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ORIGINAL ARTICLE

Can Initial ^{18}F-FDG PET-CT Imaging Give Information on Metastasis in Patients with Primary Renal Cell Carcinoma?

Haejun Lee · Kyung Hoon Hwang · Seog Gyun Kim · Geon Koh · Ji Hyun Kim

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Abstract
Purpose The aim of this study was to investigate the relationship between the maximum standardized uptake values (SUVmax) of primary renal cancers with and without metastatic lesions, if any. We also studied the relationship between the size of primary renal cancers and their SUVmax, and tried to find a clinical value of ^{18}F-FDG PET-CT for the initial evaluation of renal cell carcinoma (RCC).
Methods The cases of 23 patients, 16 men and 7 women, who underwent PET-CT examination before operation were retrospectively reviewed. We measured the SUVmax of the primary renal cancers and those of any existing metastatic lesions, and the size of the primary renal cancers. We compared the SUVmax of primary RCCs with metastases and those without metastases, SUVmax of primary RCC and those of metastases, and studied the correlation between the size and SUVmax of primary RCCs.
Results The SUVmax of primary RCC of the 16 patients without metastasis ranged from 1.1 to 5.6 with a median value of 2.6. Those of the patients with metastasis ranged from 2.9 to 7.6 with a median of 5.0. The size of the all 23 primary renal cancers ranged from 1.7 cm to 13.5 cm, with a median of 4.5 cm, and their SUVmax ranged from 1.1 to 7.6, with a median of 2.9. There was a statistically significant difference between the SUVmax of the primary RCC with metastasis (5.3 ±1.7) and those without metastasis (2.9±1.0). There was a moderate positive correlation between the sizes and SUVmax of all 23 primary RCCs. However, there was no statistically significant correlation between the sizes and SUVmax of primary RCCs with metastatic lesions and the same for RCCs without metastasis. The cutoff value of SUVmax for predicting extra-renal lesion was 4.4 and that for size was 5.8 cm according to the receiver operating characteristic curves.
Conclusions Those who have primary RCC with high SUVmax are suggested to have a likelihood of metastasis. Also, there was a moderate trend of increasing value of SUVmax of primary RCC as their size increases. Physicians should beware of missing extra-renal lesions elsewhere.

Keywords Renal cell carcinoma · Initial staging · ^{18}F-FDG · PET-CT · SUV · Metastasis

H. Lee · K. H. Hwang (✉) · S. G. Kim · G. Koh · J. H. Kim
Department of Nuclear Medicine, Gachon University Gil Hospital, Incheon, Republic of Korea
e-mail: khhwang@gilhospital.com

Introduction

Kidney cancer is one of the most common ten cancers in Western societies such as North America and Western Europe [1]. More than 270,000 new cases were diagnosed, constituting about 2 % of total cancers, and 116,000 died from the disease worldwide in year 2008 [1]. According to the National Cancer Institute in the United States, it is estimated that 65,150 people (40,430 men and 24,720 women) would be diagnosed with kidney cancers and cancers of the renal pelvis in 2013, and 13,680 would die of them [2]. Nearly 90 % of all kidney cancers are renal cell carcinomas (RCCs) [1]. In the United States, Asian Americans or Pacific Islanders have the lowest incidence of renal cancers compared to American Indians/Alaska natives, Hispanic/Latinos, Whites, or African Americans [1, 3]. RCC occurs predominantly in the 6th to 8th decades of life with median age at diagnosis around 65 years of age [4, 5]. Occurrence of renal cancer is unusual in patients under 40 years of age and rare in children [6, 7]. Worldwide incidence and mortality rates of RCC have been increasing [8, 9] at a rate of approximately 2–3 % per decade [10]. Considering gender, men have about 1.5- to 1.6-fold higher incidence than women [4, 11].

Standard imaging evaluation for the characterization of a primary renal tumors, either malignant or benign, includes ultrasonography, abdominopelvic computed tomography (CT) scan, chest radiograph or chest CT scan when metastasis is suspected, and magnetic resonance imaging (MRI) scan for the assessment of inferior vena cava [12–14], but not 2-deoxy-2-[fluorine-18]fluoro-D-glucose (^{18}F-FDG) combined positron emission tomography computed tomography (PET-CT). As widely known, because ^{18}F-FDG is physiologically accumulated and excreted in kidneys, it is not always possible to detect renal malignancies with ^{18}F-FDG PET. Still, there is also evidence that ^{18}F-FDG PET-CT is useful in detecting primary renal cancers [15] and/or metastatic RCCs [15–17] and recurrent diseases [18–21].

