

Evaluation of Asymptomatic Microscopic Hematuria by Renal Ultrasound to Detect Upper Tract Malignancy: A 20-Year Experience in a Community Hospital



Matthew R. Smith, Keaton C. Read, Matthew L. Stegman, Neil J. Kroll, and Marvin J. Van Every

OBJECTIVE	To evaluate the sensitivity of ultrasound imaging in detecting upper urinary tract malignancy in patients with asymptomatic microscopic hematuria (AMH) in an outpatient community setting.
MATERIALS AND METHODS	A list of all patients who received renal ultrasound for hematuria in our health care system between January 1, 1997 and July 1, 2015 was obtained, and electronic health records were retrospectively reviewed. Patients were excluded for age (<18 years), <3 years follow-up, prior upper tract malignancy, recent urinary tract catheterization, inpatient status, pregnancy, insufficient data, or gross hematuria. The initial ultrasound was considered positive if suspicious findings led to a subsequent diagnosis of an upper tract malignancy. False negatives were determined by electronic medical record follow-up for at least 3 years.
RESULTS	Of the 2138 patients with AMH who met inclusion criteria, ultrasound imaging detected suspicious findings in 9 of 9 patients with renal cell carcinoma and 3 of 3 patients with upper tract urothelial cancer, indicating a sensitivity of 100% and 100%, respectively. Four additional malignancies were diagnosed more than 3 years after the initial evaluation for an incidence rate of 1.6 cases of upper tract malignancy per 10,000 person-years.
CONCLUSION	The prevalence of upper urinary tract malignancy was low in patients with AMH. Ultrasonography is an appropriate modality for upper tract imaging in the initial evaluation of patients with AMH. Practice guidelines should be updated to reflect the high sensitivity of ultrasound and low risk of upper tract malignancy in patients with AMH. UROLOGY 133: 34–39, 2019. © 2019 Elsevier Inc.

Asymptomatic microscopic hematuria (AMH) can be a sign of serious underlying urinary tract disease and requires evaluation for urologic malignancy.¹⁻¹⁰ Existing guidelines agree that the bladder should be evaluated with cystoscopy, but the preferred imaging modality of the kidneys and ureters is controversial.¹¹⁻¹⁴ The most recent update from the American Urological Association (AUA) states that multiphasic computed tomographic urography (CTU) with and without intravenous contrast is the imaging procedure of choice to evaluate the upper urinary tracts in patients

with AMH.¹¹ In contrast, ultrasonography can also be a suitable imaging choice to evaluate the upper tracts in patients with AMH.^{6,8,9,12,15-17} It is widely available, is noninvasive, avoids ionizing radiation or intravenous contrast, and is less expensive than CTU. Renal ultrasound combined with cystoscopy was recently shown to be the most cost-effective strategy for the detection of urinary tract malignancy.¹⁸

A better understanding of disease prevalence has led to improved risk stratification based on patient characteristics and degree of hematuria including gross hematuria (GH), MH, and AMH. However, the sensitivity of ultrasound has been studied primarily in the context of combined gross and microscopic hematuria.^{1,3,9,17,19,20} We are aware of only 1 study that reports the performance of renal ultrasound in a population consisting of strictly AMH patients.²¹ Jaffe et al found 3 low-grade upper tract urothelial cancers (UTUCs) using intravenous urography as a

All authors have no conflict of interest to disclose.

From the Departments of Medical Education, Gunderson Health System, La Crosse, WI; the Departments of Medical Research, Gunderson Health System, La Crosse, WI; and the Departments of Urology, Gunderson Health System, La Crosse, WI

Address correspondence to: Matthew R. Smith, M.D., Ph.D., Gunderson Medical Foundation, 1900 South Avenue, La Crosse, WI 54601. E-mail: matasmith4@gmail.com

Submitted: May 8, 2019, accepted (with revisions): July 5, 2019

reference standard in 75 patients who had persistent AMH 3 months after a normal ultrasound.¹⁷

Our community health system has routinely used renal ultrasound to evaluate the upper urinary tract in the initial evaluation of patients with AMH. The purpose of this study was to use long-term follow-up to evaluate the sensitivity of renal ultrasound for detecting upper-tract malignancy in patients with AMH.

