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The impact of infection and inflammation in oncologic ^{18}F-FDG PET/CT imaging

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Abstract

Sites of infection and inflammation can be misleading in oncology PET/CT imaging because these areas commonly show ^{18}F-FDG activity. Caution in the interpretation must be taken to avoid the misdiagnosis of malignancy. Utilization of both CT findings as well as patient history can help differentiate benign infectious and inflammatory processes from malignancy, although occasionally additional work-up may be required. This article discusses the mechanism of ^{18}F-FDG uptake in infection and inflammation with illustrative examples.

Keywords

^{18}F-FDG PET/CT; Infection; Inflammation; Imaging pitfalls

1. Introduction

^{18}F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) is commonly performed in oncology patients for staging neoplasms and evaluating treatment response. However, uptake of FDG is not entirely specific for neoplasm, and in addition to treatment-induced inflammatory changes, a variety of benign infectious and inflammatory processes can result in focal radiopharmaceutical uptake. These foci of uptake are often considered diagnostic pitfalls when interpreting oncologic ^{18}F-FDG PET/CT's as they may lead to false-positive results [1]. Clinicians must be vigilant for unusual patterns of radiopharmaceutical uptake due to infectious and inflammatory etiologies in order to avoid misdiagnosis of malignancy. Patient history, knowledge of

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typical patterns of metastatic spread of the malignancy being evaluated, as well as the co-acquired CT findings can guide interpretation to the correct cause(s) of the abnormal FDG uptake. At times, additional diagnostic steps will need to be performed to confirm the etiology of abnormal patterns of FDG distribution. This review article discusses mechanisms of ^{18}F-FDG uptake in tumors in contrast to infection and inflammation with examples of infectious and inflammatory pitfalls in oncologic ^{18}F-FDG PET/CT imaging and interpretation.

2. Mechanism of uptake and metabolism of ^{18}F-FDG

Throughout the last several decades, ^{18}F-FDG, a glucose analogue, has been used for the detection and evaluation of a wide range of solid and hematological malignancies. Generally, cancer cells demonstrate increased rates of glucose utilization [2]. It is this principle of a relative increased glucose metabolism of many neoplasms that allows for the increased uptake and the depiction of malignancies using ^{18}F-FDG.

After intravenous injection, ^{18}F-FDG enters cells via glucose transporter membrane proteins. Once in the cell, ^{18}F-FDG undergoes phosphorylation by the enzyme, hexokinase. Phosphorylated glucose undergoes further metabolism in the cell through glycolysis or glycogen formation. However, unlike glucose after phosphorylation, ^{18}F-FDG cannot undergo further metabolism (Fig. 1) [3]. Although, either substrate may be dephosphorylated by glucose-6-phosphatase (G6P) if present; molecular factors leading to relative increased accumulation of ^{18}F-FDG in cancers compared to normal tissues include over-expression of glucose transport membrane proteins, increased hexokinase enzyme activity, as well as relative diminished G6P activity [4]. Cancer cells have relatively low G6P activity, hence reducing further cellular metabolism. Consequently, phosphorylated ^{18}F-FDG is often described as being “trapped” after hexokinase-mediated phosphorylation in cancer cells.

At the site of inflammation/infection, inflammatory cells (neutrophils, activated macrophages, and lymphocytes) show increased ^{18}F-FDG accumulation through a common mechanism [5,6]. Mochizuki et al. demonstrated elevated FDG uptake and glucose membrane transporter expression in rats inoculated with malignant cells (allogenic hepatoma cells) as well as rats infected with *Staphylococcus aureus* [7]. Furthermore, increased ^{18}F-FDG uptake has also been noted within inflammatory cells associated with tumors, and can be part of the cellular response to treatment [8].

3. Infectious and inflammatory pitfalls in oncologic imaging

Unexpected and incidental foci of uptake in oncologic ^{18}F-FDG PET/CT’s is relatively common with diagnostic considerations including unusual sites of metastases, a second synchronous neoplasm, surgical or procedural interventions, as well as infection and inflammation [9]. Given their increased uptake on ^{18}F-FDG PET/CT, infectious and inflammatory responses have the potential to be misinterpreted as metastatic disease. Following review of greater than 1000 patients ^{18}F-FDG PET/CT’s, Metser et al. reported greater than one quarter of these examinations contained incidental foci of benign radiopharmaceutical uptake [10]. The majority of these foci of FDG uptake were attributed

to infectious and non-infectious inflammation. Pneumonia, upper respiratory tract infections, and wound infections were among the most common etiologies identified incidentally ^{18}F-FDG PET/CT done for oncologic indications [11]. The presence of longstanding, indwelling, catheters, lines and tubes, often generate a foreign body-like inflammatory responses, characterized by formation of granulation tissues with intense FDG uptake. However, numerous additional common and uncommon benign causes of uptake have been described (Table 1) [12].

3.1. Differentiating infectious/inflammatory uptake from malignancy

The clinical challenge remains to reliably differentiate infectious and inflammatory FDG uptake from malignancy. Ideally, an easily obtained and reproducible quantifiable measurement would guide interpretation to the correct diagnosis. However, at this time no such measurement exists. Unfortunately, although an easily obtained parameter, the standard uptake value (SUV), cannot differentiate malignancy from infectious and inflammatory uptake and no reliable, absolute SUV threshold has been found that can be used clinically differentiate benign from malignant uptake due to the similar mechanism of FDG accumulation between tumor cells and white blood cells [13].

