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Radio Diagnosis

Role of MDCT in Assessment and Characterization of Renal Masses

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Abstract **Original Research Article**

Aim: The purpose of our study is to evaluate the ability of MDCT to differentiate renal masses based on CT characteristics and location and differentiate benign from malignant masses. ***Results:*** The most common benign neoplasm was renal cortical cyst, Bosniak 1 category. Normal renal cortex showed greatest enhancement in the parenchymal phase.The most common malignant neoplasm was Clear cell RCC and most common infectious lesion was renal abscess. Statistical significance ($p<0.005$) amongst tumor groups were seen in age, tumor attenuation, tumor to kidney enhancement, mean absolute attenuation and de enhancement characteristics. Tumor to kidney enhancement ratios was indicative of how many times a tumor enhanced with respect to renal parenchyma and ranged from 0.0 for simple cystic lesions to 1.7 in malignant clear cell RCC. Statistical significance amongst tumor groups was seen between sex, lesion margins, calcification, lymphadenopathy, CT density and enhancement pattern. Presence of male gender, lymphadenopathy, a heterogeneous pattern of enhancement were factors in support of malignancy. A homogeneous pattern of enhancement, coarse calcification, regular tumor margins were consistent with benign etiology. The relative attenuation with adjacent renal cortex in vascular phase was maximum for clear cell RCC. Classical Angiomyolipoma were best diagnosed in the unenhanced phase with CT attenuation of <-10 HU, diagnostic of macroscopic fat. Lipid poor angiomyolipomas had unenhanced attenuation of >45 HU and a homogeneous parenchymal phase maximum enhancement.

Keywords: MDCT Assessment and Characterization Renal Masses.

INTRODUCTION

Renal masses are a heterogeneous group of tumors ranging from benign lesions to aggressive ones [i]. Renal cell carcinoma accounts for 80-85% of all kidney neoplasms and upto 3% of all adult carcinomas. Benign tumors contribute upto 15–20% of all solid renal tumors, renal oncocytoma being the commonest solid tumor type [ii].

Multiple renal lesions are found incidentally owing to increased use of abdominal imaging. A well planned diagnostic renal imaging protocol helps to avoid any unnecessary surgery. The most common renal lesion is a simple cyst. There are two benign renal tumors that mimic a RCC are oncocytoma and angiomyolipoma. The amount of fat in angiomyolipomas is variable and about 5% are fat poor AMLs.

MDCT has revolutionalized the ongoing CT imaging techniques, with excellent spatial resolution, acquisition of multiple slices simultaneously with increased speed. MDCT evaluates tumor size, location, and venous thrombosis, infiltration of adjacent organs, lymhadenopathy and metastasis.

Staging of RCC, with an accuracy of up to at least 90% is done on CT. Characterization of renal cysts diagnosed on ultrasound is done with ease. The kidneys can be imaged in all the three phases of contrast enhancement, i.e. the cortical phase, parenchymal phase and excretory phase. Reconstruction of raw data can be done at any level. Very minute features like septations, wall thickening and nodularity can be assessed.

OBJECTIVE OF THE STUDY

1. To evaluate the ability of MDCT to differentiate Renal masses based on CT characteristics and location
2. To differentiate between benign and malignant mass lesions based on MDCT characteristics.
3. To grade cystic renal masses using Bosniak classification system on MDCT.

MATERIAL AND METHODS

The study was conducted in Department of Radio diagnosis, Sri Aurobindo Medical College & Post Graduate institute, Indore. Patients referred to the department of Radio-diagnosis for MDCT abdomen for evaluation of suspicious renal mass were subjected to MDCT abdomen.

CT images were obtained with a Siemens 64 slice MDCT scanner (Somatom Definition AS), following a preset scanning protocol that included unenhanced, vascular phase (20–40 seconds), parenchymal phase(80–90 seconds) and excretory phases(180–300 seconds.

INCLUSION CRITERIA

1) Patients of both sexes of all age group clinically suspected to have renal mass lesion
2) Patients with diagnosis of renal mass on ultrasonography

EXCLUSION CRITERIA

1) Patients with renal trauma.
2) History of hypersensitivity to intravenous contrast agents.
3) Deranged renal functions.

