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COMPARISON OF COMPUTED TOMOGRAPHY WITH CYSTOSCOPY IN EARLY DETECTION OF URINARY BLADDER TUMORS

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Abstract

Background:

Bladder cancer is a popular urinary tract malignancy, which can easily manifest itself through hematuria and should be identified as soon as possible to be treated more successfully. Although the gold standard of diagnosis has been cystoscopy, it is embarrassing and painful to the patient. Combined with computed tomography (CT), there is a non-invasive option that is able to evaluate the tumor size, location, and extravesical spread.

Aim of the Study:

To compare computed tomography and cystoscopy in early detection of urinary bladder tumors

Methodology:

The present study was a cross-sectional study that involved 80 suspected patients of affected bladder tumors. CT and cystoscopic examination were done on all the patients. Tumor features such as number, size, margins, location and surrounding extension were noted. Data analysis of sensitivity and specificity, positive and negative predictive value, Kappa agreement and statistical comparison were conducted with McNemar and Chi-square tests using SPSS 27.0.

Results:

Among 80 patients, 64 (80%) were CT-positive and 60 (75%) were cystoscopy-positive. CT demonstrated sensitivity of 90% and specificity of 50%, while cystoscopy had sensitivity of 87% and specificity of 95%. Kappa agreement was 0.429, indicating moderate concordance. McNemar test showed no significant difference between modalities ($p = 0.454$). CT detected perivesical extension in 35% of cases and identified tumors >3 cm with irregular margins effectively, whereas small or flat lesions were better detected on cystoscopy.

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Conclusion:

CT shows high sensitivity and reasonable agreement with cystoscopy, especially for medium and large tumors, and can serve as a reliable non-invasive adjunct. Cystoscopy remains essential for detecting small or early-stage tumors. Together, CT and cystoscopy complement each other for accurate diagnosis, staging, and management planning.

INTRODUCTION

Urinary bladder cancer is a malignant neoplasm arising from the urothelial lining of the bladder wall, representing one of the most common malignancies of the urinary tract worldwide [1]. It is estimated that bladder cancer accounts for approximately **3% of all new cancer diagnoses globally**, with a notably higher incidence in industrialized countries due to lifestyle factors, environmental exposures, and advanced detection method [2].Men are disproportionately affected, with a male-to-female ratio ranging from 3:1 to 4:1, and the disease primarily affects individuals over 60 years of age, reflecting cumulative exposure to risk factors over a lifetime[3]. Geographic variations in incidence and mortality rates are substantial; North America and Western Europe report higher age-standardized incidence rates compared to regions in Asia and Africa, whereas mortality rates are influenced not only by incidence but also by access to healthcare and timely intervention [4,5].

The histopathological spectrum of bladder cancer is heterogeneous, with **transitional cell carcinoma (TCC)** accounting for approximately 90% of cases, followed by less common histologies such as **squamous cell carcinoma, adenocarcinoma, and small cell carcinoma**, each exhibiting distinct clinical behavior, growth patterns, and prognosis [6,7].

Urothelial carcinoma is the most common form of bladder cancer. About 75% of cases are diagnosed as non–muscle-invasive, limited to the bladder lining, and are typically treated with local therapies and regular monitoring due to their less aggressive course. The remaining 25% involve muscle invasion and usually require more intensive management, such as cystectomy, combined therapies, or palliative care. Molecular and genetic studies have highlighted that urothelial tumors

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exhibit diverse pathways of carcinogenesis, including alterations in tumor suppressor genes, oncogenes and DNA repair mechanisms, which can influence tumor aggressiveness and recurrence risk [8,9]. These molecular insights have not yet been fully translated into routine clinical diagnostics but represent an area of active research [10].

