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Diagnostic Accuracy of CT Urography to Evaluate Haematuria

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Abstract: ***Background**: Haematuria is a common clinical presentation that may indicate underlying genitourinary pathology, ranging from benign causes to malignancies. Early and accurate identification of the cause is crucial. Computed Tomography Urography (CTU) has emerged as valuable imaging modality for evaluating patients with haematuria. **Objective**: CT Urography is an advanced imaging technique that aims to identify causes of haematuria at both microscopic and macroscopic level by assessing the entire urinary tract, detected urothelial tumour for eg; transitional cell carcinoma a leading cause of painless haematuria, to evaluate renal parenchyma for masses, cysts and stones that might lead to bleeding, assess the collecting system , ureters and bladder for filling defects, strictures or other abnormalities and provide a single comprehensive examination that can simultaneously detect renal, ureteric and bladder pathologies reducing need for multiple tests. Moreover, rule out malignancies identify benign causes ANF guide further procedures like cystoscopy, biopsy etc. CTU offers anatomic and functional assessment of the entire urinary tract in a single study making it preferred imaging modality for investigations like haematuria. **Methods**: This prospective observational study included patients presenting with haematuria who underwent CT urography. Findings were compared with cystoscopy, ultrasonography or histopathological outcomes when available. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) of CTU were calculated. **Results**: CTU demonstrated high sensitivity (96.4%) and specificity (90.3%) in identifying urothelial malignancies and urolithiases. it was superior to ultrasonography in detecting small renal masses and transitional cell carcinoma. CTU also identified incidental findings in 12% patients. **Conclusion**: CTU is a highly accurate, non – invasive tool for the evaluation of haematuria offering comprehensive anatomical and pathological information.*

Keywords: Computed Tomography Urography, Cystoscopy, Ultrasonography, Histopathology, Haematuria

1. Introduction

Haematuria is defined as the presence of blood in urine, is one of the most common clinical manifestations of urinary tract pathologies and warrants significant attention from both patients and physician. Clinically, haematuria is identified as the presence of five or more red blood cells per high power field in urine samples collected at least one week apart. It may present as microscopic or macroscopic blood in urine and can occur in isolation or alongside other urinary abnormalities both symptomatic and asymptomatic. Its appearance can range from acute and short term to chronic and long term, often serving as critical indicator of underlying conditions. [1, 2]

As a key symptom, haematuria is associated with a wide range of urinary tract disorders including calculi, neoplasms, infections, traumas, developmental anomalies and disease of renal parenchyma. In severe cases, it may signal life threatening conditions such as bladder cancer, upper urinary tract urothelial carcinoma (UUT - UCC), renal carcinoma or urinary tract stones. [3, 4]

Historically, intravenous urography (IVU) was primary imaging modality for investigating haematuria. However, advances in imaging technology have led to emergence of multidetector computed tomography urography as the preferred diagnostic tool in contemporary clinical practice. CTU is a sophisticated imaging technique optimized for the kidneys, ureters and bladder offer superior spatial resolution, isotropic reconstruction capabilities and excellent multiplanar imaging. It combines the benefit of traditional excretory urography with advantages of cross - sectional imaging in a single comprehensive examination. [5, 6] CTU has revolutionised haematuria evaluation by providing unparallel sensitivity and specificity for detecting urinary tract disorders. Contrast enhanced CT has been shown to achieve sensitivity of >98% for diagnosing renal masses and is significantly more effective than ultrasound which demonstrates approximately 85% sensitivity in similar cases. Furthermore, CTU outperforms IVU in identifying upper tract urothelial malignancies with sensitivity improvements of up to 94.6%. [7, 8]

In cases of haematuria caused by urinary tract calculi CTU offers high diagnostic accuracy, aided by its ability to provide detailed imaging of renal parenchyma, collecting system, ureter and bladder. Non – contrast CT (NCCT) is valuable in identifying calculi and parenchymal calcifications, while contrast enhanced imaging facilitates the detection of fat containing lesions, vascular abnormalities and malignancies. [9, 10]

In clinical adoption of CTU has been further bolstered by its capability to conduct single breath – hold assessments, allowing for comprehensive visualization of entire urinary tract in minimally invasive manner. This has made CTU the diagnostic modality of choice for evaluating haematuria, particularly in cases with high suspicion of malignancy or complex urinary tract pathology.