MATERIALS AND METHODS

Health System

Our healthcare system is an integrated medical center, with 33 regional clinics serving 21 counties over a tri-state region. Primary care providers and consultants share the same integrated electronic health record system that has been in place since 1997.

Evaluation of Asymptomatic Microscopic Hematuria

Microscopic hematuria is defined as 2 urinalyses with ≥ 3 red blood cells per high-power field. Further classification of AMH is appropriate after ruling out infection, symptoms, or other benign causes, consistent with the most recent AUA definition.¹¹ Our institutional approach to evaluation of AMH remained unchanged during the 20-year study period and has been as outlined in Figure 1. Renal ultrasound was ordered by either the primary care provider or via urologic consultant to evaluate the upper urinary tract. Imaging was performed within the department of radiology by general sonographers under the supervision of radiologists. The upper urinary tract was evaluated for renal and urethelial masses, parenchymal loss, stones, and ureteral obstruction. Suspicious findings on renal ultrasound prompted additional evaluation, usually by CTU. The lower urinary tract was evaluated with cystoscopy. If the initial workup with cystoscopy was negative for an identifiable cause of AMH, patients were advised to follow-up with their provider or urologic consultant if they developed GH, flank pain, or irritative voiding symptoms.

Patients

This study was approved by our Institutional Review Board (Protocol 2-18-04-004). A list of all patients who underwent a renal ultrasound in our health system from January 1, 1997 to July 1, 2015 was obtained and electronic health records were retrospectively reviewed. Patients were included in the study if they had at least 3 years of follow-up that included medical documentation by a provider. Patients were excluded if they were younger than 18 years, had a history of a prior upper tract malignancy, had a recent catheterization, had inpatient status, were pregnant, or had GH or spotting. If patients had multiple evaluations of AMH during the study period, only the initial evaluation was included. Patients were also excluded if the renal ultrasound was ordered for an indication other than hematuria (eg, surveillance of chronic kidney disease) based on provider health record documentation. Finally, patients were excluded if the health record did not contain sufficient detail to rule out GH. Owing to the dynamics of AMH guidelines during the 20-year study period, adherence to any particular guideline was not recorded.

Data

The initial ultrasound report for each patient was reviewed and any abnormalities or suggestions of malignancy were recorded. The ultrasound was considered positive if findings led to further evaluation that included additional imaging (typically CT) and resulted in diagnosis of an upper tract malignancy. Regardless of the ultrasound results, health records were then reviewed to determine whether any upper tract cancer was subsequently diagnosed to assess for false-negatives. The stage and grade of upper tract malignancies were recorded if possible, as well as the time interval between initial evaluation with renal ultrasound and diagnosis. For the malignancies diagnosed prior to standard staging templates, cancer staging was recapitulated using the American Joint Committee on Cancer guidelines. Our institutional cancer registry was used to cross reference our data to ensure that all upper tract malignancies were captured in the cohort.

