MRI and ^{18}F-FDG PET/CT findings of a giant cell tumor of the tendon sheath of the knee joint (pigmented villonodular synovitis): A case report and literature review

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Abstract
We present a case of a 33-year-old female hospitalized with a 3-month history of right knee pain when squatting. Her physical examination showed no resting pain or local skin fever. Magnetic resonance imaging (MRI) showed multiple nodular long T1 and short T2 abnormal signal shadows in the popliteal fossa region. A patchy T2 high signal shadow was found in the soft tissue around the right knee. Fluorine-18-fluorodeoxyglucose positron emission tomography/computed tomography (^{18}F-FDG PET/CT) revealed multiple soft tissue density nodules around and within the right knee joint (largest 20x13mm) with a maximum standardized uptake value (SUVmax) of 10.5 and a delayed SUVmaxof 12.0. The subsequent histopathologic examination confirmed the diagnosis of a diffuse giant cell tumor of the tendon sheath(GCTTS) and pig-mented villonodular synovitis (PVNS).

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Introduction

Pigmented villonodular synovitis(PVNS) is a proliferative lesion of the synovium that often presents as localized nodules and may originate from the synovium, tendon sheath, fascial layer or ligament tissue. Pigmented villonodular synovitis is a rare disease of unknown etiology with a prevalence of 1.8 per million [1, 2]. The pathological features of PVNS are hyperangiogenic synovium with multinucleated giant cells, macrophages and hemosiderin. Multinucleated cells express the characteristics of osteoclasts. Progressive sarcoidosis near or within the joint limits joint function and may damage adjacent bones [3]. X-rays may show the extent of bone erosion. Magnetic resonance imaging (MRI) showed a lack of signal features on T1 and T2 images, which were attributed to the presence of a large amount of hemosiderin in the synovium [4]. Positron emission tomography/computed tomography (PET/CT) revealed abnormally increased glucose metabolism. Although it is difficult to differentiate from malignant tumors, PET/CT can evaluate the whole body, stage the lesions and guide further treatment decisions [5-9].The main treatment for PVNS is resection of the lesion. Although marginal resection represents the best treatment for local giant cell tumor of the tendon sheath (TGCTS), diffuse TGCTS are more difficult to eradicate and are best treated by total or near total synovectomy [10].

Case report

A 33-year-old female was hospitalized with a 3-month history of right knee pain when squatting. Three months ago, she suffered from pain in her right knee when squatting. She was able to bear the pain without any treatment. However, the symptoms were not relieved, and the flexion movement of the right knee was limited. Her physical examination showed no resting pain or local skin fever. There was no significant family history or personal history.

Magnetic resonance imaging showed an effusion shadow in the right knee cavity and suprapatellar capsule. Multiple nodular long T1 and short T2 abnormal signal shadows were seen in the popliteal fossa region, and the articular surface cartilage signal was not

uniform. A patchy T2 high signal shadow was found in the soft tissue around the right knee (Figure 1).

According to the MRI image description, the diagnosis was as follows: Multiple abnormal signal images in the right knee bursa, possibly synovial chondroma.

In order to further define the nature of the lesion and excludewhole bodydisease, and the patient proposed the requirement of a systematic health examination, ^{18}F-FDG PET/CT examination was recommended.

Positron emission tomography/CT showed multiple soft tissue density nodules of different sizes around and within the right knee joint, with a clear boundary, the largest size of approximately 20x13mm, abnormal radioactive concentration, maximum standardized uptake value (SUVmax) 10.5, and delayed SUVmax 12.0.A slight band radioactivity concentration shadow was seen around the joint, and an arc watery density shadow was seen in the posterior patellar capsule (Figure 2).

The diagnostic comments of PET/CT are as follows: Multiple nodular nodules of soft tissue density around and within the right knee joint with abnormal increase in glucose metabolism and the possibility of nodular synovitis or synovial osteochondroma accompanied by inflammatory changes in the right knee joint and effusion in the posterior patellar sac were considered. A needle biopsy was recommended for hypermetabolism of the lesion.

Two days later, the patient underwent arthroscopy and synovectomy under spinal anesthesia. Synovial hyperplasia, a large amount of yellow pigmentation and a few nodular synovium were seen in the joint cavity during the operation; yellow pigmented synovium was seen in the posterior joint capsule and was sent for pathological examination after resection.

