



A novel insight in the diagnosis of peripheral primitive neuroectodermal tumors: a retrospective analysis of 23 patients

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Background: Peripheral primitive neuroectodermal tumors (pPNETs) are rare, small, round cell tumors with high malignancy and invasiveness and a poor prognosis. ¹⁸F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) is important in the diagnosis of pPNETs, but the current literature on PET/CT imaging of pPNETs is limited to case reports with low-quality evidence.

Methods: This study retrospectively analyzed the ¹⁸F-FDG PET/CT images of 23 patients with pPNETs. Clinical information and ¹⁸F-FDG PET/CT data were collected to analyze the PET/CT features of primary and metastatic lesions and to explore the pathological morphology, metabolism, and distribution patterns of pPNETs.

Results: Of the 23 pPNET patients, 18 were male, with an average age of 26.22 years (range, 12 to 41 years). The location of the primary lesion was bone in 16 patients and non-skeletal (muscle, lung, liver, kidney, testis and mediastinum) in 7. ¹⁸F-FDG PET/CT of all patients showed a soft tissue mass with a significantly intense ¹⁸F-FDG uptake. The maximum diameter of the lesion was 7.64±2.38 cm, and the maximum standard uptake value (SUVmax) was 11.27±3.80. Primary pPNETs with ill-defined borders, heterogeneous density and invasion into the adjacent tissues were observed in 73.9% (17/23) of the patients. Necrosis or cystic changes were found in 52.17% of the lesions. No calcification was noted in any lesions. Metastases were observed in 43.5% (10/23) of the patients, including hematogenous metastases to the bone (7 patients), bilateral lungs (4 patients), liver (3 patients), vascular tumor thrombus (2 patients), and metastasis to the pericardium (1 patient); 13.0% (3/23) of patients had lymph node metastases. The rate of multiple metastases was higher in patients with primary non-skeletal pPNET than in those with primary bone pPNET [6/7 (85.7%) vs. 4/16 (25%)].

Conclusions: Both primary and metastatic pPNETs lesions showed high uptake of ¹⁸F-FDG on ¹⁸F-FDG PET/CT imaging, which has high detection sensitivity. ¹⁸F-FDG PET/CT is of great value for the diagnosis, differential diagnosis, clinical decision-making, evaluation of efficacy, and recurrence assessment of pPNETs.

Keywords: Peripheral primitive neuroectodermal tumor (pPNET); positron emission tomography/computed tomography (PET/CT); ¹⁸F-fluorodeoxyglucose; metastasis

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Introduction

Primitive neuroectodermal tumors (PNETs) are rare, small, round cell malignant tumors originating from the neural crest of the neuroectoderm in the central and sympathetic nervous system with multidirectional differentiation potential (1,2). According to its location, PNETs are classified as central PNET (cPNET) or peripheral PNET (pPNET). cPNET refers to a PNET that presents in the cerebral hemisphere, brainstem, cerebellum, or spinal cord. pPNETs usually presents in the torso, limbs, or soft tissue in midline of the body and include Ewing's sarcoma, which occurs in the bones and soft tissue outside the bones, and Askin tumors, which occur in the chest wall, paraspinal sites, and the retroperitoneal cavity (3-5). However, pPNETs rarely present in other areas (such as the nasal cavity, pancreas, kidney, adrenal gland, intestine, and testis) (6-8). pPNETs are more common in children and adolescents. Although their incidence is very low, including only 4% of all soft tissue tumors (9), pPNETs are associated with a high degree of malignancy, low survival rate, and poor prognosis (3,5). The average median survival is 3.4 years (10). Rapid and accurate diagnosis and assessment of systemic metastases are critical for treatment decision-making and prognosis assessment for pPNET patients.

The clinical manifestations of pPNETs are diverse and nonspecific. Confirmation of the diagnosis depends on histopathology and immunohistochemical results. Noninvasive imaging studies are of great value in the diagnosis and differential diagnosis of pPNETs. However, imaging studies of pPNETs are rare and mainly performed using computed tomography (CT) and magnetic resonance imaging (MRI) (4,6,10-15). Although CT and MRI have obvious advantages in assessing the location, adjacent relationship, and blood supply of the lesion, it is difficult to accurately and rapidly assess the nature of the tumor and to comprehensively evaluate distant metastasis. In recent years, ¹⁸F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) has shown unique advantages in the diagnosis, differential diagnosis, staging, and prognosis evaluation of malignant tumors and has been considered an alternative that can compensate for the limitations of CT and MRI (16,17). However, to the best of our knowledge, all ¹⁸F-FDG PET/CT imaging studies of pPNET in the current literature are described in case reports (18-25), which represent a lower level of evidence.

This study retrospectively reviewed the clinical data and

¹⁸F-FDG PET/CT findings of 23 patients pathologically diagnosed with pPNETs. The results might be valuable for the diagnosis and assessment of pPNET metastasis.

Methods

Patients

The institutional review board of Nanfang Hospital at the Southern Medical University approved the present retrospective study and waived the requirement for written informed consent due to the retrospective nature of the study.

From September 2004 to August 2018, a total of 23 patients with pPNETs who had undergone ¹⁸F-FDG PET/CT before the diagnosis was established were enrolled in this study. The diagnosis of pPNET was established by the histopathological and immunohistochemical results. We recorded the age, sex, clinical symptoms, PET/CT findings (the maximum standard uptake value (SUVmax) for lesions, the largest diameter of the tumor, density of lesions, border of tumors, scope of involvement, lymph node metastasis, distant metastasis, etc.) and pathologic results.

