Annals of Nuclear Medicine
https://doi.org/10.1007/s12149-020-01449-8

OTHERS

Expert Consensus on clinical application of FDG PET/CT in infection and inflammation

Yaming Li[1] · Qian Wang[2] · Xuemei Wang[3] · Xuena Li[1] · Hua Wu[4] · Quanshi Wang[5] · Zhiming Yao[6] · Weibing Miao[7] · Xiaohua Zhu[8] · Fengchun Hua[9,10] · Xiaoli Zhang[11] · Chao Cheng[12] · Weifang Zhang[13] · Qingyi Hou[14] · Yuan Li[2] · Xiao-Feng Li[15]

Received: 13 January 2020 / Accepted: 9 February 2020

Abstract

To further promote the clinical application of ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) in infection and inflammation and standardize the diagnostic process, the experts in relevant fields in China carried out discussion and formed the Expert Consensus on the clinical application of FDG PET/CT in infection and inflammation. This consensus is intended to provide a reference for imaging physicians to select a reasonable diagnostic plan. However, it should be noted that it couldn't include or solve all the problems in clinical operation. Imaging physicians and technicians should develop a comprehensive and reasonable diagnostic procedure according to their professional knowledge, clinical experience and currently available medical resources when facing specific patients.

Keywords Fluorodeoxyglucose · Positron emission tomography/computed tomography · Infection · Inflammation

Yaming Li and Qian Wang contributed equally to this work.

✉ Yaming Li
ymli2001@163.com

✉ Qian Wang
wangqian20135@163.com

1 Department of Nuclear Medicine, the First Hospital of China Medical University, No.155 Nanjing North Street, Heping District, Shenyang, Liaoning 110001, People's Republic of China

2 Department of Nuclear Medicine, Peking University People's Hospital, No.11 Xizhimen South Street, Xicheng District, Beijing 100044, People's Republic of China

3 Department of Nuclear Medicine, Affiliated Hospital of Inner Mongolia Medical University, No.1 Tongdao North Street, Huimin District, Hohhot 010050, People's Republic of China

4 Department of Nuclear Medicine and Minnan PET Center, Xiamen Cancer Hospital of the First Affiliated Hospital of Xiamen University, No.55 Zhenhai Street, Siming District, Xiamen 361003, People's Republic of China

5 PET Center, Nanfang Hospital, Southern Medical University, No.1838 North Guangzhou Avenue, Baiyun District, Guangzhou 510515, People's Republic of China

6 Department of Nuclear Medicine, Beijing Hospital, National Center of Gerontology, No.1 Dongdan Dahua Street, Dongcheng district, Beijing 100730, People's Republic of China

7 Department of Nuclear Medicine, the First Affiliated Hospital of Fujian Medical University, No.20 Chazhong Street, Fuzhou 350005, People's Republic of China

8 Department of Nuclear Medicine, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, No. 1095 Jiefang Avenue, Wuhan 430030, People's Republic of China

9 PET Center, Huashan Hospital, Fudan University, 518 East Wuzhong Road, Shanghai 200235, People's Republic of China

10 Department of Nuclear Medicine, Longhua Hospital, Shanghai University of Traditional Chinese Medicine, 725 South Wanping Road, Shanghai 200032, People's Republic of China

11 Department of Nuclear Medicine, Beijing Anzhen Hospital, Capital Medical University, No.2 Anzhen Street, Chaoyang District, Beijing 100029, People's Republic of China

12 Department of Nuclear Medicine, Shanghai Changhai Hospital of the Second Military Medical University, No.168 Changhai Road, Yangpu District, Shanghai 200433, People's Republic of China

13 Department of Nuclear Medicine, Peking University Third Hospital, No.49 North Garden Road, Haidian District, Beijing 100191, People's Republic of China

14 Department of Nuclear Medicine, WeiLun PET Center, Guangdong Provincial People's Hospital and Guangdong Academy of Medical Sciences, No. 106 Zhongshan Second Street, Yuexiu District, Guangzhou 510080, People's Republic of China

15 Department of Nuclear Medicine, Shenzhen People's Hospital, No. 1017 Dongmen North Street, Luohu District, Shenzhen 518020, People's Republic of China

Published online: 21 February 2020

Introduction

^{18}F-2-Fluoro-2-deoxyglucose (^{18}F-FDG) positron emission tomography/computed tomography (PET/CT) is a non-invasive diagnostic imaging technique that displays local metabolic activity, and its oncological application has been widely recognized, while its clinical application in infection and inflammation needs to be further promoted. In recent years, there is increasing evidence that FDG PET/CT has unique value in the diagnosis and treatment of various infections and non-infectious inflammations. FDG PET/CT could timely identify the lesions of infection or inflammation before conventional imaging shows morphological changes, determine the extent and severity of active inflammatory lesions, help select the appropriate tissue biopsy site, and assess the therapeutic effect. To further promote the clinical application of FDG PET/CT in infection and inflammation and to standardize the diagnostic process, the PET/CT non-tumor application development work committee of Chinese Society of Nuclear Medicine organizes experts in relevant fields in China to carry out discussion and form the Expert Consensus on the Clinical Application of FDG PET/CT in Infection and Inflammation. This consensus is intended to provide a reference for imaging physicians to select a reasonable diagnostic plan. However, it should be noted that it couldn't include or solve all the problems in clinical operation. Imaging physicians and technicians should develop a comprehensive and reasonable diagnostic procedure according to their professional knowledge, clinical experience and currently available medical resources when facing specific patients.