Pathological examination confirmed a diffuse giant cell tumor of the tendon sheath and pigmented villonodular synovitis (Figure 3).

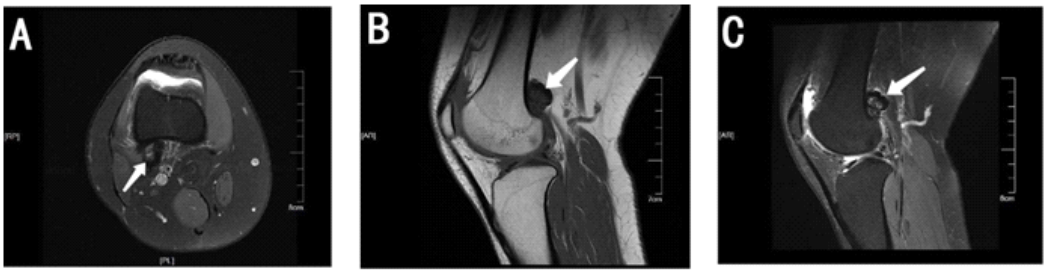

Figure 1. Magnetic resonance imaging revealed multiple nodular long T1 and short T2 abnormal signal shadows were seen in the popliteal fossa region (white arrow). A patchy T2 high signal shadow was found in the soft tissue around the right knee.

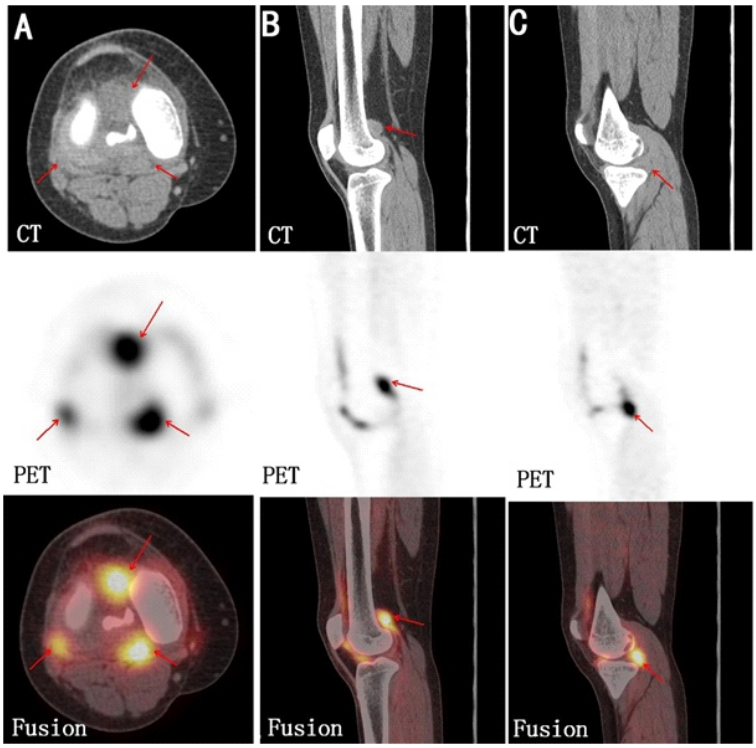

Figure 2. Positron emission tomography/CT showed multiple soft tissue density nodules (red arrow) of different sizes around and within the right knee joint, with a clear boundary, the largest size of approximately 20x13mm, abnormal radioactive concentration, SUVmax10.5, and delayed SUVmax12.0.

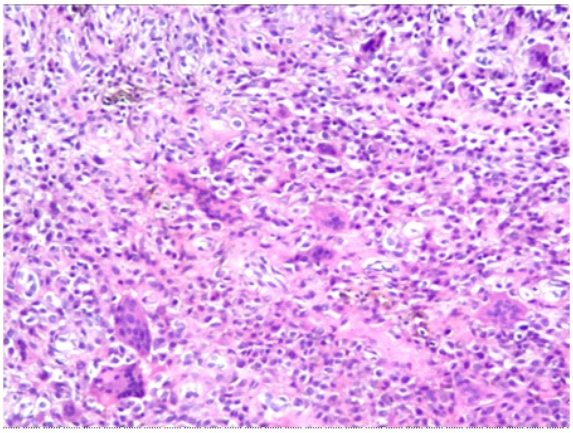

Figure 3. A biopsy confirmed a diffuse giant cell tumor of the tendon sheath and pigmented villonodular synovitis (×20).

