REVIEW

Diagnostic utility of axial imaging in the evaluation of hematuria: A systematic review and critical appraisal of the literature

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Cite as: Wallis CJD, Sayyid RK, Manyevitch R, et al. Diagnostic utility of axial imaging in the evaluation of hematuria: A systematic review and critical appraisal of the literature. *Can Urol Assoc J* 2021;15(2):48-55. http://dx.doi.org/10.5489/cuaj.6522

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This study was previously presented at the 2018 American Urologic Association Northeast Section Meeting

Abstract

Introduction: Increasing severity of hematuria is instinctively associated with higher likelihood of urological malignancy. However, the robustness of the evidentiary base for this assertion is unclear, particularly as it relates to the likelihood of upper urinary tract pathology. Thus, the value of axial imaging in the diagnostic workup of hematuria is unclear due to differences in the underlying patient populations, raising concern for sampling bias. We performed a systematic review to characterize the literature and association between severity of hematuria and likelihood of upper urinary tract cancer based on axial imaging.
Methods: MEDLINE, EMBASE, and Cochrane were systematically searched for all studies reporting on adult patients presenting with hematuria. We used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for reporting of this systematic review and meta-analysis and the Newcastle-Ottawa Scale for risk of bias assessment. Degree of hematuria was classified as "microscopic," "gross," or "unspecified." Three urological malignancies (bladder, upper tract urothelial, and renal cancer) were considered both individually and in aggregate. Random-effects model with pairwise comparisons was employed to arrive at the axial imaging diagnostic yields.
Results: Twenty-nine studies were included, of which six (20.7%) reported on patients with gross hematuria only, four (13.8%) reported on patients with microscopic hematuria only, seven (24.1%) included both, and 12 (41.4%) did not define or specify the severity of hematuria. Of 29 studies, two (6.9%) were at high-risk of bias, 21 (72.4%) at intermediate-risk, and six (20.7%) at low-risk of bias using the Newcastle-Ottawa criteria. Based on axial imaging, rates of diagnoses of renal, upper tract urothelial, and bladder cancers differed with differing severity of hematuria. Notably, rates of renal and upper tract urothelial carcinoma were higher in studies of patients with unspecified hematuria severity (3.6% and 10.4%, respectively) than among patients with gross hematuria (1.5% and 1.3%, respectively). When all urological malignancies were pooled, patients with unspecified hematuria were diagnosed more frequently (19.5%) compared to those with gross (15.3%) and microscopic hematuria (4.5%, difference=1.51%, 99% confidence interval 3.6–26.5%).
Conclusions: Lack of granularity in the available literature, particularly with regards to patients with unspecified hematuria severity, limits the generalizability of these results and highlights the need for future studies that provide sufficient baseline information, allowing for firmer conclusions to be drawn.

Introduction

Hematuria is one of the most common causes for referral to urological practice, accounting for approximately 6% of all new urological visits.[1] Hematuria is classically defined as either gross or microscopic, with reported prevalence ranging from 0.9–18% in the adult population.[2,3] While hematuria may be due to benign causes, such as urinary tract infections or nephrolithiasis, evaluation is most targeted at identifying malignant etiologies.

It seems instinctively obvious that the more severe a patient's hematuria, the higher likelihood of underlying malignancy. However, the robustness of the evidentiary base for this assertion is somewhat unclear, particularly as it relates to the likelihood of upper urinary tract disease. While nearly all international guidelines recommend cystoscopy in the evaluation of patients with hematuria, guidelines vary on their recommendations for abdominal imaging, particularly among those with microscopic hematuria.[4,5] The American Urological Association (AUA) guidelines, which recommend multiphasic computed tomography urography or magnetic resonance urography in all patients over 35 with microhematuria,[4] are based on 16 studies, of which four included patients specifically with microhematuria, eight comprised mixed populations with both gross and microhematuria, three with gross hematuria alone, and one with unspecified hematuria type. Such heterogenous literature raises the possibility of a sampling bias, whereby applying the same test to different populations changes its diagnostic performance. This affects the external validity of these results and their applicability to clinical practice.