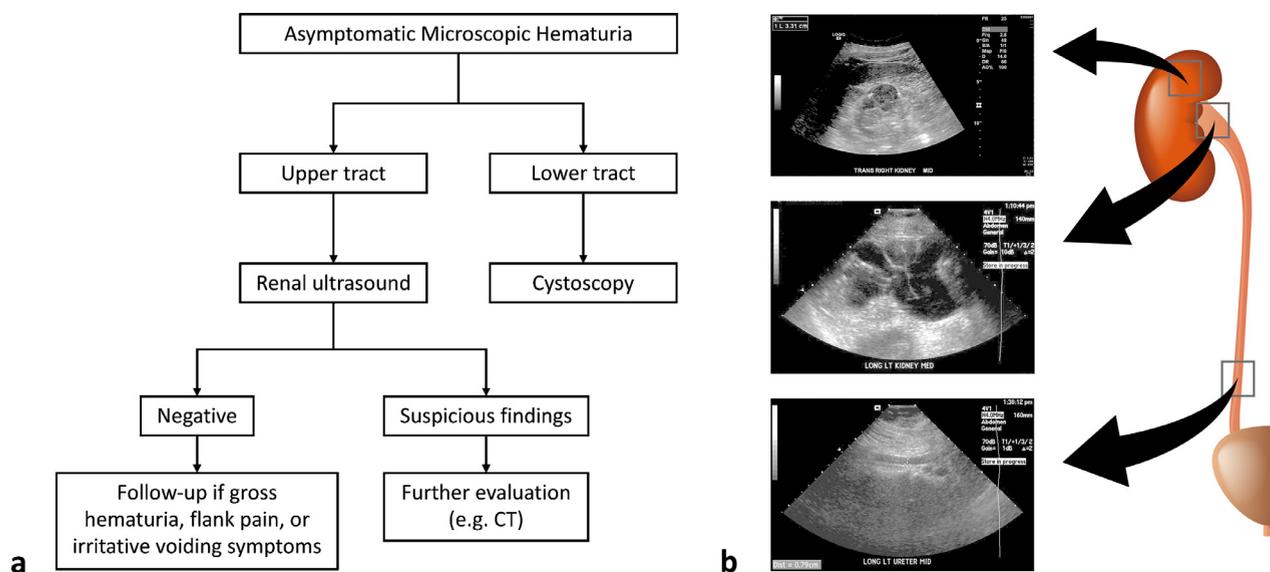


Figure 1. (a) Asymptomatic microscopic hematuria algorithm at our institution. (b) Ultrasound can evaluate for upper tract malignancies by directly visualizing renal masses (top) or detecting signs of ureteral obstruction such as expansion of the calyces (middle) and hydronephrosis (bottom).

Variables such as age, sex, smoking history, follow-up period after initial evaluation with ultrasound, and prevalence of upper tract malignancies were evaluated. Since prevalence of malignancy in patients with AMH is low at baseline, no attempt was made at further risk stratification. We calculated the incidence rate by dividing the number of new upper tract malignancies diagnosed greater than 3 years after the initial ultrasound by the cumulative number of person-years of observation. The sensitivity and negative predictive value of ultrasound to detect upper tract malignancy were calculated along with binomial confidence intervals.

RESULTS

A total of 4871 patients received a renal ultrasound from January 1, 1997 to July 15, 2015. Of those patients, 2138 met inclusion criteria (Fig. 2). The vast majority of patients fit our institutional criteria for AMH—that is, 2 consecutive urinalyses with ≥ 3 red blood cells per high-power field—prior to renal ultrasound evaluation. Demographic and clinical patient data are provided in Table 1. The average follow-up was 11.6 years (range: 3-21.6 years).

Twelve (0.6%) patients were diagnosed with upper tract malignancy (9 RCC and 3 UTUC) during their initial evaluation, all of whom had an initial ultrasound positive for malignancy (Table 1), indicating a sensitivity of renal ultrasound to detect RCC of 100% (confidence interval [CI] 66.4%-100%) with NPV 100% (CI 99.8%-100%) and the sensitivity of renal ultrasound to detect UTUC of 100% (CI 29.2%-100%) with NPV 100% (CI 99.8%-100%). The pathologic grade, stage, and tumor size of the upper tract malignancies are provided in Table 2. One case of UTUC was found in a 94-year-old patient who declined surgery and therefore no histologic confirmation was obtained for this case.