There has been interest in using relative or comparative SUV measurements to differentiate etiologies of abnormal ^{18}F-FDG uptake. Dual time point imaging, in which a second delayed acquisition is obtained, has been proposed as an alternative to increase the overall sensitivity and specificity for the detection of malignancy by ^{18}F-FDG PET/CT. With this protocol malignancies generally exhibit increased FDG uptake on the delayed acquisition, whereas infectious and inflammatory foci typically demonstrate decreased uptake on delayed imaging [14,15]. However, the performance, overall reliability and usefulness of dual time point imaging has had mixed results, limiting its routine clinical use for evaluating incidental foci of uptake on ^{18}F-FDG PET/CT [16]. Published in 2013, the EANM/SNMMI Guidelines for the use of PET/CT in infection and inflammation does not support use of dual time point imaging specifically citing poor dependability in differentiating neoplasm from infection [17].

Glucose update and utilization rates can be leveraged to distinguish metastasis from inflammation. If the intensity of ^{18}F-FDG uptake at an indeterminate site is different to that of a known malignancy, a separate process may be considered. This concept of the *metabolic signature* is based upon the presumption of similar rates of glucose utilization between the primary neoplasm and sites of metastasis. A subjective assessment is easily performed using the whole-body maximum intensity projection images. A quantified comparison can also be performed, but caution is advised as there is no relative or absolute SUV difference that can be used in clinical practice for evaluating different metabolic signatures. This concept of metabolic “signature” has demonstrated to be useful in suggesting an incidental focus of uptake on PET/CT to represent a different process other than the primary malignancy that might include a second, synchronous primary neoplasm and/or an inflammatory/infectious process [18,19].

Although metabolic signatures are useful, there are several potential pitfalls to their use. Concluding a separate process based upon different metabolic signatures in small (< 8 mm)

lesions should be avoided as processes that are below the limits of the spatial resolution of PET (< 1 cm) may lead to inaccurate SUV's. Similarly, when a lesion demonstrates a large cystic and/or necrotic component, SUV measurements may be deceptively low. Additionally, it is prudent for clinicians to be aware of neoplasms that are prone to varying degrees of differentiation including leukemias, lymphomas, thyroid cancers, and neuroendocrine tumors. In these cases, contrasting intensities of ^{18}F-FDG uptake may reflect a neoplasm with varying degrees of de-differentiation with more aggressive foci of disease generally having greater dependence upon glucose metabolism and thus higher FDG uptake [20].

Relevant patient history and symptoms may suggest the underlying etiology for the abnormal FDG uptake. Obtaining a detailed history specifically inquiring about patient oncologic history, treatment, procedures, infections, sites of pain, and other acute medical conditions can be performed in-person or by written questionnaire. The PET scan should then be interpreted in the context of the oncologic history. A knowledge of the typical pattern of metastases for the malignancy under investigation can be a very useful guide. For example, nodal metastatic disease has a tendency towards asymmetric distribution, whereas a symmetric pattern of FDG uptake in lymph nodes in the neck or in the mediastinum, often points to an inflammatory etiology. Also, certain lymph node stations are more commonly related to inflammatory or infectious processes, such as the jugulodigastric, axillary, hilar, and inguinal nodes. If possible, the images can be reviewed before the patient leaves the imaging center and more specific queries can be made about current symptoms and history to clarify the imaging findings.

In addition to patient history, corresponding CT images may guide the interpreting physician to the correct cause(s) of the focus of uptake. The interpreting physician must be familiar with common CT imaging presentations of acute inflammatory conditions such as lobar airspace disease indicating pneumonia, presence of gas locules in infections fluid collections and peri-visceral fat stranding often encountered in acute infectious/inflammatory processes in the abdomen and pelvis.

Despite these strategies, there will be indeterminate foci of uptake of ^{18}F-FDG PET/CT in oncology patients. In such cases, clinical guidance can be made to the referring physician to determine optimal post PET/CT follow up imaging strategies. Tools available include clinical correlation, immediate or short-term follow-up diagnostic imaging, or endoscopy. The choice will largely depend upon symptoms and treatment management.

4. Common incidental infectious and inflammatory findings in oncologic ^{18}F-FDG PET/CT

In addition to the general principles and strategies listed above, a familiarity of common infectious and inflammatory processes encountered in oncologic ^{18}F-FDG PET/CT is beneficial and when recognized should raise the possibility of non-malignant disease.

4.1. Head and neck

Incidental uptake in the head and neck is a relatively common. In a retrospective study evaluating incidental FDG uptake in 293 patients with head and neck cancer, 45 of the

134 incidental findings were located in the extra-thyroidal head and neck [21]. A variety of nonneoplastic processes can result in incidental ^{18}F-FDG uptake. Focal uptake in the maxilla or mandible is often seen in dental related infections and periodontal disease [22]. Variable degrees of symmetric and asymmetric uptake often are encountered in Waldeyer's ring in infection and inflammation [23]. These processes may also result in uptake in reactive lymph nodes in the head and neck. Following chemotherapy for oropharyngeal cancer mucositis may be encountered in the hypopharynx. Inflammatory and/or infectious ^{18}F-FDG uptake has also been noted in lacrimal, salivary, and thyroid glands as well the paranasal sinuses [24–27]. Classically, diffuse thyroid uptake suggests an underlying inflammatory process whereas as focal uptake requires further evaluation for a possible underlying nodule. A common procedure in patients treated for head and neck cancer, focal uptake can be seen at tracheostomy sites (Fig. 2). Brain infections including abscesses have also been described as being ^{18}F-FDG-avid [28,29].

4.2. Thorax

There are numerous causes of infectious and inflammatory uptake in the chest. A wide array of pulmonary infections can be ^{18}F-FDG-avid including typical and atypical organisms [12,28,30,31]. In lung cancer patients, particular awareness for post-obstructive pneumonias should be made as the lung neoplasm may narrow or invade the airway (Fig. 3). In this setting the central lung cancer often has a more intense metabolic signature to the diffuse uptake in the collapsed lung parenchyma. Newer immunotherapy agents can result in a pneumonitis, organizing pneumonia, and/or sarcoid-like reactions, which may demonstrate ^{18}F-FDG-avidity [32–34]. Focal organizing pneumonias can be particularly problematic as their mass-like hypermetabolic presentation is easily mistaken for malignancy [35]. The sequelae of radiation therapy in pleura and lung parenchyma will often have a geographical and diffuse or linear configuration, distinguishing it from more focal uptake from malignancy. Talc pleurodesis performed for management of malignant and benign pleural effusions with intense inflammatory foreign body response characteristically is depicted with high FDG uptake.