To better understand the effect that differing patient populations may have on the apparent value of abdominal imaging in patients with hematuria, we performed a systematic review to estimate the diagnostic yield of axial imaging in patients according to their severity of hematuria.

Methods

Research question

Does the diagnostic rate of urological malignancy on axial imaging for patients presenting with hematuria differ according to whether they present with gross or microscopic hematuria?

Types of studies

We included cohort, case-control, and cross-sectional studies. Case series lacking comparator groups were excluded. Other publications, including editorials, commentaries, review articles, and those not subject to peer-review (i.e., reports of data from Vital Statistics and dissertations or theses), were excluded. Where there was more than one publication resulting from the same patient cohort, we selected a single representative study, with a preference for more contemporary publications, larger patient populations, and more reliable methods of outcome ascertainment.

Types of participants

We considered any studies reporting on adult patients presenting with hematuria, without a known association with recent trauma.

Exposure

We considered the degree of hematuria and classified this as “microscopic,” “gross,” or “unspecified” (i.e., severity not defined in the study) according to the original report.

Outcome

We considered three urological malignancies with known associations with hematuria: renal cancer, upper tract urothelial carcinoma, and bladder cancer (though imaging is not the diagnostic choice of test for bladder cancer). These were considered individually and then in aggregate. We considered the diagnostic yield of a radiological investigation based on of the number of patients diagnosed with a relevant cancer among those who underwent the radiological test (number diagnosed/number imaged).

Methods of systematic review

We used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for reporting of this systematic review and meta-analysis.[6]

Search strategy

We performed a search of MEDLINE (OvidSP), EMBASE (OvidSP), and Cochrane (Wiley) databases from inception to October 23, 2017. We used both subject headings and text word terms for hematuria AND diagnostic imaging AND variants of renal cancer, upper tract urothelial cancer, and bladder cancer or Prognosis or Diagnosis or Risk search filters (Appendix; available at *cuaj.ca*). No limitations were placed with respect to publication language or year. All duplicates were excluded. References from review articles, commentaries, editorials, included studies, and conference publications of relevant medical societies were hand-searched and cross-referenced to ensure completeness.

Study review methods

Two authors performed study selection independently. Disagreements were resolved by consensus with the assistance of a third author. Titles and abstracts were used to screen for initial study inclusion. Full-text review was used where abstracts were insufficient to determine if the study met inclusion or exclusion criteria. One author performed all data abstraction, including evaluation of study characteristics, risk of bias, and outcome measures, with independent verification performed by another author.

Risk of bias assessment

We used the Newcastle-Ottawa Scale for risk of bias assessment. This scale assesses risk of bias in three domains:[7] 1) selection of the study groups; 2) comparability of groups; and 3) ascertainment of exposure and outcome.[8] Studies with scores of <4, 4–6, and ≥7 were considered having a high, intermediate, and low risk of bias, respectively.

Assessment of heterogeneity

We quantified heterogeneity using I^2 values.[9] Further, we employed random-effects models for each of our analyses, given the identified clinical heterogeneity.

Data synthesis/statistical analysis

Quantitative meta-analysis was performed to assess the association between the degree of hematuria and the diagnostic yield of axial imaging (computed tomography [CT] and magnetic resonance imaging [MRI]). Insufficient data were present to allow for such analysis among patients undergoing ultrasonography. We performed meta-analysis of the diagnostic yield for each diagnosis (bladder, upper tract urothelial, renal, and aggregate urological cancers) stratified according to degree of hematuria ("micro,", "gross," or "unspecified") with random-effects models using the procedure of Neyeloff, Fuchs, and Moreira.[10] Where zero events were reported, we performed a continuity correction to allow for computational processing.

We then performed pairwise comparison of the resulting pooled diagnostic yields among patients with "micro," "gross," and "unspecified" hematuria for each diagnosis by calculating the difference in diagnostic yields and calculated the pooled standard error; 95% and 99% confidence intervals [CI] of the difference in diagnostic yield were calculated. All analyses were performed using SAS Enterprise Guide 7.1 (SAS Institute Inc.).