¹⁸F-FDG PET/CT image examination

Four examinations were performed using a GE Discovery LS PET/CT scanner (GE Healthcare, Waukesha, Wisconsin, USA) and 19 examinations were carried out using a Biograph mCTx scanner (Siemens, Germany). The patients were instructed to fast for at least 6 hours before the PET/CT examination. Approximately 60 minutes after intravenous injection of 5.55 MBq/kg of ¹⁸F-FDG, whole-body PET/CT was performed according to the guidelines for tumor imaging with ¹⁸F-FDG PET/CT (26) and the established protocols at our center (27).

All PET/CT images were independently read by two nuclear medicine physicians with more than 5 years of experience. The lesions with intense ¹⁸F-FDG uptake were considered positive tumors. The regions of interest (ROI) were drawn along the margin of each lesion on the PET images to measure the SUVmax.

Statistical analysis

Statistical analyses were conducted in SPSS Statistics 22. The level of significance was set at $\alpha=0.05$ ($P<0.05$), and all tests were 2-tailed. The results for continuous

Table 1 The ^{18}F -FDG PET/CT findings of pPNET

Origination	Cases, n/%	Location	Size (cm)	Border ill-defined/well-defined	Necrosis/cystic	Density, hetero-/homogeneous	SUVmax	Metastases
Bone	16/69.57	Spine and paravertebral tissue [5]; hip [4]; skull [3]; chest wall [3]; femur [1]	7.46±2.41 (4.30 to 12.20)	12/4	10	14/2	10.01±3.10	Bone [4]; lung [1]; liver [1]
Non-bone	7/30.43	Muscle [2]; lung [1]; testis and spermatic cord [1]; liver [1]; kidney [1]; mediastinum [1]	8.07±2.48 (5.80 to 11.00)	5/2	2	3/4	14.17±3.87	Lymph nodes [3]; bone [3]; lung [3]; liver [2]; tumor thrombus [2]; pericardium [1]

pPNET, peripheral primitive neuroectodermal tumor; SUVmax, the maximum standard uptake value.

variables were expressed as the mean ± standard deviation, and frequency and ratio were used for ordinal variables. Comparisons between two groups were performed using an independent *t*-test.

Results

Clinical characteristics of pPNET

Twenty-three patients were included in this study, including 18 males (78.26%). The average age was 26.22±8.50 years (range, 12 to 41 years). Among their symptoms, 16/23 (69.6%) complained of local pain, 4/23 complained of a progressively enlarged mass, 2/23 complained of limb dyskinesia, and 1 patient with a kidney pPNET complained of hematuria.

All patients underwent surgical resection or biopsy. Among them, 9 patients underwent needle biopsy, and 14 underwent surgical resection; 18 patients received chemotherapy, and 9 patients received radiotherapy. As of August 2018, the average follow-up period was 3.5 years (range, 4 weeks to 7 years). The outcomes included death in 11 patients, relapse in 8 patients, and no recurrence in 6 patients.

^{18}F -FDG PET/CT characteristics of pPNET primary lesions

In all 23 pPNET patients, ^{18}F -FDG PET/CT showed a soft tissue mass with hypermetabolism (Table 1), and the detection rate of the tumor was 100%. The maximum diameter of the primary lesion was 7.64±2.39 cm (range, 4.00 to 12.20 cm), and the SUVmax was 11.27±3.80 (range,

5.50 to 21.10). Lesions with invasive growth and ill-defined borders were found in 17/23 (73.91%) patients. Lesions with heterogeneous density and heterogeneous increases in ^{18}F -FDG uptake were noted in 17/23 (73.91%) patients. Necrosis or cystic changes were observed in the lesions of 12/23 (52.17%) patients, and radioactive defects were found at the corresponding sites. No calcification was noted in any of the lesions. The lesions were located in bone [16/23 (69.57%) patients], muscle (2 patients), lung (1 patient), liver (1 patient), kidney (1 patient), testis (1 patient), and mediastinum tissue (1 patient).

In the 16 patients with pPNETs of bone tissue, the maximum diameter of the lesion was 7.46±2.41 cm (range, 4.30 to 12.20 cm), and the SUVmax was 10.01±3.10 (range, 5.50 to 16.00). Osteolytic bone destruction, osteogenic bone changes, and increased cortical density alone (no obvious bone destruction) were observed in 12/16 (75%), 2/16, and 2/16 patients, respectively. pPNETs of bone tissue were mainly located in the spine and its paravertebral tissue [5/16 patients, the tumor was located in the cervical vertebrae (2 patients), thoracic vertebrae (1 patient), lumbar vertebrae (1 patient), and sacrum (1 patient)], followed by the hip [(4/16 patients, the tumors were located in the ilium (2 patients) and ischium and pubic bone (2 patients)], skull [(3/16 patients, the tumors were located in the mandible (2 patients) and the sphenoid bone (1 patient)], chest wall (i.e., Askin tumor, 3/16 patients), and lower femoral metaphysis (1 patient). In 5 patients with pPNETs in the spine and its paravertebral tissue (Figure 1), the lesions had invaded the spinal canal via the adjacent intervertebral foramen; osteolytic bone destruction was observed in 4 patients, and osteogenic destruction was observed in