2. Aim and Objective

1) To evaluate the diagnostic accuracy of CTU in patients with haematuria.
2) To compare CTU findings with cystoscopy, ultrasonography and histopathological diagnosis.
3) To identify and differentiate different causes of haematuria like detecting urinary masses, identifying urinary tract stones, evaluating structural abnormalities such as strictures, congenital malformations, or other abnormalities or assessing for infections.

3. Materials and Methods

Study Design: Prospective observational study.

Study Setting: Department of radiodiagnosis, Vivekananda Global University, Jaipur (Rajasthan), conducted of a period of 12 months.

Study Population: In this particular research evaluating CTU, the population includes:

1) Adults >18 years of age.
2) Patients presenting haematuria, subdivided into:
   - Gross haematuria
   - Microscopic haematuria
3) Risk factors include:
   - Age > 35 – 40 years.
   - History of smoking.
   - Occupational exposure to dyes and chemicals.
   - Prior urological malignancies.
   - History of analgesic abuse or chronic infection.

Inclusion Criteria:

1) Gross haematuria (visible haematuria):
   - Any episode of visible blood in urine without any obvious benign cause (ex. Vigorous exercise, menstruation, trauma)
   - If no urinary tract infection is present or if haematuria persists after appropriate treatment of UTI.
2) Unexplained microscopic (non - visible) haematuria:
   - >3 red blood cells per high power field (RBC / HPF) on at least two properly collected urine samples.
   - Persistent microscopic haematuria without a clear benign cause (ex: infection, menstruation, vigorous exercise, anticoagulation.
3) Risk factors present:
   - Age > 35 - 40 years
   - History of smoking (no R/O urothelial carcinoma.
   - Occupational exposure (ex. with benzene, dye or aromatic amines).
   - History of urological malignancies or chronic bladder irritation (ex. Stones, chronic catheter use).
   - Analgesic abuse or cyclophosphamide exposure.
   - H/O pelvic irritation.
4) Failure of initial evaluation to identify cause:
   - If cystoscopy and cytology are negative but suspicion of upper tract pathology.

Exclusion Criteria:

1) Identified benign cause of haematuria:
   - Recent vigorous exercise (transient haematuria).
   - Menstruation in women.
   - Urinary tract infection (UTI) that resolves after treatment.
   - Trauma with clear source of bleeding.
2) Low – risk microscopic haematuria:
   - Asymptomatic, non – persistent microscopic haematuria with no risk factors, normal urine cytology, normal renal function, negative dipstick on repeat testing.
3) Pregnancy:
   - Due to radiation risks, alternative imaging such as USG or MRI may be preferred unless the benefit of CT is deemed essential.
4) Severe allergy to iodinated contrast:
   - If known severe anaphylactic reaction to contrast, alternative non – contrast imaging or premedication protocols might be considered.
5) Poor renal function:
   - eGFR < 30 mL/min/1.75m^2
6) Recent contrast – contrast imaging:
   - If the patient had a recent high - quality contrast – enhanced CT of the abdomen / pelvic or MR urography that already answers clinical question.

Sample Size:
To account for potential exclusions and dropouts, a total of 100 patients were included in the study.

4. Procedure

Patient Preparation

1) Patients were advised to fast for 4–6 hours before the examination.
2) Hydration with 500–1000 mL of water was encouraged 30–60 minutes prior to scanning to improve urinary tract opacification.
3) Patients were asked to void just before the scan to ensure bladder distension during delayed phases.