The concept of infection and inflammation

Inflammation is a broad concept that refers to the complex defense responses to injurious agents that occur in the living tissues of the body with a vascular system. Factors that can cause inflammation include physical factors (such as high temperature, low temperature, ultraviolet radiation, electric shock, cutting or extrusion, etc.), chemical factors (including exogenous chemicals and endogenous toxins) and biological factors (various pathogens). The basic pathological changes of inflammation are local tissue degeneration, exudation and hyperplasia, showing local symptoms of redness, swelling, heat, pain and dysfunction, and may be accompanied by systemic symptoms of varying degrees of fever, fatigue, metabolic enhancement, etc., while there are systemic reactions such as leukocytosis, monocyte−macrophage system hyperplasia and increased serum inflammatory factors. The injury and anti-injury effects of inflammatory process exist at the same time. On one hand, inflammatory factors directly or indirectly cause the destruction of tissues and cells, on the other hand, inflammatory factors can be diluted, killed and surrounded by inflammatory hyperemia and exudation reactions, and the damaged tissues can be repaired and healed through the regeneration of parenchyma and interstitial cells [1, 2].

Infection is a type of inflammation, especially the inflammatory response caused due to biological agents invading and interacting with the body. Pathogenic microorganisms, including bacteria, viruses, rickettsia, protozoa, fungi, spirochetes and parasites, invade the human body through contact transmission, blood transmission, air transmission and other means, some of them may be infectious, and toxemia or sepsis may occur in severe cases [1, 2]. Antibiotics or antivirals should be used for the treatment of infection according to the different pathogens. However, antimicrobial therapy is not effective for the non-infectious inflammation.

Non-infectious inflammation usually refers to autoimmune diseases, which are also widely defined and easily lead to semantic ambiguity. Autoimmune disease is a kind of systemic disease with damage to skin, joints, blood vessels and other systems, and it is also known as connective tissue disease, rheumatic disease or rheumatism, since it mainly involves the connective tissue. For the treatment of these diseases, the current clinical treatment is mainly through non-steroidal anti-inflammatory drugs, glucocorticoids and immunosuppressive agents and other means of suppression of excessive inflammatory response, reduction of disease symptoms, prevention of dysfunction and other adverse events [1, 2]. In addition, inflammation caused by physical or chemical factors is also non-infectious inflammation, and physical therapy can also be used to help alleviate the clinical symptoms.

Thus, in the diagnosis and treatment of infectious and non-infectious inflammatory diseases, identifying the cause is related to the establishment of treatment. The clinical diagnosis of various infectious and non-infectious diseases is mainly based on the patient's medical history, symptoms, physical examination, laboratory tests and imaging examinations, and histopathological examination is also an essential means of definitive diagnosis.

FDG inflammation imaging mechanism

Warburg OH proposed that malignant cells preferentially generate more energy than normal cells through the non-oxidative breakdown of glucose, and this "Warburg-effect" became the basis of the use of ^{18}F-FDG for tumor imaging. Another interesting phenomenon observed by Kubota R et al. was that not only the tumor cells but also the non-neoplastic cellular element would accumulate FDG, and these inflammatory cells demonstrated greater FDG uptake than tumor cells [3]. The earliest changes in inflammation are tissue hyperemia, enhanced vascular permeability, and release of inflammatory mediators, while increased tissue

blood perfusion results in greater FDG delivery to the lesion site; as inflammatory cells recruit, migrate and proliferate at the site of inflammation, large amounts of cytokines are released, with an up-regulation of glucose transporters (especially GLUT1 and GLUT3) and increased hexokinase (subtype A) activity, which result in enhanced glucose metabolism and FDG uptake in inflammatory cells. Thus, from the perspective of potential metabolic pathways, there is a similar imaging mechanism between inflammatory cells and malignant tumor cells. In addition, there is a significant linear correlation between the FDG uptake and the density of inflammatory cells in both acute and chronic inflammation, and the complex interaction of multiple factors in the inflammatory process can lead to a sustained increase in FDG uptake at sites of active inflammatory lesions. Therefore, the location, extent, and severity of inflammatory lesion involvement can be demonstrated by detection with PET/CT imaging devices [4].