Sample size

We have included 63 patients in our study (total lesions were 66, 2 and 3 lesions respectively in 2 patients). The following were the formulae used for calculation of enhancement characteristics.

Relative attenuation in vascular phase

(Tumor attenuation in vascular phase (VP) – cortex attenuation in vascular phase /cortex attenuation in vascular phase)*100%

Relative attenuation in parenchymal phase

(Tumor attenuation in parenchymal phase (PP) –cortex attenuation in parenchymal phase /cortex attenuation in parenchymal phase)*100%

Tumor- to-kidney enhancement ratio in vascular phase, VP (vascular phase)

[Tumor attenuation in vascular phase (VP) – tumor attenuation (Noncontrast)] / [kidney attenuation in vascular phase (VP) – kidney attenuation (Noncontrast)]

Tumor- to-kidney enhancement in parenchymal phase, PP (parenchymal phase)

[Tumor attenuation in parenchymal phase (PP) – tumor attenuation (Noncontrast)] / [kidney attenuation in parenchymal phase (PP) – kidney attenuation (Noncontrast)]

STATISTICAL ANALYSIS

The Statistical Analysis was done using SPSS Software. The quantitative variables were presented as means and standard deviation and compared using paired t-test. The qualitative variables were presented as frequencies and percentages and compared using chi-square test. The p value of < 0.05 was considered as significant.

RESULTS

The present study is a cross sectional study including 63 patients who had renal masses detected on MDCT.

- **NUMBER OF LESIONS**

The table below represents the mean age in benign and malignant lesions which was 46 for benign and 45 for malignant. Results were not statistically significant.

Lesion	N	Mean age
benign	43	46.47
malignant	23	45.30
Total	**32**	**11**
P VALUE	.23	

- **Enhancement pattern in benign and malignant lesions**

The table below represents the enhancement pattern of lesions. Maximum number of benign lesions were none enhancing (84%), 83% malignant lesions and 72% infections were heterogeneously enhancing. Results were statistically significant.

Enhancement pattern	benign	infection	Malignant
Heterogeneous	0	8	19
Homogeneous	7	0	4
non enhancing	25	3	0
Total	32	11	23
P VALUE	.000		

- **Tumor margin in benign and malignant lesions**

The table below represents that benign lesions had mostly regular margins (94%) and malignant lesions (65%) and infections were mostly irregular (72%). Results were statistically significant.

MARGINS	benign	infection	malignant
irregular	2	8	15
regular	30	3	8
Total	32	11	23
P VALUE	0.00		

- **Calcification in simple renal cyst (bosniak category 1)**

The table below represents the distribution of renal cysts according to Bosniak version 2019. Results were statistically significant.

TUMOR	1	2	2F	TOTAL
SIMPLE RENAL CORTICAL CYST	18	0	0	18
BOSNIAK 2	0	4	0	4
BOSNIAK II F	**0**	**0**	**1**	1
P value	.000			

- **Density in benign and malignant lesions**

The table below represents the CT density of lesions. Maximum number of benign lesions were hypodense (84%), 74% malignant lesions were either isodense or hyperdense.100% infections were hypodense. Results were statistically significant.

CT density	benign	infection	Malignant
Hyperdense	**5**	0	8
hypodense	**27**	11	6
isodense	0	0	9
Total	32	11	23
P VALUE	.000		

- **Lymphadenopathy**

The table below represents the presence of lymphadenopathy in renal masses. It was present in 9% in benign and 54 % infections and 56% malignant lesions Results were statistically significant.

lymphadenopathy	benign	infection	malignant
Absent	29	5	10
Present	3	6	13
Total	32	11	23
P VALUE	.000		

- **Normal cortex attenuation**

The below table represents the normal mean cortex attenuation in all phases. P value<0.05 is statistically significant. Anova T test was applied for quantitative variables. (NC-non contrast; VP-vascular phase; PP-parenchymal phase; EP-excretory phase).