Table 1. *Review of the literature on the imaging characteristics of PVNS or GCTTS detected by ^{18}F-FDG PET/CT.*

Patient	Age/ Gender	Diagnosis	Location	Concurrent disease	SUVmax	References
1	33F	PVNS	Right knee joint	NR	12.0	
2	66M	PVNS	Near the anterior left humeral head	Diffuse large B cell lymphoma	13.0	[11]
3	46M	PVNS	Vastus medialis tendon	NR	15.1	[12]
4	60F	PVNS	Right anterior glenoid	Tonsillar squamous cell carcinoma	6.0	[13]
5	74F	D-GCTTS	Right shoulder	NR	19.2	[14]
6	39F	D-GCTTS	Thoracic Spine	NR	9.9	[15]
7	33F	D-GCTTS	Right sacroiliac joint	NR	13.8	[16]
8	43M	D-GCTTS	Left hip joint	NR	22.2	[16]
9	33F	D-GCTTS	Left T9 facet	Papillary thyroid carcinoma	7.1	[17]
10	59M	D-GCTTS	Subscapularis muscle	mantle cell lymphoma	8.3	[18]
11	74F	D-GCTTS	Temporomandibular joint	NR	19.8	[19]
12	63F	D-GCTTS	Popliteal fossa	Melanoma	7.8	[5]
13	72M	PVNS or GCTTS	Lateral compartment of the right knee	Melanoma	25	[6]

(continued)

14	50M	GCTTS	Temporal Bone	Chondroid Metaplasia	6.4	[20]
14	41F	GCTTS	Right shoulder joint	Invasive intraductal breast carcinoma	11.8	[21]
15	45F	Localized GCTTS	First cervical spine	Choroidal melanoma	9.9	[7]
16	15M	Localized GCTTS	Mediastinum, extra-articular left hip	Multiple neurofibromatosis	12.8	[7]
17	58M	PVNS	R shoulder	Melanoma	NR	[8]
18	71M	Localized PVNS	L knee	Melanoma	5.6	[9]
19	41F	GCTTS	Rknee (gastrocnemiustendonsheath)	Melanoma	13.7	[9]
20	62M	PVNS	RL5/S1facet	Tonsillarsquamous cell	14.5	[9]
21	26F	Localized PVNS	Rknee	Melanoma	NR	[9]
22	74F	Localized PVNS	Lknee	Melanoma	6.9	[9]
23	56F	Localized PVNS	Rhip	Melanoma	11.8	[9]
24	49M	GCTTS	Lhip(obturatorexternustendonsheath)	Melanoma	6.1	[9]
25	67M	GCTTS	Rfoot(flexordigitorumtendonsheath)	Melanoma	11.5	[9]
26	60F	GCTTS	Rknee(gastrocnemiustendonsheath)	Papillarythyroid, Breastadenocarcinoma	8.7	[9]
27	46F	GCTTS	Lshoulder(teres Majortendonsheath)	Pulmonary squamous cell	4.8	[9]
28	33F	GCTTS	Lhip(quadratusfemoristendonsheath)	Ratrialmass,hypereosinophilia	9.5	[9]
29	57F	Localized PVNS	Lknee	Merkelcell	5.8	[9]
30	43F	Localized PVNS	Rhip	Colon adenocarcinoma	4.0	[9]
31	54M	GCTTS	Rhip(gluteusminimustendonsheath)	Melanoma	9.5	[9]

GCTTS,giant cell tumor of the tendon sheath; PVNS,pigmentedvillonodular synovitis; D-GCTTS,diffuse-GCTTS; L,left; R,right; NR,not reported； T9,ninth thoracic vertebra； L5/S1,5th lumbar vertebra/1st sacral vertebra;M,male;F,female.