Clinical Indications

Currently, the application of FDG PET/CT in infection and inflammation is still in the stage of rapid development. The experts in relevant fields in China refer to the EANM/SNMMI guideline, for ^{18}F-FDG use in inflammation and infection, published by the society of nuclear medicine and molecular imaging (SNMMI) and European association of nuclear medicine (EANM) in 2013 [5], and further combined them with the domestic and international clinical research results and application status in recent years to propose the recommended indications in clinical application of FDG PET/CT for infection and inflammation (Table 1). It should be noted that the clinical application of FDG PET/CT in infection and inflammation involves many types of diseases and different clinical situations. Table 1 shows the recommended items for current clinical application and research, but not all of them have sufficient level of evidence

Table 1. Recommended clinical use of FDG PET/CT for infection and inflammation

Recommended content	Recommended level[a]	Level of evidence[b]	References
Etiological diagnosis of fever of unknown origin (FUO) or inflammation of unknown origin (IUO)	I	A	[4, 6–9]
Infectious disease			
Diagnosis of vascular graft infection	I	A	[10–13]
Diagnosis of infective endocarditis after prosthetic valve replacement and cardiac pacemaker implantation	I	A	[14–17]
Diagnosis of periprosthetic infection after hip or knee joint replacement	II	B	[18–21]
Diagnosis of osteomyelitis of peripheral bone	III	C	[22–24]
Diagnosis of spinal infection (spondylitis or vertebral osteomyelitis, non-postoperative)	III	C	[25–27]
Diagnosis of metastatic infection and evaluation of patients with high-risk bacteremia	III	C	[28–31]
Diagnosis of suspected hepatic cyst and renal cyst infection in polycystic disease	III	C	[32–34]
Diagnosis of AIDS-related opportunistic infections, associated neoplasms, and Castleman's disease	III	C	[35–38]
Diagnosis of extrapulmonary tuberculosis and evaluation of tuberculosis activity	III	C	[39–42]
Assessment of sarcoidosis	II	C	[43–46]
Non-infectious inflammation			
Diagnosis and evaluation of large vessel vasculitis (giant cell arteritis and Takayasu arteritis)	I	A	[47–53]
Diagnosis and evaluation of other systemic vasculitis (polyarteritis nodosa, ANCA-associated vasculitis, Behcet's disease, etc.)	II	C	[53–56]
Diagnosis and differential diagnosis of adult onset Still's disease	II	C	[57–59]
Diagnosis and evaluation of idiopathic inflammatory myopathy	I	C	[60–63]
Diagnosis and differential diagnosis of polymyalgia rheumatica	II	C	[64–66]
Diagnosis and differential diagnosis of relapsing polychondritis	I	C	[66–68]
Rheumatoid arthritis lesion activity assessment	II	C	[69–71]
Diagnosis and activity assessment of IgG4-related diseases	II	B	[72–75]
Diagnosis and differential diagnosis of systemic lupus erythematosus	III	C	[76, 77]

[a]Recommendation level is divided into three levels: I has clear significance for clinical diagnosis and treatment; II is likely to be significant for clinical diagnosis and treatment; III may be significant for clinical diagnosis and treatment

[b]The level of evidence is classified into three levels: A: multiple randomized clinical trials or meta-analyses; B: single randomized clinical trials or large non-randomized trials; C: expert consensus or small studies, retrospective studies, registries

support. However, it can be expected that with further validation in clinical studies, FDG PET/CT may become the first-line examination for a variety of inflammatory diseases.

FDG PET/CT examination procedures

Although the conventional tumor examination protocol of FDG PET/CT is also applicable to infection and inflammation [5], the application of PET/CT in infection and inflammation involves many types of diseases and different clinical scenarios, while the distribution of disease types in the subjects varies from region to region and from medical institution to institution [9]. Therefore, during PET/CT examination, it is emphasized that special consideration should be given to some aspects according to the different clinical conditions of patients, combined with the physician's expertise, and more appropriate examination scheme should be adopted. The optimized imaging protocols for different types of diseases remain to be confirmed in future clinical applications and studies.

Understand the patient's clinical condition

After receiving the examination request form, the patient's clinical conditions such as the chief complaint, the history of present illness, the history of treatment, and the results of various laboratory tests should be fully investigated by asking the patient, the patient's family member, the physician in charge, examining the medical records, or even performing necessary physical examination. Pay attention to clinically available diagnostic clues and understand the main clinical issues that the clinicians currently want PET/CT to help address. Preset the examination scheme according to the specific circumstances of patients, and explain the precautions to patients and their family members before examination.

Preparation before examination

The main goal of preparing for examination is to minimize ^{18}F-FDG uptake by normal tissues (e.g., myocardium, skeletal muscle, fat, and urinary tract, etc.), thereby improving the ability to detect lesions. It is particularly important to prepare for the PET/CT examination in the diagnosis of infection and inflammation.

1. Patients should avoid the use of non-steroidal anti-inflammatory drugs, glucocorticoids or immunosuppressive agents before examination. For those who have used such drugs, their medication should be recorded (including drug type, medication time and daily dose, etc.).
2. In patients who may have mediastinal or cardiac lesions, high fat and low carbohydrate foods should be consumed at the last meal prior to fasting, or fasting should be prolonged to 18 h to reduce myocardial uptake of FDG [43, 44, 46].
3. For patients with suspected skeletal muscle disease, pay attention to the history of diabetes, and strictly control blood glucose and the use of insulin [78] to avoid the interference of muscle uptake on the observation of lesions in muscle tissue.
4. Pay attention to the warmth of the patient and try to avoid or reduce the interference of brown fat uptake on image interpretation.

Image acquisition and processing

Routine image acquisition can be performed according to guidelines related to FDG PET/CT, but the protocol should be revised in time according to the patient's condition.