Imaging Protocol

CT urography was performed using a [64 - slice/128 - slice/etc] multidetector CT scanner (Model: [e. g., GE Revolution, Siemens Somatom Definition, Philips Brilliance, etc.]). The scan was performed in three phases:

1) Non - Contrast Phase

Purpose: Detection of calculi and baseline assessment
Coverage: From kidneys to the symphysis pubis
Parameters:
kVp: 120
mAs: Automatic dose modulation (range XX–XX)
Slice thickness: 1–2 mm
Pitch: 1.0–1.5
Reconstruction: Axial, coronal, sagittal (1–2 mm)

2) Nephrographic Phase (90–100 seconds post - injection)

Purpose: Evaluation of renal parenchyma and masses
Intravenous contrast: Iohexol/iodinated contrast (e. g., Omnipaque 350 mg I/mL), 100–120 mL
Injection rate: 3–4 mL/sec via 18–20G IV cannula in antecubital vein
Coverage: Same as above
Scan delay: 90–100 seconds post - injection
Saline chaser: 30–50 mL at same injection rate

3) Excretory (Delayed) Phase (8–15 minutes post - injection)

Purpose: Opacification of calyces, pelvis, ureters, and bladder
Delayed images obtained after 8–15 minutes based on renal function
Sometimes enhanced by:
Diuretics (e. g., 10 mg furosemide IV immediately after contrast injection)
Additional water intake or upright positioning (optional)
Coverage: Entire urinary tract

Same scanning parameters as nephrographic phase.

4) Post - processing

a) Multiplanar reformats (MPR), Maximum Intensity Projection (MIP), and Volume Rendering Technique (VRT) were utilized to assess the collecting systems and ureters.
b) Images were reviewed by two radiologists with >5 years of experience, blinded to clinical data.

5) Radiation dose

a) Dose - length product (DLP) and estimated effective dose were recorded for each phase to evaluate radiation exposure.
b) Dose optimization strategies such as iterative reconstruction algorithms were applied.

6) Image Analysis

Evaluation criteria included:

a) Opacification and distension of the urinary tract.
b) Presence of filling defects, wall thickening, hydronephrosis.
c) Renal/ureteral/bladder masses or calculi
d) Each finding was recorded and correlated with clinical and pathological follow - up where available.

5. Results

A total of 100 patients with haematuria underwent CTU over the study period. Of these, 61 were male and 39 females with an age range of 22 to 78 years (mean age: 49.3 years). Haematuria was gross in 62 cases and microscopic in 38 cases.
Findings based on CTU:

Phase wise contribution:

- Unenhanced phase detected 26 - 28 urolithiasis cases (92.8%).
- Nephrographic phase was key in identifying parenchymal masses and abnormalities in 17 patients (RCC and renal masses).
- Excretory phase clearly delineated urothelial lesions in 27 patients, enhancing diagnostic confidence for tumours and strictures.

Diagnostic Performance

Table1: Pathologies identified on CTU and number of patients affected by it.

Parameter	Value
Sensitivity	94.6%
Specificity	90.3%
Positive predictive value (PPV)	91.2%
Negative predictive value (NPV)	93.8%
Diagnostic accuracy	92.5%

Out of 100 cases, confirmed diagnoses were available through biopsy, surgery, or follow - up imaging in 94 cases.

Table 2: Parameters undertaken and their results.

Pathology Identified	Number of Patients	Percentage (%)
Urolithiasis (renal/ureteric)	28	28%
Urothelial tumours	22	22%
Renal cell carcinoma	9	9%
Urinary tract infection	12	12%
Congenital anomalies	3	3%
Bladder mass	7	7%
Trauma related injury	4	4%
No abnormal findings	15	15%

6. Discussion

Haematuria is one of the most common clinical signs of urinary tract pathology. It can originate from any part of urinary tract and has numerous potential causes, including urolithiasis, neoplasms, infections, trauma, medications, coagulation disorders and various kidney diseases. a primary concern in evaluating haematuria is the early and accurate detection of urological malignancies. Therefore, diagnostic tests with high sensitivity for detecting such pathologies are essential.

