Comparative Assessment of CT Urography and Ultrasound in Low-Risk vs. High-Risk Patients with Hematuria & their Management strategies

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KEYWORDS

Hematuria, CT Urography, Ultrasound, Diagnostic Accuracy, Low-Risk Patients, High-Risk Patients, Surgical Management

ABSTRACT

Background: Hematuria requires accurate diagnostic evaluation to identify its underlying cause. Imaging modalities such as CT urography and ultrasound are routinely employed, but their comparative effectiveness in low-risk and high-risk patients remains underexplored.
Objective: This study aims to compare the diagnostic utility of CT urography and ultrasound in evaluating hematuria among low-risk and high-risk patients and to analyze management strategies, including surgical interventions.
Methods: A prospective study was conducted on 100 patients with hematuria, divided into low-risk and high-risk groups based on clinical criteria. All patients underwent CT urography and ultrasound. Management plans, including surgical interventions, were documented. Sensitivity, specificity, diagnostic accuracy, and detection rates for urothelial abnormalities, stones, and malignancies were compared between the two modalities.
Results: CT urography demonstrated higher sensitivity (92%) and specificity (89%) compared to ultrasound (78% sensitivity and 82% specificity) across all patient groups. In high-risk patients, CT urography detected 96% of malignancies, while ultrasound identified 80%. Surgical management varied between groups; high-risk patients underwent more extensive surgeries. CT urography outperformed ultrasound in identifying urothelial abnormalities and malignancies across both groups.
Conclusions: CT urography provides superior diagnostic accuracy, particularly in high-risk patients with suspected malignancies, influencing management decisions, including surgical interventions. Ultrasound remains a useful initial screening tool for low-risk patients due to its non-invasive nature and cost-effectiveness.

Introduction

Hematuria, defined as the presence of blood in urine, can indicate a wide spectrum of underlying conditions ranging from benign causes to life-threatening malignancies 111. Accurate diagnosis and appropriate management are crucial to prevent morbidity and mortality associated with serious underlying diseases. Management strategies for hematuria include a structured approach to identifying and treating underlying causes, which may involve medical therapy, surgical intervention, or conservative management**[1, 2]**.

Low-risk patients, typically younger individuals with transient symptoms and no significant risk factors, may benefit from initial non-invasive evaluation and management, such as lifestyle modifications, antibiotics for urinary tract infections, or observation 222**[3, 4]**. High-risk patients, often older with a history of smoking, occupational exposure to carcinogens, or associated symptoms like weight loss or persistent pain, require comprehensive imaging and may necessitate surgical interventions for malignancies or complex conditions 333**[5, 6]**.

Imaging modalities play a vital role in the diagnostic pathway for hematuria and influence management decisions**[7]**. Ultrasound is often the first-line investigation due to its wide availability, safety profile, and cost-effectiveness 444. However, it has limitations in identifying urothelial abnormalities and smaller lesions**[8, 9]**. CT urography is regarded as the gold standard for detailed evaluation of hematuria due to its superior sensitivity and specificity 555. It provides comprehensive visualization of the kidneys, ureters, and bladder, enabling the detection of a wide range of pathologies that may require surgical intervention**[10]**.

This study aims to evaluate and compare the diagnostic utility of CT urography and ultrasound in patients presenting with hematuria, stratified into low-risk and high-risk categories, and to analyze management strategies, including surgical interventions, based on imaging findings.

Materials and Methods

Study Design and Setting

This prospective, observational study was conducted at a tertiary care hospital over 10 months. Ethical approval was obtained from the Institutional Review Board, and written informed consent was obtained from all participants.

Study Population

A total of 100 patients with hematuria were enrolled, divided into:

- **Low-Risk Group (n = 50)**: Patients under 40 years of age, with no significant risk factors.
- **High-Risk Group (n = 50)**: Patients over 40 years of age or with one or more risk factors, such as smoking history, gross hematuria, persistent or recurrent symptoms, weight loss, or family history of urinary tract malignancy.