Image scanning field

For patients with clear lesion site and focus on local observation, local imaging method can be used, but it is not recommended. For example, for patients suspected of having a medical implant-related infection, although local imaging can help confirm the presence of infectious foci, imaging with larger field of view is more helpful for differential diagnosis of other systemic diseases, especially for patients with systemic symptoms as the main clinical manifestation [17]. It is recommended that the image scan field should include at least the skull base to the middle of tibia, with both upper limbs placed on the side of the body during imaging. A longer scanning trajectory of the whole-body should be used depending on the clinical suspicion. This is due to the fact that infections or non-infectious inflammatory diseases with multiple system involvement are common, and routine trunk imaging may lead to a false negative result when lesions involve joints, vessels, muscles, and subcutaneous tissues of the extremities.

CT image acquisition

It is necessary to make full use of the advantages of the equipment and the timely use of diagnostic CT or enhanced CT scanning technology to obtain more image information according to the needs of diagnosis. For patients suspected of having intrapulmonary lesions or patients with rheumatic disease who are prone to interstitial lung disease, it is recommended that high-resolution CT images of the chest should be acquired first, followed by PET/CT image acquisition,

to avoid the hypostatic effect because of prolonged supine position during the observation of intrapulmonary lesions.

Image processing

For patients with metal prostheses in the body, it is recommended to reconstruct both attenuation-corrected and non-attenuation-corrected images and observe them against each other to avoid false positives due to artifacts from excessive attenuation correction [17].

Preliminary reading

After the completion of image acquisition, preliminary reading should be performed immediately, and whether to add delayed imaging, interventional imaging or locally enhanced CT scan should be determined according to the positive findings to ensure that the obtained image information can meet the diagnostic needs.

Image interpretation and report writing

According to the current situation in China, when FDG PET/CT is used for infection and inflammation, most of the examined patients were patients presented as FUO or IUO. Their clinical manifestations are lack of specificity, and most of them are rare diseases, thus they become a problem in clinical diagnosis and treatment. The imaging diagnosis of PET/CT also faces challenges. It is recommended that imaging physicians should follow the following principles in the process of image interpretation and report writing:

1. Before reading, comprehensively review the clinical data of patients, understand the current diagnostic ideas of clinicians and the problems that need to be solved, and learn relevant knowledge of the diseases involved.
2. Carefully read the PET images and CT images within the scan field. The description of image findings should show the image characteristics corresponding to the diagnosis or the positive findings possibly related to the current disease, and the image positive findings should be compared with the clinical signs of the patient as far as possible.
3. The image examination opinions should answer the purpose of examination and should be ranked according to the significance of clinical diagnosis. Avoid vague or non-diagnostic results. For clinical diagnosis involving differentiation of tumor, infection, rheumatic immune disease, etc. (such as FUO or IUO), the report should provide multi-faceted or multi-level diagnostic information, such as the presence or absence of malignant tumor or focal infection; whether the positive image findings conform the characteristics of a disease; if the positive findings cannot be identified, further recommendations should be made for clinical diagnosis and treatment, such as suggesting the appropriate biopsy site, targeted laboratory examination, imaging examination or experimental treatment.

Clinical application status

As an imaging technique, FDG PET/CT is not usually used as a routine examination method in the diagnosis of infection and inflammation. However, when conventional imaging has limited diagnostic capabilities, FDG PET/CT has an irreplaceable advantage in the differential diagnosis of diseases, monitoring of disease activity and evaluation of treatment effect, especially for the fever of unknown origin (FUO), medical implant-related infections, multisystem involved connective tissue diseases, etc. Given that the application of PET/CT in infection and inflammation is still under development, and there is a wide range of diseases, the clinical significance of the diagnosis of different types of diseases needs to be further supported by evidence-based medical data. When FDG PET/CT is introduced into the clinical process, imaging physicians should pay attention to understand the problems that need to be solved clinically and adopt a reasonable imaging scheme, so as to provide targeted diagnostic information and solve the problems in clinical diagnosis and treatment. It is believed that with the accumulation of practice, the diagnostic value of PET/CT for different types of diseases will be better understood.

Acknowledgements This consensus is based on the Sino-Japanese cooperative research work in nuclear medicine. In the related research work, it has been guided and supported by Japanese experts, such as professors Jun Hatazawa, Hiroshi Toyama and Kazuo Kubota. We hereby express our thanks.

Funding This study has no funding.

Compliance with ethical standards

Conflict of interest No potential conflicts of interest were disclosed.

References

1. Goldman L, Schafer AI. Goldman-cecil medicine. 25thth ed ed. Amsterdam: Elsevier; 2016.
2. Vinay K, Abul KA, Jon CA. Robbins basic pathology. 10thth ed ed. Amsterdam: Elsevier; 2018.
3. Kubota R, Yamada S, Kubota K, Ishiwata K, Tamahashi N, Ido T. Intratumoral distribution of fluorine-18-fluorodeoxyglucose in vivo: high accumulation in macrophages and granulation tissues studied by microautoradiography. J Nucl Med. 1992;33:1972–80.
4. Vaidyanathan S, Patel CN, Scarsbrook AF, Chowdhury FU. FDG PET/CT in infection and inflammation—current and emerging clinical applications. Clin Raiol. 2015;70(7):787–800.