Results

Study selection

We initially retrieved a total of 5321 references from the database search. Seven citations were retrieved via a manual search, for a total of 5328 references. All references were saved in an EndNote library used to identify the 1338 duplicates. The remaining 3990 unique references underwent abstract review, of which 3899 were excluded. After full-text review of the remaining 91 manuscripts, 29 were selected for inclusion (Fig. 1).

Study characteristics

The characteristics of all included studies (n=29) are presented in Table 1.[11-39] Nine of the 29 studies (31.0%) were prospective and two were multicenter (6.9%). Six studies (20.7%) included patients with gross hematuria only, four (13.8%) with microscopic hematuria only, seven (24.1%) with either gross or microscopic hematuria, and 12 (41.4%) with unspecified hematuria (i.e., not defined if microscopic, gross, or both). Patients were recruited between 1992 and 2017 and sample size varied from 53–1608. The axial imaging of choice was CT-based in 25 (86.2%), MRI-based in two (6.9%), and CT- or MRI-based in two (6.9%) studies. Reported outcomes were urothelial carcinoma of the bladder and upper tracts, kidney cancer, or urinary tract neoplasms (unspecified). Reported outcomes range from 0.0–80.0% (Table 1).

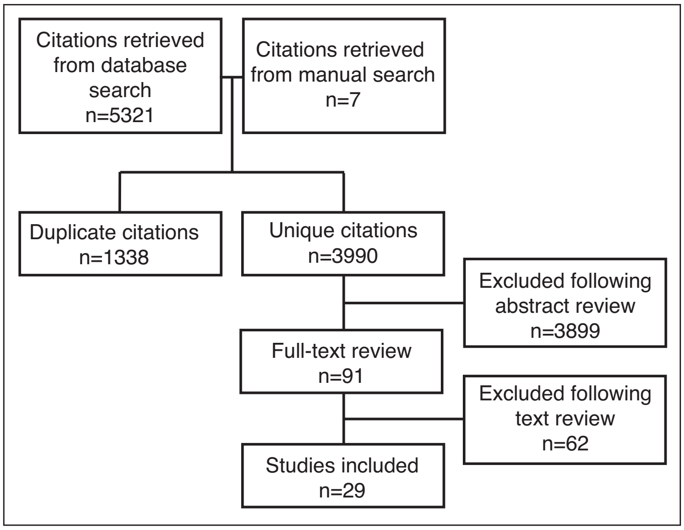

Fig. 1. Study flow chart.

Risk of bias assessment

The risk of bias assessment is tabulated in Table 1. There were six studies at low-risk for bias, two studies at high-risk for bias, and the remainder were at intermediate-risk for bias according to the Newcastle-Ottawa criteria. The primary risk of bias was not specifying gross or microscopic hematuria, and poor comparison analysis between groups.

Quantitative analysis

Renal cancer

With respect to renal cancer, we pooled data from five studies reporting on 2505 patients with gross hematuria (including those from studies reporting outcomes of both gross and microscopic hematuria patients), seven studies reporting on 2190 patients with microscopic hematuria (including those from studies reporting outcomes of both gross and microscopic hematuria), and six studies reporting on 1435 patients with unspecified degrees of hematuria. The diagnostic yield was generally quite low — 1.5% (95% CI 0.6–2.3%, I^2=61%) among patients with gross hematuria, 0.98% (95% CI 0.30–1.7%, I^2=73%) among patients with microscopic hematuria, and 3.6% (95% CI 1.5–5.6%, I^2=84%) among patients with unspecified hematuria. Heterogeneity was high, as noted, in