Inclusion Criteria

- Adults aged ≥18 years presenting with hematuria (gross or microscopic).
- Patients able to undergo both CT urography and ultrasound during the diagnostic workup.
- Willingness to provide informed consent.

Exclusion Criteria

- Patients with known malignancies or prior surgeries of the urinary tract.
- Pregnant or lactating women.
- Those with contraindications to CT urography, such as severe renal impairment or allergy to iodinated contrast agents.
- Incomplete imaging data or loss to follow-up.

Imaging Techniques

CT Urography:

- Performed using a multi-detector CT scanner.
- Protocol included non-contrast, contrast-enhanced, and excretory phases to evaluate the entire urinary tract.
- Pathologies evaluated: stones, urothelial thickening, renal masses, structural abnormalities, and vascular lesions.

Ultrasound:

- Conducted using high-resolution equipment with dedicated renal and bladder probes.
- Focused on assessing renal masses, hydronephrosis, bladder abnormalities, and ureteric stones.

Management Strategies

Based on imaging findings, patients underwent appropriate management, including:

- **Medical Management**: Antibiotics for infections, analgesics for pain, or observation for transient causes.
- **Surgical Interventions**: Endoscopic procedures, nephrectomy (partial or radical), transurethral resection, or cystectomy.
- **Conservative Management**: For benign conditions not requiring immediate intervention.

Data Collection

Patient demographics, clinical history, imaging findings, and management plans were recorded. Surgical specimens from patients undergoing surgery for renal tumors were collected, and gross pathology was documented (representative images included in supplementary material).

Outcome Measures

Primary outcomes included:

- Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of each imaging modality.
- Comparison of detection rates for malignancies, stones, and other pathologies in low-risk vs. high-risk groups.

Secondary outcomes included:

- Management strategies undertaken based on imaging findings.
- Impact of imaging results on clinical decision-making, particularly surgical interventions.

Statistical Analysis

Data were analyzed using SPSS software (version 25.0). Descriptive statistics summarized demographic and clinical data. Sensitivity, specificity, and diagnostic accuracy were calculated using standard formulas. Chi-square tests compared categorical variables, and the paired t-test assessed differences in imaging performance between CT urography and ultrasound. A p-value < 0.05 was considered statistically significant.

Results

Demographic and Clinical Characteristics: The study included 100 patients with hematuria, divided equally into low-risk and high-risk groups. The high-risk group had a significantly higher mean age (62 years) compared to the low-risk group (35 years). Gross hematuria was more prevalent in the high-risk group (85%) than in the low-risk group (20%).

Table 1: Demographic and Clinical Characteristics

Parameter	Low-Risk Group	High-Risk Group
Mean Age (years)	35	62
Male (%)	60	70
Female (%)	40	30
Gross Hematuria (%)	20	80
Microscopic Hematuria (%)	75	25

Diagnostic Performance of CT Urography and Ultrasound

CT urography demonstrated higher sensitivity and specificity compared to ultrasound across all patient groups.

Table 2: Diagnostic Sensitivity of CT Urography and Ultrasound

Parameter	CT Urography (%)	Ultrasound (%)
Sensitivity	92	78
Specificity	89	82
Positive Predictive Value (PPV)	88	80
Negative Predictive Value (NPV)	93	79

Table 3: USG & CT Features for Urolithiasis & Infections:

S.No		USG Features	CT Features
1	Urolithiasis	• Echogenic foci • Acoustic Shadowing • Twinkle Artifact on Colour doppler • ureteric jets for ureteric calculus • High RI value in obstructed kidneys	NCCT based on HU values -calcium oxalate/phosphate: 400-600 HU - Uric Acid and Cystine:100-200 HU For Radiolucent stones Indinavir – Filling defect on delayed phase Matrix – Egg Shell Calcification
2	Infections Pyelonephritis	- Debris in collecting system - Hypoechoic areas (edema) - Hyperechoic areas (hamorrhage) - Hyderonephrosis - Perinephric Fluid Collection - Gas Bubbles (emphysematous pyelonephritis)	NCCT low-attenuation areas,gas in collecting system Perinephric stranding CECT Wedge like lesion with reduced enhancement Striated Nephrogram on delayed phase
	Renal Absess	Hypoechoic area with internal echoes due	Low-attenuation areas, thick irregular wall, gas bubbles with