Sarcoidosis is a non-caseating granulomatous inflammatory disease often with manifestations in the thorax including adenopathy and interstitial lung disease including nodularity that can be hypermetabolic on ^{18}F-FDG PET/CT [36]. This can lead to the erroneous interpretation of malignancy in hypermetabolic thoracic foci as sarcoidosis is an excellent mimicker of malignancy (Fig. 4) [37]. In addition to thoracic nodal uptake, pulmonary and extra-thoracic manifestations of sarcoid can also demonstrate increased FDG uptake suggesting a more aggressive malignant process including focal uptake in abdominal viscera and in the skeleton [38,39]. Great caution should be taken when interpreting oncologic ^{18}F-FDG PET/CT in patients with sarcoidosis given the high rate of non-malignant ^{18}F-FDG-uptake.

Extra-pulmonic infectious and inflammatory foci are also routinely encountered. Present on many oncologic ^{18}F-FDG PET/CT's, mild uptake is often seen in hilar and mediastinal lymph nodes, related to chronic granulomatous disease, often associated with nodal calcifications and granulomata in the lungs. Mild increased linear uptake in the esophagus

and gastroesophageal junction is often related to inflammation including reflux esophagitis. However, when esophageal uptake is more focal and/or intense, it warrants endoscopic correlation to exclude malignant or pre-malignant conditions [40].

Other abnormal foci of infectious and inflammatory uptake in the chest associated with FDG uptake include fibrosing mediastinitis and a variety of infectious and inflammatory processes of the breasts [41,42]. In oncologic ^{18}F-FDG PET/CT imaging, myocardial uptake is variable and a variety of normal patterns have been described [43]. This is due to myocardial metabolism of both glucose and fatty acids. Despite variable physiologic uptake in the myocardium, pathologic inflammatory and/or infectious uptake in or adjacent to the heart has been described including pericarditis, myocarditis, sarcoidosis, as well as uptake in the adjacent great vessels due to inflammation/infections including vasculitis (Fig. 5) [44,45].

4.3. Abdomen and pelvis

In the abdomen and pelvis, the bowel is a common site for infectious and inflammatory processes. Abnormal focal uptake correlating to abscesses, appendicitis, infectious and inflammatory colitis, and diverticulitis have been reported (Figs. 6 and 7) [46–51]. Correlation with CT signs of inflammation is recommended as there are other causes of increased FDG uptake in the bowel including metformin as well ureteral diversion procedures in which physiologic FDG uptake in urine can be seen in the bowel lumen [52,53].

In addition to the gastrointestinal tract, other viscera in the abdomen and pelvis may demonstrate infectious and inflammatory uptake on ^{18}F-FDG PET/CT. Increased FDG uptake in the pancreas from pancreatitis may been mistaken for malignancy (Fig. 6) [54,55]. Although classically thought of resulting in increased uptake throughout the pancreas, focal uptake in the pancreas may also represent pancreatitis [56]. To make diagnostic interpretation even more challenging, a case of a hypermetabolic pancreatic mass with superimposed diffuse ^{18}F-FDG uptake throughout the pancreas from pancreatitis has been reported [57].

Additional abdominal visceral infection and inflammatory processes may be encountered when interpreting ^{18}F-FDG PET/CT. Although differentiation of from neoplasm is difficult, a ring-like distribution of abnormal radiopharmaceutical uptake in the gallbladder has been observed in cases of acute and chronic cholecystitis [58,59]. Hepatic and splenic infections including atypical etiologies from fungal and parasitic infection, i.e., amebiasis, should be considered when encountering abnormal uptake in these organs [60–63]. Non-infectious inflammatory uptake from processes such as sarcoidosis has also been described in abdominal viscera including the liver and the spleen [64]. Similarly, inflammatory ^{18}F-FDG uptake in retroperitoneal fibrosis may be mistaken for malignancy [65]. Knowledge of the radiation treatment field is valuable as inflammatory uptake in adjacent viscera has been described including in the liver in a patient with esophageal carcinoma [66].

Although the genitourinary system is a common site for infection, differentiation of abnormal ^{18}F-FDG uptake in the kidney from physiologic uptake can be challenging.

Strategies to detect abnormal uptake include appropriate windowing of the PET images as well as review of the CT images looking for focal anatomic lesions. Renal tuberculosis, acute pyelonephritis, xanthogranulomatous pyelonephritis, and renal abscesses have all been encountered on oncologic ^{18}F-FDG PET/CT and may be mistaken for a neoplastic process [67–70]. Gonadal infection has been mistaken for neoplasm on ^{18}F-FDG PET/CT including tubo-ovarian abscesses and orchitis [71–73].

4.4. Miscellaneous

Musculoskeletal processes may lead to focal uptake on ^{18}F-FDG PET/CT. Incidental inflammatory uptake from degenerative osteoarthritis is ubiquitous in oncologic ^{18}F-FDG PET imaging. However, more acute infectious processes requiring management such as discitis, osteomyelitis and septic arthritis can also demonstrate focal radiopharmaceutical uptake and may be mistaken for metastases (Figs. 8–10) [74,75]. Focal ^{18}F-FDG uptake in the muscles related to myositis may also be mistaken for sites of malignancy [76,77].