In this article, we compared the maximum standardized uptake values (SUVmax) of primary renal cancers with metastatic lesions and SUVmax of primary RCCs without metastatic lesions to investigate the relationship between SUVmax of primary renal cancers (SUVmax-T) and existence of metastasis, and then tried to elucidate a clinical value—that is, the predictive power of ^{18}F-FDG PET-CT for extra-renal lesions in an initial evaluation of RCC in terms of SUVmax of primary RCC.

Materials and Methods

Patients

We retrospectively reviewed 23 patients (16 males, 7 females; median age 59 years; range 27–77 years), who underwent ^{18}F-FDG PET-CT imaging examination at our institution before the operation for renal lesions or masses from January 2006 to December 2012. As PET-CT has no clear indication for a primary renal tumor, a relatively small number of pre-operative PET-CT images were available compared with other cancers over the same period. They were all confirmed to have RCC on histopathological examination by pre-operative tissue biopsy or after operation. There was only one patient who underwent pre-operative tissue biopsy of subcarinal lymph node which was confirmed as metastatic RCC. Other Twenty-two other patients had no pre-operative renal biopsy and were confirmed to have RCCs after operation. Eight out of 23 patients were incidentally found to have renal cancers in the middle of follow-up assessments for another malignancy and they did not show any radiological or clinical evidence of metastatic lesions due to prior cancers at least by the time PET-CT images for renal tumors were acquired. Fifteen other patients never had a history of cancer. Seven of the 15 patients were suggested to have metastatic lesions on the initial assessment for renal tumors and the 8 of the 15 patients had a solitary renal tumor without any radiological or clinical evidence of regional or distant metastasis. Metastases were confirmed histopathologically if tissues were obtained, as well as clinical and radiological follow-ups. Of all 23 patients, 20 had clear cell RCC, two had papillary renal cell carcinoma, and one had mixed clear cell and papillary carcinoma with predominant papillary component. Patients' characteristics are shown in Table 1. This study was approved by the Institutional Review Board at our institution. Informed consent was waived because of the retrospective design of this study.

Imaging Procedure

PET-CT images were acquired prior to the operation for renal lesions or masses. All 23 patients fasted for at least 6 h and their blood glucose levels were checked prior to the injection of ^{18}F-FDG. When the blood glucose level was less than 180 mg/dl, depending on a patient's weight, 370–555 MBq (10–15 mCi) of ^{18}F-FDG was injected intravenously. After resting 60 min in bed in a quiet and dimmed room for equilibration, whole-body PET-CT examination was performed on either of two integrated PET-CT imaging devices. Image acquisitions for 21 patients were conducted on a Siemens Biograph 6 (Siemens, Erlangen, Germany) which had lutetium oxyorthosilicate (LSO) scintillators for PET and six slices for CT. Two scans were acquired with Siemens Biograph mCT128 which also had LSO scintillators and 128 CT slices. Each emission scan was obtained for 2 min per single bed on both devices. No contrast agent was used for all CT scans. All images were obtained from skull base to upper thigh in three-dimensional mode and attenuation correction for PET was done based on CT data. Acquired data were reconstructed by iterative reconstruction method with a matrix size of 128×128. Field of view (FOV) of Biograph 6 was 700 mm and iterative reconstruction was performed with four iterations and eight subsets. FOV of Biograph mCT128 was 780 mm and iterative reconstruction was done with two iterations and 21 subsets.

Image Interpretation

The reconstructed images of all eligible patients were analyzed both qualitatively and semiquantitatively. Image interpretation was performed by two experienced nuclear medicine physicians with all clinical and other radiological information available. Regions of interest (ROIs) and/or volumes of interest (VOIs) were drawn for primary renal cancers and any existing extra-renal lesions in order to measure their maximum and mean SUVs on a dedicated dual Intel (Intel Corporation, Santa Clara, CA, USA) Xeon-based workstation equipped with Siemens syngo application. As urinary activity could interfere in the measurement of SUV, we preferred ROI to VOI. By referring to abdominopelvic CT to exclude urinary activity as much as possible, we carefully drew an ROI on each slice containing the kidney of interest. VOI was also measured for reference.