Health records were reviewed beyond 3 years, which allowed long-term follow-up. Four patients were diagnosed with upper tract malignancy more than 3 years after the initial ultrasound

(at 4.0, 4.5, 8.0, and 11.2 years). In all 4 cases, the initial ultrasound was negative for signs of malignancy (Table 2). The incidence rate of upper tract malignancy in patients with AMH was 1.6 new cases per 10,000 persons per year, with 4 cancers over 24,284 person-years.

DISCUSSION

We present our long-term experience of using renal ultrasound to evaluate the upper tract in patients with AMH. The cohort included 2138 patients with AMH evaluated with renal ultrasound reflecting a general population from a community outpatient setting with reliable long-term follow-up. This included representative outpatient referrals from primary care providers in an integrated care setting. The prevalence of upper tract malignancy was expectedly small in this population of patients (0.6%) which agrees with findings from several other studies.^{2,3,9,10} Long-term follow-up enabled calculation of upper tract malignancy incidence, which has not previously been possible. Importantly, ultrasound detected all 12 upper tract malignancies with a sensitivity of 100%.

There is no universally accepted radiographic imaging reference standard for detection of upper tract malignancy. Prior studies have compared the performance of renal ultrasound with that of intravenous urography^{1,3} or CTU.⁹ In this study, no comparison was made to CTU. Instead, clinical follow-up was used to assess the performance of renal ultrasound. We assumed that clinical progression of the malignancy would reveal any false-negative ultrasound result within a 3-year follow-up, a time frame that has been previously used in the literature^{12,22} and in the AUA recommendations¹¹ based on the natural progression of upper tract malignancies.²³ It is important to note that 4

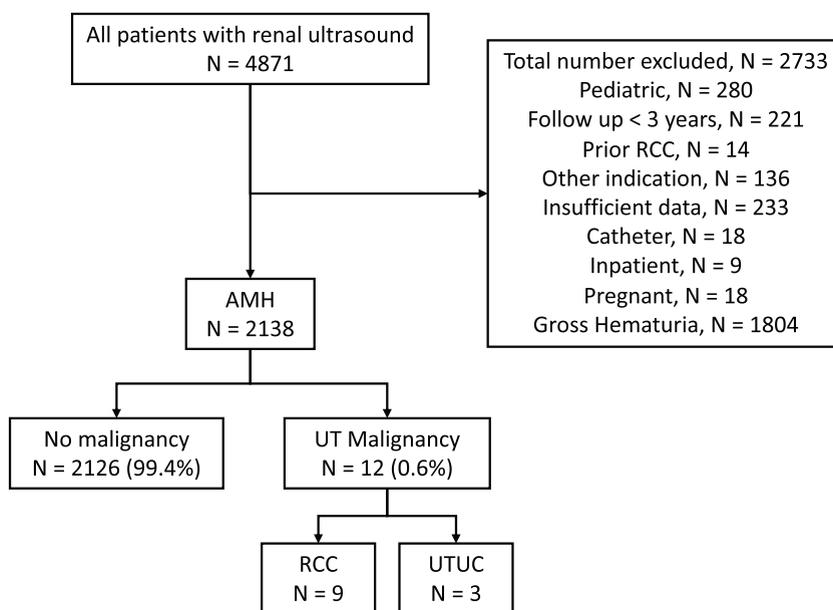


Figure 2. Patient flow chart and resulting number of upper tract malignancies. AMH, asymptomatic microscopic hematuria; RCC, renal cell carcinoma; UT, upper tract; UTUC, upper tract urothelial cancer.

Table 1. Patient characteristics and distribution of malignancies.

