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Diagnostic Accuracy of Contrast-Enhanced Computed Tomography in Differentiating Benign and Malignant Adrenal Lesions: A Histopathological Correlation Study

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Abstract **Original Research Article**

Background: The growing incidental detection of adrenal masses has emphasized the need for reliable, non-invasive diagnostic tools. Contrast-Enhanced Computed Tomography (CECT) is commonly employed to evaluate adrenal lesions due to its accessibility and detailed imaging capabilities. However, its diagnostic accuracy in distinguishing benign from malignant lesions must be critically assessed through comparison with histopathological findings, which remain the gold standard for definitive diagnosis. ***Objective:*** To evaluate the diagnostic accuracy of CECT in differentiating benign from malignant adrenal lesions using histopathological findings as the gold standard. ***Methods:*** A hospital-based cross-sectional study was carried out over a period of two years (April 2022 to March 2024) in the Department of Radiology and Imaging at Bangladesh University (BMU), Dhaka. Thirty patients with clinically or sonographically suspected adrenal masses were enrolled using purposive sampling. Each participant underwent a dedicated adrenal Contrast-Enhanced Computed Tomography (CECT) scan, performed using a standardized adrenal imaging protocol, including unenhanced, portal venous, and 15-minute delayed phases. Imaging findings were interpreted by experienced radiologists blinded to clinical and histopathological data. All patients subsequently underwent histopathological confirmation through biopsy or surgical excision, which served as the diagnostic gold standard. Comparative analysis between CECT and histopathology was conducted. Diagnostic performance metrics, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of CECT in differentiating benign from malignant adrenal lesions, were calculated using appropriate statistical tools via SPSS version 26. A p-value <0.05 was considered statistically significant. ***Results:*** In this study of 30 patients with adrenal masses, the mean age was 40.9±17.8 years, with a male-to-female ratio of 1.3:1. On contrast-enhanced CT (CECT), 80% of lesions were identified as benign and 20% as malignant, while histopathology confirmed 76.7% as benign and 23.3% as malignant. Adrenal adenoma was the most common diagnosis on both imaging (50%) and histopathology (46.7%). Lesion size showed a significant association with malignancy; 85.7% of malignant tumors were ≥4 cm compared to only 21.7% of benign ones (p = 0.003), with malignant tumors having a significantly larger mean size (8.05 cm vs 3.90 cm). The agreement between CECT and histopathology was very strong (κ = 0.902), with CECT demonstrating high diagnostic validity—sensitivity 85.71%, specificity 100%, positive predictive value 100%, negative predictive value 95.83%, and overall accuracy 96.67%—in distinguishing malignant adrenal lesions. ***Conclusion:*** CECT shows high diagnostic accuracy and excellent agreement with histopathology in differentiating adrenal lesions, suggesting its potential to guide non-invasive management and reduce reliance on invasive procedures.

Keywords: Adrenal mass, CECT, histopathology, diagnostic accuracy, benign adrenal lesion, malignant adrenal tumor.

INTRODUCTION

The adrenal glands are susceptible to a wide spectrum of pathological processes, ranging from benign adenomas to aggressive malignancies such as adrenocortical carcinoma and metastatic disease. With the increasing utilization of cross-sectional imaging modalities like ultrasonography (US), computed tomography (CT), and magnetic resonance imaging

(MRI), adrenal lesions- particularly incidentalomas- are being detected with growing frequency during imaging for unrelated abdominal or thoracic complaints [1]. These lesions are found in approximately 3–7% of the adult population, with prevalence rising with age [2].

Although most adrenal incidentalomas are benign and hormonally inactive, a subset may exhibit malignant potential or hormonal hypersecretion. Differentiating between benign and malignant adrenal masses is critical for guiding appropriate clinical decision-making. Surgical resection is typically indicated for primary adrenal malignancies and functional tumors, whereas benign, non-functioning lesions may be managed conservatively with imaging follow-up [3]. Therefore, non-invasive, accurate characterization of adrenal lesions remains a clinical priority to minimize unnecessary surgeries and avoid missed diagnoses of malignancy.