Table 1. Characteristics of included studies

Study	Hematuria	Years	Study setting	Sample size (n)	Imaging modality	Outcome Evaluated	Frequency of diagnosis (%)	ROB score
Abou-El-Ghar et al[11]	Gross	2007–2008	Single-center, prospective	130	MRI	Bladder cancer	80.0%	6
Aguilar-Davidov et al[12]	Micro	2006–2009	Single-center, retrospective	112	CTU	Bladder cancer	1.8%	6
Albani et al[13]	Unspecified	2003–2004	Single-center, retrospective	259	CTU	UTUC Kidney cancer	2.3% 1.5%	5
Arfeen et al[14]	Unspecified	2015	Single-center, retrospective	256	CT IVU	Bladder cancer Kidney cancer	1.6% 1.2%	N/A
Bhuvanagiri et al[15]	Unspecified	2014–2016	Single-center, retrospective	536	CTU	Kidney cancer	0.9%	N/A
Blick et al[16]	Unspecified	2004–2007	Single-center, retrospective	747	CTU	Bladder cancer	16.9%	5
Bretlau et al[17]	Unspecified	2015	Single-center, retrospective	771	CTU	Urinary tract Neoplasm	17.8%	5
Bromage et al[18]	Gross	2008–2010	Single-center, retrospective	457	CTU	Bladder cancer UTUC Kidney cancer	14.2% 1.1% 2.0%	6
	Micro	2008–2010	Single-center, retrospective	529	CTU	Bladder cancer UTUC Kidney cancer	3.4% 0.8% 1.1%	
Cauberg et al[19]	Gross	2006–2010	Single-center, prospective	479	CTU or MRU	UTUC Kidney cancer	1.9% 1.9%	8
	Micro	2006–2010	Single-center, prospective	362	CTU or MRU	Kidney cancer	1.4%	
Chen et al[20]	Unspecified	2012–2014	Single-center, retrospective	171	CTU	Bladder cancer UTUC Kidney cancer	18.7% 14.0% 12.9%	3
Commander et al[21]	Gross	2006–2012	Single-center, retrospective	652	CTU	Bladder cancer UTUC	4.9% 0.6%	8
	Micro	2006–2012	Single-center, retrospective	457	CTU	Bladder cancer UTUC	0.7% 0.0%	
Cowan et al[22]	Unspecified	NR	Single-center, retrospective	106	CTU	UTUC	30.2%	5
Devlin et al[23]	Gross	2013	Single-center, retrospective	234	CTU	UTUC	3.8%	5
Eisenhardt et al[24]	Unspecified	2011–2012	Single-center, prospective	113	CTU	UTUC Kidney cancer	4.4% 9.7%	N/A
Elmussareh et al[25]	Gross	2017	Single-center, retrospective	889	CTU	Urinary tract Neoplasm	23.1%	23.1%
	Micro	2017	Single-center, retrospective	688	CTU	Urinary tract Neoplasm	3.3%	
Gandrup et al[26]	Gross	2011–2013	Single-center, prospective	150	CTU or MRU	Bladder cancer	12.7%	
Gray Sears et al[27]	Micro	1998–2001	Single-center, prospective	115	CTU	Bladder cancer UTUC Kidney cancer	0.9% 0.9% 1.8%	7
Helenius et al[28]	Gross	2005–2008	Single-center, retrospective	435	CTU	Bladder cancer	11.0%	7
Klein et al[29]	Unspecified	1992–1995	Single-center, unspecified	100	MRU	Kidney cancer	6.0%	5
Lang et al[30]	Micro	1999–2002	Multicenter, prospective	600	CTU	Bladder cancer UTUC Kidney cancer	2.5% 2.7% 2.2%	8
Lisanti et al[31]	Micro	2006–2012	Single-center, retrospective	442	CTU	UTUC	0.0%	8
Lokken et al[32]	Gross	2000–2009	Single-center, retrospective	142	CTU	Kidney cancer	0.7%	5
	Micro	2000–2009	Single-center, retrospective	181	CTU	Kidney cancer	0.0%	
Mace et al[33]	Gross	2012–2013	Single-center, retrospective	53	CTU	Kidney cancer	0.0%	6
	Micro	2012–2013	Single-center, retrospective	84	CTU	Kidney cancer	0.0%	
Rheume-Lanoie et al[34]	Gross	2007–2009	Single-center, retrospective	86	CTU	Urinary tract Neoplasm	19.8%	7

CT: computed tomography; CTU: computed tomography urography; MRU: magnetic resonance urography; N/A: not able to be assessed, as data is presented in abstract form; NR: not reported; ROB: risk of bias; UTUC: upper tract urothelial carcinoma.