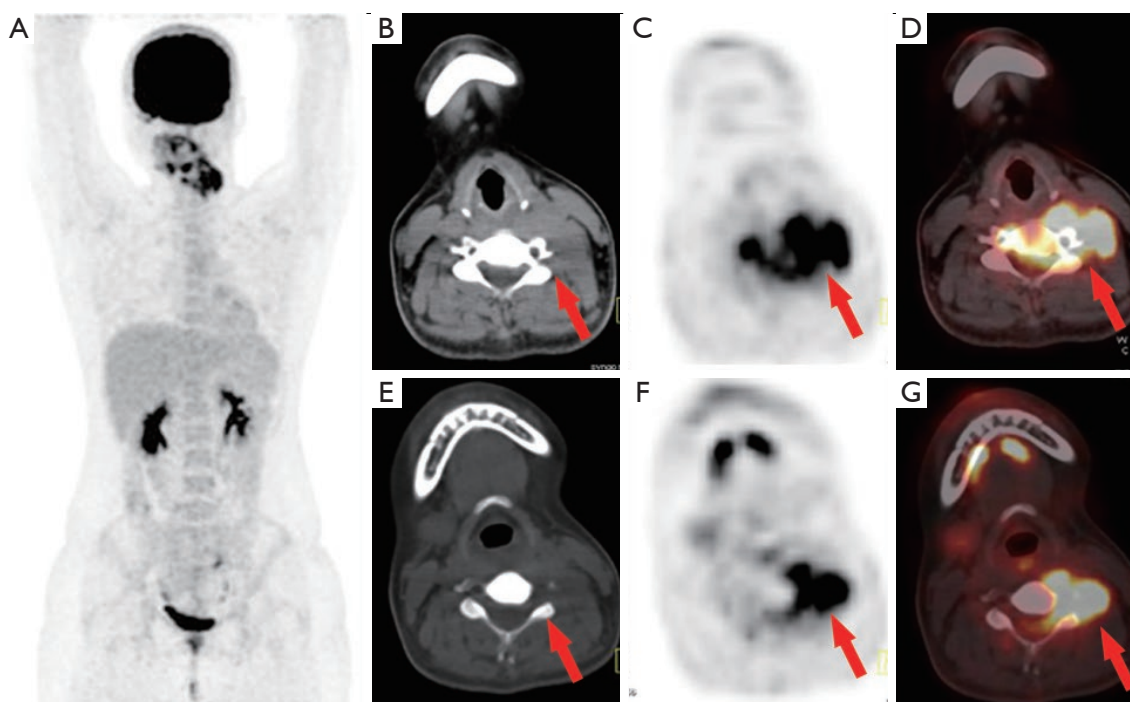


Figure 1 pPNET in a 20-year-old woman. The patient complained of palpating a soft mass in the left neck for 2 months. ^{18}F -FDG PET/CT showed a solitary pPNET lesion arising from the C3-6 vertebrae and its paravertebral tissue (A and arrows in B,C,D,E,F,G) with intense ^{18}F -FDG uptake (SUVmax, 9.4). The lesion had invaded the spinal canal via the adjacent intervertebral foramen and osteogenic destruction was observed. pPNET, peripheral primitive neuroectodermal tumor.

1 patient. Osteolytic bone destruction was present in 4 cases of pPNETs of the hip (Figure 2) and 3 cases in the skull. Askin tumors (Figure 3) were present as a single lesion with clear boundaries and compression of adjacent lung tissue in 3 patients, among these patients, osteolytic bone destruction and increased bone cortical density were observed in 2 patients and 1 patient, respectively. In 1 patient with a pPNET in the lower femoral metaphysis, only increased density of cortical bone was noted; no obvious bone destruction was observed.

In the 7 patients with pPNETs arising from non-skeletal organs, the maximum diameter for the primary lesion was 8.07 ± 2.48 cm (range, 5.80 to 11.00 cm) and SUVmax was 14.17 ± 3.87 (range, 10.6 to 21.1). The pPNETs arising from non-skeletal organs had significantly higher FDG uptake than those arising from bones ($P=0.012$). Among the pPNETs arising from non-skeletal organs, 5/7 showed infiltrated lesions with ill-defined borders, 4/7 showed homogeneous density and increased homogeneous metabolism, and only 2 showed necrosis.

^{18}F -FDG PET/CT characteristics of metastasis in Ppnet

Of the 23 patients, 10 (43.48%) showed metastasis at the time of diagnosis. The detection rate of metastatic lesions by ^{18}F -FDG PET/CT was 100%. Cases with metastasis showed higher FDG uptake (12.53 ± 3.06 vs. 10.31 ± 4.15 , $P=0.170$) than those without. However, they were similar in terms of the maximum diameter of the tumor lesion (8.25 ± 2.72 vs. 7.18 ± 2.11 cm, $P=0.297$). All cases with metastasis showed hematogenous metastases, including bones (7 cases), bilateral lungs (4 cases), liver (3 cases), vascular tumor thrombus (2 cases), and pericardium (1 case). Lymph node metastasis was observed in 13.0% (3/23) of patients, primarily arising from organs (the primary lesions were in the lung, mediastinum and testis respectively).

Patients with pPNETs arising from non-skeletal organs had much more metastasis than those with pPNETs arising from bones [6/7 (85.7%) vs. 4/16 (25%)] (Figure 4), and the metastasis mainly involved the lymph nodes (3 cases), bilateral lungs (3 cases), bones (3 cases) and liver (2 cases).