Tumor	Unenhanced attenuation(HU)	VP attenuation (HU)	PP attenuation (HU)	EP Enhancement(HU)
Simple renal cortical cyst	37.67	147.94	187.89	**105.78**
Hemorrhagic cyst-bosniak 2	42.00	210.50	236.00	**125.50**
Angiomyolipoma	36.57	184.71	164.86	**108.00**
Clear cell RCC	35.43	154.71	171.29	**110.86**
Emphysematous pyelonephritis	34.50	94.00	177.00	**102.50**
Multicystic dysplastic kidney	14.00	45.00	42.00	**21.00**
Nephroblastoma	40.50	155.25	149.00	**95.50**
Papillary RCC	36.00	126.50	182.50	**104.50**
Putty kidney	44.00	134.00	153.00	**121.00**
Renal abscess	34.43	169.00	185.57	**98.14**
Renal hydatid cyst	21.00	149.00	212.00	**104.00**
Renal lymphoma	39.00	203.00	278.00	**134.00**
metastasis	33.00	104.00	150.00	**122.00**
TB kidney	36.00	90.00	84.00	**102.00**
Urinoma	27.00	202.00	236.00	**128.00**
Neuroblastoma	30.00	150.00	115.00	**63.00**
Bosniak 2 cyst (calcified)	32.00	177.50	212.00	**117.00**
P value	**.135**	**.327**	**.009**	**.022**

- **Tumor attenuation in different phases**

The below table represents the mean tumor attenuation in various groups in all phases. P value<0.05 is statistically significant. Anova T test was applied for quantitative variables.(NC-non contrast; VP-vascular phase; PP-parenchymal phase; EP-excretory phase).

Tumor	Unenhanced attenuation (HU)	VP attenuation (HU)	PP attenuation (HU)	EP Enhancement(HU)
Simple renal cortical cyst	10.17	13.67	16.17	**12.89**
Hemorrhagic cyst-bosniak 2	73.00	72.00	68.00	**70.00**
Angiomyolipoma	-39.57	10.43	34.14	**-9.00**
Clear cell RCC	39.43	215.86	106.36	**69.43**
Emphysematous pyelonephritis	19.50	25.00	39.00	**40.50**
Multicystic dysplastic kidney	12.00	15.00	14.00	**12.00**
Nephroblastoma	43.25	61.50	82.00	**66.50**
Papillary RCC	50.00	60.00	98.00	**58.50**
Putty kidney	100.00	103.00	95.00	**95.00**
Renal abscess	30.43	68.43	77.00	**39.43**
Renal hydatid cyst	12.00	20.00	25.00	**15.00**
Renal lymphoma	20.00	100.00	123.00	**113.00**
Metastasis	30.00	52.00	38.00	**34.00**
TB kidney	5.00	5.00	5.00	**13.00**
Urinoma	15.00	19.00	27.00	**20.00**
Neuroblastoma	40.00	70.00	96.00	**82.00**
Bosniak 2 cyst (calcified)	10.50	13.50	15.00	**10.50**
P value	.000	.000	.000	.000

- **Relative attenuation in vascular phase and parenchymal phase (%)**

The below table represents the relative tumor attenuation in various groups in vascular and parenchymal phase to assess which phase makes the tumor more conspicuous. P value<0.05 is statistically significant. Anova T test was applied for quantitative variables.

Tumor	VP	PP
Simple renal cortical cyst	-90.05%	**-91.06%**
Hemorrhagic cyst-bosniak 2	-63.52%	**-70.63%**
Angiomyolipoma	-98.75%	**-79.26%**
Clear cell RCC	**46.03%**	**-36.04%**
Emphysematous pyelonephritis	-71.54%	**-69.65%**
Multicystic dysplastic kidney	-66.66%	**-66.66%**
Nephroblastoma	-55.59%	**-39.43%**
Papillary RCC	-45.63%	**-45.61%**
Putty kidney	-23.13%	**-37.90%**
Renal abscess	-58.58%	**-57.25%**
Renal hydatid cyst	-86.57%	**-88.20%**
Renal lymphoma	-50.73%	**-55.75%**
metastasis	-50.00%	**-74.66%**
TB kidney	-94.44%	**-94.04%**
Urinoma	-90.59%	**-88.55%**
Neuroblastoma	-53.33%	**-16.52%**
Bosniak 2 cyst (calcified)	-92.41%	**-92.60%**
P value	.000	.000

- **Tumor to kidney enhancement ratio in vascular and parenchymal phases**

The below table represents the tumor to kidney enhancement ratio in various groups in vascular and parenchymal phase. P value<0.05 is statistically significant. Anova T test was applied for quantitative variables.