Table 1 (cont'd). Characteristics of included studies

Study	Hematuria	Years	Study setting	Sample size (n)	Imaging modality	Outcome Evaluated	Frequency of diagnosis (%)	ROB score
Sudakoff et al[35]	Unspecified	2002–2005	Single-center, retrospective	468	CTU	Bladder cancer	4.9%	5
Tan et al[36]	Gross	2016–2017	Multicenter, prospective	1374	CT	Bladder cancer	13.8%	9
						UTUC	1.3%	
						Kidney cancer	2.3%	
	Micro	2016–2017	Multicenter, prospective	319	CT	Bladder cancer	6.3%	
						UTUC	0.0%	
						Kidney cancer	1.6%	
Turney et al[37]	Gross	2004–2005	Single-center, prospective	161	CTU	Bladder cancer	26.1%	8
Wang et al[38]	Unspecified	2004–2006	Single-center, retrospective	60	CTU	UTUC	38.3%	3
Zreik et al[39]	Unspecified	2009–2012	Single-center, prospective	1608	CTU	Bladder cancer	16.8%	N/A
						UTUC	4.7%	

CT: computed tomography; CTU: computed tomography urography; MRU: magnetic resonance urography; N/A: not able to be assessed, as data is presented in abstract form; NR: not reported; ROB: risk of bias; UTUC: upper tract urothelial carcinoma.

all three groups. No differences were found between these proportions on pairwise testing (Table 2).

Upper tract urothelial carcinoma

Assessing the diagnostic yield for upper tract urothelial carcinoma, we pooled results from 3196 patients (five studies) with gross hematuria, 2462 patients (six studies) with microscopic hematuria, and 2317 patients (six studies) with unspecified hematuria. The diagnostic yield varied according to the degree of hematuria: gross hematuria 1.3% (95% CI 0.7–1.9%, I^2=25%), microscopic hematuria 0.18% (95% CI -0.06–0.42%, I^2=70%), and unspecified hematuria 10.4% (95% CI 5.9–15.0%, I^2=91%). There were significant differences among all three pairwise comparisons: diagnostic yield was higher among patients with gross than microscopic hematuria (difference=1.11%, 99% CI 0.23–1.99%), among patients with unspecified than gross hematuria (difference=9.2%, 99% CI 3.2–15.1%), and among patients with unspecified than microscopic hematuria (difference=10.3%, 99% CI 4.3–16.2%) (Table 2).

Bladder cancer

We identified seven studies (3509 patients) that reported data on the diagnostic yield of axial imaging for bladder cancer in patients with gross hematuria, six (2132 patients) in patients with microscopic hematuria, and five (3250 patients) in those with unspecified degrees of hematuria. The diagnostic yield of axial imaging differed depending on the degree of hematuria, with pooled rates of 17.6% (95% CI 11.9–23.3%) in patients with gross hematuria, 2.4% (95%

Table 2. Pairwise comparison of diagnostic yield of axial imaging for hematuria-related urologic cancers based on the severity of hematuria

