Clinico-radio-pathologic features of a solitary solid renal mass at MDCT examination

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Background: Incidental detection of solid renal masses has been increasing since the multi-detector computed tomography (MDCT) scanner was introduced.

Purpose: To evaluate the clinico-radio-pathologic features of a solitary solid renal mass at MDCT examination.

Material and Methods: A total of 466 non-fatty solid renal masses in 466 patients undergoing nephrectomy were evaluated by MDCT examination. MDCT was performed before and after intravenous injection of contrast material. We obtained the incidences of benign tumors versus malignant tumors, renal cell carcinoma (RCC) versus non-RCC, and asymptomatic RCCs versus symptomatic RCCs. MDCT accuracy for detection of RCC was obtained with a threshold of more than 20 HU tumor attenuation difference between unenhanced and contrast-enhanced CT images. Nuclear grade was also compared between small RCCs (≤4 cm) and large RCCs (>4 cm).

Results: Of 466 tumors, 443 (95%) were malignant and 23 (5%) were benign. Of 443 malignant tumors, 437 (99%) were RCC and 6 (1%) were non-RCC. Of 437 RCCs, 324 (74%) were asymptomatic and 113 (26%) were symptomatic. Asymptomatic RCCs (n=183, 56%) were more frequently pT1a than symptomatic RCCs (n=28, 25%) (P<0.05). MDCT accuracy for detection of RCC was 94% (437/466). Of 220 RCCs ≤4 cm, low grade RCC (53%) was more common than high grade RCC (47%).

Conclusion: Most solitary solid renal masses are early stage RCCs and can be diagnosed preoperatively at MDCT examination.

Key words: Kidney; neoplasm; renal cell carcinoma; computed tomography; multidetector rows

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Early detection of renal cell carcinoma (RCC) ≤4 cm is of great importance since patients with this small RCC at stage pT1a demonstrate 5-year cancer-specific survival in excess of 95% (1, 2). Detection of small renal masses has been increasing as new imaging modalities are widely used (3). Incidental solid renal masses in patients without a history of malignancy pose a dilemma for urologists as well as radiologists, even though most of them are RCCs, because small solid renal masses (≤3 cm) are more likely to be benign than larger ones (4). For this reason, it is important to determine whether or not percutaneous biopsy should be performed when a small solitary solid renal mass is detected.

CT is most commonly used to determine whether or not renal masses are malignant. Recent advances in CT technology have led to the development of the multidetector CT (MDCT) scanner, which is now widely used for routine CT examinations. MDCT has several advantages over single-detector CT (SDCT) in acquiring more slices or sections simultaneously and increasing the speed of CT image acquisition. Besides, three-dimensional images of MDCT have better image quality due to isotropic data acquisition (5). Thanks to the development of MDCT, it could be hypothesized that more incidental renal masses could be detected, that accuracy for identification of RCC could be higher, and subsequently that pathologic results could be changed. Previous studies reported these clinico-radio-pathological features using SDCT, but not MDCT (3, 5, 6).
The purpose of our study was to evaluate the clinical-radio-pathologic features of a solitary solid renal mass detected at MDCT examination.

**Material and Methods**

Our institutional review board approved this retrospective study and waived the requirement for informed consent from patients.

**Patients**

From October 2002 to November 2007, 755 patients (510 men, 245 women; age range, 20–81 years; mean age, 54 years) with 776 renal masses were drawn from a database of patients who were referred for radical (n = 572) or partial (n = 183) nephrectomy. We excluded 310 renal tumors in 289 patients: 172 patients with hard copies of CT scans alone, 53 patients with cystic renal masses, 23 patients with contrast-enhanced CT images alone, 14 patients with two or more renal tumors, 13 patients who underwent electron beam CT, 9 patients with fatty renal masses on unenhanced CT scan, and 5 patients with MR images alone (Fig. 1). We included only non-fatty solitary solid renal tumors without evidence of metastasis and found 466 renal masses in 466 patients (328 men, 138 women; age range, 26–86 years; mean age, 54 years) who had undergone radical nephrectomy (351 patients) or partial nephrectomy (115 patients).

The medical records of these patients were reviewed to compare: (a) patient age, sex ratio, and size and incidence of asymptomatic and symptomatic renal masses; (b) pT stage of asymptomatic and symptomatic RCC; and (c) clinical manifestations in patients with symptomatic masses.