Cutaneous and subcutaneous ^{18}F-FDG uptake can be encountered in a variety of infectious and inflammatory processes including common processes such as sebaceous cysts, acne vulgaris and insect bites to less common entities such as hidradenitis suppurativa (Fig. 11) [78,79]. Granulomas in the subcutaneous soft tissues and muscles are commonly seen with iatrogenic injections. Fortunately, direct inspection of the skin is easily done clinically and can assist to determining the etiology of abnormal unexpected uptake. Similarly, knowledge of recent procedures is useful as postoperative inflammation, infections, and/or other complications may be encountered on subsequent ^{18}F-FDG PET/CT and may result in abnormal uptake (Fig. 12) [80].

5. F-FDG for infection localization

Given this often-encountered incidental infectious and inflammatory uptake in ^{18}F-FDG PET/CT, there is a potential clinical use for ^{18}F-FDG for infection imaging as an alternative to traditional radiolabeled leukocyte imaging with either ^{111}In or ^{99m}Tc. Potential advantages of ^{18}F-FDG for localization of infection include high sensitivity, relatively shorter imaging times and higher spatial resolution compared to traditional leukocyte imaging [5]. Modern PET acquisition is typically accompanied with whole-body CT correlation, which can assist in interpretation. Furthermore, ^{18}F-FDG imaging does not require radiolabeling white blood cells, which alleviates potential risks that accompany the handling blood products [81]. Limitations of ^{18}F-FDG PET/CT include clinical availability (lack of reimbursement in the U.S.), imperfect specificity of FDG uptake, as well as a wide variety of variants of physiologic FDG uptake that might confound interpretation. Similar to radiolabeled leukocytes, ^{18}F-FDG PET/CT cannot distinguish infection from inflammation.

Although infection localization is not an FDA approved indication for ^{18}F-FDG PET/CT in the United States, national societies have provided practice guidelines. In 2013, the Society of Nuclear Medicine and Molecular Imaging (SNMMI) and the European Association of Nuclear Medicine (EANM) published a joint practice guideline regarding the utilization of ^{18}F-FDG PET/CT for infection and inflammation detection including clinical indications and technical protocols [17]. These societies identified the major clinical indications for

^{18}F-FDG infection localization including peripheral osteomyelitis (non-diabetic and non-postoperative foot), spinal infection, fever of unknown origin, metastatic infection, and bacteremia in high-risk patients.

6. Conclusion

^{18}F-FDG PET/CT continues to be a frequently performed imaging study in oncologic imaging. Accurate staging requires the interpreting physician to be familiar with non-oncologic causes of focal uptake, which may be mistaken of foci of malignancy and strategies to avoid such errors. As ^{18}F-FDG appears to be an excellent detector of infection, the use of ^{18}F-FDG PET/CT to detect and localize sites of infection will likely increase in the future.

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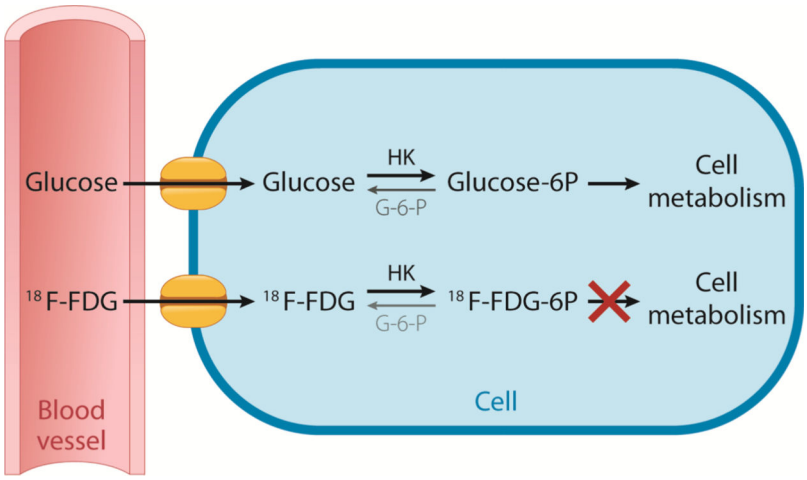

Fig. 1.

Glucose and ^{18}F-FDG Cellular Uptake and Metabolism. Both glucose and ^{18}F-FDG enter the cells by glucose transporter membrane proteins. Once in the cell, both are phosphorylated by hexokinase (HK), which can be reversed by glucose-6-phosphatase (G-6-P) if present. Phosphorylated glucose (Glucose-6 P) is available to be further metabolized by the cell, whereas phosphorylated ^{18}F-FDG (^{18}F-FDG-6 P) cannot be further metabolized and is therefore considered “trapped”.

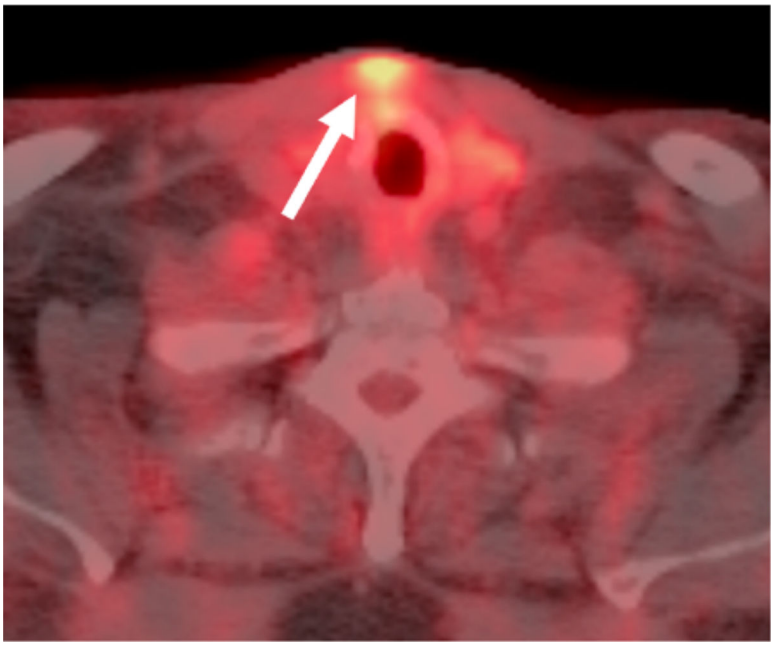

Fig. 2.