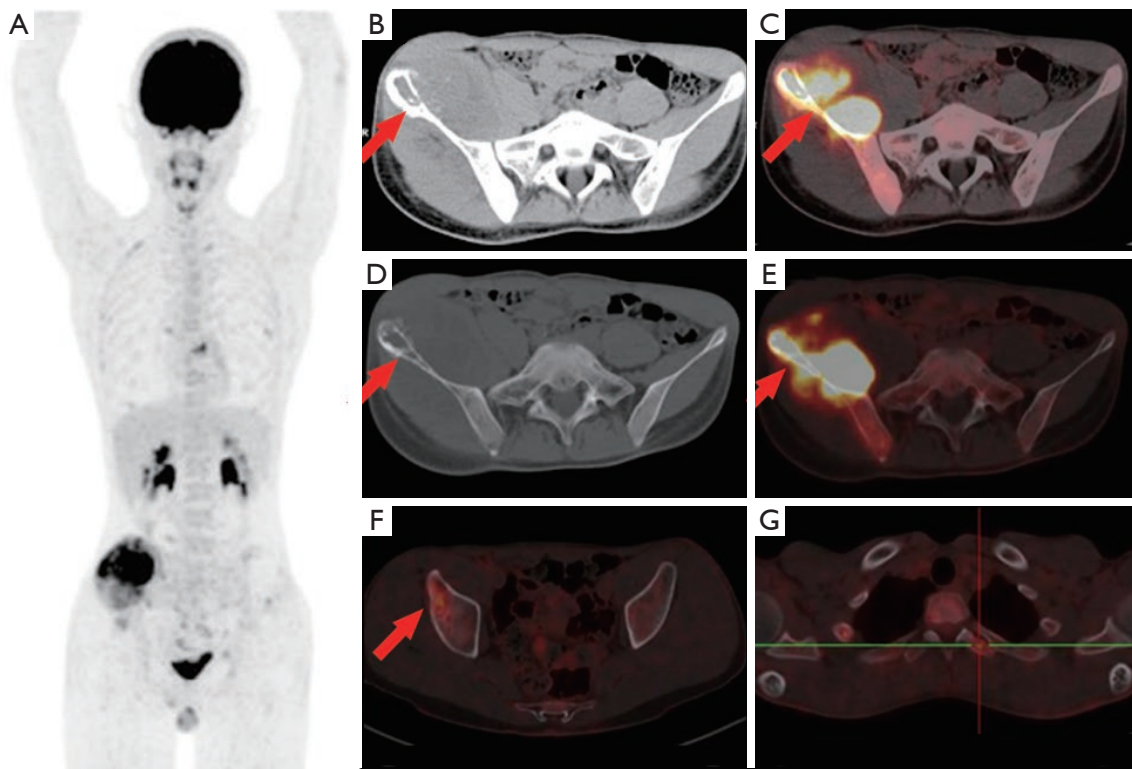


Figure 2 pPNET in a 17-year-old man. The patient complained of pain in the right buttock for 2 months. ^{18}F -FDG PET/CT showed a primary pPNET lesion with ill-defined border, invasion into the adjacent soft tissues and intense ^{18}F -FDG uptake (SUVmax, 14.2) in the right ilium (A and arrows in B,C,D,E). Osteolytic bone destruction was obvious in this primary bone pPNET. Multiple bone metastatic lesions were also revealed by ^{18}F -FDG PET/CT (arrow in F and cross arrow in G). pPNET, peripheral primitive neuroectodermal tumor.

One kidney pPNET case showed tumor thrombus in the left renal vein and left pulmonary artery (*Figure 5*). One liver pPNET case showed multiple intrahepatic metastases and inferior vena cava tumor thrombus. One pPNET case arising from the mediastinum showed lymph node metastasis and multiple pericardial metastases (*Figure 6*).

Pathological characteristics of pPNET

The pPNET lesions were composed of uniform small round cells with deep nuclear staining and obvious mitosis. The tumor cells were diffuse or scattered, and some were arranged into Homer-Wright rosettes. Immunohistochemical analysis of the 23 pPNET lesions revealed that 22 were positive for CD99, and the positive rates of Fli, Vim (vimentine), Syn (synaptophysin), NSE (neurospecific enolase) and CgA (chromogranin A) were 65.22% (15/23), 56.52% (13/23), 56.52% (13/23), 47.83% (11/23) and 21.74% (5/23), respectively. Two

groups were defined based on a Ki67 proliferation index cutoff of 50%. A high Ki67 index ($\text{Ki67} \geq 50\%$) accounted for 56.52% (13/23), and a low Ki67 index ($\text{Ki67} < 50\%$) accounted for 43.48% (10/23). The pPNET primary lesions with a high Ki67 index showed higher FDG uptake (12.74 ± 4.01 vs. 9.37 ± 2.61 , $P < 0.05$).

Discussion

Clinical and pathological characteristics of pPNETs

pPNETs are more common in children and adolescents (5,6,10,11). In this study, most of the patients were young men (the mean age was 26.22 years, and males accounted for 78.26% of all patients). Age differences among pPNET patients may be associated with differences in the origin of the tumor (12). The most common primary site of pPNETs was bone tissue (16/23, 69.57%), followed by the muscles (2 patients), lungs (1 patient), liver (1 patient), kidneys (1 patient), testis (1 patient), and mediastinum (1 patient).