5. Jamar F, Buscombe J, Chiti A, Christian PE, Delbeke D, Donohoe KJ, et al. EANM/SNMMI Guideline for ^{18}F-FDG Use in Inflammation and Infection. J Nucl Med. 2013;54(4):647–57.
6. Besson FL, Chaumet-Riffaud P, Playe M, Noel N, Lambotte O, Goujard C, et al. Contribution of (18)F-FDG PET in the diagnostic assessment of fever of unknown origin (FUO): a stratification-based meta-analysis. Eur J Nucl Med Mol Imaging. 2016;43(10):1887–955.
7. Takeuchi M, Dahabreh IJ, Nihashi T, Iwata M, Varghese GM, Terasawa T. Nuclear Imaging for Classic Fever of Unknown Origin: Meta-Analysis. J Nucl Med. 2016;57(12):1913–9.
8. Schönau V, Vogel K, Englbrecht M, Wacker J, Schmidt D, Manger B, et al. The value of ^{18}F-FDG-PET/CT in identifying the cause of fever of unknown origin (FUO) and inflammation of unknown origin (IUO): data from a prospective study. Ann Rheum Dis. 2018;77(1):70–7.
9. Wang Q, Li YM, Li Y, Hua FC, Wang QS, Zhang XL, et al. ^{18}F-FDG PET/CT in fever of unknown origin and inflammation of unknown origin: a Chinese multi-center study. Eur J Nucl Med Mol Imaging. 2019;46:159–65.
10. Kim SJ, Lee SW, Jeong SY, Pak K, Kim K. A systematic review and meta-analysis of ^{18}F-fluorodeoxyglucose positron emission tomography or positron emission tomography/computed tomography for detection of infected prosthetic vascular grafts. J Vasc Surg. 2019;70(1):307–13.
11. Rojoa D, Kontopodis N, Antoniou SA, Ioannou CV, Antoniou GA. ^{18}F-FDG PET in the diagnosis of vascular prosthetic graft infection: A diagnostic test accuracy meta-analysis. Eur J Vasc Endovasc Surg. 2019;57(2):292–301.
12. Sah BR, Husmann L, Mayer D, Scherrer A, Rancic Z, Puippe G, et al. Diagnostic performance of ^{18}F-FDG-PET/CT in vascular graft infections. Eur J Vasc Endovasc Surg. 2015;49(4):455–64.
13. Husmann L, Ledergerber B, Anagnostopoulos A, Stolzmann P, Sah BR, Burger IA, et al. The role of FDG PET/CT in therapy control of aortic graft infection. Eur J Nucl Med Mol Imaging. 2018;45(11):1987–97.
14. San S, Ravis E, Tessonier L, Philip M, Cammilleri S, Lavagna F, et al. Prognostic value of 18F-fluorodeoxyglucose positron emission tomography/computed tomography in infective endocarditis. J Am Coll Cardiol. 2019;74(8):1031–40.
15. Granados U, Fuster D, Pericas JM, Llopis JL, Ninot S, Quintana E, et al. Diagnostic Accuracy of ^{18}F-FDG PET/CT in Infective endocarditis and implantable cardiac electronic device infection: A cross-sectional study. J Nucl Med. 2016;57(11):1726–32.
16. Mahmood M, Kendi AT, Ajmal S, Farid S, O'Horo JC, Chareonthaitawee P, et al. Meta-analysis of ^{18}F-FDG PET/CT in the diagnosis of infective endocarditis. J Nucl Cardiol. 2019;26(3):922–35.
17. Li Y, Wang Q, Wang L. Localization and etiologic diagnosis of suspected pacemaker-related infection with ^{18}F-FDG PET/CT. Chin J Nucl Med Mol Imaging. 2017;37(5):284–8 **[Article in Chinese]**.
18. Kiran M, Donnelly TD, Armstrong C, Kapoor B, Kumar G, Peter V. Diagnostic utility of fluorodeoxyglucose positron emission tomography in prosthetic joint infection based on MSIS criteria. Bone Joint J. 2019;101-B(8):910–4.
19. Kumar R, Kumar R, Kumar V, Malhotra R. Potential clinical implication of (18) F-FDG PET/CT in diagnosis of periprosthetic infection and its comparison with (18) F-Fluoride PET/CT. J Med Imaging Radiat Oncol. 2016;60(3):315–22.
20. Jin H, Yuan L, Li C, Kan Y, Hao R, Yang J. Diagnostic performance of FDG-PET or PET/CT in prosthetic infection after arthroplasty: a meta-analysis. Q J Nucl Med Mol Imaging. 2014;58:85–93.