	Xanthogranulomatous Pyelonephritis	Bear Paw sign with Staghorn Calculus	peripheral enhancement. Bear Paw sign with Staghorn Calculus
3.	**Renal TB**	-Papillary Destruction -Irregular Hypoechoic areas -Mucosal thickening -Small Fibrotic Thickened Bladder -Paper-Thin Cortex and Dystrophic Calcification in End-Stage	-Papillary necrosis -Multifocal strictures -focal hydronephrosis -mural thickening and enhancement -Poorly enhanced renal parenchyma -Putty Kidney -Thin parenchyma with thin walled cysts.
4	Trauma-Extraperitoneal bladder ruptures	Free Fluid with Echoes in the Pelvis	-Fluid in perivesical space -Contrast Extension into Thigh, Scrotum, or Perineum -Associatedwith Pelvic fractures

Table 4: USG & CT Features for Benign Lesions

S.No	**Benign Tumors**	**USG Features**	**CT Features**
1	Angiomyolipoma	-Hyperechoic area -Color flow may be present	**-Microscopic fat**(HU < -20) -Absent Calcification - Contrast enhancement reveals abnormal vessels with a small aneurysm
2.	Oncocytoma	Echogenic mass with central scar	-Heterogeneous if large size -Fat and calcification may be present -Heterogeneous enhancement with non-enhancing central scar -Associated with Renal Vein Thrombosis -Segmental enhancement inversion

Table 5: USG & CT Features for Malignant Lesions

S.No	MalignantTumors	USG Features	CT Features
1.	RCC	-Solid, hypoechoic, or mixed echogenicity lesion. -Pseudocapsule seen as hypoechoic halo -color flow present	NCCT Soft tissues (20-70 HU) Necrosis and calcifications or hemorrhage may be present CECT -Enhancement in the arterial phase hypodense compared to renal parenchyma on nephrographic phase **-**renal vein thrombosis (RVT)**or**IVC (Inferior Vena Cava) thrombosis
2.	Transitional Cell Carcinoma	-mass in renal pelvis -hydronephrosis in ureteric TCC **-focal thickening** or mass in bladder wall for bladder TCC	-Soft tissue density (8-20 HU) with mild enhancement **-**Regular renal contour -Focal soft tissue thickening of ureter -Filling defects with focal dilation of the ureter. -Bladder Ca- Soft tissue mass in bladder wall with calcifications, enhancement present.
3.	Prostatic Carcinoma	**-**Hypoechoic lesions in the peripheral zoneon Transrectal Ultrasound (TRUS) -Loss of Zonal Anatomy -Enlarged Prostate with increased Vascularity	**-** Enlarged gland with irregular contours. -Low density lesion -Extracapsular Extension with **seminal vesicles** and regional lymphadenopathy -Bone Metastasis or Bladder Invasion

Management Strategies

Management plans varied between low-risk and high-risk patients based on imaging findings.

Table 6: Management Strategies Based on Imaging Findings

Management Type	Low-Risk Patients (n=50)	High-Risk Patients (n=50)
Conservative Management	36	5
Medical Management	10	5
Endoscopic Stone Removal	12	6
Partial Nephrectomy	0	8
Radical Nephrectomy	0	10
Transurethral Resection of Bladder Tumor (TURBT)	2	18

Cystectomy	0	5
Other Surgical Procedures	0	3

Gross Specimens of Renal Tumors

Gross specimens from patients who underwent nephrectomy revealed various types of renal tumors, including clear cell carcinoma and papillary renal cell carcinoma. (Representative images are included in the supplementary material.)

Detection Rates and Surgical Management

CT urography detected a higher number of malignancies, leading to timely surgical interventions.