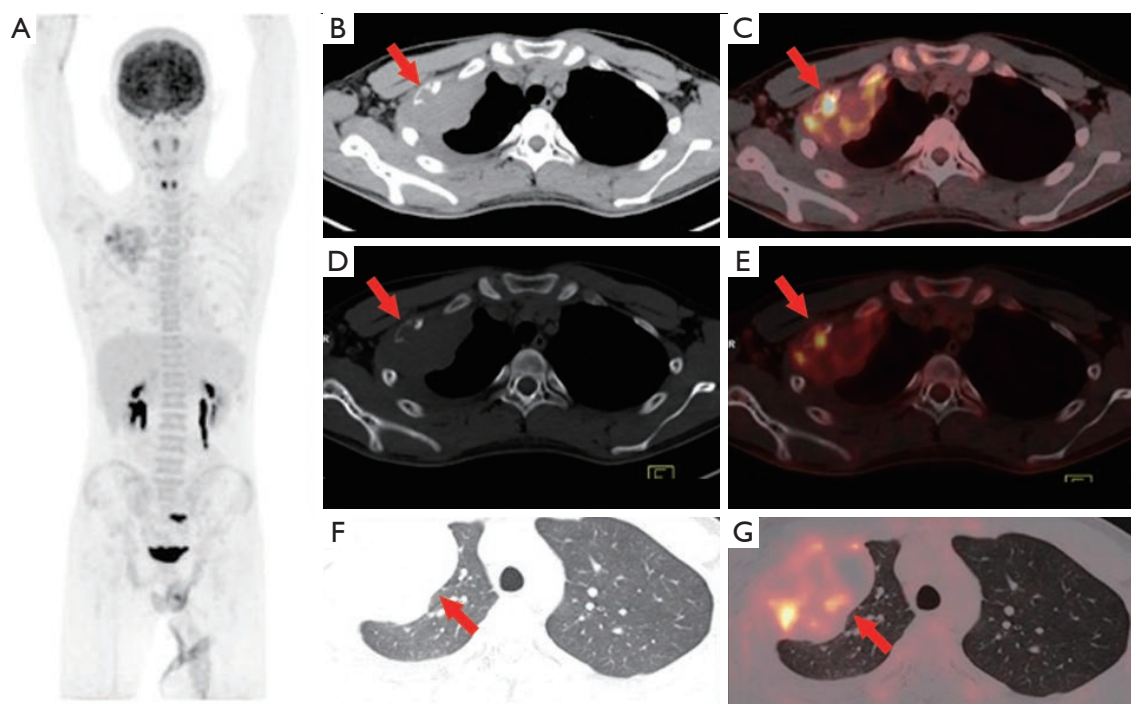


Figure 3 pPNET in a 16-year-old man. The patient complained of chest pain for 4 months. ^{18}F -FDG PET/CT displayed a single pPNET lesion arising from the right chest wall (i.e., Askin tumor) with well-defined boundaries, intense ^{18}F -FDG uptake (SUVmax, 8.6) and compression of adjacent lung tissue (A and arrows in B,C,D,E,F,G). The osteolytic bone destruction of the second rib was observed. pPNET, peripheral primitive neuroectodermal tumor.

pPNETs of bone tissue were more common in the spine and paravertebral tissue, followed by the hip, chest wall (Askin tumor), and skull. The primary site of pPNETs in this study is consistent with previous studies (10,11,14,15).

pPNETs belong to the family of malignant small round cell tumors, and their diagnosis depends on pathological and immunohistochemical results. The characteristic structure of a pPNET is Homer-Wright rosettes under the microscope (28). CD99, the product of MIC gene, is a relatively specific antibody for pPNET family tumors. In this study, the positive rate of CD99 was as high as 95%, whereas other markers of neural differentiation characteristics (such as Vim, Syn, NSE, CgA) showed various expression levels, consistent with previous studies (13,29).

^{18}F -FDG PET/CT characteristics of pPNET primary and metastatic lesions

^{18}F -FDG PET/CT is a new type of noninvasive imaging technique that has been widely used in the diagnosis of malignant tumors (30-32). ^{18}F -FDG is a glucose analog.

The uptake of ^{18}F -FDG by tumors can reflect the glucose metabolism, levels of glucose transporters (especially GLU-1 and GLU-3), and the expression level of hexokinase in the tumor (33,34). To date, the ^{18}F -FDG PET/CT imaging features of pPNETs have only been published in case reports (18-25) (see Table 2 for a summary). A soft tissue mass with high uptake of ^{18}F -FDG and the SUVmax ranging from 4.36 to 17.2 is observed in most pPNET lesions (18-24). Significantly high ^{18}F -FDG uptake by pPNET lesions was observed in all 23 patients reported in this study. The SUVmax was 11.27 ± 3.80 (range, 5.50 to 21.10), suggesting abnormally increased glycolysis in pPNET lesions. This study analyzed the correlation between the SUVmax and the Ki67 index (i.e., the tumor cell proliferation index) of pPNETs and found that a high Ki-67 index of pPNETs was associated with increased ^{18}F -FDG uptake. This result further suggests that the increased metabolism of pPNETs reflect their extremely active proliferation and high degree of malignancy. However, high uptake of ^{18}F -FDG may be not observed in all pPNET lesions. Musana *et al.* reported the absence of