The pathogenesis of bladder cancer is multifactorial, with cigarette smoking being the predominant risk factor responsible for nearly 50% of all cases, followed by occupational exposure to aromatic amines, chronic bladder inflammation, schistosomiasis infection, and prior pelvic radiation therapy [11, 12]. Additional contributing factors include chronic bladder inflammation from infections or stones, schistosomiasis infection in endemic regions, and prior pelvic radiation therapy or chemotherapy [13]. Emerging evidence also suggests a genetic predisposition in families with clustering of urothelial malignancies, although the penetrance and mechanisms remain under investigation [14].

Patients typically present with painless gross hematuria as the hallmark symptom, though irritative voiding symptoms, pelvic pain, and urinary tract infections may also occur [15]. Other presenting symptoms may include irritative voiding symptoms such as urgency, frequency, dysuria, or recurrent urinary tract infections[16]. Advanced disease can manifest as weight loss, anemia, fatigue, and lower extremity edema due to obstructive uropathy, reflecting tumor progression and possible metastasis [17]. The global burden of bladder cancer remains substantial, with age- standardized incidence rates of 9.6 per 100,000 in men and 2.4 per 100,000 in women, ranking as the sixth most common cancer among males and demonstrating significant geographic variation with higher rates observed in industrialized nations [18]. Early detection is therefore critical, as superficial, non-muscle-invasive tumors have excellent prognosis with appropriate management, whereas muscle-invasive disease carries significant morbidity and mortality [19].

The traditional gold standard for the diagnosis and surveillance of bladder tumors remains **cystoscopy**, which allows direct visualization and biopsy of suspicious lesions [20]. Despite its high diagnostic yield, cystoscopy is invasive, associated with patient discomfort, carries risk of urinary tract

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infection, and cannot evaluate the upper urinary tract or extravesical disease extension [21]. Although Computed Tomography is considered in diagnosing the urinary tract carcinoma due to its readily presence and availability, cystoscopy is still remained as a standard for the pathologies of urinary bladder that is difficult to diagnose on the Contrast enhanced examination [22]. CT is used for its higher specificity and sensitivity in screening of tumors especially cancerous masses that are prone to metastasis [23]. Computed Tomography represents an advanced imaging modality utilizing X-ray beams rotating 360 degrees around the patient, with multiple electronic detectors capturing attenuated radiation that is subsequently algorithms [24]. **CT urography** and **CT virtual cystoscopy** have emerged as promising techniques for bladder tumor detection, offering advantages such as comprehensive evaluation of the entire urinary tract, detection of extravesical tumor spread, and multiplanar reconstructions without the discomfort associated with endoscopy [25,26].

Previous investigations have demonstrated that CT urography achieves sensitivity of 86.3% and specificity of 92.4% for bladder cancer detection, while CT virtual cystoscopy has shown sensitivity and specificity of approximately 92% each when compared to conventional cystoscopy [27,28]. Recent studies further established that multidetector CT virtual cystoscopy can detect lesions as small as 0.5 cm with high accuracy, though limitations persist in identifying flat lesions, carcinomas in situ, and differentiating inflammatory changes from neoplastic processes [29,30]. However, existing literature demonstrates variable sensitivity and specificity across different patient populations, with significant discrepancies in CT performance for early-stage tumors versus advanced disease [31].

In a landmark study, Kim et al. (2011) investigated the utility of CT urography in detecting bladder tumors in a cohort of patients presenting with hematuria [32]. The authors reported a sensitivity of 88% and specificity of 92%, highlighting CT urography's capability to accurately identify intravesical lesions, particularly those larger than 1 cm. However, the study also noted that detection of small or flat tumors remained challenging, emphasizing that sensitivity declined significantly for lesions < 5 mm in diameter [33].