21. Basu S, Kwee TC, Saboury B, Garino JP, Nelson CL, Zhuang H, et al. FDG-PET for diagnosing infection in hip and knee prostheses: prospective study in 221 prostheses and subgroup comparison with combined 111In-labeled leukocyte/99mTc-sulfur colloid bone marrow imaging in 88 prostheses. Clin Nucl Med. 2014;39:609–15.
22. Lankinen P, Seppanen M, Mattila K, Kallajoki M, Knuuti J, Aro HT. Intensity of (18)F-FDG PET uptake in culture-negative and culture-positive cases of chronic osteomyelitis. Contrast Media Mol Imaging. 2017;2017:9754293.
23. van Vliet KE, de Jong VM, Termaat MF, Schepers T, van Eck-Smit BLF, Goslings JC, et al. FDG-PET/CT for differentiating between aseptic and septic delayed union in the lower extremity. Arch Orthop Trauma Surg. 2018;138(2):189–94.
24. Demirev A, Weijers R, Geurts J, Mottaghy F, Walenkamp G, Brans B. Comparison of [18F] FDG PET/CT and MRI in the diagnosis of active osteomyelitis. Skeletal Radiol. 2014;43(5):665–72.
25. Schmitz A, Risse JH, Grünwald F, Gassel F, Biersack HJ, Schmitt O. Fluorine-18 fluorodeoxyglucose positron emission tomography findings in spondylodiscitis: preliminary results. Eur Spine J. 2001;10:534–9.
26. Sminds C, Kouijzer IJ, Vos FJ, Sprong T, Hosman AJ, de Rooy JW, et al. A comparison of the diagnostic value of MRI and18F-FDG-PET/CT in suspected spondylodiscitis. Infection. 2017;45(1):41–9.
27. Yin Y, Liu X, Yang X, Guo J, Wang Q, Chen L. Diagnostic value of FDG-PET versus magnetic resonance imaging for detecting spondylitis: a systematic review and meta-analysis. Spine J. 2018;18(12):2323–32.
28. Kouijzer IJ, Blokhuis GJ, Draaisma JM, Oyen WJ, de Geus-Oei LF, Bleeker-Rovers CP. ^{18}F-FDG PET/CT in detecting metastatic infection in children. Clin Nucl Med. 2016;41(4):278–81.
29. Berrevoets MAH, Kouijzer IJE, Aarntzen EHJG, Janssen MJR, De Geus-Oei LF, Wertheim HFL, et al. ^{18}F-FDG PET/CT optimizes treatment in Staphylococcus Aureus bacteremia and is associated with reduced mortality. J Nucl Med. 2017;58(9):1504–10.
30. Vos FJ, Bleeker-Rovers CP, Sturm PD, Krabbe PF, van Dijk AP, Cuijpers ML, et al. ^{18}F-FDG PET/CT for detection of metastatic infection in gram-positive bacteremia. J Nucl Med. 2010;51(8):1234–40.
31. Brøndserud MB, Pedersen C, Rosenvinge FS, Høilund-Carlsen PF, Hess S. Clinical value of FDG-PET/CT in bacteremia of unknown origin with catalase-negative gram-positive cocci or Staphylococcus aureus. Eur J Nucl Med Mol Imaging. 2019;46(6):1351–8.
32. Lantinga MA, Drenth JP, Gevers TJ. Diagnostic criteria in renal and hepatic cyst infection. Nephrol Dial Transplant. 2015;30(5):744–51.
33. Bobot M, Ghez C, Gondouin B, Sallée M, Fournier PE, Burtey S, et al. Diagnostic performance of [(18)F]fluorodeoxyglucose positron emission tomography-computed tomography in cyst infection in patients with autosomal dominant polycystic kidney disease. Clin Microbiol Infect. 2016;22(1):71–7.
34. Jouret F, Lhommel R, Beguin C, Devuyst O, Pirson Y, Hassoun Z, et al. Positron-emission computed tomography in cyst infection diagnosis in patients with autosomal dominant polycystic kidney disease. Clin J Am Soc Nephrol. 2011;6:1644–50.
35. Polizzotto MN, Millo C, Uldrick TS, Aleman K, Whatley M, Wyvill KM, et al. 18F-fluorodeoxyglucose positron emission tomography in kaposi sarcoma herpesvirus-associated multicentric castleman disease: Correlation with activity, severity, inflammatory and virologic parameters. J Infect Dis. 2015;212(8):1250–60.
36. Sathekge M, Maes A, Van de Wiele C. FDG-PET imaging in HIV infection and tuberculosis. Semin Nucl Med. 2013;43(5):349–66.
37. Sathekge M, Goethals I, Maes A, van de Wiele C. Positron emission tomography in patients suffering from HIV-1 infection. Eur J Nucl Med Mol Imaging. 2009;36(7):1176–84.

