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Subcapsular beaded appearance of the kidney on contrast-enhanced CT: indicative of dilated subcapsular lymphatics?

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AIM: To assess the renal subcapsular beaded appearance (RSBA) seen on contrast-enhanced multidetector-row computed tomography (CT).

MATERIALS AND METHODS: In total, 2,020 consecutive MDCT examinations with both non-contrast-enhanced and contrast-enhanced procedures were assessed retrospectively to identify interconnecting lobular structures in the renal subcapsular area that created a beaded appearance on contrast-enhanced CT. Positive cases were investigated for CT attenuation on unenhanced CT and were then compared with fat-suppressed heavily T2-weighted magnetic resonance imaging (MRI) and follow-up CT if available. The degree of RSBA occupying the renal periphery was evaluated using a three-grade system (Grade I: <25%, Grade II: 25–75%, Grade III: >75% of surface involvement). Only Grades II and III were defined as a positive RSBA. Possible associated findings such as hypertension, chronic kidney disease (CKD), renal atrophy, and liver cirrhosis were also evaluated.

RESULTS: The RSBA was positive in 33 (1.63%) of patients and was more commonly found in patients in their seventies (39.4%) with male predominance (male:female ratio, 7:3; p=0.005). Of 33 positive cases, five showed low CT attenuation predominance, 25 showed iso-attenuation, and three showed high attenuation on unenhanced CT. In five positive cases, T2-weighted MRI showed markedly high signal intensity, suggesting prominent capsular lymphatic structures. The RSBA was associated with hypertension (p=0.001) and CKD (p=0.011).

CONCLUSION: The MRI findings suggested that the RSBA probably reflects dilated subcapsular lymphatics. Knowledge of this CT finding is clinically important because it might be misinterpreted as other pathological findings.

Introduction

Various pathological conditions and pseudolesions can occur at the periphery of the kidney. These abnormal tissues can be perinephric or subcapsular in origin and are not always distinguishable.[1,2] The aetiology of such abnormal findings seen on radiological images varies and may include solid tumours, fluid collections, and inflammatory or proliferative syndromes.[1–4] These conditions can sometimes cause systemic problems such as hypertension and renal dysfunction, which may affect mortality.[5,6]

Benign conditions, such as lymphangiomatosis, fibrosis, or haematomas, can be found without a clear clinical history or symptoms, eliminating the need for biopsy or other invasive procedures. Thus, the diagnosis depends on the radiological

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appearance. A common imaging appearance of these pathologies is characterised by a homogeneous interconnecting lobular structure in the perinephric area, creating a beaded or rind-like appearance to the renal cortex.[1–5] Although commonly seen, this appearance has not been well described.

A subcapsular band-like structure with an irregular contour resulting in a beaded appearance on contrast-enhanced computed tomography (CT) is encountered frequently. Although this CT finding is suggestive of perirenal lymphatic system enlargement, no evidence has been obtained.[6–9] To the authors' knowledge, no consecutive analysis of the renal subcapsular beaded appearance (RSBA) has been performed. The purpose of the present study was to evaluate the prevalence of the RSBA and identify any associated findings.

Materials and methods

Patient selection

The present retrospective study was approved by two institutional review boards, and the requirement for informed consent was waived. This study used secondary data from 2,120 consecutive patients who underwent abdominal multidetector-row CT (MDCT) from January 2013 to September 2018. These patients had undergone CT examinations for various clinical indications. Clinical and historical records were evaluated with follow-up scans to exclude malignancy. All examinations were performed with intravenous contrast medium. Ninety-five patients were excluded due to artefacts and poor-quality images, and five patients were excluded due to renal carcinoma and hydronephrosis. The status of the perinephric and subcapsular area was assessed retrospectively in a final total of 2,020 patients (983 male and 1,037 female patients; mean age, 65 years; age range, 13–94 years; Fig 1).