Age, y	N	Male	Female	Follow-up Years, Mean \pm SD	Smoking History, N (%)	UTUC	RCC	Ultrasound Positive
≤ 40	285	110	175	11.9 \pm 4.8	114 (40)	0	0	0
41-50	388	159	229	13.0 \pm 4.7	152 (39)	0	1	1
51-60	471	226	245	12.7 \pm 4.9	226 (48)	0	1	1
61-70	439	220	219	11.8 \pm 4.7	219 (50)	0	2	2
71-80	398	197	201	10.0 \pm 4.2	176 (44)	1	5	6
≥ 81	157	66	91	7.7 \pm 3.6	48 (31)	2	0	2
Totals	2138	978	1160	11.6 \pm 4.9	935 (44)	3	9	12

upper tract malignancies were diagnosed after a 3-year follow-up. This study assumes that these 4 malignancies were not present at the initial evaluation. One case of UTUC presented after several episodes of intermittent GH and flank pain. The other 3 renal tumors were incidentally noted during imaging for other indications which included lumbar magnetic resonance imaging for back pain, staging CT for rectal cancer, and renal ultrasound to evaluate chronic kidney disease. Despite improved detection rates and earlier surgical intervention of small renal tumors, mortality rates have not improved and therefore observation has been increasingly considered appropriate for some patients.²⁴ It is possible that the RCCs detected at 4.0 and 4.5 years were present but very small in size at the initial evaluation. However, both tumors were T1a stage and there was no harm in delay of diagnosis.

Despite data collection over a 20-year time frame, only 3 cases of UTUC were identified. The low prevalence of UTUC in patients with AMH underscores the appropriateness of avoiding radiation risk and cost associated with CTU in this population. In addition, this study only supports that renal ultrasound can detect UTUC of advanced

stage. Of the 3 UTUC cases identified 2 were advanced stage (T2 and T3). However, these advanced cases presented as AMH and by definition without any symptoms. Based on our limited cases of UTUC, AMH caused by UTUC was not detected until the malignancy was late stage and would be very challenging to identify without any symptoms by any method.

The AUA recommendations in 2012 for management of patients with asymptomatic AMH states CTU are the imaging procedure of choice to maximize diagnostic certainty.¹¹ Given the low prevalence of malignancy in patients with AMH and high sensitivity of renal ultrasound supported by this study, the diagnostic benefit of CTU in this low-risk group is controversial.^{6,9,20} Additionally, Yecies et al have recently shown that the theoretical risk of malignancy from the ionizing radiation of CT outweighs the beneficial sensitivity when compared with renal ultrasound using a sensitivity of renal ultrasound of 82% as the model input.⁸ As the sensitivity of ultrasound approaches 100%, as measured by our study, CTU has diminishing benefit in detection of upper tract malignancies. In addition to radiation exposure, CTU

Table 2. Distribution and characterization of upper tract malignancies.

Diagnosis Interval, y*	Type [†]	Pathologic Stage	Tumor Size (cm)	Age	Sex	Smoking History
US positive						
≤ 0.5	RCC (clear cell)	T1	7.0	75	M	Yes
≤ 0.5	RCC (clear cell)	T1a	3.0	43	M	Yes
≤ 0.5	RCC (clear cell)	T3a	7.2	66	M	No
≤ 0.5	RCC (clear cell)	T1	2.1	77	F	No
≤ 0.5	RCC (papillary)	T1a	1.6	75	M	Yes
≤ 0.5	RCC (clear cell)	T3b	12.0	59	M	Yes
≤ 0.5	RCC (clear cell)	T3b	9.5	78	F	No
≤ 0.5	RCC (clear cell)	T1a	3.3	79	M	Yes
≤ 0.5	RCC (clear cell)	T1a	1.4	66	M	Yes
≤ 0.5	UTUC (HG)	T3	3.5	71	F	No
≤ 0.5	UTUC (HG)	T2	1.5	88	F	Yes
≤ 0.5	UTUC [‡]			94	F	No
US negative						
4.0	RCC (clear cell)	T1a	3.0	61	F	Yes
4.5	RCC (clear cell)	T1a	3.0	61	M	No
8.0	RCC (clear cell)	T3a	4.5	46	M	Yes
11.2	UTUC (LG), RCC x2 (papillary)	T1, T1a, T1a	2.2, 2.8, 0.5	56	M	Yes

* Time between initial renal ultrasound and pathologic diagnosis.