38. Liu Y. Demonstrations of AIDS-associated malignancies and infections at FDG PET-CT. Ann Nucl Med. 2011;25(8):536–46.
39. Kim IJ, Lee JS, Kim SJ, Kim YK, Jeong YJ, Jun S, et al. Double-phase ^{18}F-FDG PET-CT for determination of pulmonary tuberculoma activity. Eur J Nucl Med Mol Imaging. 2008;35(4):808–14.
40. Sathekge M, Maes A, D'Asseler Y, Vorster M, Gongxeka H, Van de Wiele C. Tuberculous lymphadenitis: FDG PET and CT findings in responsive and nonresponsive disease. Eur J Nucl Med Mol Imaging. 2012;39(7):1184–90.
41. Malherbe ST, Shenai S, Ronacher K, Loxton AG, Dolganov G, Kriel M, et al. Persisting PET-CT lesion activity and Mycobacterium tuberculosis mRNA after pulmonary tuberculosis cure. Nat Med. 2016;22(10):1094–100.
42. Lawal I, Fourie B, Mathebula M, Moagi I, Lengana T, Moeketsi N, et al. FDG-PET/CT as a non-invasive biomarker for assessing adequacy of treatment and predicting relapse in patients treated for pulmonary tuberculosis. J Nucl Med. 2019. https://doi.org/10.2967/jnumed.119.233783.
43. Ohira H, Ardle BM, deKemp RA, Nery P, Juneau D, Renaud JM, et al. Inter- and intraobserver agreement of ^{18}F-FDG PET/CT image interpretation in patients referred for assessment of cardiac sarcoidosis. J Nucl Med. 2017;58(8):1324–9.
44. Tang R, Wang JT, Wang L, Le K, Huang Y, Hickey AJ, et al. Impact of patient preparation on the diagnostic performance of ^{18}F-FDG PET in cardiac sarcoidosis: a systematic review and meta-analysis. Clin Nucl Med. 2016;41(7):327–39.
45. Lu Y, Grant C, Xie K, Sweiss NJ. Suppression of myocardial ^{18}F-FDG uptake through prolonged high-fat, high-protein, and very-low-carbohydrate diet before FDG-PET/CT for evaluation of patients with suspected cardiac sarcoidosis. Clin Nucl Med. 2017;42(2):88–94.
46. Ahmadian A, Pawar S, Govender P, Berman J, Ruberg FL, Miller EJ. The response of FDG uptake to immunosuppressive treatment on FDG PET/CT imaging for cardiac sarcoidosis. J Nucl Cardiol. 2017;24(2):413–24.
47. Duftner C, Dejaco C, Sepriano A, Falzon L, Schmidt WA, Ramiro S. Imaging in diagnosis, outcome prediction and monitoring of large vessel vasculitis: a systematic literature review and meta-analysis informing the EULAR recommendations. RMD Open. 2018;4(1):e000612.
48. Fuchs M, Briel M, Daikeler T, Walker UA, Rasch H, Berg S, et al. The impact of ^{18}F-FDG PET on the management of patients with suspected large vessel vasculitis. Eur J Nucl Med Mol Imaging. 2012;39(2):344–53.
49. Hooisma GA, Balink H, Houtman PM, Slart RH, Lensen KD. Parameters related to a positive test result for FDG PET(/CT) for large vessel vasculitis: a multicenter retrospective study. Clin Rheumatol. 2012;31(5):873–5.
50. Zhang Y, Shen M. Value of positron emission tomography/computed tomography in the diagnosis and disease activity assessment of systemic vasculitis. Chin J Allergy Clin Immunol. 2014;8(1):70–5 **[Article in Chinese]**.
51. Nielsen BD, Gormsen LC, Hansen IT, Keller KK, Therkildsen P, Hauge EM. Three days of high-dose glucocorticoid treatment attenuates large-vessel ^{18}F-FDG uptake in large-vessel giant cell arteritis but with a limited impact on diagnostic accuracy. Eur J Nucl Med Mol Imaging. 2018;45(7):1119–28.
52. Grayson PC, Alehashemi S, Bagheri AA, Civelek AC, Cupps TR, Kaplan MJ, et al. ^{18}F-Fluorodeoxyglucose-positron emission tomography as an imaging biomarker in a prospective, longitudinal cohort of patients with large vessel vasculitis. Arthritis Rheumatol. 2018;70(3):439–49.
53. Bleeker-Rovers CP, Bredie SJ, van der Meer JW, Corstens FH, Oyen WJ. F-18-fluorodeoxyglucose positron emission tomography in diagnosis and follow-up of patients with different types of vasculitis. Neth J Med. 2003;61(10):323–9.
54. Kemna MJ, Vandergheynst F, Vöö S, Blocklet D, Nguyen T, Timmermans SA, et al. Positron emission tomography scanning in anti-neutrophil cytoplasmic antibodies-associated vasculitis. Medicine (Baltimore). 2015;94(20):e747.
55. Frary EC, Hess S, Gerke O, Laustrup H. 18F-fluoro-deoxyglucose positron emission tomography combined with computed tomography can reliably rule-out infection and cancer in patients with anti-neutrophil cytoplasmic antibody-associated vasculitis suspected of disease relapse. Medicine (Baltimore). 2017;96(30):e7613.
56. Trad S, Bensimhon L, El Hajjam M, Chinet T, Wechsler B, Saadoun D. 18F-fluorodeoxyglucose-positron emission tomography scanning is a useful tool for therapy evaluation of arterial aneurysm in Behçet's disease. Joint Bone Spine. 2013;80(4):420–3.
57. Dong MJ, Wang CQ, Zhao K, Wang GL, Sun ML, Liu ZF, et al. 18F-FDG PET/CT in patients with adult-onset Still's disease. Clin Rheumatol. 2015;34(12):2047–56.
58. Jiang L, Xiu Y, Gu T, Dong C, Wu B, Shi H. Imaging characteristics of adult onset Still's disease demonstrated with ^{18}F-FDG PET/CT. Mol Med Rep. 2017;16(3):3680–6.
59. Yamashita H, Kubota K, Takahashi Y, Minamimoto R, Morooka M, Kaneko H, et al. Clinical value of (18)F-fluoro-dexoxyglucose positron emission tomography/computed tomography in patients with adult-onset Still's disease: a seven-case series and review of the literature. Mod Rheumatol. 2014;24(4):645–50.
60. Li Y, Zhou Y, Wang Q. Multiple values of ^{18}F-FDG PET/CT in idiopathic inflammatory myopathy. Clin Rheumatol. 2017;36(10):2297–305.
61. Martis N, Viau P, Zenone T, Andry F, Grados A, Ebbo M, et al. Clinical value of a [18F]-FDG PET-CT muscle-to-muscle SUV ratio for the diagnosis of active dermatomyositis. Eur Radiol. 2019;29(12):6708–16.
62. Mahmmod S, Martínez R, de Llano S. 18F-FDG PET detection of unknown primary malignancy in dermatomyositis. Clin Nucl Med. 2012;37(8):e204–205.
63. Kundrick A, Kirby J, Ba D, Leslie D, Olsen N, Foulke G. Positron emission tomography costs less to patients than conventional screening for malignancy in dermatomyositis. Semin Arthritis Rheum. 2019;49(1):140–4.
64. Yamashita H, Kubota K, Takahashi Y, Minaminoto R, Morooka M, Ito K, et al. Whole-body fluorodeoxyglucose positron emission tomography/computed tomography in patients with active polymyalgia rheumatica: evidence for distinctive bursitis and large-vessel vasculitis. Mod Rheumatol. 2012;22(5):705–11.
65. Rehak Z, Sprlakova-Pukova A, Kazda T, Fojtik Z, Vargova L, Nemec P. 18F-FDG PET/CT in polymyalgia rheumatica-a pictorial review. Br J Radiol. 2017;90(1076):20170198.
66. Kubota K, Yamashita H, Mimori A. Clinical Value of FDG-PET/CT for the Evaluation of Rheumatic Diseases: Rheumatoid Arthritis, Polymyalgia Rheumatica, and Relapsing Polychondritis. Semin Nucl Med. 2017;47(4):408–24.
67. Lei W, Zeng H, Zeng DX, Zhang B, Zhu YH, Jiang JH, et al. (18)F-FDG PET-CT: a powerful tool for the diagnosis and treatment of relapsing polychondritis. Br J Radiol. 2016;89(1057):20150695.
68. Qiu LH, Wang Q. The value of 18F-flurodeoxyglucose positron emission tomography/computed tomography for detecting the relapsing polychondritis in patients with fever of unknown origin. Chin J Rheumatol. 2017;21(12):841–3 **[Article in Chinese]**.
69. Beckers C, Ribbens C, André B, Marcelis S, Kaye O, Mathy L, et al. Assessment of disease activity in rheumatoid arthritis with ^{18}F-FDG PET. J Nucl Med. 2004;45(6):956–64.