Additional data were collected regarding clinical history, age, sex, hypertension, renal atrophy, renal function, and the presence of liver cirrhosis. Hypertension was defined as blood pressure of $\geq$130/80 mmHg.[10] Possible associated findings, such as liver cirrhosis and renal atrophy, were diagnosed based on multidetector-row CT findings.[11] Chronic kidney disease was defined as an estimated glomerular filtration rate of $<$60 ml/min/1.73 m^2.[12]

Imaging technique

Images were acquired using a 64- or 320-section multidetector-row CT system (Aquilion; Toshiba Medical Systems, Tochigi, Japan) at 120 KVp, 200–400 mAs, rotation time of 0.5 seconds, and pitch of 0.98 (32 detectors) or 0.84 (320 detectors). All examinations were performed with and without 100 ml contrast material (Omnipaque 300; Daiichi Sankyo, Tokyo, Japan or Iopamiron 370; Bayer, Berlin, Germany). All images were retrieved using a picture archiving and communication system (SYNAPSE 3.0 MR-001; Fujifilm, Tokyo, Japan) and were evaluated in multiplanar post-processing with 1-mm interval reconstructions.

Imaging analysis

An RSBA was defined as the presence of multiple lobulate structures interconnecting in the subcapsular or perinephric region and adhering to some or all of the renal surface on contrast-enhanced CT. This appearance has no definite mass or enhancement within the lesions. The area of the renal surface involved by the RSBA was qualitatively estimated and categorised by percentage into Grade I ($<$25% involvement of the renal border), Grade II (25–75%),

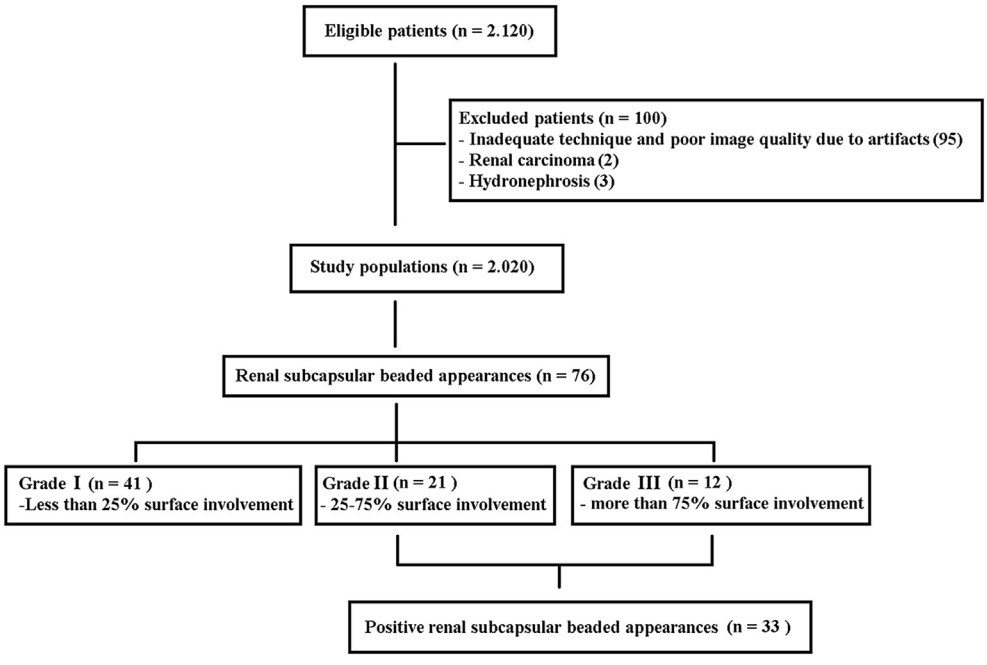

Figure 1 Patient flow chart.

and Grade III (>75%; Fig 2). This estimation was made using CT axial sections with most lesions visualised in 1-mm thickness in either the corticomedullary or nephrogenic phase (whichever most effectively facilitated visualisation of the finding). Grades II and III were considered a positive RSBA. If the RSBA was recognised in both kidneys (bilateral lesions), the higher grade was chosen to represent the patient's condition. This grading system was evaluated in a blinded manner by two abdominal radiologists with 32 and 8 years of experience, respectively. The thickness and CT attenuation of all lesions were measured. Abdominal default window settings with width of 300 HU and level of 30 HU was used for the classification of low, iso- and high attenuation based on the reader interpretation. Associated findings, such as liver cirrhosis and renal atrophy, were also evaluated. All lesions were compared if any follow-up CT imaging or magnetic resonance imaging (MRI) data were available.