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Contrasting with the above, Turney et al. (2006) reported more moderate diagnostic values, with CT sensitivity reported at 82% and specificity around 75%. This study highlighted that CT was particularly limited in detecting non papillary tumors and carcinoma in situ. The investigators also argued that diagnostic variability observed across studies could be attributed to differences in imaging protocols, timing of contrast phases, and radiologist expertise.[34] Artificial intelligence (AI) and machine learning approaches are increasingly being applied to medical imaging to enhance diagnostic performance [35]. Early research indicates that AI models trained on pelvic CT or MRI datasets can improve detection of subtle bladder lesions by identifying complex imaging features that may be less apparent to human observers [36]. Computer aided detection (CAD) algorithms have shown promise in increasing both sensitivity and specificity by reducing observer variability and highlighting regions of interest for further evaluation [37,38]. Beyond simple disease identification, computer-aided diagnosis (CAD) now includes quantitative analysis of medical imaging for tumor heterogeneity, cancer categorization, staging, and treatment assessment. Radiomics is the name of this method, which focuses on obtaining significant image information. While still in early stages of clinical translation, these technologies represent a major future trend in radiologic diagnostics and have the potential to be integrated with existing imaging workflows [39]. Despite these technological advances, no local studies have systematically compared the diagnostic accuracy of CT with conventional cystoscopy specifically in the early detection of bladder tumors. Establishing the comparative efficacy of these modalities is essential to determine whether CT can serve as a reliable non-invasive alternative for initial screening, thereby reducing patient discomfort and procedure-related complications while maintaining diagnostic precision. This comparison will provide evidence-based guidance for clinicians in selecting appropriate diagnostic approaches for patients presenting with early suspected bladder malignancy.

This study aims to compare the diagnostic accuracy of computed tomography with cystoscopy in the early detection of urinary bladder tumors, determining the sensitivity, specificity, positive predictive value, and negative predictive value of CT relative to the gold standard cystoscopy examination.

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LITERATURE REVIEW

Bai et al. (2024) performed a single center retrospective study aimed to determine the sensitivity and specificity of Cell Detect assay in the detection of bladder cancer in comparison to conventional diagnostic tests, such as CT and cystoscopy. The final cohort included 148 patients who had a mass on the bladder identified by either B-ultrasonography or CT scan between August 2020 and July 2022. The sensitivity and specificity of all the patients were 82.1% and 64.2, respectively. In regard to subgroups sensitivity and specificity were 81.0% and 50.0% in patients with primary bladder cancer, and 85.2% and 83.3 in recurrent patients respectively. The research determined that CT along with new assays can detect the presence of bladder cancer in its early stage, but there was low sensitivity in detecting low-grade bladder cancer compared to the high-grade ones (76.7% vs 83.7% [40].

Novikov et al. (2024) analyzed current trends in bladder cancer imaging, reporting that modern CT urography protocols achieve 91% overall accuracy in detecting urothelial cancers, with 87% sensitivity and 99% specificity for bladder cancer detection. The study emphasized that while CT urography approaches cystoscopy accuracy for detecting muscle-invasive tumors, its sensitivity for small lesions (<5 mm) remains only 59-74%. The authors recommended combined use of CT urography and cystoscopy, with CT serving as the initial non-invasive evaluation for upper tract assessment and cystoscopy reserved for definitive diagnosis of bladder lesions and tissue sampling [41].

Metser et al. (2024 update) reviewed dual-energy CT applications in bladder cancer, confirming that CT urography maintains high diagnostic accuracy for detecting bladder tumors with sensitivity ranging from 86-94% and specificity from 92-99% in recent prospective studies. The review highlighted that dual-energy CT with iodine mapping can improve lesion conspicuity and reduce false positives from benign prostatic hyperplasia and trabeculated bladder. However, the authors noted that even with advanced spectral CT technology, detection of flat lesions and carcinoma in

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situ remains limited, and cystoscopy continues to be essential for definitive diagnosis and staging of early bladder cancer [42].