Pairwise comparison	Pooled diagnostic yield – group 1 (%)	Pooled diagnostic yield – group 2 (%)	Difference in diagnostic yield (%)	95% CI of difference (%)	99% CI of difference (%)
Bladder cancer					
Gross vs. micro	17.61	2.351	15.26	9.412 to 21.11	7.574 to 22.95
Gross vs. unknown	17.61	11.55	6.058	-3.162 to 15.23	-6.059 to 18.17
Micro vs. unknown	2.351	11.55	-9.202	-16.60 to -1.808	-18.92 to 0.516
Upper tract urothelial carcinoma					
Gross vs. micro	1.289	0.179	1.110	0.438 to 1.782	0.227 to 1.993
Gross vs. unknown	1.289	10.44	-9.154	-13.71 to -4.600	-15.14 to -3.166
Micro vs. unknown	0.179	10.44	-10.26	-14.78 to -5.745	-16.20 to -4.324
Renal cancer					
Gross vs. micro	1.453	0.979	0.474	-0.594 to 1.542	-0.930 to 1.877
Gross vs. unknown	1.453	3.554	-2.101	-4.323 to 0.121	-5.021 to 0.818
Micro vs. unknown	0.979	3.554	-2.575	-4.747 to -0.403	-5.430 to 0.280
Aggregate urological malignancies					
Gross vs. micro	15.38	4.452	10.93	-0.440 to 22.29	-4.012 to 25.86
Gross vs. unknown	15.38	19.51	-4.132	-17.92 to 9.655	-22.25 to 13.99
Micro vs. unknown	4.452	19.51	-15.06	-23.78 to -6.338	-26.52 to -3.597

CI: confidence interval.

CI 0.95–3.7%) in patients with microscopic hematuria, and 11.6% (95% CI 4.3–18.8%) in patients with unspecified hematuria. Perhaps unsurprisingly, heterogeneity was highest among patients with unspecified hematuria (I^2=98%), though it was also high in patients with gross (I^2=82%), but not microscopic hematuria (I^2=18%). Pairwise comparisons demonstrated a significant difference in the diagnostic yield among patients with gross and microscopic hematuria (difference=15.3%, 99% CI 7.6–23.0) (Table 2).

All hematuria-related urological malignancies

Finally, we assessed aggregate rates of hematuria-associated urological malignancies. We examined five studies reporting on 2859 patients with gross hematuria, six studies reporting on 2335 patients with microscopic hematuria, and five studies reporting on 3118 patients with unspecified hematuria. The pooled rates of diagnostic yield were as follows: 15.3% (95% CI 4.4–26.4) among patients with gross hematuria, 4.5% (95% CI 1.7–7.2%) among patients with microscopic hematuria, and 19.5% (95% CI 11.2–27.8%) among patients with unspecified hematuria. Pairwise testing identified a significant difference at the alpha=0.01 for the comparison of microscopic and unspecified hematuria (difference=15.1%, 99% CI 3.6–26.5%).

Discussion

In this systematic review and meta-analysis, we found significant limitations in the evidentiary base assessing the relationship between the severity of hematuria and the likelihood of underlying malignant etiology, as diagnosed based on axial imaging. A significant proportion of relevant studies (12 studies, 41%) did not clearly specify the presenting characteristics (gross or microscopic hematuria) of the patients included in their analysis. Further, a meaningful proportion of the remainder of the identified studies were at high risk of bias due to methodological limitations. Thus, despite a relatively intuitive hypothesis, the data underpinning the assumption that patients with more severe hematuria are more likely to have an underlying malignant cause is poor. Interesting, in this pooled analysis, we found that cohorts with unspecified hematuria (i.e., not characterized in the manuscript) reported the highest rates of urological malignancies.

Given that unspecified hematuria likely represents a mixture of gross and microscopic hematuria, it would have been expected that this cohort have a malignancy risk that falls in between those reported for patients with gross and microscopic hematuria. With regards to bladder cancer, this assumption held, with studies reporting on patients with unknown hematuria having a risk (11.6%) that approximates the combined mean of those reported in patients with gross (17.6%) and microscopic hematuria (2.4%). However, the higher risk of upper tract urothelial, renal, and aggregate urological cancers in these patients with unspecified hematuria raises the concern for a spectrum bias. The various study populations are likely to have differed with regards to their baseline risk of malignancy — specifically, known risk factors such as increasing age, positive family history, and smoking status — that increase the pre-test probability of malignancy and, thus, influenced the cancer detection rate.