Table 1 Characteristics of patients with RCC (mean age for men was 58 years and 55 years for women) and histopathological results of renal tumors. Patients 1-7 had metastatic lesions; patients 8–23 had no radiological or clinical evidence of metastasis

Patient no.	Age	Sex	SUVmax of RCC in pre-op PET/CT	SUVmean of RCC in pre-op PET/CT	SUVmax of metastasis in pre-op PET/CT	SUVmean of metastasis in pre-op PET/CT	Length of long axis of primary RCC (cm)	Pathology
1	46	M	7.6	3.6	0.7	0.6	13.5	Clear cell type
2	52	M	5.0	2.7	3.2	1.3	4.5	Clear cell type
3	67	M	4.6	2.9	4.2	3.0	13.5	Clear cell type
4	48	M	5.3	2.9	5.4	1.6	6.8	Clear cell type
5	48	M	2.9	1.9	5.5	3.3	9.0	Clear cell type
6	42	M	7.4	2.8	7.4	5.5	7.5	Clear cell type
7	62	M	4.5	3.2	11.5	4.1	6.0	Clear cell type
8	61	M	1.1	0.8			2.0	Clear cell type
9	65	M	2.0	1.4			4.0	Clear cell type
10	57	F	2.2	1.6			2.0	Clear cell type
11	65	F	2.2	1.9			3.8	Clear cell type
12	76	M	2.4	1.7			4.0	Clear cell type
13	75	M	2.5	1.3			10.0	Clear cell type
14	63	F	2.5	1.7			3.0	Papillary type
15	55	F	2.6	1.9			5.5	Clear cell type
16	60	M	2.6	1.7			1.7	Clear cell type
17	59	M	2.8	2.0			3.1	Clear cell type
18	77	M	2.9	1.8			2.8	Clear cell type
19	46	M	3.1	2.5			2.8	Clear cell type
20	61	F	3.6	2.7			3.5	Clear cell type
21	53	F	3.7	2.8			5.5	Clear cell type
22	50	M	4.3	3.0			5.5	Mixed papillary and clear cell type (predominant papillary)
23	28	F	5.6	4.8			7.0	Papillary type

SUVmax maximum standardized uptake value, *SUVmean* mean standardized uptake value, *RCC* renal cell carcinoma, *pre-op* pre-operative

We additionally measured average SUV (SUVmean) to see its behavior compared with SUVmax. Size of primary RCC was defined as the longest length of renal tumors. We primarily used size data given by official histopathological reports after nephrectomy to get rid of interpersonal variation of measurement on images as there was difficulty in measuring the size of primary RCC on the non-enhanced CT portion of PET-CT, causing controversy. However, we also checked the official reports of other radiological examinations, such as abdominopelvic CT or ultrasonography, for reference.

Statistical Analysis

Basically, statistical analysis was done by both nonparametric and parametric methods as the sample size was not large enough. We compared the means of SUVmax to see whether there was any difference between the SUVmax of the primary renal cancers with metastasis and those without metastasis using the Mann–Whitney *U* test and Student's *t*-test. A relationship between the SUVmax of primary renal cancers and their sizes was analyzed also by both nonparametric and parametric methods. As all the patients had nephrectomy surgery, we referred to the reports of surgery and histopathology. All *P* values were considered statistically significant when they were less than 0.05. Receiver operating characteristic (ROC) curves were drawn to estimate cutoff values of SUVmax and size of primary renal cancer for prediction of extra-renal lesion. Statistical analysis was performed with SPSS 18.0 (IBM SPSS Statistics, IBM Corporation, Somers, NY, USA).

Results

SUVmax of Primary RCC

The values of SUVmax-T and those of any existing metastatic lesions (SUVmax-M) together with the sizes of primary renal cancers are shown in Table 1. Sixteen patients did not show obvious evidence of metastasis in radiological examinations such as PET-CT as well as CT or magnetic resonance imaging (MRI).

The SUVmax-T in these cases ranged from 1.1 to 5.6 with a median value of 2.6. Figure 1 demonstrates one of these cases. Seven patients were suggested to have metastatic lesions and the SUVmax-T for them ranged from 2.9 to 7.6, with a median of 5.0. Their SUVmax-M ranged from 0.7 to 11.5, with a median of 5.4. Figure 2 illustrates an RCC case with lung metastases.

The ratios of the SUVmax-M to SUVmax-T were calculated. They were 0.096, 2.6, 1.0, 0.65, 1.0, 1.9, and 0.92. Three (42.9 %, 3/7) of all seven cases with metastasis showed the ratios of near one; that is, less than 10 % of difference. Three (42.9 %, 3/7) had differences of more than 90 % and one (14.3 %, 1/7) presented a difference of 35.1 %.