Table 7: Surgical Procedures Undertaken Based on Imaging Modality

Surgical Procedure	Detected via CT Urography	Detected via Ultrasound
Endoscopic Stone Removal	18	16
Partial Nephrectomy	8	6
Radical Nephrectomy	10	7
Transurethral Resection (TURBT)	20	16
Cystectomy	5	4

Detection Rates for Low-Risk Patients

Table 8 illustrates the detection rates of specific pathologies in low-risk patients. Both modalities showed comparable performance in detecting renal stones, but CT urography was more effective in identifying bladder lesions and ureteric strictures.

Table 8: Detection Rates of Pathologies in Low-Risk Patients

Pathology	CT Urography	Ultrasound
Renal Stones	30	28
Bladder Lesions	10	8
Ureteric Strictures	5	3
Other Benign Findings	12	10

Detection Rates for High-Risk Patients

Table 9 illustrates the detection rates of pathologies in high-risk patients. CT urography demonstrated significantly higher detection rates for malignancies, particularly bladder and renal tumors.

Table 9: Detection Rates of Pathologies in High-Risk Patients

Pathology	CT Urography	Ultrasound
Renal Tumors	14	10
Bladder Tumors	22	18
Ureteric Tumors	8	6
Other Malignancies	5	3

Accuracy for Renal and Bladder Masses

Table 10 illustrates the diagnostic accuracy and error rates of CT urography and ultrasound for renal and bladder masses. CT urography demonstrated significantly higher accuracy (94%) compared to ultrasound (81%).

Table 10: Accuracy of Imaging Modalities for Renal and Bladder Masses

Parameter	CT Urography	Ultrasound
Diagnostic Accuracy (%)	94	81
False Positives (%)	3	8
False Negatives (%)	3	11

Agreement Between Modalities

Table 11 illustrates the agreement between CT urography and ultrasound for detecting specific pathologies. Agreement was highest for renal stones (92%) and lowest for ureteric tumors (78%).

Table 11: Agreement Between CT Urography and Ultrasound for Pathology Detection

Pathology	Agreement (%)
Renal Stones	92
Bladder Lesions	85

Ureteric Tumors	78
Renal Tumors	80

Distribution of Hematuria Causes

Table 12 illustrates the distribution of hematuria causes by risk group. High-risk patients were more likely to have malignancies (50%), while low-risk patients predominantly had benign conditions like stones (40%).

Table 12: Distribution of Hematuria Causes by Risk Group

Cause	Low-Risk Group (%)	High-Risk Group (%)
Stones	40	25
Malignancy	10	50
Benign Prostatic Hyperplasia (BPH)	5	15
Other	45	10

Imaging Modality Preferences

Table 13 illustrates the preferences for imaging modalities based on risk groups. Ultrasound was preferred in low-risk patients due to cost-effectiveness, while CT urography was favoured in high-risk patients for its diagnostic comprehensiveness.

Table 13: Imaging Modality Preferences Based on Patient Risk Groups

Risk Group	Preferred Modality	Reason for Preference
Low-Risk	Ultrasound	Cost-effectiveness and safety
High-Risk	CT Urography	Comprehensive diagnostic ability