[†] HG, high-grade; LG, low-grade; RCC, renal cell carcinoma; UTUC, upper tract urothelial carcinoma.

[‡] Clinical diagnosis only, patient refused surgery.

imposes financial burdens to the health system. Halpern et al extensively analyzed the additional cost from substitution of CT in lieu of renal ultrasound with limited added value.¹⁸ At this writing, the Medicare reimbursement for our health system is \$471 for CTU and \$145 for renal ultrasound, a factor of 3.2 difference, consistent with the aforementioned study. Not only is CTU more costly, but it can also reveal incidental findings that can lead to other expensive and invasive procedures. Lai et al found CTU led to increased costs of \$694.50 per initial patient screened to evaluate extraordinary findings.²⁵ Although CTU is highly sensitive, its benefit should outweigh the expense^{10,18,25,26} and the risks of contrast-induced nephropathy, contrast reactions, and radiation exposure.⁸ Future development of CTU techniques to reduce radiation exposure²⁷ and contrast²⁸ may decrease these burdens and enable its widespread use. CUT does have the advantage of revealing potentially important findings outside the urinary tract,²⁹ but at this time we believe its advantages do not outweigh the risks and costs.

Many groups have recommended the use of ultrasound as initial evaluation of the upper tracts in patients with AMH.^{1,6,8,9,12,15,17,20,30} The American College of Radiology reports Appropriateness Criteria for workup of hematuria in which they recommend ultrasound as the first-line imaging modality in patients with a very low risk of having a malignant cause of hematuria.¹⁵

This study has several limitations. First, our findings should be interpreted in the context of our study design and patient population. Our institutional algorithm uses 2 simple categories of AMH and GH to determine the appropriate evaluation method since the additional risk prognosis offered by the degree of hematuria is controversial.^{2,5,10} We assumed that all patients with AMH had been evaluated with ultrasound and were included in our study, but it is possible that primary care providers deemed some patients at such low risk that a watchful waiting approach was taken without radiographic evaluation. Had these patients been included in our analysis, the prevalence of patients with AMH who had an upper tract malignancy may have been even lower than we reported. It should be noted that providers could have ordered a CTU as the initial radiographic evaluation instead of renal ultrasound, but this would have deviated significantly from the well-established institutional protocol. The size of the study mitigates the influence of any particular provider that varied from the institutional protocol of evaluating AMH. In addition, our population included those patients who never made it to consultation with urology due to negative initial evaluation by renal ultrasound or primary care provider discretion. Although the large majority of our study population stayed within our health care system supported by the average long-term follow-up of 11.6 years, some patients might have changed to another provider group, left the geographical area, or never sought further care. Ultrasound is subject to user variability; thus, the sensitivity of ultrasound is based on the skill of the sonographer to find and assess

abnormalities. Over the time frame of the study, each renal ultrasound was acquired by a dedicated ultrasonographer in the department of radiology under supervision of a radiologist to mitigate those effects. Finally, as technology improved, the ultrasound equipment of our institution was appropriately updated; therefore image quality likely varied over time.

In conclusion, this work adds to the growing body of literature that supports renal ultrasound as an appropriate and effective method to evaluate for upper tract malignancy in patients with AMH. In addition, patients can be advised to return for further evaluation if they develop GH, flank pain, or irritative voiding symptoms if initial renal ultrasound shows no signs of malignancy.

Acknowledgments. The authors wish to acknowledge Cary Rasmussen and Cathy Fischer for assistance in this study.