The average standardized uptake values (SUVmean) of primary renal cancers ranged from 0.8 to 4.8 with a median of 2.0. SUVmean of extra-renal lesions ranged from 0.6 to 5.5 with a median of 3.0. SUVmean were presented in Table 1.

Considering the histopathological results, the SUVmax of the 20 clear cell RCCs ranged from 1.1 to 7.6 with a median of 2.9. The SUVmax of the two papillary RCCs were 2.5 and 5.6. Two papillary RCC patients showed no definite evidence of extra-renal lesions.

SUVmax vs Size of Primary RCC

The SUVmax of all the primary renal cancers were from 1.1 to 7.6 with a median of 2.9 and the sizes ranged from 1.7 cm to 13.5 cm with a median of 4.5 cm.

Metastatic Foci and Their SUVmax

Of the seven cases with metastases, three were with lung metastases, one with both pleural and cervical spine metastases, one with subcarinal lymph node metastasis, one with hepatic metastasis, and one with both pulmonary and adrenal metastases. The SUVmax of the metastatic lesions ranged from 0.7 to 11.5 with a median of 5.4. The lesion with SUVmax of 0.7 was a small lung lesion. The patient with this lesion had primary RCC of 13.5 cm in size with SUVmax of 7.6 and he also had several pulmonary nodules whose sizes were about 1.0 cm. These lung lesions were diagnosed as metastasis by radiological follow-ups for more than half a year. We chose the highest SUVmax among the pulmonary lesions. All seven patients with metastatic lesions had clear cell RCC.

Statistical Analysis

There was a statistically significant difference between the SUVmax-T with metastasis (5.3±1.7) and those without metastasis (2.9±1.0) according to Mann–Whitney U test (P value=0.002) and Student's t-test (P value<0.001), two-sample assuming equal variances (F-test gave us P value> 0.05). Table 2 shows this briefly. In terms of SUVmean, there was also a statistically significant difference between SUVmean of primary RCC without metastasis and primary RCC, with metastasis with a P value<0.05. Because of the