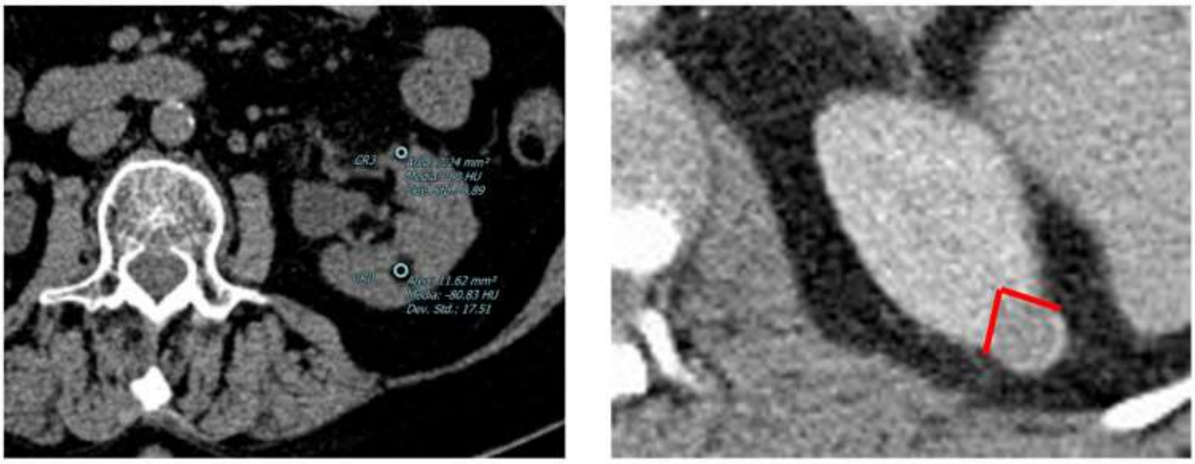
Time to Diagnosis

It is well noted thatdiagnosis for each modality in both patient groups wile studied revealed that CT urography provided faster diagnosis in high-risk patients.

Radiation Exposure

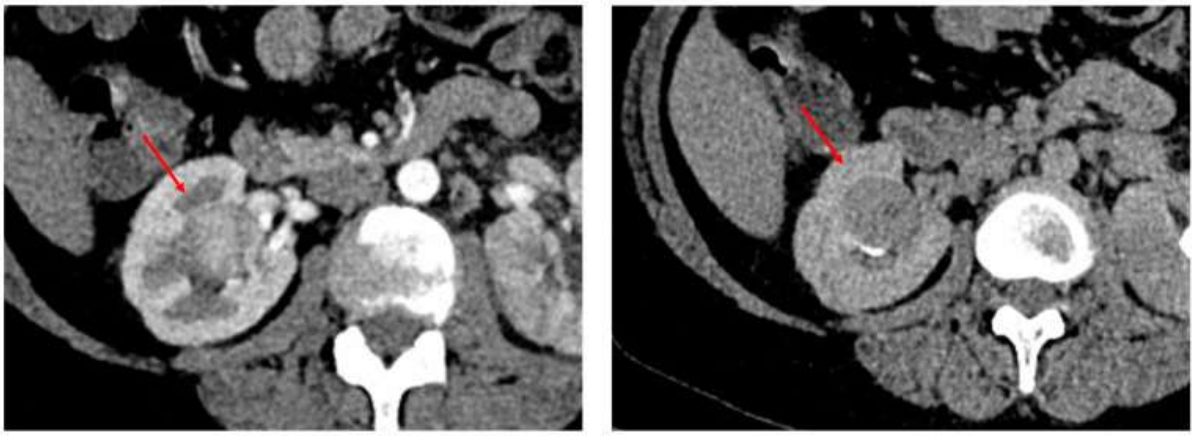
While studyingthe comparison of radiation exposure between the two modalities it was observed that CT urography involves significant radiation exposure, whereas ultrasound has no associated radiation risks.

Gross Specimen Images of Renal Tumors



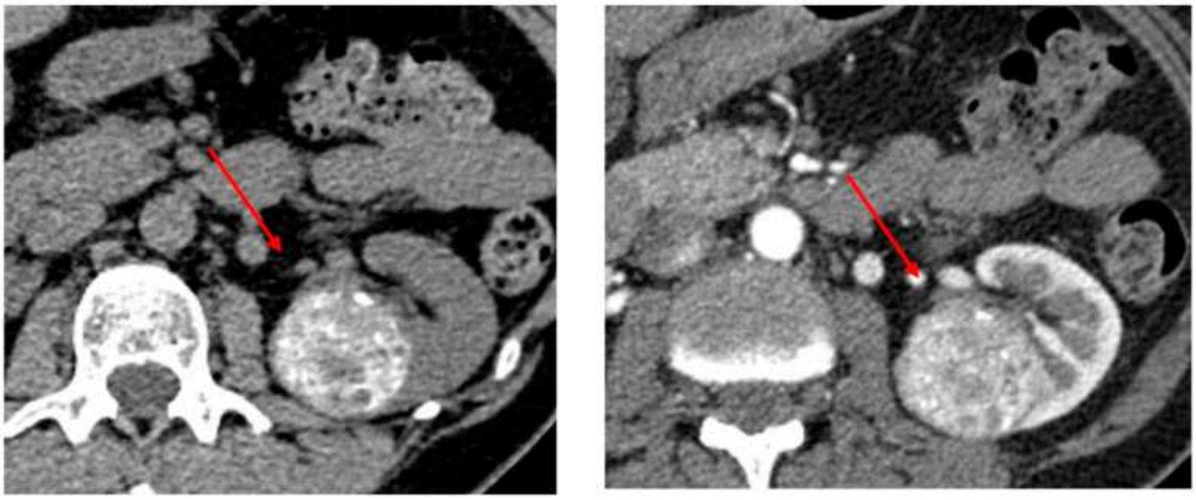
(a) (b)