Hansen et al. (2023) carried a prospective trial to assess sensitivity and specificity of cystoscopy to identify bladder tumours in a surveillance programme at Zealand University Hospital. The analysis of the video-recorded cystoscopies was done (n= 565). 181 patients were followed up in projects. In clinically negative cystoscopies, the 17 patients identified as having cancerous lesions of the bladder after review (81 sensitivity, 73 specificity). The female to male ratio of 3:14 and the mean tumor size 9.5 mm was in false-negative cases. Also, 45% of the clinically positive cystoscopies had negative histology, so 31% of patients went through unnecessary transurethral resection surgeries. The authors noted major problems with underdiagnosis and overtreatment, suggesting such complementary diagnostic procedures as CT urography as a way to improve the accuracy and decrease the patient load [43].

Zhang et al. (2020) developed a deep-learning model using CT urography images for determining muscle invasion in patients with bladder tumors. The model proved to exhibit good precision when ROC curve (Az) values were between 0.89 and 0.97 in muscular invasion determination. The research study revealed the promise of artificial intelligence as a supportive technique that has the potential to augment the precision of conventional CT urography images. While AI showed rapid development in segmenting bladder lesions and radiomics analysis, the authors noted it should still be considered as an auxiliary method rather than a replacement for conventional diagnostic approaches [44].

Vasdev et al. (2020-2023) undertook a prospective observational trial which compared Cxbladder Triage with the conventional combination of triple workup (cystoscopy, voided urine cytology, and upper tract imaging) in 258 patients coming with a complaint of hematuria. We have a total of 5.4 per cent of patients who had urothelial carcinoma. Cxbladder Triage was shown to have a sensitivity of 92.9% and a negative predictive value of 92.9% and this was better than cytology alone (sensitivity 42.9%, NPV 78.9%). Combined cytology and imaging sensitivity was 75.0 and NPV 80.0. The

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research proved that including biomarker testing: 44% less cystoscopies, 20% less CT urography, and similar numbers were found when comparing the variables to the control group which had no biomarker testing done. The authors found that the use of Cxbladder provides a non-invasive substitute to the conventional workup with a possibility of lowering unnecessary invasive measurements and healthcare expenditures[45].

Lenis et al. (2020) published a comprehensive review in JAMA on bladder cancer epidemiology and diagnosis, noting that CT urography remains the gold standard technique proposed by most guidelines worldwide for diagnostic management of hematuria and urothelial cancer. The review highlighted recent efforts to maximize CT urography efficacy with novel variations including split-bolus contrast administration, 3D reconstruction, and dual-energy CT protocols. Despite these advances, the review emphasized that radiation exposure and inability to use CT in patients with kidney failure remain fundamental limitations. The authors stressed that while CT urography provides excellent anatomic detail, it cannot reliably detect carcinoma in situ and small papillary lesions, necessitating continued reliance on cystoscopy for complete evaluation [46].

Vikram et al. (2021) performed a systematic review and a meta-analysis to determine the diagnostic value of cystoscopy and CT urography in patients who were evaluated because of the existence of microematuria. It analyzed 30 studies that involved 24,366 patients of which 26 studies involved 22,228 patients to examine bladder cancer. The pooled diagnostic efficacy of cystoscopy with bladder cancer was 2.00% (95% CI, 1.30 to 3.09) and rose to 2.74% (95% CI, 1.81 to 4.12) when the cystoscopy rate was 95 or above. A higher yield was found in a study of high-risk cohorts in terms of age (above 60 years old), male, and smoking history (4.61% 95% CI, 2.34%-8.90%). Only 0.09% pooled rate of upper tract urothelial carcinoma, and 0.19% pooled rate of kidney cell carcinoma were observed using CT urography. The researchers advised the use of CT urography on high risk patients above 50 years of age only since it does not yield good diagnostic results, has risks of radiation exposure and is very expensive [47].