While it is perhaps clinically intuitive that the severity of hematuria would be associated with the likelihood of underling malignancy, it highlights the potential for spectrum bias when we consider the use of the same diagnostic tests (e.g., CT urography) in different populations (e.g., gross and microhematuria). Spectrum bias refers to inherent differences in the study population characteristics affecting the performance of the diagnostic tests and, thus, limiting the generalizability of these results. While sensitivity and specificity are well-known characteristics of diagnostic tests, clinical use relies much more heavily on positive and negative predictive values. Unlike sensitivity and specificity, positive and negative predictive values are meaningfully affected by the underlying prevalence of disease in the population under study. Thus, changing the characteristics of a study population, or applying a test to a differing population, may change the performance of a diagnostic test, resulting in spectrum bias or the spectrum effect — a form of sampling bias.

The implications of these findings, while almost intuitive, are potentially profound. Guideline development, as with nearly every clinical decision, is premised on the balance of risk and benefits. Applying data that are subject to this sampling bias is highly likely to overestimate the accuracy of a diagnostic test, particularly when evaluation of a diagnostic test occurs among patients with more severe disease than the target population.[40] Thus, extrapolation of data from mixed populations or patients with gross hematuria to those with asymptomatic microhematuria, as is described in the current AUA guideline on the diagnosis, evaluation and followup of asymptomatic microhematuria in adults,[4] overestimates the benefit of axial abdominal imaging. Further, recent evidence has emerged highlighting the potential risks of this approach in patients with asymptomatic hematuria, including radiation-induced malignancies and diagnosis of incidentalomas.[41-43] Thus, to best guide care for these patients, it is imperative that patients included in studies used to guide treatment decisions are explicitly defined and comparable to those for whom the guidelines are applied. The National Institute for Health and Care Excellence (NICE) clinical guidelines are the only ones to specifically recognize the issues with the evidence underlying guidelines on this topic, noting that they "merged all urinary tract cancers, making it difficult to tease out specifics" related to bladder or renal cancer, and did not distinguish between visible and non-visible hematuria, but largely grouped these two together as "hematuria."[44]

Limitations

Despite strengths, there are limitations to this review, most notably due to limitations of the underlying literature. Available studies were predominantly retrospective in nature, which inherently introduces an element of selection bias. This is exemplified by the occasional reluctance of primary care physicians to refer patients with hematuria for a urological workup, with studies suggesting that the referral rate for such patients may only be 49–64%[1] or lower. This invariably introduces selection bias, with referred patients likely to have had additional worrisome features that prompted referral. The lack of granularity in the literature, both with regards to underlying type of hematuria and baseline patient characteristics, at least in part, explains some of the unanticipated variability seen in this study's results. Microscopic hematuria reports included patients with varying numbers of red blood cells per high-power field and, thus, varying microscopic hematuria severities. Additionally, the degree of heterogeneity, as quantified by the I^2 value, was consistently higher in those studies with unspecified type of hematuria. It is also important to emphasize that the reported risks of malignancy are based only on axial imaging, which is not sufficient for a complete hematuria workup.[4,5] While the absolute incidence of bladder cancer is likely underestimated by the exclusion of cystoscopic diagnosis, this was beyond the scope of this study, which specifically sought to assess spectrum bias within the context of axial abdominal imaging. Lastly, no a priori protocol was published for this systematic review, which exposes this study to inherent biases with regards to study selection.

Conclusions

The severity of hematuria is associated with the likelihood of diagnosis of urological malignancy on axial imaging. However, many studies assessing diagnostic performance of imaging tests in patients with hematuria do not specify these details. To provide generalizable results and avoid incorrect extrapolations, future studies should report degree of hematuria. Physicians and guideline authors should recognize differing underlying risks of malignancy in patients with differing severity of hematuria.

Competing interests: The authors report no competing person or financial interests related to this work.

Funding: Drs. Lokeshwar and Klaassen are funded by 1R01CA227277-01A1, an NIH grant assessing novel biomarkers for the clinical management of bladder cancer.

This paper has been peer-reviewed.

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