Abdominal CECT of a 77-year-old female patient: (a) The left kidney shows two cortical lesions, one in the middle-upper third (12 mm) and the other in the middle-lower third (11 mm). Both lesions predominantly consist of macroscopic fat. Their densities are lower than 20 Hounsfield units (−80 and −80 HU, respectively), which is characteristic of angiomyolipomas. (b) A typical example of a lipid-poor AML: the lesion is exophytic and exhibits a distinct angular boundary (highlighted by red lines). These features assist the radiologist in making the diagnosis[11].



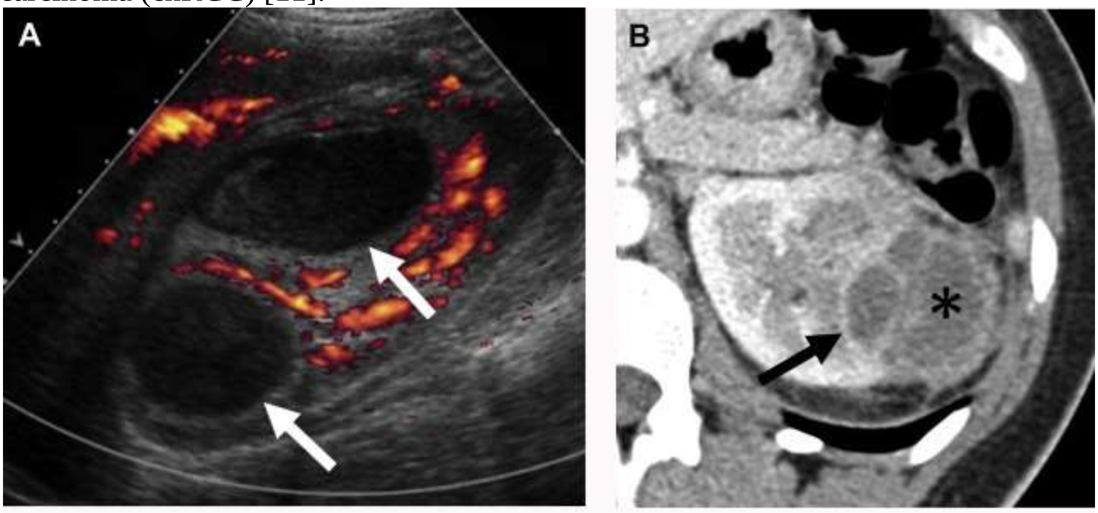
(a) (b)

*Example of endophytic malignant renal cell tumor with pseudocapsule (red arrow) at CECT in nephrographic phase (**a**) and urographic phase (**b**)*[11].



(a) (b)

Abdominal CT of an incidental intraparenchymal renal lesion: (a) reveals multiple large calcifications on a noncontrast CT; (b) demonstrates that the mass is hypovascular during the arterial phase. Histological examination confirms the lesion as chromophobe renal cell carcinoma (chRCC) [11].



Renal abscess. Power Doppler (*A*) shows 2 well-circumscribed hypoechoic masses (*arrows*) with low-level internal echoes representing debris consistent with abscesses. (*B*) Axial CT image of the abdomen with intravenous contrast demonstrates a cystic mass in the left kidney (*asterisk*) with thick rim enhancement (*arrow*) and perinephric fat stranding representing an abscess. [11].