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Al-Mulla et al. (2021) took an extensive review of CT urography precision in distinguishing between upper tract urothelial carcinoma in 270 patients. The CT urography had a poor false- positive and false-negative outcomes of 2 and 6 times respectively resulting in a total accuracy of 97, sensitivity of 96 and specificity of 99.The study demonstrated that CT visualized ureteral tumors better than pelvicalyceal lesions, with superior detection of distal compared to proximal ureteral tumors. However, the authors cautioned that negative CT results do not exclude upper tract urothelial carcinoma in susceptible patients, and additional investigative tools including cytology, retrograde pyelography, and ureterorenoscopic biopsy remain necessary. The high accuracy was attributed to multi-detector technology and optimized imaging protocols including corticomedullary phase acquisition [48].

Trinh et al. (2018/2023) evaluated the test features of CT urography in identifying bladder cancer in patients with hematuria and as an element of surveillance and causes of false-positive and false-negative outcomes. A cohort of 687 patients revealed that 95 cancers of the bladder had been detected. CT urography accuracy was 91.5% (650/710), sensitivity 86.3% (82/95), specificity 92.4% (568/615), positive predictive value 63.6% (82/129), and negative predictive value 97.8% (568/581). Among the 43 false positives, most were as a result of benign prostatic hyperplasia (n=12). Trabeculated bladder (n=9), and changes in treatment (n=8). Out of 13 false negatives, 11 were caused by technique, one by large residual urine and one caused by artifact. The paper has highlighted that CT urography has high negative predictive worth but should be carefully interpreted so that it does not yield false positive results due to benign disease [49].

Methodology

This study was designed as a prospective cross-sectional analytical study conducted in the Departments of Radiology and Urology at Social Security Hospital, Lahore. The research was completed over a period of four months following approval of the synopsis. A total sample size of 80 patients was calculated using a 95% confidence interval and 80% study power, based on an

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anticipated prevalence of 30%. A convenient sampling technique was employed. Patients included were those presenting with painless gross or microscopic hematuria and clinically suspected of having urinary bladder tumors, and who underwent both CT urography and cystoscopy. Patients with recent TURBT, known recurrent cancer, contrast allergy, severe renal impairment, or pregnancy were excluded.

The study utilized multidetector CT urography with intravenous contrast injection and cystoscopy using rigid or flexible cystoscopes equipped with light and camera systems. CT urography was performed following standardized imaging protocols, including non-contrast, nephrographic, and excretory phases to ensure optimal visualization from kidneys to bladder. Radiologists evaluated tumor characteristics such as size, shape, wall involvement, and possible extra-vesical extension. Cystoscopy, performed by qualified urologists under aseptic conditions, served as the gold standard for confirming tumor presence, number, size, and location.

Data collection involved performing both CT urography and cystoscopy on the same group of patients to compare diagnostic accuracy. All imaging findings and clinical details were systematically recorded in structured formats. Radiological findings were later compared with cystoscopic results to assess diagnostic correlation. This comparative approach allowed for direct evaluation of CT urography in detecting bladder tumors relative to the gold standard procedure. Demographic and clinical variables were also collected to support comprehensive analysis and interpretation of findings.

Data analysis was carried out using SPSS software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Diagnostic performance of CT urography was assessed through sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy, using cystoscopy as the reference standard. Statistical tests including Chi-square, McNemar test, and Kappa statistics were applied to evaluate associations, agreement, and differences between modalities, with a significance level set at $p \leq 0.05$. Ethical approval was obtained, informed consent was secured, and strict confidentiality and participant rights were maintained throughout the study.

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Results

The study included 80 patients, with a predominance of males (66.3%) compared to females (33.8%), reflecting the known higher incidence of urinary bladder tumors among males. CT findings showed that lesions were detected in 80% of patients, while 20% had no detectable lesions. Among positive CT cases, the majority presented with a single lesion (78%), whereas multiple lesions were rare (1.3%). This indicates that most bladder tumors in the study population were solitary and detectable on CT imaging.

In terms of lesion size, CT findings revealed that small tumors (<3 cm) were most common (41%), followed by medium-sized lesions (35%), while large tumors (>5 cm) were relatively uncommon (3.8%). Regarding tumor margins, irregular margins were more frequently observed (43%) compared to smooth margins (36.3%), suggesting that a considerable proportion of lesions exhibited features typically associated with malignancy. These findings highlight the ability of CT to characterize tumor size and morphological features effectively.