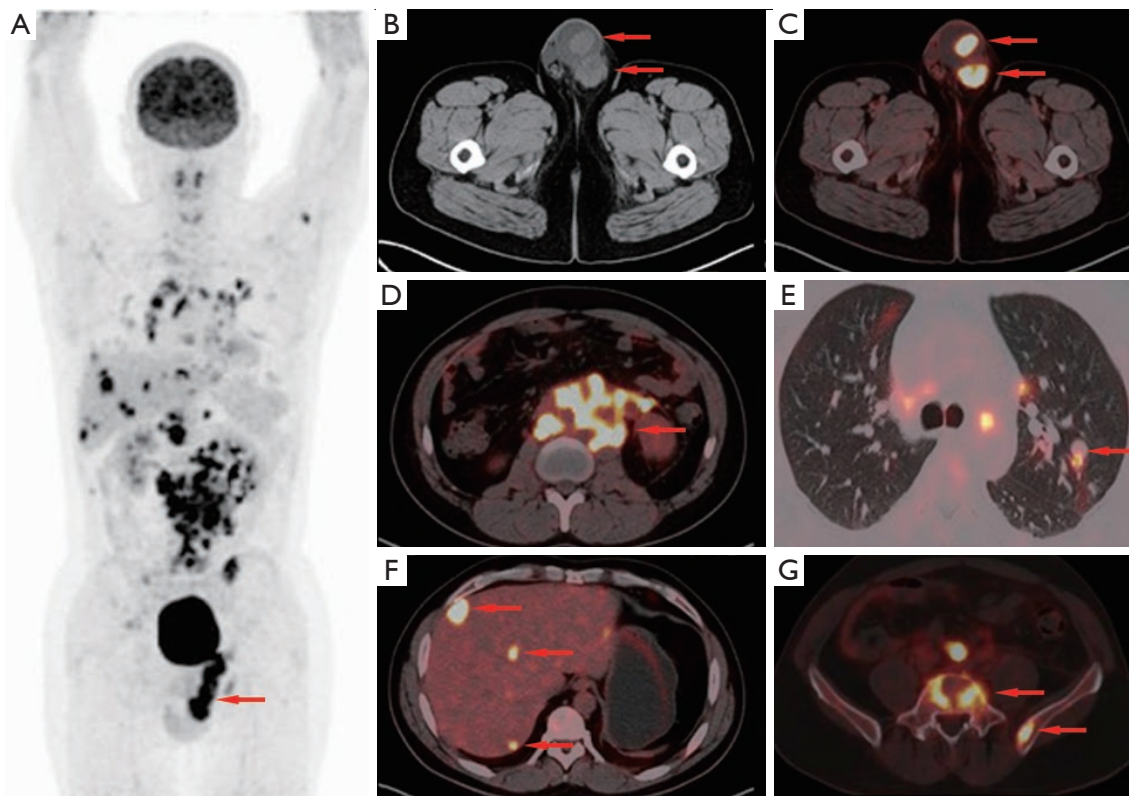


Figure 4 pPNET in a 36-year-old man. The patient complained of swelling of the left testis for 2 months. ^{18}F -FDG PET/CT revealed a primary pPNET lesion with intense ^{18}F -FDG uptake (SUVmax, 12.2) in the swollen left testis (arrows in B,C) with invasion into the left epididymis and the spermatic cord (arrows in A). Multiple metastases in lymph nodes (arrow in D), lung (arrow in E), liver (arrows in F) and bone (arrows in G) were observed. pPNET, peripheral primitive neuroectodermal tumor.

^{18}F -FDG uptake in a patient with a pPNET in the right arm and lung metastasis (25). This finding may be due to differences in the biological behavior and metabolism of pPNETs in different organs. In this particular case, the pPNET may exhibit low expression levels of GLU-1 and/or hexokinase II.

pPNETs are prone to early metastasis, which was observed in 43.48% (10/23) of patients in this study at the time of diagnosis. Lymph node metastasis of pPNETs is not common (15,18,24), and hematogenous metastasis to bone, lung, and liver tissue (4,11,25) is more prevalent and may cause vascular tumor thrombus (8,20) in some cases. Lymph node metastasis was reported in only 3 patients in this study. In contrast, hematogenous metastasis was observed in 10 patients, and bone tissue (7/23) was mainly involved, followed by the lungs (4/23), liver (3/23), vascular tumor thrombus (2/23) and the pericardium (1/23). Lymph node metastasis was observed in only 13.0% of patients. This study revealed that the metabolic rate of non-skeletal

primary pPNETs was significantly higher than that of pPNETs of bone tissue, and the incidence of metastasis of the former was significantly higher than that of the latter (85.7% *vs.* 25%). This finding strongly suggests that non-skeletal pPNETs are more malignant, proliferative, and prone to distant metastasis.

Advantages of ^{18}F -FDG PET/CT vs. CT or MRI

Previously, CT and MRI were the major methodologies for imaging studies of pPNETs (4,6,10-15). Both CT and MRI have shown that pPNETs are manifested as soft tissue masses with heterogeneous density, ill-defined borders, and cystic or necrotic areas and invasion into adjacent normal tissues (4,6,10-15). Calcification is very rare (11,13). MRI shows an isointense or hypointense mass on T1 weighted imaging (WI) and a hyperintense mass on T2WI (4,6,10,13). Enhanced CT and T1WI display heterogeneous enhancement of the mass (4,6,10,12-14). In this study,

