.3.1 | Summary of current evidence

A total of 8 studies, including 3 systematic reviews, addressed ultrasound accuracy (Table 5 in Supplement B).[6,7,12,29,44-47] These studies did not consistently use the same reference standard. The following 3 different aspects of ultrasound were evaluated: ability to detect hydronephrosis, association between hydronephrosis seen on ultrasound and ureterolithiasis, and overall ability to diagnose ureteral stone. In the detection of hydronephrosis, ultrasound was found to have a sensitivity range between 72% and 90.8% and a specificity range between 73% and 87% compared with CT.[29,44,47] The studies showed that hydronephrosis did strongly correlate with the presence of a stone. Hydronephrosis was found to have a positive predictive value between 77% and 92.9%, a negative predictive value between 65% and 88.5%, a sensitivity between 76% and 85.2%, and a specificity between 37% and 94.5%.[29,44,46,47] Regarding the overall ability of ultrasound to diagnose stones, the sensitivity ranged between 70.2% and 85%, and the specificity ranged from 50% to 75.4%.[7,12]

5.4 | Stakeholder-derived question: Can the presence of a stone be predicted by other factors without using CT?

5.4.1 | Summary of current evidence

A total of 14 studies sought to develop and validate prediction rules with the goal of predicting the likelihood that a patient with flank pain has ureterolithiasis (Table 6 in Supplement B).[24,30,32,48–58] Of the 14 studies included, 1 was a 2019 meta-analysis that sought to assess the performance of existing prediction rules. The STONE score and the CHOKAI score were most frequently evaluated.[32,51] The STONE score demonstrated increasing risk of stone with higher score.[32] Several studies have validated this risk stratification score.[24,36,52,54–56] One study demonstrated that the performance for low-risk and moderate-risk groups, characterized by the STONE score, is significantly improved by incorporating ultrasound.[24] In validation studies, the risk of ureterolithiasis with low (0–5), moderate (6–9), and high (10–13) scores ranged from 8.3% to 14%, 48.3% to 58.0%, and 75.8% to 89.7%. A recent meta-analysis reported the pooled prevalence of urolithiasis in low-risk, moderate-risk, and high-risk groups of 12% (95% CI, 9%–15%), 53% (95% CI, 43%–62%), and 83% (95 CI, 75%–91%), respectively, and suggested that it should not be used to rule in nephrolithiasis. The review suggested that the CHOKAI score performed better but had little external validation.

Of note, several articles suggested that the elimination of race as part of the STONE score might improve its test characteristics in settings with a different racial makeup from the original study.[55,56]

6 | PROGNOSIS

6.1 | Stakeholder-derived question: What is my chance of admission and will a CT change my chance of admission?

6.1.1 | Summary of evidence

Admission rates ranged from 4% to 19% in the 7 studies included, with studies including patients who were older and sicker having higher admission rates (Table 7 in Supplement B).[1,12,23,28,37,59,60] Ultrasound findings could risk stratify patients, with patients with hydronephrosis having a higher likelihood of an admission, but most patients with hydronephrosis were discharged. There are limited data comparing the admission rates for those receiving versus those not receiving a CT scan. The 1 study rated as "good" in this group found that the likelihood of admission was not affected by the receipt of a CT.[12]

6.2 | Stakeholder-derived question: What is the ED revisit rate and is it higher if a patient does not get a CT?

6.2.1 | Summary of current evidence

ED revisits at 30–60 days ranged from 12% to 30% in these 6 studies (Table 8 in Supplement B).[12,28,44,58,60,61] Of these studies, 2 RCTs and 2 additional studies made direct comparisons that suggested a diagnostic pathway involving ultrasound (as the only imaging or first imaging) will not lead to an increase in ED revisits.

6.3 | Clinicians: What is the overall likelihood the patient will need a procedure (and therefore should have a CT)? Patient-oriented question: Will getting a CT change my chance of needing a procedure? Stakeholder-derived question: Can ultrasound predict the likelihood of needing a procedure?

6.3.1 | Summary of current evidence

In 9 studies, the urologic procedure rate varied from 6% (at 7 days) to 33% (at 30–60 days) (Table 9a and 9b in Supplement B).[22,23,24,59,62–70] The only large population-level study showed a procedure rate of 13% in patients aged 18–64 years who were initially discharged from the ED. Stone size and location (as judged via CT), pain scores on discharge, and having private health insurance were found to be associated with a subsequent intervention in some studies. Studies that compared imaging modalities did not find differing rates or timing of urologic intervention based on initial imaging modality.

A total of 4 studies evaluated if ultrasound can predict the likelihood of a urologic procedure. The results suggested that ultrasound can risk stratify patients and give the approximate likelihood a patient will need an intervention. Patients with moderate or greater hydronephrosis or a stone visualized on ultrasound had an 18%–33% chance of needing an intervention, whereas those with no or mild hydronephrosis had a rate of intervention that ranged from zero to 10%.

7 | COST

7.1 | Stakeholder-derived question: What will I be charged for each option?

7.1.1 | Summary of current evidence

Only 5 studies addressed the issue of charges or costs for an ED visit for nephrolithiasis (Table 10 in Supplement B).[71–75] Current data suggest that patients in the US will be charged between $2300 and $6000 for an ED visit for ureterolithiasis. As population-level data demonstrated that the majority of these patients received a CT scan during their visit, and costs for POCUS and radiology-performed ultrasound are lower than the costs for CT, it is possible, but not clearly demonstrated, that an ED visit using only ultrasound would result in lower charges.

