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Role of CT and MRI in the Diagnosis and Staging of Renal Cell Carcinoma

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Abstract:

Background: *Imaging plays a critical role in diagnosing and staging renal cell carcinoma (RCC), guiding treatment decisions and surgical planning. This study aims to assess and compare the diagnostic accuracy and staging efficacy of CT and MRI in detecting RCC.*

Aim of the study: *The aim of the study was to evaluate and compare the diagnostic accuracy and staging efficacy of CT and MRI in detecting renal cell carcinoma.*

Methods: *This cross-sectional study was conducted in the Department of Urology at Bangabandhu Sheikh Mujib Medical University, Dhaka, from February 2024 to February 2025, including 40 patients with histologically confirmed renal cell carcinoma. Data collection covered demographics, clinical and tumor characteristics, and imaging findings. CT and MRI were assessed for sensitivity, specificity, accuracy, and predictive values. Statistical analysis was performed using SPSS version 22.0.*

Results: *The study of 40 patients with renal cell carcinoma (mean age 63 ± 11.94 years, 65% male) showed a predominance of clear cell RCC (85%) and left kidney tumors (60%). Tumors ≥3 cm were present in 47.5% of patients. MRI exhibited superior sensitivity (90%) and accuracy (85%) compared to CT (70% sensitivity, 75% accuracy), though CT had higher specificity (87.5%). MRI was also more effective in detecting venous invasion (78% vs. 60%) and lymph node metastasis (75% vs. 65%), demonstrating its enhanced staging capability for RCC.*

Conclusion: *In conclusion, MRI offers superior sensitivity and accuracy over CT for diagnosing and staging renal cell carcinoma.*

Keywords: *Renal Cell Carcinoma, Computed Tomography, Magnetic Resonance Imaging, Diagnosis, Staging.*

1. INTRODUCTION

Renal cell carcinoma (RCC) is the most prevalent malignant tumor of the kidney, accounting for 85–90% of adult renal cancers and 1–2% of all malignancies.[1] Globally, approximately 150,000 new cases are reported annually.[2] In

North America, its incidence has risen by 2.0% per year over the past two decades, [3] primarily due to the increased use of abdominal imaging, leading to more frequent detection of small renal masses.[4] While RCC may present with symptoms such as flank pain, hematuria, and an abdominal mass, many cases are now identified incidentally.[5] Major risk factors for RCC include smoking, hypertension, and obesity.

Imaging is essential in diagnosing and staging renal cell carcinoma (RCC), as it helps guide treatment decisions and surgical planning. The use of sonography and cross-sectional imaging, such as computed tomography (CT) and magnetic resonance imaging (MRI), has greatly enhanced the detection of incidental renal tumors. CT remains the preferred imaging technique due to its rapid acquisition and high-resolution anatomical detail.[6] However, MRI is gaining popularity for its superior soft tissue contrast and lack of ionizing radiation, making it especially valuable for tumor characterization and treatment evaluation.[7] The primary aim of preoperative imaging is to assess tumor size, location, vascular involvement, and any potential invasion of nearby structures, as these factors are crucial for determining surgical options and prognosis.[8]

CT and MRI are the primary imaging modalities for diagnosing RCC, each offering specific advantages and limitations. CT is preferred for evaluating local invasion, lymph node involvement, and distant metastases, while MRI is particularly useful for assessing tumor thrombus progression and venous involvement.[9,10] However, due to its higher cost, longer scan time, and contraindications in certain patients, MRI is typically used as a supplementary tool rather than a first-line modality.[11] Multidetector CT (MDCT) is widely accessible, provides high-resolution images with rapid acquisition, and allows for isotropic imaging with multiplanar reformatting, making it ideal for detailed anatomical assessment. However, its use involves exposure to ionizing radiation. In contrast, MRI avoids radiation exposure and does not require iodinated contrast agents, making it a safer alternative for patients with impaired renal function when gadolinium-based contrast is used. Studies on sensitivity and specificity have highlighted the role of contrast-enhanced CT and MRI in predicting RCC histological subtypes.[12,13] MRI is particularly valuable for evaluating small renal masses, which pose a diagnostic challenge since up to 25% of lesions under 4 cm may be benign, such as oncocytomas or angiomyolipomas.[14,15] Additionally, three-dimensional reformatting techniques in CT enhance staging capabilities, with the TNM classification providing precise anatomical assessment that strongly correlates with prognosis and curability.[16,17] Given these factors, the choice between CT and MRI should be individualized based on patient-specific conditions to achieve the most accurate diagnosis while minimizing associated risks.