Follow-up CT or MRI

Follow-up CT was performed using the same equipment and parameters as the initial study. MRI was performed using an Ingenia 3 T system (Philips Medical Systems, Best, Netherlands) to create standard T1-weighted images (500 ms repetition time [TR], 9.5 ms echo time [TE]), T2-weighted images (4000 ms TR, 95–250 ms TE), and fat-suppressed three-dimensional fast spin-echo heavy T2-weighted images using volume isotropic turbo spin-echo acquisition (987 ms TR, 236 ms TE, 32×32 cm field of view, 268×278 matrix, interpolated to 560×560< 1.2 mm section thickness, and flip angle of 90° with refocusing flip angle of 70°).

Data analysis

All statistical analyses were performed using commercial software (SPSS version 22; IBM, Armonk, NY, USA). The interobserver agreement for the grading of the appearances between the two investigators was evaluated using the weighted kappa statistic, with k values of 0.00–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.00 taken to indicate slight, fair, moderate, substantial, and almost perfect agreement, respectively. Associations between a positive RSBA and hypertension, diabetes, renal atrophy, liver cirrhosis, and renal function were analysed using the independent *t*-test for numerical variables and the chi-square test for categorical variables. A *p*-value of <0.05 was taken to indicate statistical significance.

Results

Patients' demographic and imaging findings

Among all 2,020 patients, renal surface involvement was recognised in 76 (3.76%) patients (Grade I in 52.6% of patients, Grade II in 28.9%, and Grade III in 18.4%). Linear weighted kappa statistics demonstrated near-perfect agreement between the two readers ($p<0.001$, k=0.86). Only Grades II and III (n=33, 1.63%) were considered to indicate a positive RSBA. The mean age of the patients was 74 years (range, 50–88 years; $p=0.006$). From all the positive cases, 22 were found on the nephrogenic phase, while 11 detected on the corticomedullary phase. Occurrence of the RSBA in the seventh decade of life was most frequent (39.4%), followed by the sixth decade of life (27.3%). Significant male predominance was noted ($p=0.005$) with a male:female ratio of 7:3. The RSBA was bilateral in 78% of patients, and the right side was slightly more commonly affected (55.6%) among the unilateral cases. Chronic kidney disease was found in 63.6% of patients, and hypertension was found in 69.7% of patients. There was a significance difference in incidence of hypertension ($p=0.001$) and chronic kidney disease ($p=0.011$) between patients with and without the RSBA (Table 1).

The mean maximum thickness of the RSBA was 3.8 mm (range, 1.9–13.2 mm). The RSBA showed predominantly low attenuation in five (15.1%) patients (mean, 6.3 HU; range, 1.5–14.7 HU), iso-attenuation in 25 (75.8%) patients (mean, 33.2 HU; range, 15.1–38.5 HU), and high attenuation in