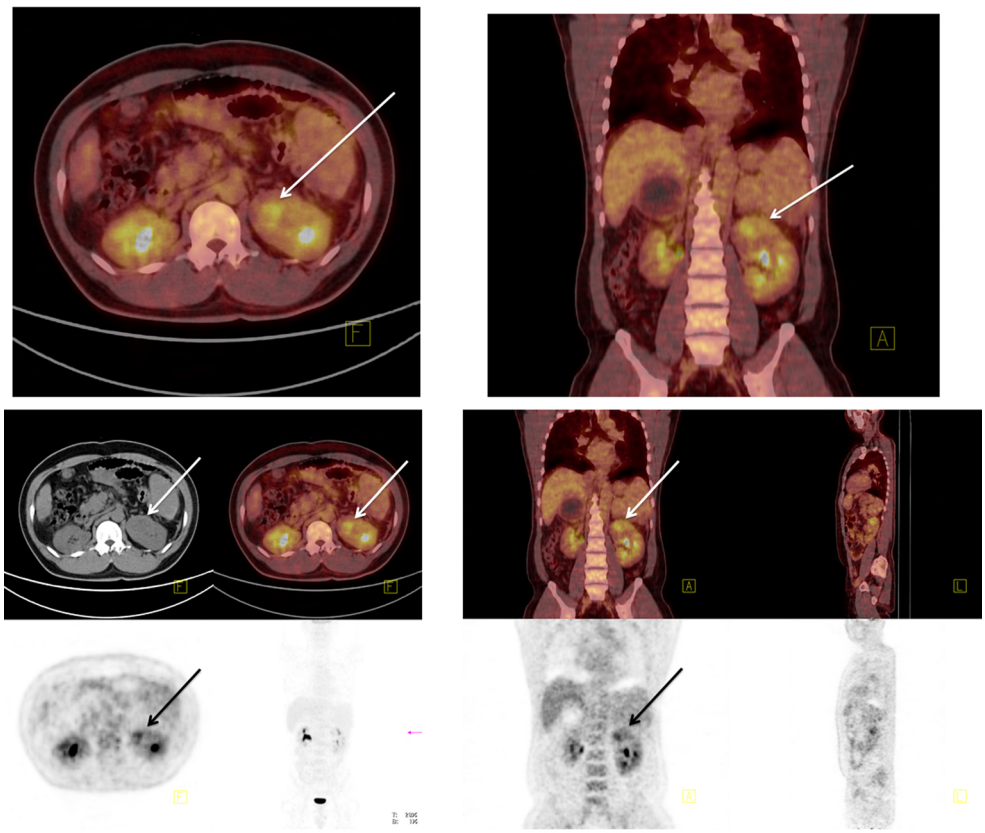

Fig. 1 A case of clear cell renal cell carcinoma (RCC). SUVmax of the primary RCC was 4.3. This patient had no evidence of metastasis on PET-CT as well as other imaging studies

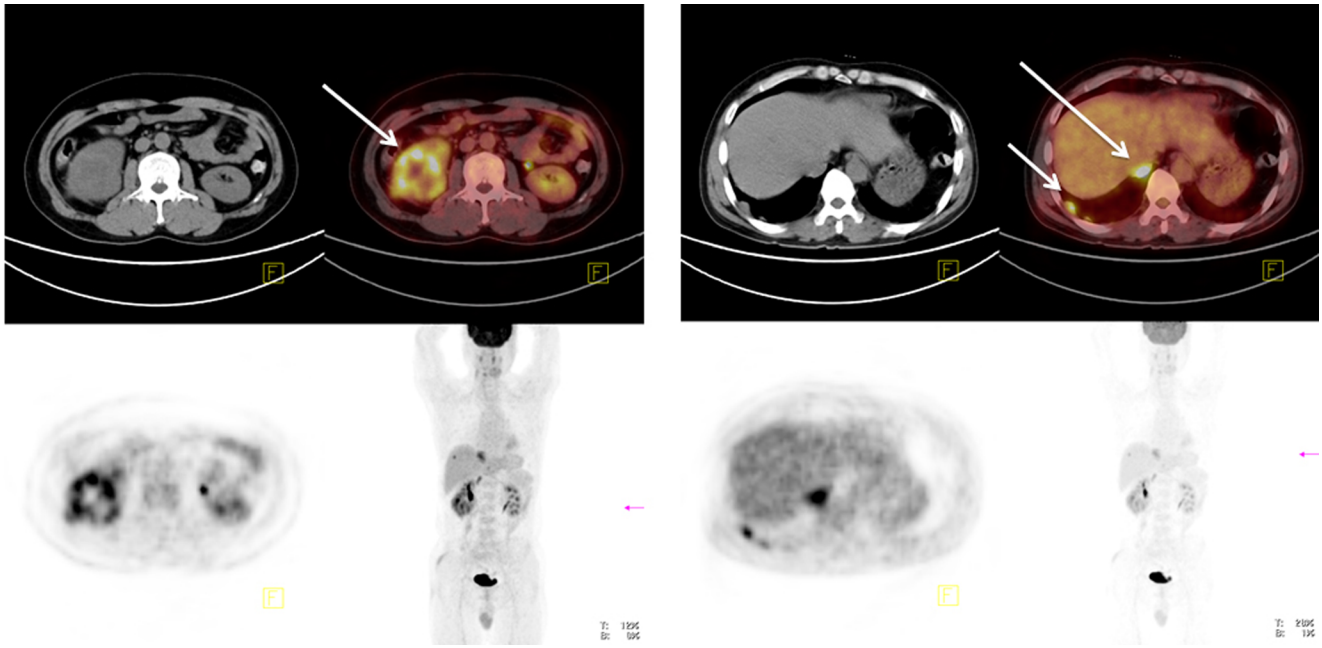

Fig. 2 A clear cell RCC case with lung metastases. Image on the left shows the primary RCC (SUVmax 7.4) and its pulmonary metastases (SUVmax 7.4) are seen *on the right*

small sample size, we were not sure about the distribution, so it was reasonable to perform both nonparametric and parametric tests.

For the patients with metastases, regardless of the location, there was no significant correlation between the SUVmax-T and SUVmax-M according to both nonparametric and parametric correlations. According to Spearman's *rho*, Kendall's *tau-b*, and Pearson correlation, the correlation coefficients were −0.464 (*P* value=0.294), −0.333 (*P* value=0.293), and −0.303 (*P* value=0.509) respectively.