Discussion

Giant cell tumor of the tendon sheath is a rare but recognized proliferative lesion of synovial tissue. There are two types: diffuse and localized GCTTS. Diffuse GCTTS (D-GCTTS) is also called PVNS [22]. Limited GCTTS almost always involves a single joint; the knee and foot are most often affected, while the shoulder, wrist, hand and hip are less affected. The onset age of D-GCTTS is younger than that of localized GCTTS (at less than 40 years old). The main symptoms are swelling (86%), pain (82%), stiffness (73%), limited movement (64%) and joint instability (64%) [3].

Previous studies show that MRI has important diagnostic value in PVNS, but pathology is still the gold standard of final diagnosis. On T1 and T2 images, hemosiderin showed low or no signal. The most typical MRI feature of PVNS is a nodular mass with low signal intensity on T1, T2 and proton images [4]. The lesion synovium and focal mass showed the best signal on T2 images, showing a low signal area. This is due to hemosiderin deposition [4]. On T1 images, the lesions were hypointense. Hemorrhagic synovitis may be confused with PVNS.

Fluorine-18-FDG PET/CT is a very sensitive imaging method that is used to detect, stage and evaluate the treatment response of malignant tumors. Although malignant tumors tend to show a stronger uptake of ^{18}F-FDG, ^{18}F-FDG is not tumor specific, which will lead to a variety of potential misinterpretations. Stephen et al. (2016) [9] reported the PET/CT imaging features of 14 patients with PVNS. The mean SUVmax of all lesions was 8.7. In our case, multiple soft tissue nodules of different sizes with clear boundaries were found on CT. On PET images, ^{18}F-FDG uptake was increased, and delayed imaging was higher. Because the lesion is limited to the knee joint, it is relatively easy to determine the nature of the lesion. However, if combined with other malignant tu-mors, PVNS is easily misdiagnosed as metastasis.

We performed electronic literature searches of the Pub Med, Embase and Cochrane Library databases for English-language articles from the earliest available date of indexing through 31 March 2021. The following key words were used for the selection of studies: ^{18}F-FDG, PET, PVNS or GCTTS. All English case reports of ^{18}F-FDG PET/CT for PVNs or GCTTs were included in the analysis. Finally, we found that there were 16 articles that met the criteria, and a total of 30 patients were diagnosed as PVNs or GCTT after using PET/CT (Table 1). Among them, 12 cases [5-9] were complicated with malignant melanoma. Because the metabolism of ^{18}F-FDG uptake in metastatic lesions of malignant melanoma is increased and PVNS also takes up^{18}F-FDG, it is difficult to correctly distinguish the two in the evaluation of PET/CT images. Pathological biopsy results can correctly differentiate malignant melanoma from PVNS. Comfort et al. (2016) [11] reported that a patient with lymphoma had abnormal ^{18}F-FDG uptake at the shoulder joint during PET/CT evaluation of the curative effect, with an SUVmax of 13.0. At that time, it was thought that the shoulder joint was involved in lymphoma, but MRI confirmed that it was PVNS. Paul et al. (2013) [12] thought that even if PET imaging detected high SUV lesions are not necessarily malignant, benign lesions can also show this high metabolism.

With the advent of biotherapy, the number of PET imaging cases of PVNS may increase. PVNS is similar to malignant/metastatic entities, showing significantly high metabolic activity, and its activity will be appropriately reduced in the context of targeted therapy [23]. In the case of recurrent disease, PET/CT is used to evaluate the biological activity of the lesion before and after treatment. Recurrent PVNS showed higher metabolic activity than previously recorded, which supports that this patient may have mimicking malignant/metastatic disease. The evaluation after treatment showed that the metabolic activity decreased, indicating that the treatment was effective. This behavior further supports the argument that PVNS may have a tumor origin [23].

In conclusion, both PVNS and GCTTS show strong ^{18}F-FDG hypermetabolism, which can simulate musculoskeletal metastasis on ^{18}F-FDG PET/CT images. Both PVNS and GCTTS show significant increases in metabolic activity in a series of tests, both in the context of aggressive untargeted chemotherapy and between treatments. Considering this and the rarity of intra-articular metastasis, patients with intra-articular focal ^{18}F-FDG-avid uptake on ^{18}F-FDG PET/CT should also be evaluated for GCTTS or PVNS.

The authors declare that they have no conflicts of interest.

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