**CT analysis**

All patients underwent CT examinations using one of five MDCT scanners (Lightspeed QX/I, LightSpeed Ultra 8, LightSpeed Ultra 16; GE Healthcare, Milwaukee, Wisc., USA; Brilliance 40; Philips Medical Systems, Cleveland, Ohio, USA; Aquilion 64; Toshiba, Tokyo, Japan). The 4-, 8-, 16-, 40-, and 64-detector CT scanners examined 92, 48, 232, 63, and 31 patients, respectively. MDCT scans were performed to evaluate asymptomatic patients with renal masses detected on CT and ultrasound (US) examinations performed for unrelated reasons and in patients with symptoms or signs including flank pain, hematuria, palpable mass, and weight loss.

About 30 min before the CT scanning, all the patients were instructed to drink 700–1000 ml of water. The scanning parameters of 4-, 8-, and 16-detector CT scanners were 120 kVp, 200 mAs, 0.625–2.5 mm collimation, and 7.5–17.5 mm/s (a pitch of 0.75–1.35), and those of 40- and 64-detector CT scanners were 120 kVp, 200 effective mAs, 0.5–0.625 mm collimation, and 23.2–26.5 mm/s (a pitch of 0.828–0.926). These CT scans consisted of unenhanced and single-phase contrast-enhanced CT images (n = 41) obtained at 60 s or two-phase contrast-enhanced CT images (n = 425) that were obtained at 40 and 180 s after a total of 120 ml non-ionic contrast material was intravenously injected at a rate of 2–3 ml/s using an automatically controlled power injector.

Preoperative diagnosis of RCC was made both if a mass had no fatty tissue identified on unenhanced CT, and if the lesion increased in attenuation value by 20 HU or more on contrast-enhanced CT images. Interpretation of MDCT images was done in consensus by two radiologists who had more than 8 years experience.

![Flow diagram showing process of selecting the study sample.](image-url)
in abdominal imaging. They were not aware of clinical or pathological information at image interpretation. The region of interest was placed within the solid area of an RCC but was not placed in calcification, vessels or cystic or necrotic areas. In cases with two contrast-enhanced CT scans, the higher attenuation value of the renal mass was used to obtain the attenuation difference of the lesion before and after contrast material enhancement. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for detection of RCC with preoperative CT scan were evaluated. MDCT accuracies for RCC were classified into four groups: diagnostic accuracy: sensitivity, specificity, positive and negative predictive value, and accuracy. Pathologic results were used for a standard reference of MDCT accuracy for determination of RCC.

Pathologic analysis
Pathologic reports of all patients undergoing radical or partial nephrectomy were reviewed to evaluate the incidence of benign and malignant tumors according to tumor size, incidence of RCC and non-RCC malignant masses, incidence of histologic RCC subtypes, and nuclear grades of RCC. RCC stages were based on the latest revision of the American Joint Committee on Cancer (AJCC) cancer staging manual (7). The nuclear grade for all histologic subtypes was assessed according to standardized criteria, in which grade 1 and 2 were defined as low grade and grade 3 and 4 were defined as high grade (8).

Statistical analysis
Unpaired t tests were used to compare patient ages and sizes of asymptomatic and symptomatic masses and attenuation values of benign and malignant masses. Fisher’s exact test was used to compare the sex ratio and nephrectomy types of asymptomatic and symptomatic renal masses and pT stages of asymptomatic and symptomatic RCCs. The incidence of benign and malignant tumors according to size, and the incidence of RCC ≤4 cm and RCC >4 cm according to nuclear grade were also compared.

A P value of <0.05 was considered statistically significant. Statistical analyses were performed using commercially available software (SAS for Windows, version 9, 2005, SAS Institute, Cary, NC, USA).

Results
Clinical manifestations
Among 466 renal masses detected, 347 (74%) were asymptomatic and 119 (26%) were symptomatic (Table 1). Asymptomatic masses ranged from 0.7 to 18.5 cm in size (mean 4.4±3.0 cm, median 3.5 cm) and symptomatic masses ranged from 0.9 to 19.5 cm in size (mean 6.5±3.6 cm, median 6.0 cm). The mean size of the asymptomatic masses was significantly different from that of the symptomatic masses (P<0.05). Partial nephrectomy was more commonly performed in patients with asymptomatic masses, whereas radical nephrectomy was more commonly done in patients with symptomatic masses (P<0.05). There were no significant differences between asymptomatic and symptomatic masses regarding age, sex ratio, and malignancy status (P>0.05).

