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CT Morphologic Features and Size Criteria in Differentiating Benign from Malignant Adrenal Tumors

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Abstract

Background: Differentiating benign from malignant adrenal tumors is critical for determining appropriate clinical management. Although histopathology is the definitive diagnostic tool, contrast-enhanced computed tomography (CT) offers valuable non-invasive insights. Specific morphologic features- such as size, shape, margins, and enhancement patterns- can help predict malignancy. Establishing reliable CT-based criteria enhances diagnostic confidence and aids in selecting patients who may benefit from surgery or further evaluation. ***Objective:*** To evaluate the diagnostic value of CT morphologic features and tumor size in distinguishing benign from malignant adrenal tumors. ***Methods:*** This cross-sectional study was conducted at the Department of Radiology and Imaging, Bangladesh Medical University (BMU), Dhaka, over a two-year period and included 30 patients with clinically or radiologically suspected adrenal masses. All patients underwent contrast-enhanced CT (CECT) using a standardized adrenal protocol, including unenhanced, portal venous, and delayed phases. Tumor characteristics such as size, shape, margins, enhancement pattern, internal architecture, necrosis, calcification, and attenuation were assessed. CT findings were interpreted by radiologists blinded to histopathological results. Final diagnoses were confirmed by histopathological examination of biopsy or surgical specimens. CT features and lesion size were then correlated with histopathological outcomes to evaluate their significance. ***Results:*** Among the 30 patients evaluated, the mean age was 40.9 ± 17.8 years, with a male-to-female ratio of 1.3:1. CT revealed left-sided adrenal masses in 40%, right-sided in 33.3%, and bilateral involvement in 26.7%. Most lesions (63.3%) were <4 cm, and 53.3% appeared hypodense on pre-contrast imaging. Post-contrast, 50% of lesions showed homogeneous enhancement, while 46.7% showed heterogeneous enhancement. Hemorrhage and necrosis were noted in 23.3% of cases, and invasion into adjacent structures was observed in 6.7%, both exclusively in malignant lesions. Hypodensity was predominantly seen in benign lesions (46.6%), whereas hemorrhage, necrosis, and invasion were exclusive to malignancies. Among lesions <4 cm, 94.7% were benign; among those ≥4 cm, 54.5% were malignant. The odds of a lesion ≥4 cm being malignant were 21 times higher (OR: 21; 95% CI: 2.1–223.6; p = 0.002). Malignant tumors had a significantly larger mean diameter (8.05 ± 5.06 cm) than benign tumors (3.90 ± 2.14 cm; p = 0.003). Adrenal adenoma was the most common lesion (50%), followed by hyperplasia (13.3%) and adrenocortical carcinoma (10%). ***Conclusion:*** CT morphologic features, particularly lesion size, enhancement pattern, and structural alterations such as necrosis or invasion, are valuable indicators for distinguishing benign from malignant adrenal tumors. Lesions ≥4 cm and those showing heterogeneous enhancement or invasive characteristics were significantly associated with malignancy.

Keywords: Adrenal tumor, Benign lesion, Malignant lesion, Multidetector CT (MDCT), Contrast-enhanced CT, Tumor size.

INTRODUCTION

Adrenal tumors represent a heterogeneous group of lesions that may be benign, malignant, functioning, or non-functioning. With the increasing use of cross-sectional imaging for unrelated abdominal complaints, incidental detection of adrenal masses—commonly termed "adrenal incidentalomas"—has become more frequent, occurring in up to 4–7% of abdominal CT scans [1]. While the majority of these lesions are benign and non-functional, distinguishing them from primary adrenal malignancies or metastatic deposits is essential due to the significant differences in clinical management, prognosis, and therapeutic approach [2,3].

Histopathological confirmation remains the diagnostic gold standard; however, it is invasive and not always feasible for every patient. Therefore, imaging, particularly contrast-enhanced computed tomography (CECT), plays a crucial role in the initial assessment and triage of adrenal tumors. CT is widely available and offers high-resolution anatomical detail, enabling the evaluation of key morphologic features such as size, shape, margins, enhancement patterns, attenuation, presence of necrosis, and calcifications [4,5].

Lesion size is one of the most consistently reliable predictors of malignancy. Numerous studies suggest that adrenal tumors ≥4 cm in diameter are significantly more likely to be malignant compared to smaller lesions [1,6,7]. Additionally, irregular or ill-defined margins, heterogeneous enhancement, and the presence of central necrosis or hemorrhage further raise the suspicion of malignancy [8,9]. Unenhanced CT attenuation values >10 Hounsfield units (HU) and poor washout characteristics on delayed imaging are also associated with non-adenomatous and malignant tumors [5,10.