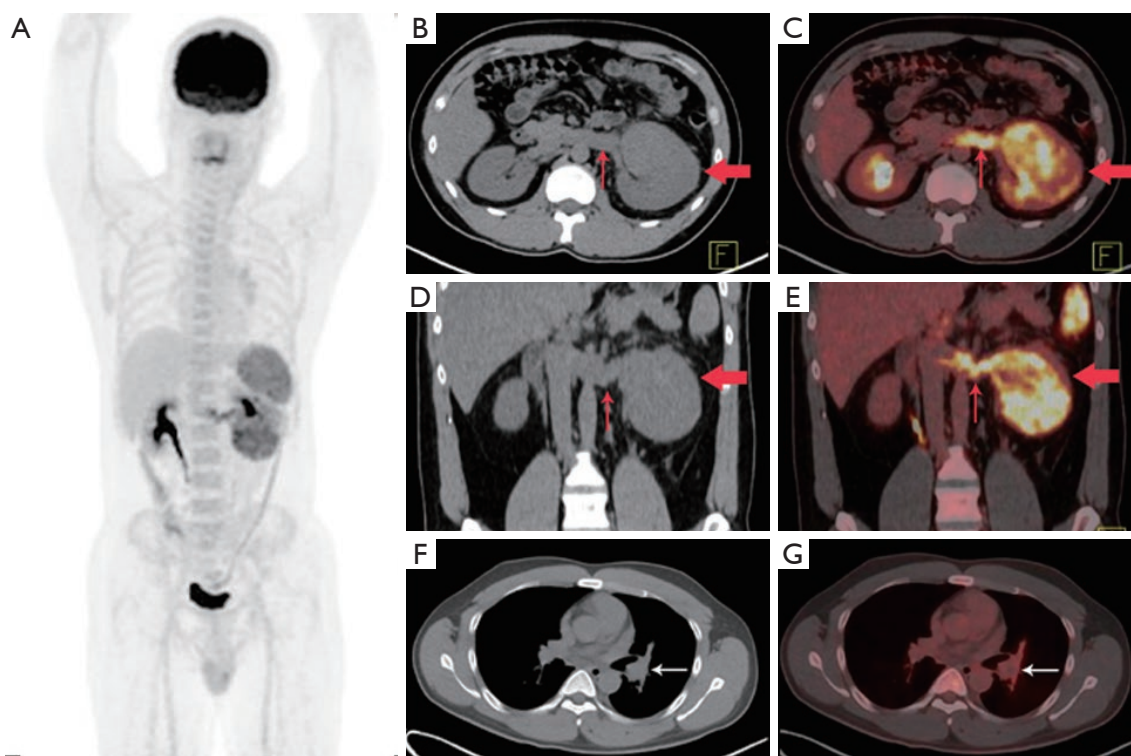


Figure 5 pPNET in a 26-year-old man. The patient complained of hematuria for 10 days. ^{18}F -FDG PET/CT revealed a primary pPNET lesion with an ill-defined border, heterogeneous density and intense ^{18}F -FDG uptake (SUVmax, 10.6) in the left kidney (A and thick red arrows in B,C,D,E), and tumor thrombus in the left renal vein (thin red arrows in B,C,D,E) and left pulmonary artery (arrows in F,G). pPNET, peripheral primitive neuroectodermal tumor.

^{18}F -FDG PET/CT showed that the primary pPNET lesion was a large soft tissue mass (average diameter, 7.64 cm); 73.9% of lesions showed ill-defined borders, heterogeneous density, and invasion into adjacent tissues, and 52.17% of lesions showed cystic changes or necrosis. No lesions exhibited calcification. Therefore, PET/CT is not inferior to CT and MRI in terms of identifying the location, extent, boundary, density, presence or absence of cystic/necrosis, and relationship with adjacent tissues in the primary lesions. However, PET/CT can more intuitively reflect the biological behavior of the tumor due to varying degrees of ^{18}F -FDG uptake in pPNET primary lesions and has advantages for the detection rate of the lesions and the determination of benign and malignant tumors.

In addition, ^{18}F -FDG PET/CT allows whole-body imaging and is significantly better than CT and MRI for the detection of distant metastases. In particular, rapid and accurate detection of metastatic lesions has important clinical value in the treatment of pPNETs because they exhibit a high degree of malignancy and early metastasis. In

this study, at the time of diagnosis, metastatic pPNETs were identified in 10 patients by ^{18}F -FDG PET/CT, which had an important impact on treatment decisions.

Additionally, ^{18}F -FDG PET/CT can simultaneously display the metabolic rates of primary and metastatic pPNET lesions and play an important role in the efficacy evaluation and follow-up (20,21). In this study, 5 patients with pPNETs underwent ^{18}F -FDG PET/CT for systemic examination after surgery and/or chemoradiotherapy (between 3 months and 2 years). No obvious signs of recurrence were noted in 2 patients. The volume and FDG uptake of primary or metastatic lesions was significantly reduced in 2 patients, suggesting that the tumors were significantly suppressed or inactivated. One patient had obvious signs of recurrence and was treated with re-operation and repeat chemotherapy.