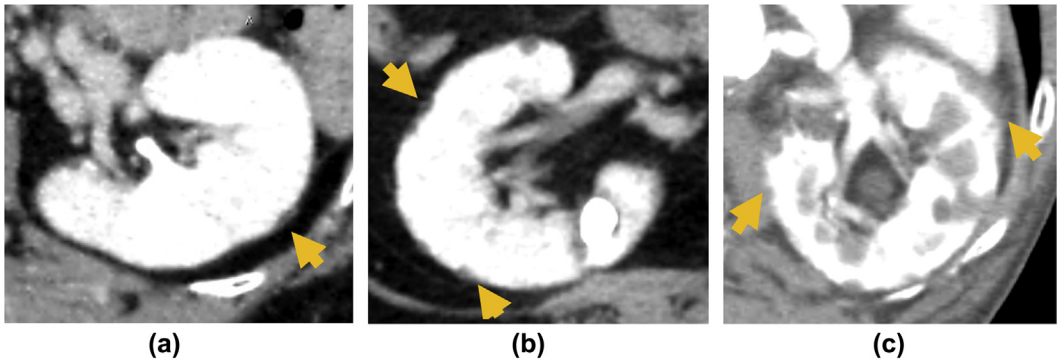

Figure 2 Examples of the RSBA as assessed by the three-grade scale (arrow). (a) Grade I (<25% involvement of the renal border). (b) Grade II (25–75% involvement). (c) Grade 3 (>75% involvement). Grade I might portray the normal subcapsular lymphatic system as morphologically very similar to that described by Matsumoto *et al.*[13] using MRI. Thus, only Grades II and III were considered remarkable enough to possibly indicate a pathological condition.

Table 1
Demographic and clinical characteristics of patients with (positive group) and without (normal group) a renal subcapsular beaded appearance.

Characteristics	Normal (n=1,946)	Positive (n=33)	p-Value
Mean age (±SD)	65 (±12.3)	74 (±8.8)	0.006
Age group (%)			
Under 50	17.4	3	
51–60	12.3	6.1	
61–70	29.1	27.3	
71–80	28.1	39.4	
Over 80	13.1	24.2	
Male (%)/female (%)	47.8/52.2	69.7/30.3	0.005
Hypertension (%)	25	69.7	0.001
Hypertension group (%)			
Stage 1 (systolic ≥130 or diastolic >80 mmHg)	61.6	82.6	
Stage 2 (systolic ≥140 or diastolic >90 mmHg)	38.4	17.4	
Crisis (systolic >180 or diastolic >120 mmHg)	0	0	
Liver cirrhosis (%)	5.4	6.1	0.331
Renal atrophy (%)	10.6	12.1	0.148
Chronic kidney disease (%)	35.5	63.6	0.011

p-Value based on independent t-test on numerical variables and chi-squared test for categorical variables.

three (9.1%) patients (mean, 74.6 HU; range, 53.9–98.7 HU). All three of the high-attenuation RSBAs showed consistency in size and density throughout the follow-up period.

Correlation with MRI

T1-weighted, T2-weighted, and heavily T2-weighted MRI with fat suppression was performed on five (15.2%) of the positive cases. These MRI examinations were performed <6 months from the CT examinations. All MRI examinations showed low signal intensity on T1-weighted imaging and high signal intensity on T2-and heavy T2-weighted imaging, indicating fluid signal intensity on MRI for the beaded appearance suggestive of a prominent lymphatic system (Fig 3).

Course of the RSBA

Follow-up CT images were reviewed to assess changes in the size and attenuation of the RSBA. Follow-up CT images of 32 (96.9%) patients were obtained two to 134 months (mean, 31.5 months) after the initial CT for various clinical and radiological indications. Three patients showed changes in the area of involvement, but the qualitative evaluation of CT attenuation showed no change during the course of follow-up (Fig 4). All patients with high attenuation of the RSBA showed no significant attenuation changes during CT follow-up (Fig 5).

No associations were found between the grade of the RSBA and hypertension or chronic kidney disease. Other variables could not be tested because of the small numbers of positive findings.

Discussion

The renal periphery can host a variety of conditions found by the radiologist on a daily basis.[7] One of these findings is the RSBA, which was quite common (1.63%) in the present study. Venkateswar *et al.*[7] described various subcapsular lesions as “rind-like soft-tissue masses,” and Dedekam *et al.*[14] described such lesions as a “crescentic hyperdensity” which may indicate lymphangiectasia, fibrosis, or haematoma. The present findings showed an irregular border creating a lobulate or beaded appearance to the renal surface, which may be different from those previously described.