Patients with asymptomatic masses had 183 (56%) RCCs in the pT1a stage, whereas those with symptomatic masses had 28 (25%) RCCs in the pT1a stage (P<0.05) (Table 2). Stage pT3a and pT3b lesions were more common in symptomatic RCCs than in asymptomatic RCCs (P<0.05). There were no significant differences between asymptomatic and symptomatic masses regarding the other pT stages. Patients with symptomatic masses had one or more of the following clinical manifestations: hematuria (n=67), flank pain (n=51), palpable masses (n=5), and weight loss (n=1). There was no patient with symptomatic masses who had all the features of hematuria, flank pain, and palpable masses.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Asymptomatic (n=347)</th>
<th>Symptomatic (n=119)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>54</td>
<td>56</td>
<td>0.075</td>
</tr>
<tr>
<td>Sex ratio (M:F)</td>
<td>245:102</td>
<td>83:36</td>
<td>0.908</td>
</tr>
<tr>
<td>Mean mass size (cm)</td>
<td>4.4±3.0</td>
<td>6.5±3.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Partial nephrectomy</td>
<td>28.8% (n=100)</td>
<td>12.6% (n=15)</td>
<td>0.000</td>
</tr>
<tr>
<td>Radical nephrectomy</td>
<td>72.2% (n=247)</td>
<td>87.4% (n=104)</td>
<td>0.000</td>
</tr>
<tr>
<td>Benign tumor</td>
<td>6.0% (n=21)</td>
<td>2.0% (n=2)</td>
<td>0.083</td>
</tr>
<tr>
<td>Malignant tumor</td>
<td>94.0% (n=326)</td>
<td>98.0% (n=117)</td>
<td>0.083</td>
</tr>
</tbody>
</table>

Table 2. Pathologic tumor (pT) stages of asymptomatic and symptomatic RCC.

<table>
<thead>
<tr>
<th>pT stage</th>
<th>Asymptomatic (n=324)</th>
<th>Symptomatic (n=113)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pT1a</td>
<td>183</td>
<td>28</td>
<td>0.000</td>
</tr>
<tr>
<td>pT1b</td>
<td>74</td>
<td>32</td>
<td>0.253</td>
</tr>
<tr>
<td>pT2</td>
<td>32</td>
<td>12</td>
<td>0.979</td>
</tr>
<tr>
<td>pT3a</td>
<td>22</td>
<td>25</td>
<td>0.000</td>
</tr>
<tr>
<td>pT3b</td>
<td>12</td>
<td>14</td>
<td>0.002</td>
</tr>
<tr>
<td>pT3c</td>
<td>0</td>
<td>0</td>
<td>NP</td>
</tr>
<tr>
<td>pT4</td>
<td>1</td>
<td>2</td>
<td>0.165</td>
</tr>
</tbody>
</table>

NP, not performed.
CT accuracy
The attenuation values of pathologically proven benign masses \((n=23)\) ranged from 20 to 54 HU \((38\pm10\text{ HU},\ \text{median } 38\text{ HU})\) on unenhanced CT images and from 67 to 212 HU \((130\pm40\text{ HU},\ \text{median } 125\text{ HU})\) on contrast-enhanced CT images \((\text{Fig. } 2)\). The attenuation differences between unenhanced and contrast-enhanced CT images ranged from 42 to 181 HU \((85\pm43\text{ HU},\ \text{median } 85\text{ HU})\).

The attenuation values of pathologically proven malignant masses \((n=443)\) ranged from 1 to 70 HU \((34\pm10\text{ HU},\ \text{median } 35\text{ HU})\) on unenhanced CT images and from 36 to 287 HU \((119\pm42\text{ HU},\ \text{median } 110\text{ HU})\) on contrast-enhanced CT images \((\text{Fig. } 2)\). The attenuation differences between unenhanced and contrast-enhanced CT images ranged from 22 to 252 HU \((92\pm42\text{ HU},\ \text{median } 76\text{ HU})\). There were no significant differences in attenuation values between benign and malignant masses on unenhanced or contrast-enhanced CT images \((P>0.05)\). For benign and malignant masses, attenuation differences between unenhanced and contrast-enhanced CT images were not significantly different either \((P>0.05)\).

The accuracy of the preoperative MDCT scan for RCC was 94% \((437/466)\). Sensitivity, specificity, and positive predictive value were 100% \((437/437)\), 0% \((0/29)\), and 94% \((437/466)\), respectively. Of 466 masses, 89 were \(\leq 2\text{ cm}\), 149 were \(>2\text{ cm}\) and \(\leq 4\text{ cm}\), and 228 were \(>4\text{ cm}\) in size: according to the tumor sizes, the MDCT accuracies were 88%, 95%, and 95%, respectively. It was impossible to obtain negative predictive values because the attenuation differences of all solid masses were calculated as 20 HU or more.

