Pictorial Essay
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Benign Thyroid and Neck Lesions Mimicking Malignancy with False Positive Findings on Positron Emission Tomography-Computed Tomography

양전자 방출 컴퓨터단층촬영(Positron Emission Tomography-Computed Tomography)에서 위양성을 보이는 양성 갑상선 및 경부 병변

Ye Ri Yoon, MD[1], Shin Young Kim, MD[1]*, Sang Mi Lee, MD[2], Deuk Young Lee, MD[3]
Departments of [1]Radiology, [2]Nuclear Medicine, Soonchunhyang University Cheonan Hospital, Cheonan, Korea
[3]Department of Surgery, Younsei Angelot Women's Clinic, Cheonan, Korea

The increasing use of positron emission tomography-computed tomography (PET/CT) has led to the frequent detection of incidental thyroid and neck lesions with increased ^{18}F-deoxyglucose (FDG) uptake. Although lesions with increased FDG uptake are commonly assumed to be malignant, benign lesions may also exhibit increased uptake. The purpose of this pictorial essay is to demonstrate that benign thyroid and neck lesions can produce false-positive findings on PET/CT, and to identify various difficulties in interpretation. It is crucial to be aware that differentiating between benign and malignant lesions is difficult in a considerable proportion of cases, when relying only on PET/CT findings. Correlation of PET/CT findings with additional imaging modalities is essential to avoid misdiagnosis.

Index terms
Positron Emission Tomography
Thyroid Neoplasms
Neck

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***Corresponding author:** Shin Young Kim, MD
Department of Radiology, Soonchunhyang University Cheonan Hospital, 31 Suncheonhyang 6-gil, Dongnam-gu, Cheonan 31151, Korea.
Tel. 82-41-570-3514 Fax. 82-41-576-9026
E-mail: taloo@hanmail.net

INTRODUCTION

Positron emission tomography-computed tomography (PET/CT) is a scanning technique that combines the advantages of two different scanning modalities and provides both anatomic and functional information. PET/CT using ^{18}F-deoxyglucose (FDG) is generally employed for the diagnosis and staging of malignancy. The use of PET/CT as an evaluation tool has increased rapidly, not only for diagnosis but also for monitoring therapeutic effects, detecting local recurrence, and screening (1). Therefore, incidental thyroid lesions with focal and diffuse FDG uptake are frequently detected in patients undergoing PET/CT (1). Lee et al. (2) reported that the frequency of finding incidental thyroid lesions with PET/CT in patients with non-thyroidal cancer was 8.4% (226/2703). Normal thyroid glands are typically not envisioned in a whole body PET scan because of the very low-grade FDG uptake. Hence, focally increased FDG uptake in the thyroid typically suggests malignancy. According to Bae et al. (1), both malignant and benign thyroid lesions can show focal and diffuse FDG uptake. Furthermore, lesions with increased FDG uptake in the neck are common. When lesions having increased FDG uptake are detected in a patient with underlying cancer, a malignancy, such as metastasis, is strongly suspected. However, these lesions do not always indicate malignancy. Numerous causes of false positives in PET/CT interpretation have been reported, such as physiologic uptake, increased FDG uptake by benign thyroid nodules with high glucose metabolism, inflammation or infection, recent chemoradiotherapy, and surgery (3). Because it is difficult to differentiate between benign and malignant lesions, it can be helpful to evaluate standardized uptake values (SUVs). SUVs greater than 3 are generally considered to indicate a neoplasm. However, acute infections, such as sinusitis, suppurative lymphadenopathy, and abscesses can also produce SUVs greater than 3 (4). Therefore, sequential follow-up imaging, ultrasonography, and fine needle aspiration (FNA) may be helpful to eliminate ambiguity. Any recent chemoradiotherapy and surgery can cause inflammation, edema, hyperemia, fibrosis, and increased FDG uptake, which may be wrongly identified as residual tumor tissue. According to previous studies, PET/CT performed within the first month of therapy may yield false-positive findings (4). Therefore, it is recommended that PET/CT be performed at least 2–3 months after the completion of therapy to determine the disease status more accurately and to avoid misdiagnosis (3). The purpose of this pictorial essay is to demonstrate that benign thyroid and neck lesions can produce false-positive findings on PET/CT, and to identify various interpretation pitfalls. Correlation of PET/CT findings with additional imaging modalities is essential to avoid misdiagnosis in a considerable proportion of cases.