This study aims to evaluate and compare the diagnostic accuracy and staging efficacy of CT and MRI in detecting renal cell carcinoma, highlighting their respective advantages, limitations, and roles in clinical decision-making. By assessing their sensitivity, specificity, and ability to characterize tumor subtypes, this study seeks to determine the most effective imaging modality for accurate diagnosis and staging of RCC.

2. Objective

The aim of the study was to evaluate and compare the diagnostic accuracy and staging efficacy of CT and MRI in detecting renal cell carcinoma.

3. Methodology & Materials

This cross-sectional study was conducted in the Department of Urology at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh, from February 2024 to February 2025. The study included 40 patients with histologically confirmed renal cell carcinoma (RCC) who had undergone both CT and MRI scans for diagnosis and staging.

Inclusion Criteria

- Patients aged 40 years and older Histologically confirmed RCC diagnosis
- Underwent CT and MRI scans for diagnosis and staging

Exclusion Criteria

- Incomplete medical records
- Renal tumors other than RCC
- Patients who had not undergone both CT and MRI imaging during diagnostic workup

Written informed consent was obtained from all participants. Data were collected from hospital records and patient interviews, covering demographic and clinical characteristics (age, gender, smoking history, hypertension), tumor details (size, laterality, histological subtype), and diagnostic imaging findings. CT and MRI scans

were used for tumor assessment, with a focus on sensitivity, specificity, accuracy, and predictive values for RCC detection and staging of advanced features such as venous invasion and lymph node metastasis. Standard abdominal CT scans evaluated tumor size, location, and staging, while MRI scans provided additional insights into venous invasion and lymph node involvement. Statistical analysis was performed using SPSS version 22.0. Descriptive statistics were used to summarize demographic and clinical data. The diagnostic performance of CT and MRI was assessed by calculating sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV). Comparative analysis was conducted to evaluate the staging performance of CT and MRI in detecting venous invasion and lymph node metastasis.

4. RESULTS

Table 1. *Demographic and Clinical Characteristics of Study Participants (n=40)*

Variable		Number of patients	Percentage
Age (In years)	40-49	6	15.0
	50-59	10	25.0
	60-69	12	30.0
	70-79	8	20.0
	80-89	4	10.0
	Mean±SD (years)	63±11.94	
Gender	Male	26	65.0
	Female	14	35.0
Smoking History	Yes	24	60.0
	No	16	40.0
Hypertension	Yes	25	62.5
	No	15	37.5

The study included 40 participants with renal cell carcinoma (RCC). The majority of patients were in the 60-69 years age group (12 patients, 30.0%), followed by the 50-59 years age group (10 patients, 25.0%), the 70-79 years age group (8 patients, 20.0%), the 40-49 years age group (6 patients, 15.0%), and the 80-89 years age group (4 patients, 10.0%). The mean age of the participants was 63 ± 11.94 years. Males constituted the majority of the cohort (26 patients, 65.0%), while females accounted for 35.0% (14 patients). A history of smoking was reported in 24 patients (60.0%), and 25 patients (62.5%) had hypertension.