Contrast-enhanced computed tomography (CECT) is widely regarded as the first-line imaging modality for adrenal lesion evaluation, primarily due to its accessibility, high resolution, and ability to delineate lesion morphology and enhancement characteristics. CECT enables radiologists to assess important imaging features such as lesion size, shape, internal attenuation, contrast washout dynamics, and presence of calcification, necrosis, or vascular invasion- all of which are critical in lesion characterization [4,5]**.**

Benign adrenal adenomas typically demonstrate low attenuation on unenhanced CT scans (≤10 Hounsfield Units) due to their intracellular lipid content, show homogeneous enhancement, and exhibit rapid contrast washout. In contrast, malignant lesions such as adrenocortical carcinoma or metastatic deposits often present with irregular margins, heterogeneous enhancement, larger size (commonly >4 cm), delayed contrast washout, and signs of local invasion or metastasis **[**6,7**].** Washout analysis using absolute and relative percentage washout values after delayed imaging further improves diagnostic specificity- adenomas usually demonstrate an absolute washout of >60% or relative washout of >40% at 15 minutes. [8]

Despite these well-defined imaging characteristics, overlap in radiological features- particularly in lipid-poor adenomas and necrotic malignant lesions- can limit diagnostic certainty. Thus, histopathological examination remains the gold standard for definitive diagnosis and validation of imaging-based assessments.

In this context, this study aims to evaluate the diagnostic accuracy of Contrast-Enhanced Computed Tomography (CECT) in differentiating benign from malignant adrenal lesions by correlating imaging findings with histopathological results. Establishing the reliability of CECT in lesion characterization will support its role as a non-invasive tool in clinical decision-making and potentially reduce the need for invasive diagnostic procedures.

METHODS

Study Design and Setting: This was a hospital-based cross-sectional observational study conducted in the Department of Radiology and Imaging at Bangladesh Medical University (BMU), Dhaka, over a two-year period from April 2022 to March 2024. The study aimed to assess the diagnostic performance of Contrast-Enhanced Computed Tomography (CECT) in differentiating benign from malignant adrenal lesions, using histopathology as the reference standard.

Study Population and Sampling: A total of 30 patients were included in the study. Participants were selected using purposive sampling based on clinical suspicion or sonographic evidence of adrenal masses. All patients were referred from various departments (including surgery, endocrinology, and internal medicine) for further evaluation with adrenal CT imaging.

Inclusion and Exclusion Criteria

Inclusion Criteria:

- Patients of any age and sex with clinically suspected or incidentally discovered adrenal masses on imaging.
- Patients willing to undergo both CECT and histopathological confirmation.
- Informed written consent obtained.

Exclusion Criteria:

- Pregnant women.
- Patients with known hypersensitivity to iodinated contrast media.
- Patients with bleeding diathesis or systemic sepsis.
- Those who refused biopsy, surgery, or follow-up.

CECT Imaging Protocol

All patients underwent CECT using a 128-slice Siemens SOMATOM Definition AS multidetector CT scanner. The adrenal protocol consisted of three phases:

Unenhanced Scan: Axial sections with 2.5 mm collimation through the adrenal glands.

Contrast-Enhanced Portal Venous Phase: Acquired 60–70 seconds after intravenous administration of 100 mL non-ionic contrast agent at 3 mL/sec using a power injector.

Delayed Phase: Additional images taken at 15 minutes post-contrast administration.

Mean attenuation values (in Hounsfield Units) were measured by placing elliptical regions of interest

(ROI) over the adrenal lesions. Absolute and relative percentage washout were calculated using standard formulas:

Absolute Percentage Washout (APW) = [(Enhanced HU – Delayed HU) / (Enhanced HU – Unenhanced HU)] × 100

Relative Percentage Washout (RPW) = [(Enhanced HU – Delayed HU) / Enhanced HU] × 100

An APW >60% or RPW >40% was considered indicative of a benign adenoma.[5]

Histopathological Evaluation

Tissue samples were obtained via percutaneous biopsy or surgical excision and examined by experienced pathologists blinded to the imaging findings. Histopathological diagnosis was considered the gold standard for determining the benign or malignant nature of the adrenal mass.

Data Collection and Variables

Data were collected using a structured proforma, including demographic details, clinical findings, CT characteristics (size, density, enhancement pattern, washout), and histopathological outcomes. Independent variables included age, sex, lesion size, and CECT parameters, while the dependent variable was the final histopathological diagnosis.

Statistical Analysis

All data were compiled and analyzed using SPSS version 26.0. Descriptive statistics were calculated for demographic and clinical variables. Diagnostic performance of CECT was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. Agreement between CECT and histopathology was evaluated using Cohen's kappa coefficient. A p-value <0.05 was considered statistically significant.

Ethical Consideration

The study protocol was approved by the Institutional Review Board (IRB) of BMU prior to data collection. All patients or their legal guardians provided informed written consent. Confidentiality was maintained by anonymizing patient data and limiting access to research personnel only.