Focal Inflammatory ^{18}F-FDG uptake at Site of a Previous Tracheostomy. Axial fused PET/CT demonstrates focal uptake in the soft tissues (arrow) in the anterior neck superficial to the thyroid gland that correlated to the site of postsurgical inflammation at the site of a previous tracheostomy.

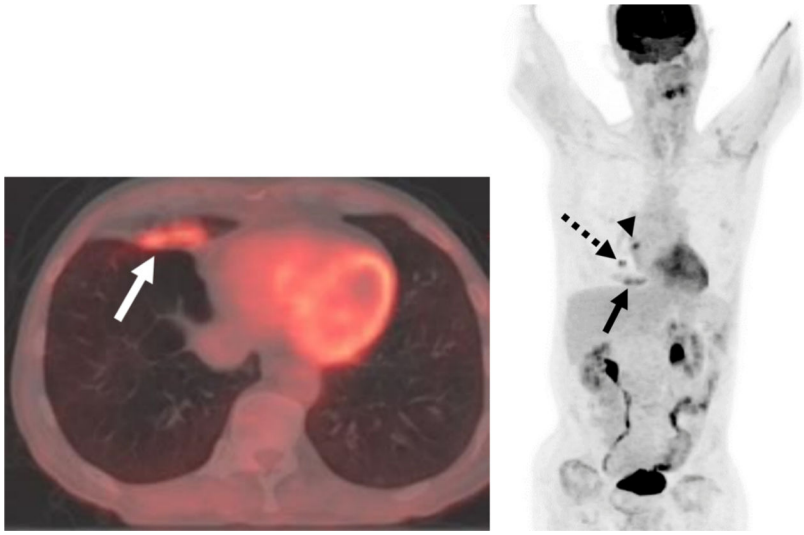

Fig. 3.

Postobstructive ^{18}F-FDG-avid Airspace Disease in a Patient with Lung Malignancy.

A, B Axial fused PET/CT and maximum intensity projection image demonstrates focal uptake in right middle lobe airspace disease (solid arrows) in a patient with a hypermetabolic central right lung nodule (dashed arrow) and an adjacent right hilar lymph node (arrowhead).

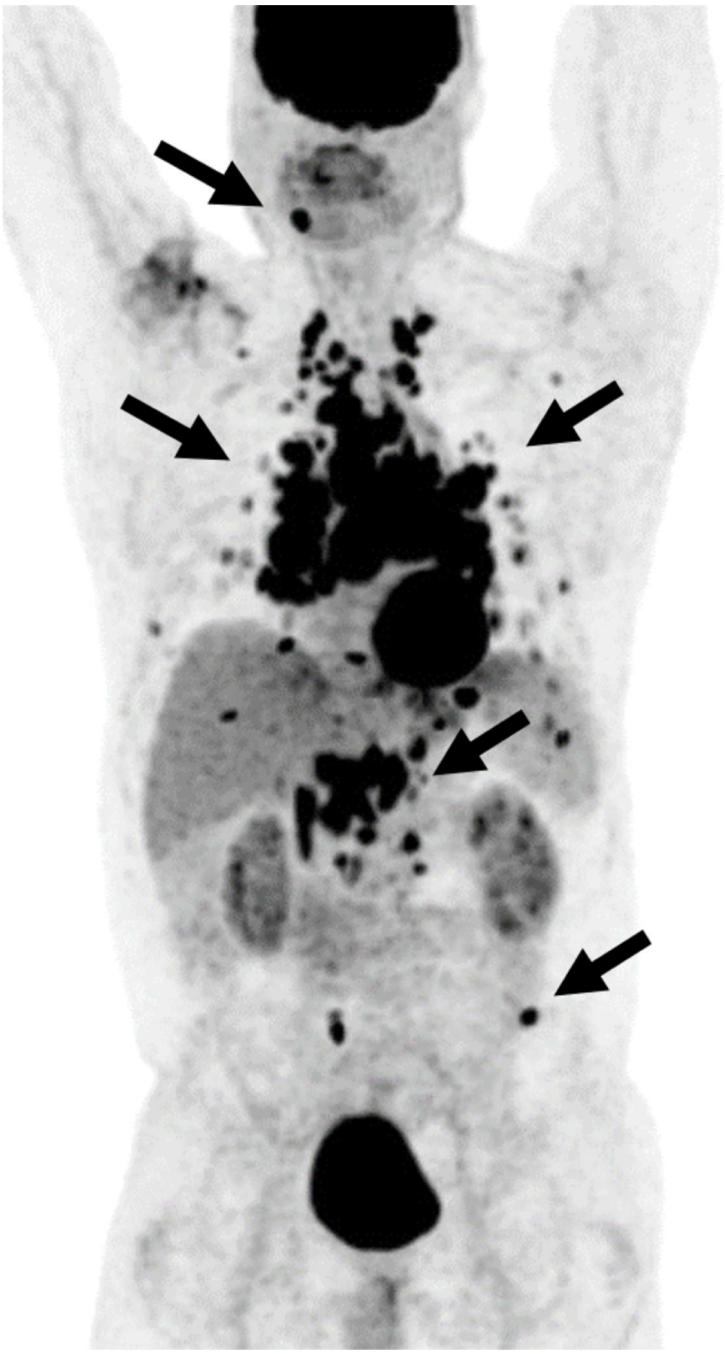

Fig. 4.

Multiple Foci of Abnormal Uptake in a 56-year-old male with ^{18}F-FDG-avid Sarcoidosis. Maximum intensity projection image from an ^{18}F-FDG PET/CT multiple hypermetabolic foci (arrows) in lymph nodes, pulmonary nodules, as well as several osseous foci that were initially viewed with concern for a malignancy such as lymphoma. However, subsequent tissue sampling revealed sarcoidosis as the underlying cause.