Table 2. *Tumor Characteristics and Histological Subtypes of Study Participants (n=40)*

Variable		Number of patients	Percentage
Tumor size (cm)	≥3	19	47.5
	<3	21	52.5
Laterality	Right Kidney	16	40.0
	Left Kidney	24	60.0
Histological Subtype	Clear Cell RCC	34	85.0
	Papillary RCC	4	10.0
	Chromophobe RCC	2	5.0

Tumor characteristics and histological subtypes were analyzed in the 40 patients with RCC. Nearly half of the patients (19 patients, 47.5%) had tumors measuring ≥3 cm, while 21 patients (52.5%) had tumors <3 cm. Tumors were more frequently located in the left kidney (24 patients, 60.0%) compared to the right kidney (16 patients, 40.0%). Histologically, clear cell RCC was the most common subtype (34 patients, 85.0%), followed by papillary RCC (4 patients, 10.0%) and chromophobe RCC (2 patients, 5.0%).

Table 3. *Diagnostic Performance of CT and MRI in Renal Cell Carcinoma*

Modality	Sensitivity	Specificity	Accuracy	PPV	NPV
CT scan	70.0	87.5	75.0	95.0	50.0
MRI	90.0	67.5	85.0	90.0	67.5

The diagnostic performance of CT and MRI in detecting RCC was evaluated. MRI demonstrated higher sensitivity (90.0%) compared to CT scan (70.0%), indicating its superior ability to correctly identify RCC cases. However, CT scan showed higher specificity (87.5%) than MRI (67.5%), suggesting it was more accurate in ruling out non-RCC cases. Overall, MRI had higher accuracy (85.0%) compared to CT scan (75.0%). The positive predictive value (PPV) was slightly higher for CT scan (95.0%) than MRI (90.0%), while the negative predictive value (NPV) was higher for MRI (67.5%) compared to CT scan (50.0%).

Table 4. *Comparison of CT and MRI in Stage Detection of Renal Cell Carcinoma*

Stage Detection	CT (%)	MRI (%)
Venous Invasion	60.0	78.0
Lymph Node Metastasis	65.0	75.0

The performance of CT and MRI in detecting advanced RCC features was compared. MRI outperformed CT scan in identifying venous invasion (78.0% vs. 60.0%) and lymph node metastasis (75.0% vs. 65.0%), highlighting its superior capability in staging RCC.

5. Discussion

This study evaluates and compares the diagnostic accuracy and staging efficacy of computed tomography (CT) and magnetic resonance imaging (MRI) in detecting renal cell carcinoma (RCC). RCC, a common malignancy of the kidney, requires accurate imaging techniques for proper diagnosis and staging, as they guide treatment decisions and prognostication. The results emphasize the strengths and limitations of both CT and MRI in assessing tumor characteristics, with MRI showing superior sensitivity for RCC detection and CT demonstrating higher specificity for ruling out non-RCC cases. The study also highlights the critical role of imaging in staging advanced features such as venous invasion and lymph node metastasis, which are crucial for determining the extent of the disease and informing therapeutic approaches.

In our study, the mean age of participants was 63 ± 11.94 years, with the majority in the 60–69 years age group (30.0%), followed by the 50–59 years group (25.0%). This aligns with findings by Hallscheidt et al.[18] and Kim et al.[19], who reported a higher prevalence of renal cell carcinoma (RCC) in older adults. A male predominance (65.0%) was observed, consistent with previous studies, including Fateh et al.[20], which highlighted the higher incidence of RCC in men. This gender disparity has been attributed to hormonal influences and lifestyle-related risk factors. Additionally, a significant proportion of patients had a history of smoking (60.0%) and hypertension (62.5%), both of which are well-established contributors to RCC development. These findings underscore the importance of considering patient demographics and comorbidities when evaluating imaging modalities for RCC detection and staging.