Tumor	VP	PP
Simple renal cortical cyst	**.03**	**.04**
Hemorrhagic cyst-bosniak 2	**-.0001**	**-.027**
Angiomyolipoma	**.44**	**.64**
Clear cell RCC	**1.59**	**.51**
Emphysematous pyelonephritis	**-.96**	**.32**
Multicystic dysplastic kidney	**.09**	**.07**
Nephroblastoma	**.23**	**.47**
Papillary RCC	**.12**	**.32**
Putty kidney	**.03**	**-.04**
Renal abscess	**.29**	**.31**
Renal hydatid cyst	**.06**	**.06**
Renal lymphoma	**.48**	**.43**
metastasis	**.30**	**.06**
TB kidney	**.00**	**.00**
Urinoma	**.02**	**.05**
Neuroblastoma	**.25**	**.65**
Bosniak 2 cyst (calcified)	**.02**	**.02**
P value	.000	.000

The mean patient age ± the standard deviation was 46 ± 17 years and 45 ± 26 years for benign and malignant lesions respectively. Birnbaum et al. [iii] in 1996 in their study found that malignant renal mass was predominantly seen in older age group.

The total number of males (56%) outnumbered females in our study with clear cell RCC (13/14 cases), papillary RCC and simple renal cortical cysts more common in males. Renal abscesses were commoner in females 95/7 lesions).The results were statistically significant.

Mean tumor size in our study for benign lesions was 4.4 cm and malignant lesions was 7.9 cm, correlating to the study by Frank I et al. [iv].The odds of having a malignant compared to a benign tumor increased significantly as tumor size increased in our study.

Malignant masses were ill-defined and benign masses were well defined in our study. 93.7% of benign lesions were regular while only 34.7% of malignant lesions were regular. Similar results were seen in studies by Cohan et al. [v] Birnbaum et al. [vi].

The malignant masses predominantly demonstrated heterogenous enhancement pattern (83%). While majority of benign lesions either was none enhancing (78%) or showed homogeneous pattern of enhancement (21%). Larger masses demonstrated a heterogeneous enhancement pattern. Similar results were seen in a study by Kim et al. [vii].

The mean attenuation value of benign masses in our study was 6.06 HU, 22.44 HU, 29.65 HU, 16. 55 HU in unenhanced, vascular, parenchymal and excretory phases. The mean attenuation value of malignant masses in our study was 39.78 HU, 156.95 HU, 98.69 HU, 68.86 HUin unenhanced, vascular, parenchymal and excretory phases.

The amount of tumor enhancement was greater in all RCCs .The degree of enhancement is the most important parameter for differentiation of subtypes of RCC, because clear cell RCCs enhance to a greater degree than other subtypes of malignant lesions according to study of Manal H et al. [viii].

All solid lesions were detected in all phases, renal parenchymal tumours in the arterial phase and angiomyolipomas in the unenhanced phase. These results corresponded to study by Dahlman P et al. [ix].

The mean attenuation of normal renal cortex in all the lesions non enhanced, vascular, parenchymal and excretory phases were 35.84, 154.8, 177, 105 respectively. These results correspond to the studies by Satish et al. [x], Cm Shetty et al. [xi].

The majority of lesions in our study were simple renal cortical cysts (27%) of Bosniak category 1, according to version 2019 of Bosniak classification, according to study of Silverman et al. [xii] No statistically significant differences in the cysts when the vascular and parenchymal phases were compared. Simple renal cysts with a mean attenuation value of less than 20 HU on unenhanced CT may have a mean attenuation greater than 20 HU on contrast enhanced CT due to pseudoenhancementaccording to study of Tappouni et al. [xiii].

Two cases of hemorrhagic cysts were seen as hyperdense solitary regularly marginated homogeneous, non-enhancing lesions with mean absolute attenuation of 70.7 HU. Jonisch AI, et al. [xiv] in 2007 concluded that a homogeneous renal mass measuring greater than 70 HU at unenhanced CT has a greater chance of representing a high-attenuation renal cyst rather than renal cell carcinoma.

Bosniak II calcified cysts diagnosed in our study were solitary ball lesions (Bosniak II category [xv]). The highest tumor density was 70 HU in vascular phase. The tumor to kidney enhancement in vascular and parenchymal phases was about 0.02 and 0.25 times respectively.