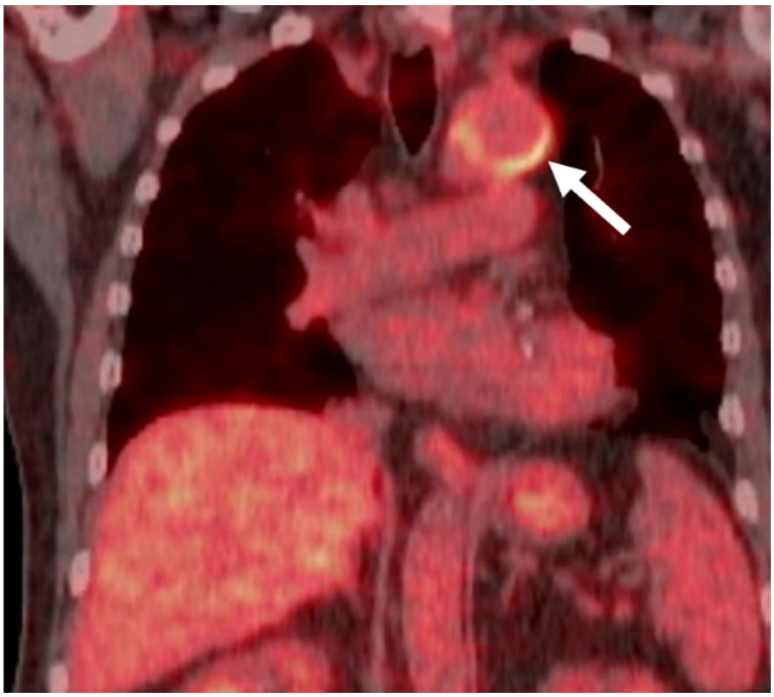

Fig. 5.

Incidental Non-infectious Inflammatory Uptake in a Recently Placed Thoracic Aortic Graft in a 59-year-old male.

Fused coronal ^{18}F-FDG PET/CT demonstrates mild intensity curvilinear uptake (arrow) along portions of a recently placed thoracic aortic graft in an oncology patient without signs/symptoms of infection.

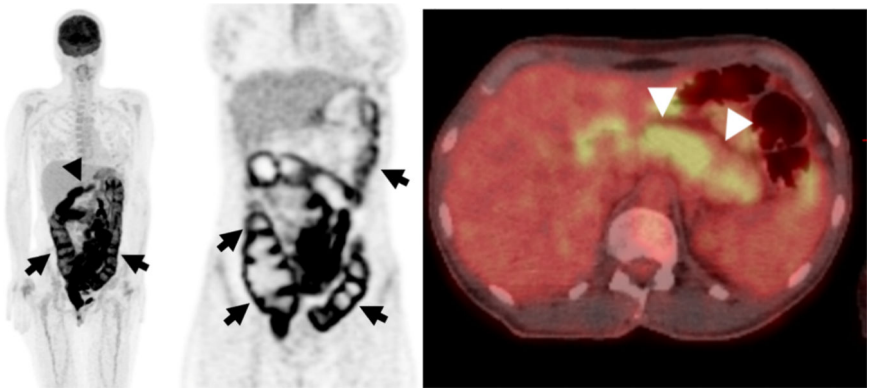

Fig. 6.

42-year-old Woman Receiving Immunotherapy for Metastatic Melanoma.

A, Maximum intensity projection image from an ^{18}F-FDG PET/CT demonstrates diffuse hypermetabolic activity in the colon (arrows) and diffuse uptake involving the pancreas (arrowhead).

B, Coronal PET images show diffuse uptake throughout the entire colon consistent with colitis (arrows), an adverse effect related to immunotherapy. </p/> C, Axial fused PET/CT show diffuse uptake throughout the pancreas (arrowheads) consistent with pancreatitis related to immunotherapy.

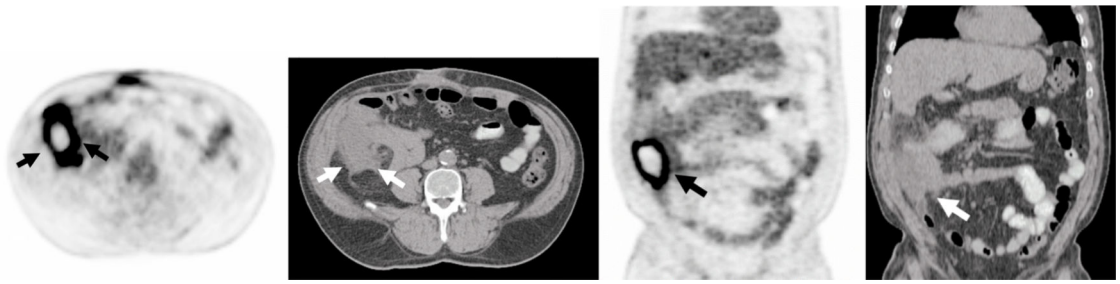

Fig. 7.

Hypermetabolic Right-sided Abdominal Abscess 64 year-old Man.

A, B Axial and C, D coronal PET and CT images from an ^{18}F-FDG PET/CT demonstrates a hypermetabolic fluid collection with peripheral uptake and central photopenia in the right abdomen (arrows). The patient had recent colonoscopy and biopsy of a polyp at the cecum with suspicion for perforation after the procedure. The abscess required to surgical drainage and antibiotic treatment.