70. Kubota K, Ito K, Morooka M, Mitsumoto T, Kurihara K, Yamashita H, et al. Whole-body FDG-PET/CT on rheumatoid arthritis of large joints. Ann Nucl Med. 2009;23:783–91.
71. Kubota K, Ito K, Morooka M, Minamimoto R, Miyata Y, Yamashita H, et al. FDG PET for rheumatoid arthritis: basic considerations and whole-body PET/CT. Ann N Y Acad Sci. 2011;1228:29–38.
72. Zhang J, Chen H, Ma Y, Xiao Y, Niu N, Lin W, et al. Characterizing IgG4-related disease with 18F-FDG PET/CT: a prospective chort study. Eur J Nucl Med Mol Imaging. 2014;41(8):1624–34.
73. Zhao Z, Wang Y, Guan Z, Jin J, Huang F, Zhu J. Utility of FDG-PET/CT in the diagnosis of IgG4-related diseases. Clin Exp Rheumatol. 2016;34(1):119–25.
74. Berti A, Della-Torre E, Gallivanone F, Canevari C, Milani R, Lanzillotta M, et al. Quantitative measurement of ^{18}F-FDG PET/CT uptake reflects the expansion of circulating plasmablasts in IgG4-related disease. Rheumatology. 2017;56(12):2084–92.
75. Mavrogeni S, Markousis-Mavrogenis G, Kolovou G. IgG4-related cardiovascular disease. The emerging role of cardiovascular imaging. Eur J Radiol. 2017;86:169–75.
76. Curiel R, Akin EA, Beaulieu G, DePalma L, Hashefi M. PET/CT imaging in systemic lupus erythematosus. Ann NY Acad Sci. 2011;1228:71–80.
77. Makis W, Ciarallo A, Gonzalez-Verdecia M, Probst S. Systemic lupus erythematosus associated pitfalls on ^{18}F-FDG PET/CT: reactive follicular hyperplasia, Kikuchi-Fujimoto disease, inflammation and lymphoid hyperplasia of the spleen mimicking lymphoma. Nucl Med Mol Imaging. 2018;52(1):74–9.
78. Boellaard R, Delgado-Bolton R, Oyen W, Giammarile F, Tatsch K, Eschner W, et al. FDG PET/CT: EANM procedure guidelines for tumour imaging: version 2.0. Eur J Nucl Med Mol Imaging. 2015;42(2):328–54.