References

1. Edwards TJ, Dickinson AJ, Natale S, Gosling J, McGrath JS. A prospective analysis of the diagnostic yield resulting from the attendance of 4020 patients at a protocol-driven haematuria clinic. *BJU Int.* 2006;97:301–305. <https://doi.org/10.1111/j.1464-410X.2006.05976.x>.
2. Jung H, Gleason JM, Loo RK, Patel HS, Slezak JM, Jacobsen SJ. Association of hematuria on microscopic urinalysis and risk of urinary tract cancer. *Int Braz J Urol.* 2011;37:285–286. <https://doi.org/10.1590/S1677-55382011000200027>.
3. Khadra MH, Pickard RS, Charlton M, Powell PH, Neal DE. A prospective analysis of 1,930 patients with hematuria to evaluate current diagnostic practice. *J Urol.* 2000;163:524–527.
4. Madeb R, Golijanin D, Knopf J, et al. Long-term outcome of patients with a negative work-up for asymptomatic microhematuria. *Urology.* 2010;75:20–25. <https://doi.org/10.1016/j.urology.2009.06.107>.
5. Loo RK, Lieberman SF, Slezak JM, et al. Stratifying risk of urinary tract malignant tumors in patients with asymptomatic microscopic hematuria. *Mayo Clin Proc.* 2013;88:129–138. <https://doi.org/10.1016/j.mayocp.2012.10.004>.
6. Commander CW, Johnson DC, Raynor MC, et al. Detection of upper tract urothelial malignancies by computed tomography urography in patients referred for hematuria at a large tertiary referral center. *Urology.* 2017;102:31–37. <https://doi.org/10.1016/j.urology.2016.10.055>.
7. Elmussareh M, Young M, Ordell Sundelin M, Bak-Ipsen CB, Graumann O, Jensen JB. Outcomes of haematuria referrals: two-year data from a single large university hospital in Denmark. *Scand J Urol.* 2017;51:282–289. <https://doi.org/10.1080/21681805.2017.1310759>.
8. Yecies T, Bandari J, Fam M, Macleod L, Jacobs B, Davies B. Risk of radiation from computerized tomography urography in the evaluation of asymptomatic microscopic hematuria. *J Urol.* 2018;200:967–972. <https://doi.org/10.1016/j.juro.2018.05.118>.
9. Tan WS, Sarpong R, Khetrapal P, et al. Can renal and bladder ultrasound replace computerized tomography urogram in patients investigated for microscopic hematuria. *J Urol.* 2018;200:973–980. <https://doi.org/10.1016/j.juro.2018.04.065>.
10. Samson P, Waingankar N, Shah P, Friedman D, Kavoussi L, Han J. Predictors of genitourinary malignancy in patients with asymptomatic microscopic hematuria. *Urol Oncol Semin Orig Invest.* 2018;36:10.e1–10.e6. <https://doi.org/10.1016/j.urolonc.2017.09.011>.
11. Davis R, Jones JS, Barocas DA, et al. Diagnosis, evaluation and follow-up of asymptomatic microhematuria (AMH) in adults: AUA guideline. *J Urol.* 2012;188(6 SUPPL.):2473–2481. <https://doi.org/10.1016/j.juro.2012.09.078>.
12. Wollin T, Laroche B, Psooy K. Canadian guidelines for the management of asymptomatic microscopic hematuria in adults. *J Can Urol Assoc.* 2009;3:77–80.