In one study that compared the mean costs (not charges) for patients who were randomly assigned to different initial imaging modalities, the costs of hospitalization vastly outweighed the ED costs even though most patients were discharged. As admission rates did not differ by initial imaging, the mean costs by group did not differ. However, looking solely at ED costs, 1 study found that these were trivially lower for those in the radiology-performed ultrasound group versus the CT-first group ($423 vs $449; $P < 0.0001$).[74] Another study found a slightly larger cost difference when looking at ED-performed ultrasound versus CT ($259 vs $319; $P < 0.001$).[75]

7.2 | Stakeholder-derived question: How long will each option keep me in the ED?

7.2.1 | Summary of current evidence

Little evidence exists regarding the effect of imaging modality on length of stay (LOS) (Table 11 in Supplement B).[12,59,75] Current evidence suggests that if a diagnosis is made via POCUS, this results in the shortest LOS, but that if a second imaging study is needed, the LOS becomes longer.[12,59,75] Diagnosis using radiology ultrasound may take longer than diagnosis via other modalities.[12]

8 | LIMITATIONS

Although we performed an extensive search, the comprehensive nature of our search did not allow us to include abstracts or any other publications with incomplete data. This would bias toward the inclusion of positive studies, which are more likely to be published. In addition, there was marked heterogeneity of the included studies. Conclusions for each question are derived from studies with very different designs and inclusion criteria. Although this allowed us to survey the breadth of research into this issue, it limited our ability to state strong conclusions. For example, in recent consensus guidelines, Moore et al suggested avoiding CT in a 35-year-old man with no history of kidney stones who has a classic renal colic story, no red flags, and is clinically improving in the ED—but few of the included studies are limited to young, healthy patients such as the patient in this scenario.[6]

Lastly, we failed to see an effect of CT on many patient-centered outcomes, but lack of evidence of an effect is not equivalent to evidence of lack of an effect. In a few areas, high-quality evidence, such as multicenter RCTs, demonstrated no effect, but not all areas had a substantial evidence base from which to draw.

9 | DISCUSSION

Our scoping review provides a broad understanding of the current evidence regarding the effects—and lack of effects—of the use of CT scan in the ED diagnosis of ureterolithiasis. CT scan is the clear gold standard for accuracy of diagnosis, and the low-dose CT scan may be nearly as accurate as the standard-dose CT scan; however, CT scans in general did not appear to have substantial discernable positive effects on other patient-centered outcomes (procedure rates, admission rates, ED revisits, cost, LOS). Our review failed to find that routine CT scanning changes outcomes for patients with ureterolithiasis—a finding first suggested by Westphalen et al, who noted a 10-fold increase in the use of CT scans from 1996 to 2007 without an associated change in the proportion of diagnoses of kidney stones, significant alternate diagnoses, or admissions to the hospital.[76]

Although the 2 decades of research collated here leaves many questions, some answers are becoming clear. Low-dose CT is nearly clinically equivalent to renal protocol CT and should be the test of choice if CT is felt to be necessary. Although individual CTs carry low amounts of radiation—1 renal protocol CT at 13 mSv is equal to 2–3 years of background radiation or 130 chest X-rays—the radiation exposure may be compounded over multiple visits and multiple episodes of renal colic. Although dangerous diagnoses cannot always be ruled out without a CT, risk stratification tools and ultrasound can help reduce this risk to a number that may be acceptable to patients and clinicians. An individual's chance of needing a procedure, should he or she be well enough for discharge, appears to be low and should not be the driving reason for routine CT.

Despite the breadth of our review, only 2 RCTs were found that attempted to discern the effects of altering initial imaging modality. The first, from Smith-Bindman et al, compared an "ultrasound-first" diagnostic pathway to a "CT-first" pathway via 3 arms: POCUS first, radiology performed ultrasound first, and CT first.[12] This well-executed multicenter RCT reported decreased total radiation for the ultrasound-first arms with no increase in "high-risk" (or delayed) diagnoses. Subsequent secondary analyses did not find a difference in the admission or procedure rates and only a small difference in ED costs (with the arm receiving a radiology-performed ultrasound having lower mean costs than the CT-first arm). The second RCT, from Lindqvist et al, compared immediate CT to delayed CT for patients with suspected uncomplicated renal colic. The results of this study also did not support the idea that immediate CT is safer or changes other outcomes.[28] However, in both studies clinicians were able to order a CT when they felt it was necessary, regardless of the arm to which the patient was randomly assigned. These studies highlight that although routine CT is not necessary, routine avoidance of CT is likely not appropriate either.

It is notable that although we found many studies about diagnosing ureterolithiasis with ultrasound and risk stratifying patients with various risk stratification tools, we found no studies evaluating gestalt. It is unclear, from this literature, how physician gestalt may play a role. However, if one considers that both RCTs allowed physicians to order CTs for the non-CT groups, that safety outcomes were the same, and that many patients did not receive a CT, this suggests that physicians' gestalt about who needed a CT was likely fairly accurate.

Lastly, our review did suggest that avoiding CT—and using SDM to decide about the use of immediate CT—may be more appropriate for younger patients, defined as younger than 50 or 55 years in different studies. This is because the main benefit of CT—finding a dangerous alternative diagnosis—is more likely as patients get older, whereas the main risk—of the radiation causing a future cancer—is higher for younger patients. Because of this, the decision aid created in conjunction with this scoping review is intended for use with patients aged 18–55 years.[8]

Based on this scoping review, future studies should not focus solely on the diagnostic utility of imaging modalities, but should attempt to include the effects of imaging modality on prognosis, such as interventions, ED revisits, admissions, and other patient-oriented outcomes.

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AUTHOR CONTRIBUTIONS

ES and LW designed the study with help from BG. ES, ED, and SG carried out data abstraction and analysis. ES, ED, SG and LW discussed and collated the results, and all authors contributed to the drafting of the manuscript. ES takes responsibility for the work as a whole.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

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