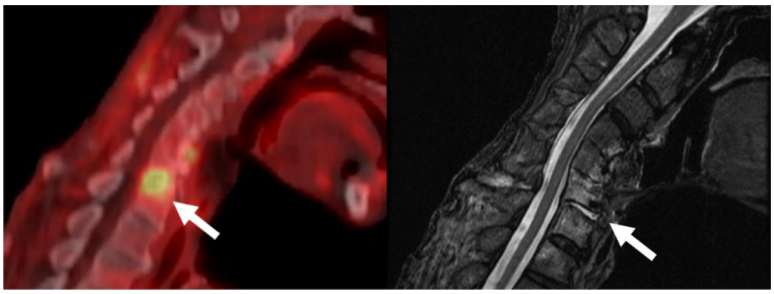

Fig. 8.

67-year-old Male with Focal ^{18}F-FDG uptake correlating to Cervical Discitis/Osteomyelitis. A, Fused sagittal ^{18}F-FDG PET/CT demonstrates focal uptake at C6-C7 (*arrow*) concerning for infection.

B, Sagittal T2 weighted images demonstrates focal edema/fluid in the C6-C7 disc space and adjacent vertebral bodies (*arrows*) concerning for discitis/osteomyelitis. Patient's spinal infection was determined to be a complication of his treatment for his head and neck cancer.

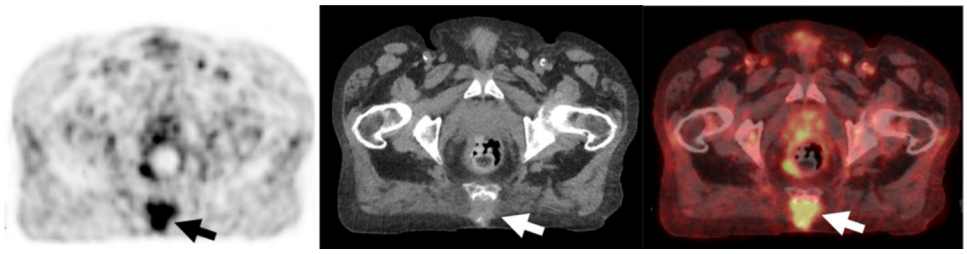

Fig. 9.

72-year-old Man with Sacral Decubitus Ulcer.

A-C, Axial PET, CT and fused from an ^{18}F-FDG PET/CT demonstrates focal uptake within an ulcer with extension to the involve the sacrum consistent with infected sacral decubitus ulcer and sacral osteomyelitis.

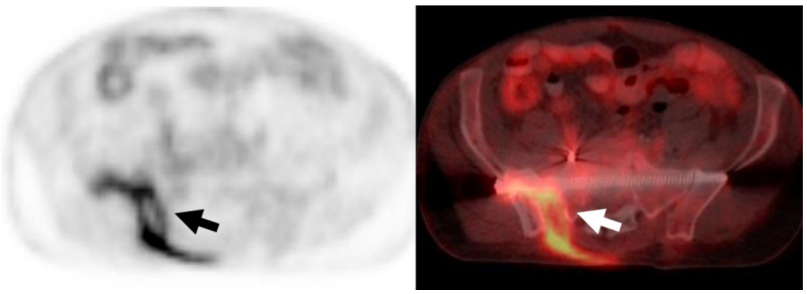

Fig. 10.

Hypermetabolic Septic Arthritis Incidentally Detected in on ^{18}F-FDG PET/CT performed for a Solitary Pulmonary Nodule Evaluation.

A, B, Axial ^{18}F-FDG PET and fused PET/CT demonstrates curvilinear uptake in the right sacroiliac joint and surrounding soft tissues (arrows) corresponding to a septic joint with a sinus tract. The patient had a history of multiple pelvic surgeries due to prior trauma.

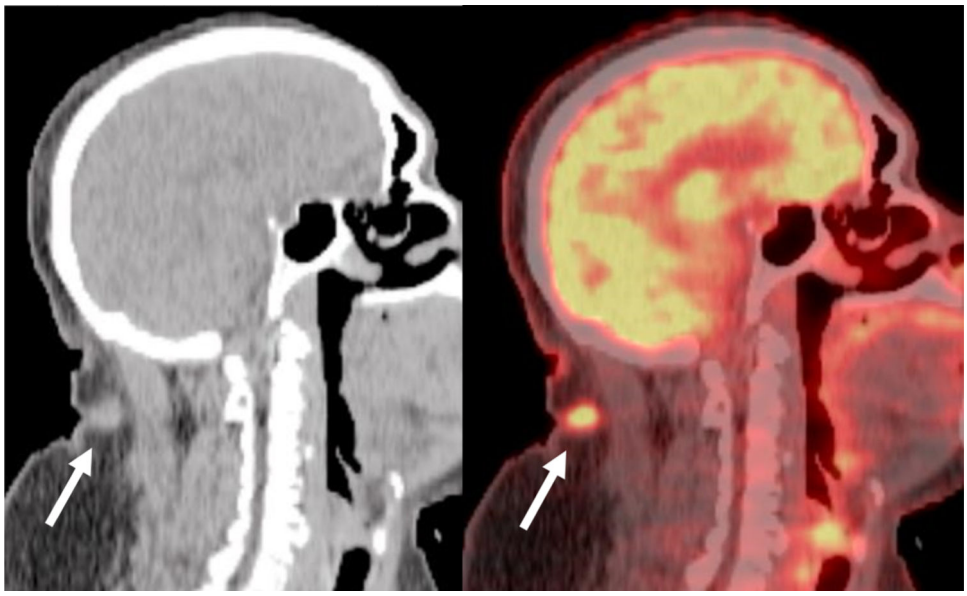

Fig. 11.

72-year-old male with Lung Cancer with Incidental Focal Uptake in the Neck.

A, B, Sagittal CT and fused ^{18}F-FDG PET/CT of the neck demonstrates a small subcutaneous hypermetabolic nodule in the posterior soft tissues of the neck (*arrow*). Clinically this site corresponded to a furuncle (boil) with adjacent skin erythema.