13. Sharp VJ, Barnes KT, Erickson BA. Assessment of asymptomatic microscopic hematuria in adults. *Am Fam Physician*. 2013;88:747–754.
14. Nager CW, Sung VW, Whiteside JL. Asymptomatic microscopic hematuria in women. *Obstet Gynecol Surv*. 2017;72:650–651. <https://doi.org/10.1097/OGX.0000000000000496>.
15. Shen L, Raman SS, Beland MD, et al. American College of Radiology ACR Appropriateness Criteria: Hematuria. 2014.
16. Cauberg ECC, Nio CY, de la Rosette JMCH, Laguna MP, de Reijke TM. Computed tomography-urography for upper urinary tract imaging: is it required for all patients who present with hematuria. *J Endourol*. 2011;25:1733–1740. <https://doi.org/10.1089/end.2011.0225>.
17. Jaffe JS, Ginsberg PC, Gill R, Harkaway RC. A new diagnostic algorithm for the evaluation of microscopic hematuria. *Urology*. 2001;57:889–894. [https://doi.org/10.1016/S0090-4295\(00\)01124-9](https://doi.org/10.1016/S0090-4295(00)01124-9).
18. Halpern JA, Chughtai B, Ghomrawi H. Cost-effectiveness of common diagnostic approaches for evaluation of asymptomatic microscopic hematuria. *JAMA Intern Med*. 2017;177:800–807. <https://doi.org/10.1001/jamainternmed.2017.0739>.
19. Datta SN, Allen GM, Evans R, Vaughton KC, Lucas MG. Urinary tract ultrasonography in the evaluation of haematuria—a report of over 1000 cases. *Ann R Coll Surg Engl*. 2002;84:203–205.
20. Ünsal A, Çalişkan EK, Erol H, Karaman CZ. The diagnostic efficiency of ultrasound guided imaging algorithm in evaluation of patients with hematuria. *Eur J Radiol*. 2011;79:7–11. <https://doi.org/10.1016/j.ejrad.2009.10.027>.
21. Howard RS, Golin AL. Long-term follow-up of asymptomatic microhematuria. *J Urol*. 1991;145:335–336. [https://doi.org/10.1016/S0022-5347\(17\)38331-3](https://doi.org/10.1016/S0022-5347(17)38331-3).
22. Pichler R, Heidegger I, Leonhartsberger N, et al. The need for repeated Urological evaluation in low-risk patients with microscopic hematuria after negative diagnostic work-up. *Anticancer Res*. 2013;33:5525–5530.
23. Genega EM, Porter CR. Urothelial neoplasms of the kidney and ureter. *Pathol Patterns Rev*. 2008;117(suppl_1):S36–S48. <https://doi.org/10.1309/cctj-mkk1-xu0t-x3dy>.
24. Drangsholt S, Huang WC. Current trends in renal surgery and observation for small renal masses. *Urol Clin North Am*. 2017;44:169–178. <https://doi.org/10.1016/j.ucl.2016.12.003>.
25. Lai WS, Ellenburg J, Lockhart ME, Kolettis PN. Assessing the costs of extraordinary findings of computed tomography urogram in the evaluation of asymptomatic microscopic hematuria. *Urology*. 2016;95:34–38. <https://doi.org/10.1016/j.urology.2016.06.009>.
26. Morgan AE, Berland LL, Ananyev SS, Lockhart ME, Kolettis PN. Extraordinary incidental findings on CT for hematuria: the radiologist's role and downstream cost analysis. *Am J Roentgenol*. 2015;204:1160–1167. <https://doi.org/10.2214/AJR.14.12483>.
27. Shaish H, Newhouse JH. Split-bolus CT urogram: is less more. *Abdom Radiol*. 2017;42:2119–2126. <https://doi.org/10.1007/s00261-017-1098-3>.
28. Lisanti CJ, Toffoli TJ, Stringer MT, DeWitt RM, Schwoppe RB. CT evaluation of the upper urinary tract in adults younger than 50 years with asymptomatic microscopic hematuria: is IV contrast enhancement needed. *Am J Roentgenol*. 2014;203:615–619. <https://doi.org/10.2214/AJR.13.11891>.
29. Pooler BD, Kim DH, Pickhardt PJ. Potentially important extracolonic findings at screening CT colonography: incidence and outcomes data from a clinical screening program. *Am J Roentgenol*. 2016;206:313–318. <https://doi.org/10.2214/AJR.15.15193>.
30. Schmitz-Dräger BJ, Kuckuck EC, Zuiverloon TCM, et al. Microhematuria assessment an IBCN consensus—based upon a critical review of current guidelines. *Urol Oncol Semin Orig Investig*. 2016;34:437–451. <https://doi.org/10.1016/j.urolonc.2016.05.030>.