Pathological results
Among the 466 masses, 443 \((95\%)\) and 23 \((5\%)\) were confirmed to be malignant and benign tumors, respectively. As lesion size decreased, the possibility of a mass being a benign tumor increased \((\text{Table } 3)\). Benign tumors accounted for 29% of all masses \(\leq 1\text{ cm}\) in size. The diagnosis of a benign tumor was significantly more likely among renal masses \(\leq 3\text{ cm}\) than among the larger masses \((P<0.05)\). The benign tumors made up 9% \((15/174)\) of the masses \(\leq 3\text{ cm}\) and 3% \((8/292)\) of the masses \(>3\text{ cm}\). Pathologic diagnosis of benign solid tumors \((n=23)\) included angiomyolipoma \((n=15)\), oncocytoma \((n=6)\), leiomyoma \((n=1)\), and metanephric adenoma \((n=1)\).

Of the 443 malignant tumors, 437 were RCCs \((99\%)\) and 6 were non-RCCs \((1\%)\). Pathologic diagnoses of non-RCC malignant tumors included metastasis \((n=4)\), sarcoma \((n=1)\), and lymphoma \((n=1)\). The subtypes of RCCs were clear cell \((n=375, 85.6\%)\), papillary \((n=24, 5.5\%)\), chromophobe \((n=28, 6.4\%)\), collecting duct \((n=2, 0.5\%)\), and unclassified \((n=8, 2.0\%)\). Of 220 RCCs \(\leq 4\text{ cm}\), 116 \((53\%)\) were low grade \((\text{grade } 1\text{ and } 2)\) and 104 \((47\%)\) were high grade \((\text{grade } 3\text{ and } 4)\), whereas of 217 RCCs \(>4\text{ cm}\), 69 \((32\%)\) were low grade and 148 \((68\%)\) were high grade. Low grade tumors were more common in RCCs \(\leq 4\text{ cm}\) than in RCCs \(>4\text{ cm}\) \((P<0.05)\).

Discussion
Asymptomatic masses detected on MDCT accounted for 73% of all solitary solid renal masses. The proportion of asymptomatic RCCs was higher than those in previous studies reporting that the percentage of asymptomatic renal masses increased up to 61% using US and SDCT \((3, 9, 10)\). The mean size \((4.4\text{ cm})\) of these lesions was smaller than those \((5.7\text{ cm})\) reported previously \((3, 9)\). The proportion \((56\%)\) of pT1a RCC in asymptomatic patients was also higher than that \((36\%)\) of a previous study \((3)\). RCCs \(\leq 4\text{ cm}\) were more commonly low grade than RCCs \(>4\text{ cm}\) \((6)\). Therefore, MDCT is likely to identify asymptomatic, low nuclear grade, and low pT stage RCCs and subsequently lead to better prognoses for patients \((3, 9)\). The proportion of pT1 staged tumors among all RCCs in our study was

Table 3. Incidence of benign and malignant tumors according to lesion size.

<table>
<thead>
<tr>
<th>Mass size (cm)</th>
<th>No. of masses</th>
<th>Benign tumors</th>
<th>Malignant tumors</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0 &lt; \text{mass} \leq 1\text{ cm})</td>
<td>7</td>
<td>29% ((n=2))</td>
<td>71% ((n=5))</td>
</tr>
<tr>
<td>(1 &lt; \text{mass} \leq 2\text{ cm})</td>
<td>82</td>
<td>11% ((n=9))</td>
<td>89% ((n=73))</td>
</tr>
<tr>
<td>(2 &lt; \text{mass} \leq 3\text{ cm})</td>
<td>85</td>
<td>5% ((n=4))</td>
<td>95% ((n=81))</td>
</tr>
<tr>
<td>(3 &lt; \text{mass} \leq 4\text{ cm})</td>
<td>64</td>
<td>2% ((n=1))</td>
<td>98% ((n=63))</td>
</tr>
<tr>
<td>(\text{Mass} &gt; 4\text{ cm})</td>
<td>228</td>
<td>3% ((n=7))</td>
<td>97% ((n=221))</td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate the number of renal masses.
73%, which was higher than those (36–46%) in previously reported studies (3, 11). Our study also showed that partial nephrectomy had been more commonly performed in patients with asymptomatic tumors. However, this finding is not surprising, because exophytic, smaller masses are much more suitable for partial nephrectomy. Those small masses were mostly diagnosed incidentally and expected to be asymptomatic.