Conclusions

The significant characteristics of ^{18}F -FDG PET/CT

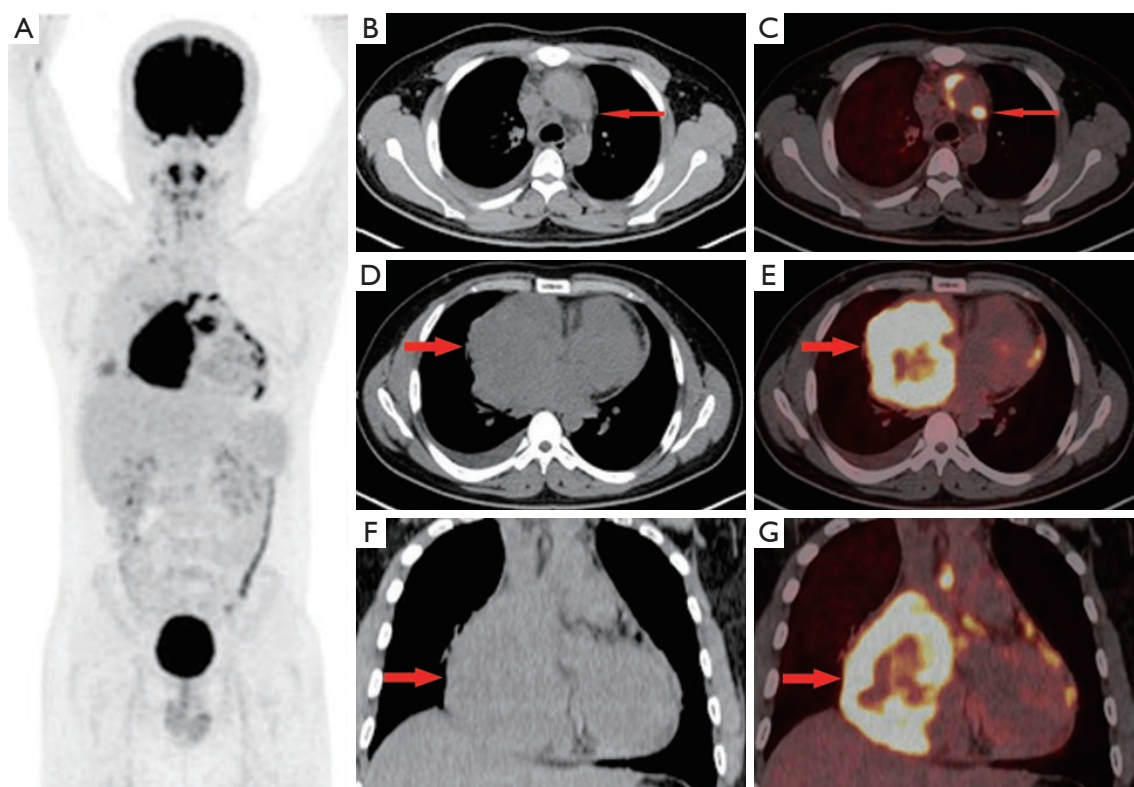


Figure 6 pPNET in a 24-year-old man. The patient complained of chest pain for 1 month. ^{18}F -FDG PET/CT showed a large, ill-defined soft mass with necrotic or cystic foci and intense ^{18}F -FDG uptake (SUVmax, 13.4) in the right mediastinum (A and arrows in D,E,F,G). Multiple lymph nodes metastases (arrows in B,C) and extensive pericardium metastases (D,E,F,G images) were also observed on ^{18}F -FDG PET/CT. pPNET, peripheral primitive neuroectodermal tumor.

Table 2 Previous PET/CT findings of pPNET

Reference	Sex/age	Location	Dmax	CT characteristics	SUVmax	LN-M	Distant M
Yu (18)	F/24 y	Ileal	NA	Pelvic ileal wall thicken	12.3	+	–
Dong (19)	F/35 y	Retroperitoneum	19.0 cm	A large cystic-solid lesion	17.2	–	–
Aras (20)	M/19 y	Gastric	NA	A large gastric mass (corpus and antrum)	11.5	–	Portal venous tumor thrombus
Mao (21)	M/28 y	Both lungs	7.0 cm	Multiple heterogeneous soft tissue masses	5.3	–	–
Kara Gedik (22)	M/73 y	Pleural	7.0 cm	Pleural-based tumor in the left lung	4.36	–	–
Demir (23)	M/17 y	Right chest wall	10.0 cm	A circumscribed soft tissue mass	8.3	–	–
Kamaleshwaran (24)	M/18 y	Right chest wall	NA	A large soft-tissue mass with lytic lesion	Hypermetabolic*	+	–
Musana (25)	F/36 y	Right upper extremity	11.0 cm	A soft-tissue mass	–	–	Lung

NA & *, detailed data was not provided. F, female; M, male; Dmax, the largest diameter of the lesion; SUVmax, the maximum standard uptake value; LN, lymph node; M, metastases; –, negative; +, positive.

imaging of pPNETs include primary lesions are soft tissue masses with a significantly high FDG uptake and ill-defined borders, heterogeneous density, and invasion into adjacent tissues. Necrosis or cystic changes are observed in some cases, and lesions are free of calcification. pPNETs are prone to early metastasis. The ¹⁸F-FDG uptake of metastatic lesions is significantly increased. Hematogenous metastasis to bone, lung, and liver tissue is common, but lymph node metastasis is rare. ¹⁸F-FDG PET/CT can easily detect pPNETs, but the final diagnosis relies on pathological and immunohistochemical examinations. However, ¹⁸F-FDG PET/CT can clearly show the location, extent, boundary, density, presence or absence of cystic changes/necrosis, relationship with adjacent tissues and organs, and metabolic status of the primary lesions; thus, it can be used to comprehensively evaluate lymph node and distant metastasis. Compared to traditional CT imaging and MRI, ¹⁸F-FDG PET/CT has significant advantages for assessing the possibility of tumor resection, degree of systemic metastasis, therapeutic efficacy, postoperative residual tumor, and recurrence.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/tcr.2018.12.24>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The institutional review board of Nanfang Hospital at the Southern Medical University approved the present retrospective study and waived the requirement for written informed consent due to the retrospective nature of the study.

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