Emphysematous pyelonephritis on the basis of detection of air foci in and around the altered nephrogram and in the pelvicalyceal system indicated high sensitivity of MDCT in the diagnosis of the same. The lowest density seen in vascular phase was -848 HU, i.e. air attenuation. Tumor to kidney enhancement in vascular and parenchymal phases were -.96 and .32 times respectively.

Renal abscesses (evolving) superimposed on a background of pyelonephritis were seen in 5/7 patients and 2 were misdiagnosed as Bosniak IIF cyst and RCC. The lesions were complex cystic masses with heterogeneous, predominantly peripheral enhancement according to study of Browne RF et al. [xvi]. Average relative attenuation was –58% and -57% in vascular and parenchymal phases respectively. The tumor to kidney enhancement in vascular and parenchymal phases were about 0.29 and 0.31 times respectively.

In a case of renal tuberculosis, there was no enhancement seen in the affected renal parenchyma(tumor to kidney enhancement was 0.0 each in vascular and parenchymal phases).The collecting system demonstrated urothelial thickening with narrowing of infundibulum corresponding to studies by Kenney PJ et al. [xvii] and Hartman DS et al.[xviii].

There was one case of putty kidney with homogeneous ground glass like calcification with maximum attenuation of 294 HU. Our results were consistent with the study of Premkumar et al. [xix] who called calcification 'putty-like' if there was a uniform area of calcification > 1 cm in diameter. The very low tumor to kidney enhancement ratios in vascular and parenchymal phases signifies non functionality of the affected kidney.

The clear cell RCCs detected in our study had maximum attenuation in vascular phase. All cases showed significant heterogeneous contrast enhancement in vascular phase, washout in parenchymal phase, positive enhancement in vascular phase. The tumor to kidney enhancement ratios was high in both vascular and parenchymal phases [xx].

There were 2 papillary RCCs, which were diagnosed as hypoenhancing RCC on CT. They were hyperdense with homogeneous enhancement. The tumor grade in our study was T2B and T1 stages i.e low stage and low grade.We suggest the use of low tumor to kidney enhancement ratio of <0.25 as propounded by Herts BR et al. to diagnose papillary renal cell carcinoma from Clear cell RCC irrespective of size of lesion.

We diagnosed 5/7 Classic angiomyolipomas in our study as well defined small lesions with a negative CT attenuation (threshold of −10 HU [xxi]. with homogeneous enhancement in vascular and parenchymal phase with no evidence of calcification [xxii]. They were best conspicuous in non-enhanced phase (average -69 HU). Average relative attenuation was -110 % and –97 % in vascular and parenchymal phases respectively.

There were 2 cases of lipid poor angiomyolipoma <3 cm which appeared hyperattenuating [xxiii] on non-enhanced phase and showed homogenous enhancement, with maximum attenuation in the parenchymal phase [xxiv]. Fat-poor AML has a higher attenuation than clear cell RCC, seen in our 2 cases [xxv].

On imaging Nephroblastoma (wilm's tumor) were large heterogeneous lesions with moderate maximum enhancement in parenchymal phase. There was evidence of metastasis in only 1 out of 4 cases. The differential, neuroblastoma tends to be a mass crossing the midline, encasing and displacing vessels, while a tumor thrombus in the renal vein or inferior vena cava is highly predictive for Wilms' tumor, also seen in our case (75%) [xxvi].

CT findings in a case of Neuroblastoma revealed a large heterogeneous irregularly marginated heterogeneously enhancing tumor, encasing the renal artery and metastatizing to the lung and liver [xxvii]. One of the key defining features is the presence of calcification seen in 80-90% of CT studies, also seen in our study [xxviii].

Renal lymphoma was seen in 1 patient. They are hypoenhancing masses with homogeneous enhancement. Various studies reveal that at CT, these masses are hypoattenuating and enhance less intensely compared with the adjacent parenchyma.

There was one case of renal metastasis from gall bladder carcinoma. They were bilateral, small, multicentric hypodense lesions with heterogeneous enhancement. They showed low attenuation in all phases, indicating the relatively hypovascular nature.