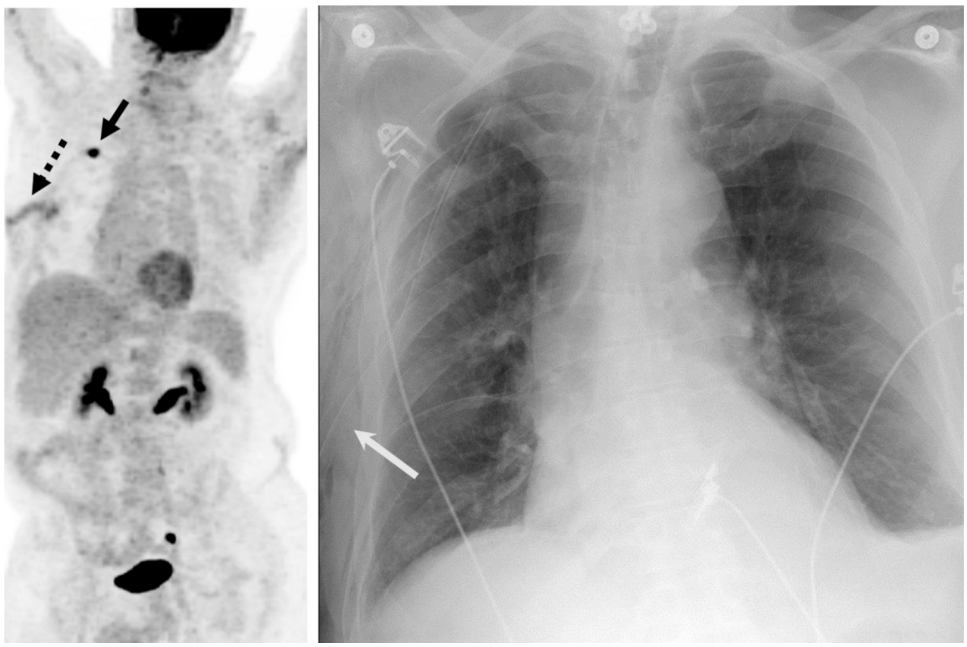

Fig. 12.

67-year-old man with a Recent Diagnosis of Lung Carcinoma.

A, Maximum intensity projection image from an ^{18}F-FDG PET/CT demonstrates a hypermetabolic right upper lobe mass (*solid black arrow*) with an additional linear focus of uptake in the subcutaneous tissues of the right chest wall (*dashed arrow*) that was inflammatory due to a right thoracotomy tube placed due to a post-biopsy pneumothorax. B, Frontal chest radiograph demonstrates the location of the right thoracotomy tube (solid white *arrow*) confirming the inflammatory etiology of the FDG uptake.

Table 1

Common and uncommon benign inflammatory and infectious causes of FDG uptake in oncology patients.

Location	Etiology
Brain / CNS	Brain abscess
	Toxoplasmosis
	Viral encephalitis
	Septic emboli
	Nocardia
	Meningitis
Head and Neck	Lymphoid tissue, Waldeyer's ring, palatine and lingual tonsils
	Thornwaldt cyst
	Sinusitis (maxillary, ethmoid, nasal, frontal)
	Inflammatory jugulo-digastric lymph nodes
	Dental infections
	Parotitis
	Thyroiditis
	Mucositis after chemoradiation therapy
	Otitis media
	Otitis externa
	Mastoiditis
	Tracheostomy
Thorax	
Lungs	Pneumonia
	Atelectasis / collapse
	Opportunistic infections (pneumocystis, nocardia, fungal)
	Sarcoidosis
	Tuberculosis
	Rheumatoid nodules
	Bleomycin toxicity
	Septic emboli
	Post-radiation inflammation
Pleura	Talc pleurodesis
	Exudative pleural effusions
Mediastinum	Chronic granulomatous disease
	Sarcoidosis
	Tuberculosis
Heart and large vessels	Endocarditis (abscess)
	Myocarditis
	Sarcoidosis
	Infected prosthetic valves
	Iatrogenic (LVAD, surgical clips, pacemakers wires, AICD wires)
	Infected central lines

Location	Etiology
	Mycotic aneurysms
	Large-vessel vasculitis
Miscellaneous	Esophagitis
	Mastitis
	Breast abscess
	Fat necrosis
	Inflammatory axillary lymph nodes
Abdomen	
Liver	Liver abscess
	Hepatitis
	Cholangitis
Gallbladder	Cholecystitis
Pancreas	Pancreatitis, pancreatic pseudocyst
Spleen	Granulomatous disease
Large and small bowel	Ulcerative colitis
	Pseudomembranous colitis immunotherapy related colitis
	Bowel perforation
	Appendicitis
	Diverticulitis
	Small bowel ischemia
	Duodenitis
	Mesenteric adenitis
	Percutaneous drains and feeding tubes
Stomach	Gastritis
Kidneys	Pyelonephritis
	Renal abscess
	Retroperitoneal fibrosis
Pelvis	Inflammatory inguinal lymph nodes
	Salpingo-oophoritis
	Endometritis
	Prostatitis
	Epididymo-orchitis
Musculoskeletal	
Bone	Discitis
	Osteomyelitis
	Inflammatory degenerative disease
	Pressure sores
	Infected diabetic foot ulcers
	Orthopedic prosthesis infections and surgical hardware
	Chronic migratory recurrent osteomyelitis
Muscles and joints	Dermatomyositis
	Polymyositis

Location	Etiology
	Rheumatoid arthritis
	Rhabdomyositis
	Intramuscular abscess
Vessels	Giant cell arteritis
	Vasculitis
	Infected aortic-iliac-femoral grafts
	Infected A-V fistula
Skin / subcutaneous soft tissues	Hidradenitis suppurativa
	Wound infections
	Sebaceous cyst
	Acne
	Eczema
	Fournier's gangrene
	Iatrogenic injection granuloma

From references [12,21–42,44–51,53–80].