The present Grade II and III findings were similar to the milder version of lymphangiectasia described in several case reports. These case reports described multiloculate cysts or, as Restrepo *et al.*[16] reported, “lobular perinephric accumulations with fluid attenuation enveloping the kidney”, some of which were confirmed at MRI as multiloculate connected cysts, especially when using the fat-suppressed heavily T2-weighted technique.[6,15,16] Lymphangiectasia is a rare benign mesenchymal neoplas mthat mostly occurs in asymptomatic adults; <40 cases have been

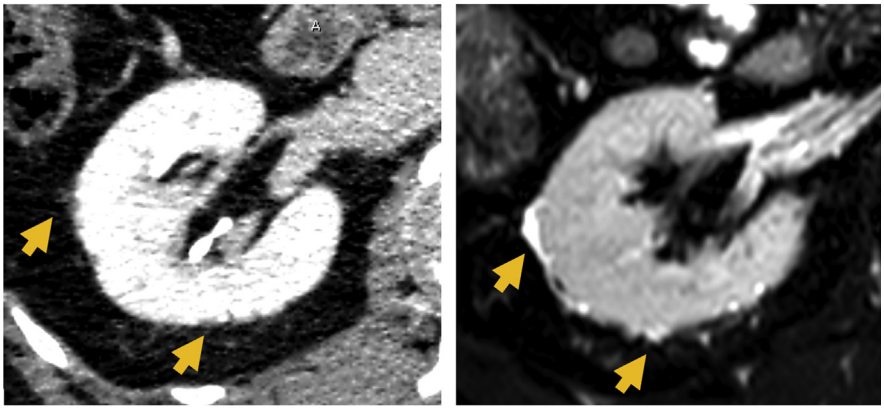

Figure 3 Images from a 70-year-old man with intraductal papillary mucinous neoplasm of the pancreas. (a) An irregularity was noted on the right renal surface and recognised as a Grade II RSBA (arrows). (b) Fat-suppressed heavily T2-weighted MRI image shows a subcapsular cyst with connections (arrows), suggestive of a dilated subcapsular lymphatic system.

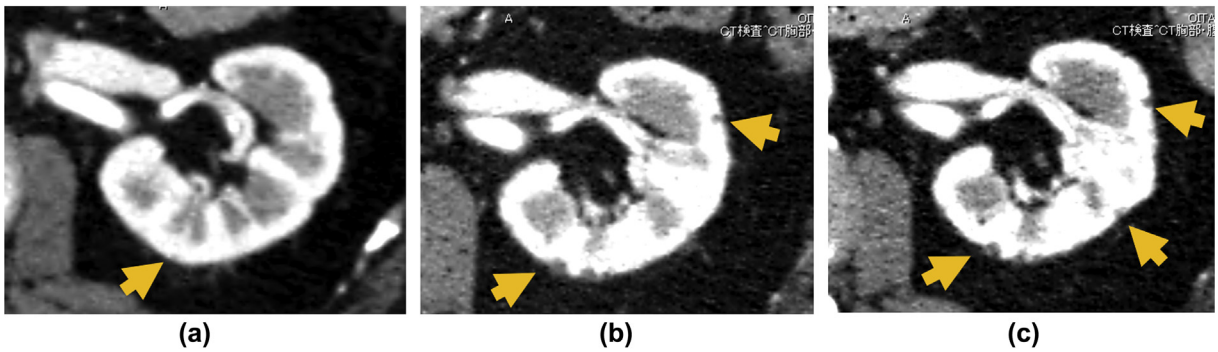

Figure 4 Images of the right kidney of a 77-year-old man with an aortic aneurysm from (a) 2006, (b) 2016, and (c) 2018. The kidney exhibited slow progression of the irregularity on the surface with a clear lesion border, which can be interpreted as progression from a Grade II RSBA in the earliest year to a Grade III RSBA on the later images.