We found one case of hydatid cyst as thick walled cystic unilateral lesion with calcification and minimal wall enhancement, Bosniak II F category [xxix]. Calcification of the cyst is not restricted to inactive stage, but occurs in all stages and in up to 50% of cysts [xxx].

A case of post traumatic perirenal collection was evaluated for the enhancement characteristics and revealed a thick walled subcapsular collection with predominant fluid attenuation and a maximum enhancement of 27 HU in parenchymal phase. The attenuation increased progressively after intravenous administration of contrast material because contrast-enhanced urine enters the urinoma [xxxi]. Urinoma can manifest as a renal abscess and our result were consistent with studies by Vaidya R et al. [xxxii].

A case of multicystic dysplastic kidney revealed low enhancement characteristics of renal cortex indicating poor functioning [xxxiii] and multiple variable sized bosniak category 1 cysts.

SUMMARY AND CONCLUSION

In our study, 63 patients underwent renal protocol CT scanning in unenhanced, vascular phase, parenchymal phase and excretory phases. 66 renal lesions were detected, 18 simple renal cortical cysts, 2 hemorrhagic cysts, 7 angiomyolipoma, 14 clear cell RCC, 2 cases of emphysematous pyelonephritis, 1 multicystic dysplastic kidney, 4 nephroblastoma, 2 papillary RCCs, 1 Putty kidney, 7 renal abscesses, 1 renal hydatid cyst, 1 renal lymphoma, 1 renal metastasis, 1 TB kidney,1 case of post traumatic urinoma, 1 neuroblastoma, 1 calcified bosniak cyst. The following conclusions were drawn.

The most common benign neoplasm was Renal cortical cyst, Bosniak 1 category (56% of benign lesions). The most common malignant neoplasm was Clear cell RCC. (61% of total malignant lesions).

The most common infectious lesion was renal abscess (64%). Renal cortex showed greatest enhancement in the parenchymal phase compared with that in vascular phase. ($p<0.001$).Statistical significance ($p<0.005$)amongst tumor groups were seen in age, tumor attenuation in all phases, tumor to kidney enhancement in vascular and parenchymal phases, mean absolute attenuation and de enhancement characteristics.

There was no statistical age difference when comparing benign and malignant lesions in our study. Tumor attenuation varied amongst groups in different phases, with malignant tumors showing >20 HU cut off enhancement.

Tumor to kidney enhancement ratios were indicative of how many times a tumor enhanced with respect to renal parenchyma and ranged from 0.0 for simple cystic lesions to 1.7 in malignant clear cell RCC.

The enhancement characteristics followed a variable course when malignant lesions were considered and were more consistent amongst benign noninfectious lesions.

Statistical significance ($p<0.005$) amongst tumor groups were seen between sex, lesion margins, calcification, lymphadenopathy, CT density,

enhancement pattern, and distribution of ball and bean lesions. When comparing benign and malignant lesions, presence of male gender, lymphadenopathy, a heterogeneous pattern of enhancement were factors in support of malignancy. A homogeneous pattern of enhancement, coarse calcification, regular tumor margins were consistent with benign etiology.

The relative attenuation with adjacent renal cortex in vascular phase was maximum for clear cell RCC (+46%). The relative attenuation of tumor with adjacent renal cortex in parenchymal phase was maximum for a case of putty kidney and neuroblastoma and clear cell RCC.

Mean absolute attenuation was maximum for clear cell RCC. Clear cell RCC showed maximum tumor attenuation in vascular phase, positive vascular phase relative attenuation and early de enhancement in parenchymal phase.

Papillary RCC showed maximum attenuation in parenchymal phase and a tumor to kidney attenuation of <0.25 in vascular phase. The hypovascular and homogeneous nature was hence established.

Classical Angiomyolipoma were best diagnosed in the unenhanced phase with CT attenuation of <-10 HU, diagnostic of macroscopic fat.

Lipid poor angiomyolipomas had unenhanced attenuation of >45 HU and a homogeneous parenchymal phase maximum enhancement (in contrast to clear cell RCC).

Based on our study we can invariably say that Multidetector CT is the most important imaging technique for diagnosis and prognostication of suspected renal masses. MDCT efficiently evaluates tumor size, shape, location and metastasis to characterize a lesion as benign or malignant. This helps the clinician to better form a management plan and rule in or rule out surgical intervention.

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