RESULTS

Table-1: Demographic characteristics of the study patients (n=30)

Variables	Number of patients	Percentage (%)
Age group (years)		
9-19	3	10.0
20-29	5	16.7
30-39	7	23.3
40-80	15	50.0
Mean ± SD	40.9±17.8	
Sex		
Male	17	56.7
Female	13	43.3
Male: Female ratio	1. 3: 1	

A total of 30 patients with adrenal masses were included in the study. The mean age was 40.9±17.8 years (range: 9–80 years). Half of the patients (50.0%) were aged 40 years or above, and 23.3% were between 30–39 years. There were 17 males (56.7%) and 13 females (43.3%), yielding a male-to-female ratio of 1.3:1.

Table-2: Distribution of Benign & Malignant lesions by CECT diagnosis (n=30)

CECT diagnosis	Frequency	Percentage (%)
Benign	24	80.0
Malignant	6	20.0
Total	30	100.0

On CECT, 24 patients (80.0%) were diagnosed with benign adrenal lesions, while 6 (20.0%) were diagnosed as malignant.

Table-3: Distribution of benign & malignant adrenal lesions by histopathological diagnosis (n=30)

Histopathological diagnosis	Frequency	Percentage (%)
Benign	23	76.7
Malignant	7	23.3
Total	30	100.0

The most common diagnosis on CECT was adrenal adenoma (15 patients, 50.0%), followed by adrenal hyperplasia (13.3%), adrenocortical carcinoma (10.0%), and adrenal metastases (6.7%).

Table-4: Distribution of Adrenal Lesions by CECT diagnosis (n=30)

CECT diagnosis	Frequency	Percentage (%)
Adrenal Adenoma	15	50.0
Adrenal Myelolipoma	2	6.7
Adrenal Metastases	2	6.7
Adrenocortical carcinoma	3	10.0
Neuroblastoma	1	3.3
Hyperplasia	4	13.3
Histoplasmosis	2	6.7
Adrenal tuberculosis	1	3.3
Total	30	100.0

The most common diagnosis on CECT was adrenal adenoma (15 patients, 50.0%), followed by adrenal hyperplasia (13.3%), adrenocortical carcinoma (10.0%), and adrenal metastases (6.7%).

Table-5: Distribution of Adrenal Lesions by histopathological diagnosis (n=30)

Histopathological diagnosis	Frequency	Percentage (%)
Adrenal Adenoma	14	46.7
Adrenocortical carcinoma	4	13.3
Myelolipoma	1	3.3
Metastases	2	6.7
Neuroblastoma	1	2.9
Adrenal Hyperplasia	5	16.7
Histoplasmosis	2	6.7
Adrenal tuberculosis	1	3.3
Total	30	100.0

Histopathological evaluation revealed adrenal adenoma in 14 patients (46.7%), adrenocortical carcinoma in 4 (13.3%), adrenal hyperplasia in 5 (16.7%), and metastatic lesions in 2 (6.7%).

Table-6: Correlation between adrenal tumor size and Histopathology finding in the diagnosis of Malignant and Benign adrenal tumors (n=30)

Size of lesion (cm)	Histopathological findings		p-value
	Malignant (n=7)	Benign (n=23)	
< 4 cm	1(14.3%)	18(7803%)	
≥ 4 cm	6(85.7%)	5(21.7%)	
Total	7(100.0%)	23(100.0%)	
Mean±SD	8.05±5.06	3.90±2.14	0.003

p-value obtained by Unpaired t-test, p<0.05 considered as a level of significance

Lesions measuring ≥4 cm were significantly more likely to be malignant. Among malignant lesions (n=7), 6 (85.7%) were ≥4 cm, while only 1 (14.3%) was <4 cm. Conversely, 18 benign lesions (78.3%) were <4 cm. The mean size of malignant lesions was 8.05 ± 5.06 cm, significantly larger than that of benign lesions (3.90 ± 2.14 cm), with a statistically significant difference (p = 0.003).

Table-7: Relation of CECT and histopathological findings in diagnosis of Benign and Malignant adrenal lesion

	Histopathological findings			Kappa value
	Malignant (n=7)	Benign (n=23)	Total	
CECT(Benign)	1(14.3%)	23(100.0%)	24	
CECT(Malignant)	6(85.7%)	0(0.00%)	6	0.902
Total	7(100.0%)	23(100.0%)		

The cross-tabulation between CECT and histopathology showed that all 6 cases labeled malignant on CECT were confirmed malignant on histopathology (true positives), and all 23 benign histological cases were correctly identified by CECT (true negatives). One malignant lesion was misclassified as benign (false negative), and no false positives were recorded. Kappa value 0.902 obtained by Cohen's kappa test signifies 'Very Good Agreement' level of association between CECT and Histopathological diagnosis of benign and malignant adrenal lesion

Table-8: Diagnostic validity test between CECT and histopathological findings in the diagnosis of malignant adrenal lesion (n=30)

	Values (%)	95% CI
Sensitivity	85.71%	42.13% to 99.64%
Specificity	100.00%	85.18% to 100.00%
Positive Predictive Value	100.00%	54.07% to 100.00%
Negative Predictive Value	95.83%	78.93% to 99.30%
Accuracy	96.67%	82.78% to 99.92%

CECT demonstrated high diagnostic accuracy in detecting malignant adrenal lesions, with a sensitivity of 85.71%, specificity of 100%, PPV of 100%, NPV of 95.83%, and overall accuracy of 96.67%.