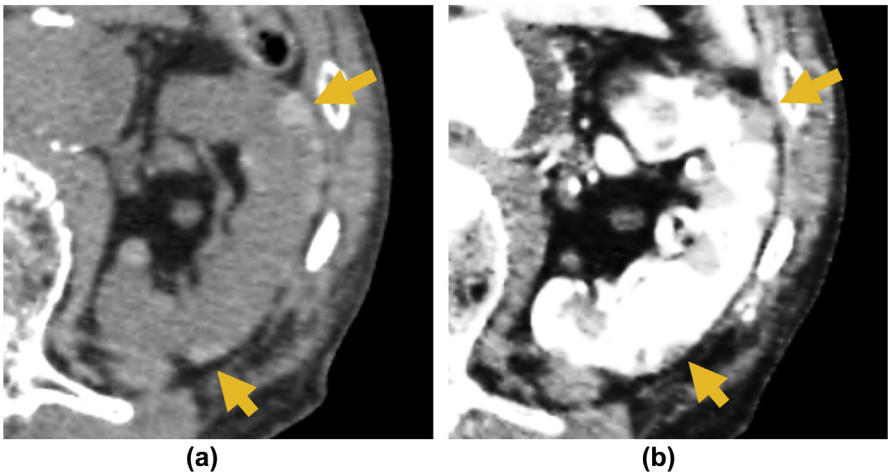

Figure 5 Images from an 81-year-old man with an aortic aneurysm. (a) A high-attenuation Grade III RSBA was seen in most of the subcapsular area (arrow). (b) Contrast-enhanced examination showed no enhancement of the RSBA. Follow-up CT examination (not shown) showed similar findings with a <10 HU difference in the RSBA attenuation.

reported worldwide. More extensive cases tend to be heterogeneous due to haemorrhage and cystic–myxoid degeneration.[7,15] Restrepo *et al.*[16] explained that this finding may be caused by continuous generation of fluid from the perirenal lymphatic system in combination with an altered retroperitoneal lymphatic pressure balance that prevents the fluid from being appropriately reabsorbed.

Possible differential diagnoses include spontaneous haematoma or fibrosis due to renal atrophy.[2,4,7] In the present study, neither high signal intensity on T1-weighted images nor prominent low signal intensity suggesting shading within the lesions on T2-weighted images was identified in any of the patients who had undergone MRI. Furthermore, the present follow-up studies showed no significant changes in CT attenuation, suggesting that a high-attenuation RSBA is more likely to reflect a proteinaceous content. Renal atrophy can sometimes mimic the beaded appearance because of the irregular renal surface. Thus, the present of non-enhancing iso-attenuation to low-density lesion becomes important for differential diagnosis.

The RSBA was predominantly found in male patients in the present study, with a male:female ratio of 7:3. To the authors' knowledge, no comprehensive study of sex-related differences in lymphangiectasia, renal hematoma, or fibrosis has been performed. In their single-centre study, Pandya *et al.*[17] found a male:female ratio of 3:1 among patients with renal lymphangiectasia. Matsumoto *et al.*[13] also found an association between male sex and detectability of the capsular and communicating capsular lymphatics in both kidneys. To the authors' knowledge, however, no study has been performed to explain this association. The present study also showed an association between the RSBA and the incidence of chronic kidney disease (p=0.011) and hypertension (p=0.001). Ischaemia, tubular obstruction, and degeneration are associated with acquired cystic kidney disease, chronic kidney disease, and renal hypertension. These processes may also be involved in perirenal lymphatic system blockade, leading to the beaded appearance.[18,19] Mild spontaneous subcapsular haematomas are also often found in patients with chronic kidney disease and may lead to Wunderlich syndrome in rare cases.[20]

This study has several limitations. First, no biopsy or aspiration was performed because the patients were asymptomatic; therefore, the content of the lesions could not

be confirmed. Second, no comparison between asymptomatic patients exhibiting the RSBA and symptomatic patients was performed. Third, there was a small number of positive MRI findings, and therefore, confirmatory evidence of this CT appearance could not be obtained in all cases. Finally, some positive findings of the RSBA were found in either the corticomedullary or nephrogenic phase, and further study is needed to determine which phase more effectively demonstrates this finding.

In conclusion, the RSBA seen on contrast-enhanced MDCT is not as rare as previously thought, is more commonly seen in older men, and is associated with hypertension and chronic kidney disease. This CT finding is thought to reflect dilated subcapsular lymphatics. Knowledge of the RSBA is clinically essential to differentiate among various subcapsular renal pathologies.

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Conflict of interest

The authors declare no conflict of interest.

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