Traditionally, an increase in attenuation by 10 HU has been accepted as a guide to indicate unequivocal renal lesion enhancement (12). This threshold level should be higher when evaluating small renal tumors because small renal cysts are likely to show pseudo-enhancement of 20 HU or less on MDCT images (13, 14). For this reason, 20 HU was considered the cut-off value for renal lesion enhancement and no benign renal cysts were identified as pathological in our study. In addition, an attenuation difference of more than 20 HU between unenhanced and contrast-enhanced CT images indicates unequivocal enhancement within the renal mass and that of 10–20 HU is regarded as equivocal enhancement (15).

With the exception of the four-row detector scanner, MDCT can reconstruct isotropic sagittal and coronal images as well as axial images, enabling excellent spatial resolution in evaluating preoperative CT images. Overall MDCT accuracy (94%) for RCCs was higher compared with that of a previous study, ranging from 60 to 66% (16). For these reasons, the proportion (5%) of benign renal tumors detected in our study was low compared with a previous study, which found 13% (6). A benign diagnosis was significantly more likely among renal masses ≤3 cm than among larger masses (P<0.05). Therefore, preoperative percutaneous renal mass biopsy should be performed in selected cases with imaging features including hyperdense solid mass on unenhanced CT, gradually enhancing renal mass, and renal masses with central scar, suggesting angiomylipoma or oncocytoma (17). Recently, however, Blumenfeld et al. reported that percutaneous biopsy of renal masses may help to identify patients who are candidates for observation only, because a biopsy has a possibility of underestimating the nuclear grade (18).

MDCT can also improve the accuracy of preoperative T NM staging for RCC and subsequently help to inform treatment plan decisions (19, 20). The number of papillary RCCs detected in our study was smaller than that of chromophobe RCCs, although the former is known to be the second most common RCC subtype (6, 11). Our study included only single renal masses and excluded sporadic or hereditary multifocal RCCs. These inclusion criteria may affect the incidence of papillary RCC, which tends to be multifocal (11).

In our study, angiomylipoma was the most common false-positive lesion for RCC on MDCT images and oncocytoma was the next, whereas Frank et al. reported that the most common benign tumors were oncocytoma and angiomylipoma, in decreasing order (6). However, in their study no comment was made regarding how to pathologically assess the removed renal masses. Immunohistochemical staining may help to differentiate oncocytoma from chromophobe RCC in addition to hematoxylin and eosin staining and may shift a substantial number of previously diagnosed oncocytomas to RCC (17).

A recent study reported that almost all small oncocytomas have segmental enhancement inversion on biphasic contrast-enhanced MDCT. This imaging feature was so characteristic as to be helpful to differentiate small oncocytomas from small RCCs (21). The preoperative diagnosis of angiomylipoma with minimal fat was the most problematic using MDCT images. Homogeneous and prolonged enhancement is a characteristic CT finding for this tumor but is also frequently present in papillary RCCs (22). Pixel distribution analysis of unenhanced MDCT images is not useful in differentiating angiomylipoma with minimal fat from RCC for the detection of fatty tissue (23).

MDCT may expose the patient to a higher radiation dose than traditional modalities; this is a negative trade-off to improved image resolution (5). The parameters affecting radiation dose vary according to CT scanner design and these variations may determine radiation dose increase according to voxel size. The detector configuration and beam collimation used for a particular acquisition also affect the voxel size and the relationship between spatial resolution and radiation dose. Therefore, image quality and radiation dose should be weighed according to the as low as reasonably achievable principle.

Our study has some limitations. First, a relatively large number of cases were excluded for various reasons. The possibility of selection bias cannot be completely excluded and might thus affect the results of our study. Further investigations are required in a prospective design to support our results. Second, a substantial number of renal masses in our study population were detected first on US examination. In general, US is inferior to CT regarding the detection and characterization of renal masses due to frequent false-positive or -negative lesions. From this point of view, US is not an optimal imaging modality for evaluating incidental solid renal masses. Therefore, solitary solid renal masses should be evaluated by CT or MR for characterization.

The accuracy of MDCT is increased because it provides a better image quality than that of single-detector
CT. We believe that setting a threshold to 20 HU may reduce not only a false-positive rate of RCCs but also the number of cases that are pathologically proven to be benign following nephrectomy. Optimal MDCT protocols are not established at present, but at least two MDCT scans (unenhanced CT scan and contrast-enhanced CT scan performed 1 min after intravenous injection) are necessary to discriminate between benign and malignant tumors. Two-phase MDCT is also useful for evaluating renal masses but may deliver a higher radiation dose to patients.

In conclusion, a non-fatty solitary solid renal mass is most frequently RCC. MDCT accuracy for detection of RCC is so high that most RCCs can be diagnosed preoperatively. These RCCs tend to be asymptomatic, early stage, and low grade. Therefore, the use of MDCT might decrease the number of unnecessary biopsies and surgical procedures.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References