Despite the growing literature, diagnostic performance varies depending on imaging technique, reader experience, and patient population. Therefore, ongoing evaluation of CT criteria is necessary to refine diagnostic thresholds and enhance clinical decision-making [2,11].

The present study was conducted to evaluate the diagnostic value of CT morphologic features and lesion size in differentiating benign from malignant adrenal tumors. By correlating imaging findings with histopathological outcomes, this study aims to reinforce and refine existing radiologic criteria to improve diagnostic accuracy in routine clinical practice.

METHODS

This cross-sectional observational study was conducted in the Department of Radiology and Imaging at Bangladesh Medical University (BMU), Dhaka, over a two-year period. A total of 30 patients with suspected adrenal masses were included using purposive sampling. Inclusion criteria were adult patients with incidentally or clinically detected adrenal lesions who underwent contrast-enhanced computed tomography (CECT) followed by histopathological evaluation through surgical resection or image-guided biopsy. Patients with incomplete imaging or missing histological data were excluded.

All patients underwent CECT of the abdomen using a standard adrenal protocol. Images were acquired in unenhanced, portal venous, and delayed phases. Lesion characteristics were assessed on axial and multiplanar reformatted images. CT features analyzed included maximum tumor diameter, lesion shape (round, oval, lobulated), margin definition (smooth or irregular), enhancement pattern (homogeneous or heterogeneous), presence of necrosis, calcification, and attenuation values in Hounsfield units (HU).

Two radiologists, blinded to histopathological outcomes, independently evaluated the CT images. Discrepancies were resolved by consensus. Final histopathological diagnoses were considered the reference standard for comparison. Lesions were classified as benign or malignant based on pathology reports.

Statistical analysis was performed using SPSS version 26.0. Descriptive statistics summarized patient demographics and lesion features. Differences between benign and malignant lesions were evaluated using chi-square test for categorical variables and independent-sample t-test for continuous variables. A p-value <0.05 was considered statistically significant.

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 the study patients by multidetector CT findings (n=30)

Multi detector CT findings	Frequency	Percentage (%)
Site of the lesion		
Right adrenal mass	10	33.3
Left adrenal mass	12	40.0
Bilateral adrenal mass	8	26.7
Size of the lesion		
< 4cm	19	63.3%
≥ 4cm	11	36.6%
Pre-contrast CT examination		
Hypodense	16	53.3
Iso-dense	6	20.0
Mixed density	8	26.7
Post contrast CT examination		
No enhancement	1	3.3
Homogeneous enhancement	15	50.0
Heterogeneous enhancement	14	46.7
Presence of hemorrhage and necrosis	7	23.3
Invasion to surrounding structure	2	6.7

Multidetector CT (MDCT) analysis revealed that the adrenal mass was located on the left in 40.0% of cases, on the right in 33.3%, and bilaterally in 26.7% (Table 2). The majority of lesions (63.3%) measured less than 4 cm, while 36.7% were ≥4 cm. On pre-contrast CT, 53.3% of the lesions were hypodense, 20.0% isodense, and 26.7% mixed density. Post-contrast evaluation showed homogeneous enhancement in 50.0% of lesions and heterogeneous enhancement in 46.7%, with only one case showing no enhancement. Hemorrhage and necrosis were identified in 23.3% of cases, and 6.7% demonstrated invasion into surrounding structures.

Table-3: MDCT morphologic findings of Benign & Malignant adrenal lesions

MDCT morphologic findings	**Benign adrenal lesion**	**Malignant adrenal lesion**
Size of lesion:		
1.05 cm to 4 cm (n=19)	18(94.7%)	1(5.3%)
4 cm to 18 cm (n=11)	5(45.5%)	6(54.5%)
Hypodensity	14(46.6%)	2(6.7%)
Hemorrhage & Necrosis		7(23.3%)
Invasion to surrounding structure		2(6.7%)

Among lesions <4 cm, 94.7% were benign and only 5.3% were malignant, whereas 54.5% of lesions ≥4 cm were malignant. Hypodensity was more common in benign lesions (46.6%), while hemorrhage, necrosis (23.3%), and invasion (6.7%) were observed exclusively in malignant tumors. These features suggest that larger size and aggressive CT findings are strong indicators of malignancy.

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**

On CECT, the most common lesion was adrenal adenoma (50.0%), followed by adrenal hyperplasia (13.3%), adrenocortical carcinoma (10.0%), adrenal metastases (6.7%), and myelolipoma (6.7%). Less common findings included histoplasmosis (6.7%), neuroblastoma (3.3%), and adrenal tuberculosis (3.3%).