DISCUSSION

This cross-sectional observational study was conducted in the Department of Radiology and Imaging at Bangladesh Medical University (BMU), Dhaka, with the aim of evaluating the diagnostic accuracy of contrast-enhanced computed tomography (CECT) in differentiating benign from malignant adrenal lesions, using histopathological findings as the reference standard. The findings confirm that CECT is a highly accurate, non-invasive imaging modality, demonstrating strong diagnostic performance with a sensitivity of 85.71%, specificity of 100.00%, positive predictive value (PPV) of 100.00%, negative predictive value (NPV) of 95.83%, and an overall accuracy of 96.67%. These outcomes align with the earlier findings by Korobkin *et al.,*[4], who established the utility of unenhanced CT attenuation values for differentiating adrenal adenomas from non-adenomas, and were further supported by Caoili *et al.,*[5], who validated the role of combined unenhanced and delayed-enhanced CT in characterizing adrenal masses. Subsequent studies, such as those by Park *et al.,*[9] and Albano *et al.,*[6], reinforced the diagnostic value of dynamic washout criteria in improving the accuracy of adrenal lesion evaluation. The present study adds to this evidence base by demonstrating that, when standardized imaging protocols are applied, CECT can reliably distinguish benign from malignant adrenal tumors in a South Asian tertiary care setting.

In the current study, the majority of patients were above 40 years of age, with a mean age of 40.9 ± 17.8 years. A male predominance was observed (male-to-female ratio 1.3:1), similar to previous reports by Kunjuraman and Chacko [10] and Mohamed *et al.,*[11], who also reported wide age ranges and slightly higher male incidence. This reflects the typical epidemiologic pattern of adrenal masses, which are increasingly detected incidentally in middle-aged and older adults.

Clinical presentations were also in line with known functional characteristics of adrenal tumors. Hypertension was the most frequent symptom (43.3%), followed by features suggestive of cortisol excess (23.3%). These findings are supported by Dunnick *et al.,*[12], who described cortisol-producing adrenocortical carcinomas as a common cause of Cushingoid features in adrenal malignancies.

In this study, adrenal adenoma was the most common lesion diagnosed both radiologically (50%) and histologically (46.7%), followed by adrenal hyperplasia and adrenocortical carcinoma. The radiological-histopathological concordance was excellent, as indicated by a Cohen's kappa value of 0.902, suggesting very good agreement. No false-positive cases were recorded, and only one malignant lesion was missed by CECT, reflecting its high specificity and reliability.

A key finding in this study was the strong correlation between tumor size and malignancy. Among malignant lesions, 85.7% were ≥4 cm, while 78.3% of benign lesions were <4 cm. The mean size of malignant tumors (8.05 ± 5.06 cm) was significantly larger than that of benign tumors (3.90 ± 2.14 cm), with a statistically significant difference (p = 0.003). This supports the established size thresholds reported by Mayo-Smith *et al.,*[1], Park *et al.,*[9], and Blake *et al.,*[13], which suggest that adrenal lesions larger than 4–6 cm warrant greater suspicion of malignancy. Although detailed washout analysis (absolute and relative percentage washout) was not presented separately, the CT protocol in this study followed standard adrenal imaging criteria. Prior literature confirms that absolute percentage washout <60% and relative percentage washout <40% are highly suggestive of malignancy. [8] Overall, the findings reaffirm the diagnostic value of CECT in evaluating adrenal lesions. The combination of lesion size, enhancement pattern, and contrast washout behavior offers a comprehensive non-invasive

assessment strategy. However, the presence of one false-negative case in this series underscores the need for caution in small or atypical tumors, where imaging findings may overlap.

CONCLUSION

Contrast-enhanced CT is a highly accurate and non-invasive modality for differentiating benign from malignant adrenal lesions, demonstrating strong agreement with histopathological findings. Lesion size, particularly ≥4 cm, significantly correlates with malignancy. Given its high specificity and diagnostic accuracy, CECT remains a valuable first-line tool in the evaluation of adrenal masses, aiding in clinical decision-making and reducing unnecessary interventions.

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