The correlations between the size of all 23 primary RCCs and their SUVmax according to Spearman's *rho* and Kendall's *tau-b* were 0.598 (*P* value=0.003) and 0.465 (*P* value=0.002) respectively. The correlation coefficient was 0.617 (*P* value=0.002) for Pearson correlation (Table 3 and Fig. 3). There was a moderate to good positive correlation between the size and SUVmax of all 23 primary RCCs. But the correlation coefficients between the size and SUVmax of primary RCCs without metastatic lesions were 0.322 (*P* value=0.224) by Spearman, 0.256 (*P* value=0.174) by Kendall's *tau-b*, and 0.423 (*P* value=0.102) by Pearson correlation. Those between the size and SUVmax of primary RCCs with metastatic lesions were 0.180 (*P* value=0.699) by Spearman, 0.195 (*P* value=0.543) by Kendall's *tau-b*, and 0.225 (*P* value=0.628) by Pearson correlation respectively. These showed no statistically significant correlation between the size and SUVmax of primary RCCs with metastatic lesions and the same for RCCs without metastasis.

ROC curves for cutoff values of SUVmax (AUC, 0.911, 95 % confidence interval 0.783–1.000, *P* value=0.002) and size (AUC, 0.923, 95 % confidence interval 0.801–1.000, *P* value=0.002) were drawn and optimal values were 4.4 and 5.8 cm respectively (Table 4).

Table 2 Maximum standardized uptake values for primary RCCs with and without extra-renal lesions. *P* values by both nonparametric and parametric methods are given

	SUVmax-T with metastasis (n=7)	SUVmax-T without metastasis (n=16)	*P* value
SUVmax (mean ± SD)	5.3±1.7	2.9±1.0	0.002 (Mann–Whitney *U* test)<0.001 (Student's *t*-test)

SUVmax maximum standardized uptake value, *SUVmax-T* SUVmax of primary renal cancer

Discussion

RCCs are found incidentally with various ratios, about 15-39 % [22–25]. RCCs are suspected when a patient shows

Table 3 The correlations between the size and SUVmax of all 23 primary RCCs. A moderate positive correlation is shown between them

Correlation method	Correlation coefficient	*P* value
Spearman's *rho*	0.598	0.003
Kendall's *tau-b*	0.465	0.002
Pearson	0.617	0.002

SUVmax maximum standardized uptake value

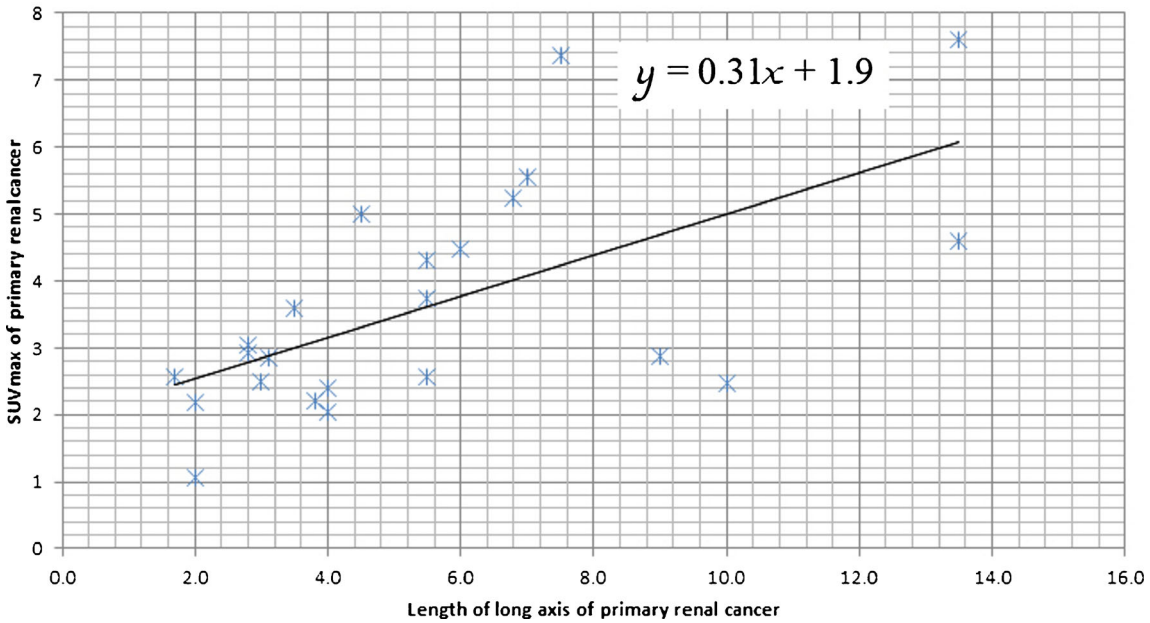

Fig. 3 Correlation between the length of long axis of primary renal tumors and SUVmax for all 23 patients. The correlation coefficient was 0.617 (*P* value=0.002) by Pearson correlation. According to nonparametric methods, Spearman's *rho* and Kendall's *tau-b* were 0.598 (*P* value=0.003) and 0.465 (*P* value=0.002) respectively