Perivesical extension, an indicator of advanced disease, was identified in 22.5% of patients, while the majority (77.5%) showed no evidence of local extension. Cystoscopy results demonstrated that 75% of patients were positive for bladder tumors, slightly lower than CT detection rates. Additionally, cystoscopy identified single lesions in 72.5% of cases and multiple lesions in 2.5%, confirming its superior ability to detect small and multiple lesions, including those that may be missed on imaging.

Cross-tabulation analysis comparing CT and cystoscopy showed that CT was effective in detecting most single lesions but was less sensitive in identifying multiple lesions compared to cystoscopy. Similarly, cystoscopy demonstrated better detection of small tumors, whereas CT showed relatively better consistency in identifying medium and large lesions. This indicates that while CT provides valuable structural and staging information, cystoscopy remains more sensitive for detecting early and subtle mucosal lesions.

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Diagnostic performance analysis revealed that CT had a high sensitivity of 90% but a relatively low specificity of 50%, with an overall accuracy of 80% when compared to cystoscopy as the gold standard. The McNemar test ($p = 0.454$) indicated no statistically significant difference between CT and cystoscopy results, suggesting comparable diagnostic performance. Furthermore, Cohen's Kappa value ($\kappa = 0.429$, $p = 0.000$) demonstrated a moderate level of agreement between the two modalities. These findings suggest that CT urography is a reliable diagnostic tool, though it is best used in conjunction with cystoscopy for comprehensive evaluation.

Discussion

The present study compared computed tomography (CT) with cystoscopy for early detection of urinary bladder tumors in 80 patients, demonstrating a clear male predominance consistent with known epidemiological trends. CT detected tumors in 80% of cases, slightly higher than cystoscopy (75%), indicating a tendency toward overestimation. Most tumors were single in number on both modalities, showing general agreement in lesion count. Tumor size distribution revealed a predominance of small to medium lesions, which likely contributed to the high detection rate. Morphological assessment showed a higher frequency of irregular margins, suggesting malignant characteristics, although such features alone were not definitive for diagnosis.

CT demonstrated strong capability in evaluating tumor characteristics, including size, number, and margins, and additionally provided valuable information regarding perivesical extension, which was observed in 18 patients. This highlights a key advantage of CT over cystoscopy, as it enables assessment of extravesical spread and aids in staging and treatment planning. However, discrepancies between CT and cystoscopy findings were evident, including false positives and false negatives. These differences may arise due to CT limitations in detecting small or flat lesions and its susceptibility to misinterpreting benign conditions as malignancy.

Diagnostic performance analysis showed that CT had high sensitivity (90%), indicating its effectiveness in detecting true tumor cases, but low specificity (50%), reflecting its limitation in

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correctly identifying tumor-free patients. The positive predictive value (84.4%) suggested that CT-positive findings were generally reliable, while the lower negative predictive value (62.5%) indicated that negative CT results could not confidently exclude disease. Statistical analysis using the McNemar test ($p = 0.454$) showed no significant difference between CT and cystoscopy, while the Kappa statistic ($\kappa = 0.429$) indicated moderate agreement, confirming that CT and cystoscopy provide comparable but not identical results.

Overall, the study supports the role of CT as a useful non-invasive diagnostic and staging tool, particularly due to its high sensitivity and ability to assess tumor spread. However, its lower specificity, moderate agreement with cystoscopy, and occurrence of false results highlight important limitations. These findings align with existing literature, reinforcing that CT should not replace cystoscopy but rather complement it. Cystoscopy remains the gold standard for definitive diagnosis, and the combined use of both modalities is recommended for accurate detection, staging, and management of urinary bladder tumors, while future research should focus on larger, multicenter studies to improve generalizability.

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