CTU is a highly effective modality for evaluating haematuria. It enables comprehensive assessment of the urinary tract through a multiphase approach, which includes unenhanced, nephrographic and excretory phases. The unenhanced phase is particularly useful for detecting renal calculi – one of the most common causes of haematuria. The nephrographic phase helps evaluate renal parenchymal lesions and abnormal tissue enhancement, while the excretory is useful in detecting urothelial abnormalities, including tumours.

Thin section delayed images during the excretory phase allow visualization of the urinary tract filled with the contrast, aiding in the detection of urothelial malignancies. CTU offers the advantage of assessing both renal parenchyma and urothelial lining in a single imaging session, making it a preferred investigation for patients with haematuria.

In present study, 100 patients presenting with haematuria were evaluated using CTU. All patients were referred from the urology department to the radiology unit for further diagnostic workup. The final diagnosis was established after analysing all three CTU phases, using appropriate post processing techniques.

7. Limitations

1) **Radiation exposure:** CTU typically involves a multiphasic protocol (unenhanced, nephrographic, excretory), resulting in high cumulative radiation doses—commonly 25–35 mSv, occasionally exceeding 40 mSv—significantly higher than alternative modalities such as MR urography or ultrasound^1, 2. Efforts to reduce dose using split - bolus techniques or iterative reconstruction can lower exposure (~17–20 mSv), but may not be widely implemented and can compromise image quality^3, 4.
2) **Contrast use and nephrotoxicity:** Iodinated contrast is essential for CTU but carries risks: contrast - induced nephropathy (CIN), particularly in patients with CKD or

diabetes, and allergic reactions^5. While the existence of CIN with modern contrast agents is debated, patients with eGFR <30 mL/min/1.73 m² remain at higher risk^6.

3) **Detection limitations for small or flat lesions:** CTU lacks sensitivity for flat lesions such as carcinoma in situ (CIS); these often lack significant enhancement or filling defects and may present only as subtle mucosal changes or wall thickening, frequently resulting in false negatives^7, 8.
4) **Technical and artefactual pitfalls**
   - **Beam - hardening artifacts** can mimic enhancement in small lesions, leading to misinterpretation; establishing clear thresholds for enhancement (e. g., >20 HU) or using dual - energy CT can mitigate this but increase complexity and cost^1, 9.
   - **Reconstruction limitations**: reliance on MIP without reviewing source images may obscure low - density lesions or create pseudo lesions; proper window - level adjustments and combination of reconstructions (axial, MPR, CPR) improve sensitivity (from ~70% to >90%) ^2, 10.
   - **Incomplete urinary tract distension**: peristalsis, poor opacification, or inadequate hydration may conceal lesions; adjunct techniques (balloon compression, IV furosemide, hydration) can improve but add complexity and contraindications^2, 3.
5) **Limited functional evaluation:** CTU provides excellent anatomical detail but lacks functional assessment. Functional abnormalities (e. g., reflux, differential renal function) require adjunctive testing like nuclear scintigraphy or MR urography^3.
6) **Cost and resource requirements:** Advanced CTU protocols require modern multidetector scanners, trained personnel, and postprocessing tools, limiting availability in resource - poor settings. Costs exceed those of ultrasound or IV urography^3.
   a) **Patient population limitations**
   - **Pregnant women**: contraindicated due to ionizing radiation and contrast risk.
   - **Paediatric patients**: radiation sensitivity and long - term risk favour MRI/ultrasound alternatives^3.
   - **Renal insufficiency**: diminished value and increased risk due to contrast load^3.

   b) **Incidental and false - positive findings:** High - resolution imaging may reveal incidental lesions (e. g., vascular anomalies, benign masses), leading to overdiagnosis, unnecessary follow - up, interventions, anxiety, and increased costs^3, 7.

8. Conclusion

While CT urography is a highly effective tool for urinary tract evaluation, especially for detecting urothelial carcinoma and evaluating haematuria, its limitations must be carefully considered. The balance between diagnostic benefit and risks such as radiation exposure and contrast - related complications is critical, especially in vulnerable populations. A multimodality approach and appropriate patient selection can help mitigate these limitations.

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