symptoms associated with the tumor itself and/or metastasis. With an advancement and wide use of diagnostic tools, incidentally detected asymptomatic RCC patients have increased [22]. In our study, it was 43.5 % (10/23).

In the evaluation of renal lesions including metastatic renal tumors [26], the role of ^{18}F-FDG PET is limited because of its relatively low sensitivity [27–29] and the detected solid renal lesions are hardly characterized as a primary renal malignancy or metastatic lesion [30]. Moreover, physiological urinary activity is also bothersome. PET-CT has not been the first line examination for renal tumors because of the reasons above. Among papers about the role of PET-CT on renal masses, Ak et al. [31] stated that ^{18}F-FDG PET might have a role in the diagnostic evaluation of patients with RCC and primary staging of the disease. Wang et al. [32] reported that a PET-CT system was helpful for detecting extra-renal metastasis rather than renal lesions. Nakhoda et al. [33] suggested that PET revealed differences in metabolic activity based on histopathological type, which might be useful for purposes of individualized medicine. Ramdave et al. [34] proposed that ^{18}F-FDG PET could accurately detect local disease spread and metastatic disease in patients with RCC and altered treatment in 40 %. Therefore it might have a role in the diagnostic evaluation of patients with RCC preoperatively and staging of metastatic disease. On the contrary, Miyakita et al. [29] suggested ^{18}F-FDG PET might not be a useful diagnostic tool for RCC. The exact usefulness of ^{18}F-FDG PET-CT in an evaluation of renal tumors is still in question. Nonetheless, ^{18}F-FDG PET is reported in some articles—including those mentioned above—to be useful in detecting distant metastases [31, 35], evaluating indeterminate renal masses and restaging [36, 37].

Table 4 Cutoff values for SUVmax and size of primary renal cancers by receiver operating characteristic (ROC) curves, which may give information on metastasis

		AUC	95 % CI	*P* value
Cutoff for SUVmax	4.4	0.911	0.783–1.000	0.002
Cutoff for size	5.8 cm	0.923	0.801–1.000	0.002

SUVmax maximum standardized uptake value, *AUC* area under an ROC curve, *CI* confidence interval

Currently, our main focus is on the relationship between the SUVmax of the primary RCC and the existence of metastasis. For the SUVmax of the primary RCC in patients with metastasis and those in patients without metastasis at initial presentation, there is sufficient evidence at a confidence level of 0.05 to conclude that the SUVmax of the two groups differ from each other with statistical significance (*P* value<0.01) and primary RCCs with metastasis showed higher SUVmax than primary RCCs without metastasis. Also, by drawing a ROC curve (AUC, 0.911, 95 % confidence interval 0.783–1.000, *P* value=0.002), the optimal cutoff value of SUVmax for predicting extra-renal lesion was 4.4, with a sensitivity of 0.857 and a specificity of 0.938. In other words, when a patient has an SUVmax greater than or equal to 4.4 for his or her primary RCC, he or she may have an increased likelihood of extra-renal lesion. There are evidence of a prediction of metastasis based on SUVmax in other primary malignancies [38–41].

Metastatic RCCs are found in about a quarter to a third of patients by the time they are diagnosed with RCC [42–44].

Seven out of 23 (30.4 %) had metastatic RCCs in our study, which is within the range of known ratios. Frequent sites for metastatic RCC include lung, bone, liver, adrenal gland, contralateral kidney, retroperitoneum, and brain [45–47].