In our study, tumor characteristics and histological subtypes were evaluated in 40 patients with renal cell carcinoma (RCC). Tumor size distribution revealed that 47.5% of patients had tumors measuring ≥3 cm, while 52.5% had tumors <3 cm, which is consistent with the findings of Yang et al.[21], who reported a similar size distribution in RCC cases. Tumors were more commonly located in the left kidney (60.0%) compared to the right kidney (40.0%), aligning with Türkvatan et al.[22], who also noted a left-sided predominance in RCC. Histologically, clear cell RCC was the most prevalent subtype (85.0%), followed by papillary RCC (10.0%) and chromophobe RCC (5.0%), mirroring the distribution reported in the study by Türkvatan et al.[22] These findings reinforce the established tumor characteristics of RCC and highlight the need for accurate imaging modalities for tumor localization and subtype differentiation.

The diagnostic performance of CT and MRI in detecting renal cell carcinoma (RCC) was assessed, revealing that MRI had a higher sensitivity (90.0%) than CT scan (70.0%), indicating its superior ability to correctly identify RCC cases. This aligns with the findings of Yang et al.[21], who also reported enhanced sensitivity with MRI. However, CT scan demonstrated higher specificity (87.5%) compared to MRI (67.5%), suggesting it was more reliable in ruling out non-RCC cases. Overall, MRI showed greater accuracy (85.0%) than CT scan (75.0%), reinforcing its role as a preferred imaging modality for RCC detection. While the positive predictive value (PPV) was slightly higher for CT scan (95.0%) than MRI (90.0%), MRI had a superior negative predictive value (NPV) (67.5%

vs. 50.0%), making it more effective in excluding RCC when results were negative. These findings emphasize the complementary roles of both imaging modalities in RCC diagnosis, with MRI excelling in detection and CT scan aiding in specificity.

In our study on the role of CT and MRI in the diagnosis and staging of renal cell carcinoma (RCC), we observed that MRI demonstrated superior sensitivity in detecting both venous invasion and lymph node metastasis compared to CT. Specifically, MRI showed a sensitivity of 78% for venous invasion and 75% for lymph node metastasis, while CT demonstrated sensitivities of 60% and 65% respectively. These findings are consistent with the study by Reznek et al.[23], which highlighted the advantages of MRI in providing detailed imaging for precise staging, particularly in identifying venous involvement and metastatic lymph nodes. The enhanced sensitivity of MRI can be attributed to its superior soft-tissue contrast and multiplanar imaging capabilities, which allow for better visualization of vascular and lymphatic structures. Conversely, while CT showed lower sensitivity, it remains a valuable tool due to its higher specificity and ability to provide rapid imaging. These results suggest that MRI may be more effective for comprehensive initial diagnosis and staging of RCC, while CT can serve as a confirmatory tool to complement MRI findings. Combining both modalities could potentially enhance the overall diagnostic accuracy and staging precision for RCC, leading to better clinical outcomes.

In the context of BSMMU and Bangladesh, where CT scans are more commonly used due to their availability and affordability, our findings suggest that MRI offers significant advantages in detecting advanced RCC features, such as venous invasion and lymph node metastasis. While CT remains a valuable first-line imaging modality, MRI should be considered for comprehensive staging, particularly in complex cases or when advanced disease is suspected.

6. Limitations of the Study

This study had some limitations:

- The study was conducted in a selected tertiary-level hospital.
- The sample was not randomly selected.
- The study's limited geographic scope may introduce sample bias, potentially affecting the broader applicability of the findings.

7. Conclusion

In conclusion, our study demonstrated that MRI outperforms CT in the detection and staging of renal cell carcinoma (RCC). MRI exhibited higher sensitivity, accuracy, and negative predictive value, making it a superior modality for identifying RCC and its advanced features, such as venous invasion and lymph node metastasis. Although CT showed higher specificity and positive predictive value, it was less effective in detecting these critical staging factors. These findings suggest that MRI should be considered the preferred imaging technique for comprehensive RCC diagnosis and staging, while CT can still be useful for confirming negative cases.

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