Table-5: 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		OR 95CI%	p-value
	Malignant (n=7)	Benign (n=23)		
< 4 cm	1(14.3%)	18(78.3%)	21 (2.1-223.6)	0.002
≥ 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

Tumor size showed a strong correlation with malignancy. Among lesions ≥4 cm, 85.7% were malignant, while only 14.3% of malignant lesions were <4 cm. Conversely, 78.3% of benign lesions were <4 cm. The mean size of malignant tumors (8.05 ± 5.06 cm) was significantly greater than benign ones (3.90 ± 2.14 cm; p = 0.003). The odds of a lesion ≥4 cm being malignant were 21 times higher (OR: 21; 95% CI: 2.1–223.6; p = 0.002).

DISCUSSION

This cross-sectional study was carried out at the Department of Radiology and Imaging, Bangladesh Medical University (BMU), to evaluate the diagnostic utility of CT morphologic features and tumor size in differentiating benign from malignant adrenal lesions. Given the increasing detection of adrenal masses due to widespread imaging, especially in asymptomatic individuals, a reliable, non-invasive diagnostic approach is essential. Although histopathological confirmation remains the gold standard, CT-based parameters like lesion size, enhancement pattern, and architectural changes can significantly guide preoperative assessment and reduce unnecessary surgeries.

In this study, 30 patients with adrenal masses were evaluated. The mean age was 40.9 ± 17.8 years, with 50% of the patients aged 40 years or older. Males constituted 56.7% of cases, and females 43.3%, yielding a male-to-female ratio of 1.3:1. These findings align with prior studies by Mohamed *et al.,* [12] and Kunjuraman and Chacko [11], which noted similar age distributions and a slight male predominance in adrenal tumor presentations. Although age alone does not distinctly differentiate benign from malignant tumors, older patients have a higher likelihood of incidental adrenal lesions, particularly adenomas [2].

A key finding in our study was the strong correlation between lesion size and malignancy. Among lesions ≥4 cm, 85.7% were malignant, whereas only 14.3% of malignant lesions were <4 cm. Conversely, 78.3% of benign lesions were <4 cm. The mean size of malignant tumors (8.05 ± 5.06 cm) was significantly larger than benign ones (3.90 ± 2.14 cm, $p = 0.003$). The odds of malignancy increased 21-fold when lesion size exceeded 4 cm (OR: 21; 95% CI: 2.1–223.6; $p = 0.002$). These results are consistent with those of Park *et al.,* [6] and Song *et al.,* [2], who advocated for the 4 cm threshold as a key decision point in managing adrenal masses.

CT morphologic features added significant value in characterizing lesions. Hypodensity on pre-contrast imaging—a hallmark of lipid-rich adenomas—was observed in 46.6% of benign lesions and only 6.7% of malignant ones, aligning with prior reports by Korobkin *et al.,* and Caoili *et al.,* [8,10] Malignant tumors were more likely to exhibit heterogeneous enhancement, intratumoral hemorrhage, necrosis, and invasion into adjacent structures—features that were exclusive to malignant lesions in this cohort. These findings mirror those in Ng *et al.,* [4] and Albano *et al.,* [9], who highlighted these CT features as critical red flags for malignancy.

The distribution of adrenal lesions on CT in this study reflected known prevalence patterns. Adrenal adenomas were most common (50.0%), followed by hyperplasia (13.3%) and adrenocortical carcinoma (10.0%). Rare diagnoses included metastases, neuroblastoma, histoplasmosis, and adrenal tuberculosis. These findings are in agreement with previous series emphasizing the predominance of adenomas in incidentally discovered adrenal lesions [11,12].

In clinical practice, the integration of morphologic CT features with size criteria enhances diagnostic confidence and guides appropriate management. While small, homogenous, hypodense lesions are likely benign and may warrant surveillance, larger lesions (>4 cm) with necrotic or invasive features should prompt further investigation or surgical referral. This multimodal CT assessment is particularly valuable in resource-limited settings where advanced hormonal assays or PET imaging may not be readily available.

CONCLUSION

CT morphologic features, particularly lesion size, enhancement pattern, and structural characteristics, provide critical non-invasive parameters for differentiating benign from malignant adrenal tumors. In

this study, lesions ≥4 cm, those exhibiting heterogeneous enhancement, hemorrhage, necrosis, or invasion were significantly associated with malignancy. Multidetector CT, when interpreted systematically, offers high diagnostic utility and can effectively guide clinical decision-making, especially in settings where histopathological confirmation is delayed or unavailable.

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