In the seven cases with extra-renal lesions, interestingly the relationship between the SUVmax-T and SUVmax-M was not significant in opposition to our expectation. Three of them (43 %) were outliers, which might have exerted influence and resulted in greater variance, and therefore could have affected correlation seriously in this small sample size group. Extra-renal lesions which do exist but in small sizes are likely to have low SUVmax [48]. In our study, five patients had pulmonary metastases with various sizes. As lung is most frequent site for metastatic RCC, small metastatic pulmonary nodules which may have low SUVmax might matter. However, one study reported that FDG-PET was an accurate modality to differentiate solitary pulmonary lesions in patients with RCC [49]. Therefore, FDG PET may help in finding pulmonary metastases. For tiny pulmonary lesions, nuclear medicine physicians should carefully look for any pulmonary lesions on CT images provided by combined PET-CT or another discrete chest CT, even if no abnormal FDG uptake is seen on PET. This may assist early detection of pulmonary metastases, overcoming the resolution problem of PET. The possibility of a different result for the relationship between SUVmax-T and SUVmax-M may exist if the number of cases is larger and the sizes of metastatic lesions are greater. Further study is needed to clarify these questions. But for now any extra-renal lesions, including pulmonary ones, with FDG uptake should be suspected and studied for metastases, particularly when primary RCC shows high SUVmax.

With regard to the relationship between the sizes of the primary RCCs and their maximum SUVs, the correlation coefficient for all 23 patients was 0.617 (P value=0.002) indicating a moderate positive correlation. In other words, there is a moderate tendency of having higher SUVmax for primary renal carcinomas of increasing sizes. However, it remained unexplained for each patient group without or with metastasis because there were no valid statistical results. In our study, the optimal cutoff value for tumor size was 5.8 cm, with a sensitivity of 0.857 and a specificity of 0.923, by drawing a ROC curve (AUC, 0.923). For some other cancers, there are articles about the relationship between the sizes of primary or metastatic malignancies and their maximum SUVs. Uchiyama et al. [50] stated that the SUV of primary colorectal cancers tended to increase in proportion to tumor size. Khalaf et al. [51] observed that the sensitivity of PET-CT rose when the sizes of pulmonary lesions increased. These all support the trend of increasing SUVmax when the sizes of primary or metastatic lesions increase. Again, the correlation coefficient for the sizes of the primary RCCs and their mean SUVs was 0.472, presenting a positive moderate correlation, yet a lower value than that related to SUVmax (correlation coefficient=0.617). It would be reasonable to adopt the value related to SUVmax for correlation.

There are several choices for the treatment of RCC, such as surgery, radiation therapy, chemotherapy, biological therapy (immunotherapy), and targeted therapy. A lot of trials are being done to fight primary and/or metastatic cancers to achieve advantages in survival. For example, Khandani et al. [52] suggested that primary clear cell RCC with lower standardized uptake value base were more likely to respond to neoadjuvant sorafenib, whereas this trend was not observed for non-clear cell RCC. Namura et al. [53] proposed that the survival of patients with advanced RCC can be predicted by evaluating their SUVmax using ^{18}F-FDG PET/CT. These are some of the evidence that the SUVmax of primary renal carcinoma from PET-CT could also be considered as one of the references or criteria for patient selection and medication for personalized treatment, and also for a prediction of survival. But ^{18}F-FDG is still needed to be assessed as a therapy-response monitoring tool [54].

The present study has a few limitations. We did our best not to include urinary activity when drawing ROIs and/or VOIs in kidneys in order to minimize the possibility of error in measuring SUVmax of the primary RCC; however, we might not be completely free from it. The likelihood of this error could be minimized by drawing an ROI/VOI along the exact boundary of renal cancers several times avoiding urinary activity. As mentioned above, the total number of cases is small and that of patients with metastasis is even smaller. To overcome this, the statistical analysis was done with nonparametric methods as well as parametric methods.

To conclude, as about a quarter to a third of patients with RCC are reported to have metastatic lesions at presentation, when a patient with primary renal cancer of large enough size (larger than 5.8 cm) visits for an initial evaluation, there is a chance of having a high SUVmax for it, and if the SUVmax is great (higher than 4.4) he or she may have a likelihood of metastatic lesions. Thus, one of the values of PET-CT in initial evaluation of a patient with primary renal cancer seems to be in predicting extra-renal lesions. Furthermore, treatment choice for each patient could be considered based on SUVmax of primary RCC.

Conclusions

Those who have primary RCCs with high SUVmax are suggested to have a likelihood of metastasis. Also, there was a moderate trend of increasing value of SUVmax of primary RCCs as their size increases. Therefore, if a primary RCC one has high SUVmax and large size, physicians should pay careful attention in order not to miss extra-renal lesions elsewhere.

Conflicts of interest The authors declare that they have no conflicts of interest.

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