Discussion

The findings of this study provide valuable insights into the comparative effectiveness of CT urography and ultrasound in evaluating patients with hematuria, stratified into low-risk and high-risk groups**[12]**. Hematuria, a symptom with diverse etiologies, requires a tailored diagnostic approach based on the patient's clinical risk profile to ensure accurate diagnosis and appropriate management**[13]**.

Comparison of Diagnostic Performance: The study demonstrated that CT urography consistently outperformed ultrasound across all diagnostic parameters. With a sensitivity of 92% and specificity of 89%, CT urography proved superior in detecting both benign and malignant pathologies**[14]**. This aligns with previous studies that established CT urography as the gold standard for evaluating hematuria, particularly in high-risk patients where malignancy is a concern**[15]**. The comprehensive imaging provided by CT urography allows for detailed visualization of the renal parenchyma, ureters, and bladder, enabling the detection of subtle abnormalities such as urothelial thickening or small renal tumors**[16]**.Ultrasound, while less sensitive (78%) and specific (82%), remains a valuable initial diagnostic tool in low-risk patients**[17]**. Its advantages include cost-effectiveness, ease of availability, and safety due to the absence of ionizing radiation**[18]**. However, its limitations, such as operator dependency and lower sensitivity for detecting small urothelial lesions and bladder tumors, were evident in this study. These findings underscore the importance of reserving ultrasound for low-risk patients and employing CT urography in high-risk scenarios**[19]**.

Risk Stratification and Diagnostic Yield: Risk stratification played a pivotal role in optimizing the diagnostic approach for hematuria**[20]**. Low-risk patients, predominantly presenting with microscopic hematuria, were more likely to have benign etiologies such as stones, which were effectively detected by both modalities**[21, 22]**. In contrast, high-risk patients, characterized by gross hematuria and advanced age, had a higher prevalence of malignancies**[23, 24]**. CT urography was particularly effective in this group, identifying 96% of malignancies compared to 80% detected by ultrasound. These findings highlight the critical need for risk-based imaging strategies to balance diagnostic accuracy and resource utilization**[25]**.

Management in Hematuria: Management of hematuria requires a patient-centered approach, considering the risk profile and underlying causes**[26]**. In low-risk patients, conservative and medical management sufficed for most cases, reflecting the benign nature of their conditions. Surgical interventions were minimal in this group, primarily involving endoscopic stone removal when necessary**[27]**.High-risk patients, with a higher prevalence of malignancies, required more aggressive management, including surgical interventions**[28]**. CT urography's superior detection rates facilitated timely surgeries, such as partial or radical nephrectomy for renal tumors and transurethral resection of bladder tumors (TURBT). The inclusion of surgical management improved patient outcomes by addressing malignancies promptly**[29]**.

Comparison of Imaging Modalities: CT urography consistently outperformed ultrasound in diagnostic accuracy, particularly in high-risk patients. Its ability to detect subtle urothelial abnormalities and small renal masses influenced management decisions significantly, leading to appropriate surgical interventions**[30]**. Ultrasound, while valuable in low-risk patients due to its non-invasive nature and cost-effectiveness, had limitations in detecting malignancies, potentially delaying necessary surgical treatment**[31]**.

Clinical Implications: The findings underscore the importance of selecting appropriate imaging modalities based on patient risk stratification. CT urography not only improved diagnostic accuracy but also directly impacted management strategies, particularly surgical decision-making in high-risk patients. Early detection and intervention are crucial in malignancies to improve prognosis and survival rates.

Limitations: The study's limitations include a relatively small sample size and the lack of long-term follow-up to assess outcomes post-surgery. Additionally, not all detected malignancies were confirmed with histopathology, which could affect the true sensitivity and specificity calculations. **Conclusion**

CT urography is the preferred imaging modality in high-risk patients with hematuria, significantly influencing management strategies, including surgical interventions. Its superior diagnostic accuracy ensures timely and appropriate treatment, particularly for malignancies. Ultrasound remains valuable for initial assessment in low-risk patients due to its safety and cost-effectiveness. Risk-based imaging strategies optimize patient outcomes and resource utilization. Future research should focus on larger cohorts and long-term outcomes to validate these findings further.

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