Nodular Hyperplasia

Nodular hyperplasia is the most common benign lesion of the thyroid gland, accounting for 80–85% of all thyroid nodules. There are diffuse and nodular patterns of hyperplasia, and on ultrasonography, they typically appear as well-circumscribed isoechoic or hyperechoic nodules (5). In one of our cases, a 67-year-old woman with breast cancer underwent PET/CT for metastatic evaluation. PET/CT demonstrated an increased focal FDG uptake in the right thyroid gland (SUVmax = 5.09) (Fig. 1A), suggesting the presence of a malignancy. Previous reports indicated that increased focal uptake can be observed in thyroid malignancy, whereas a mild, diffuse, symmetrical uptake may be observed in normal thyroid glands, diffuse goiters, and autoimmune thyroiditis. The risk of malignancy in an area of focal FDG uptake is reported to be in the range of 36–63% (3). This case was difficult to diagnose with only PET/CT findings. Therefore, ultrasonography and FNA were also performed to exclude thyroid cancer. Ultrasonography identified an oval-shaped isoechoic nodule in the right thyroid gland, and FNA confirmed nodular hyperplasia (Fig. 1B). Focal FDG uptake may be attributable to several benign conditions, including nodular hyperplasia, Hürthle cell and follicular neoplasms, and lymphocytic thyroiditis (6). Although the maximum SUV of a malignant thyroid lesion is considerably higher than that of a benign lesion (3), Karantanis et al. (7) reported a case of a nodular goiter with a moderate-to-intense FDG uptake in both lobes of the thyroid gland with SUV > 6 (right SUVmax = 6.5, left SUVmax = 6.3). It is essential to be aware that intense FDG uptake (SUV > 3) does not always indicate malignancy and to correlate findings with other imaging modalities.

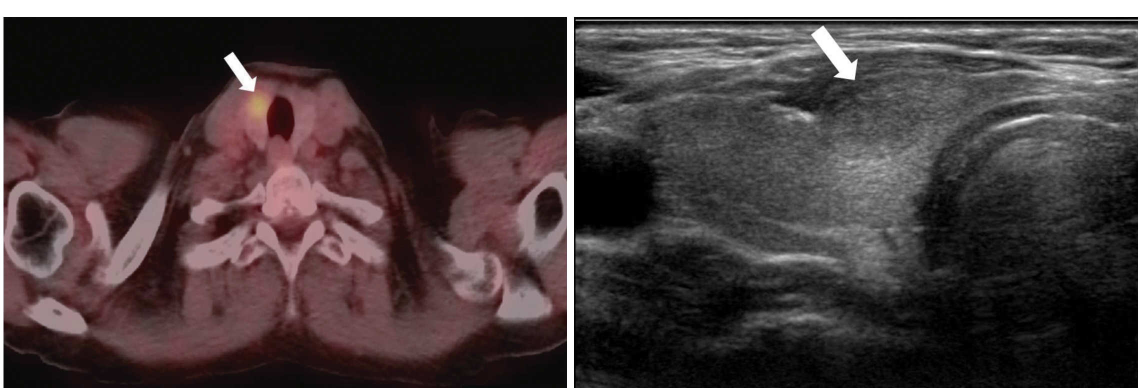

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Fig. 1. Nodular hyperplasia, a 67-year-old woman with breast cancer.
A. PET/CT transaxial fusion image shows focal FDG uptake in the right lobe of the thyroid gland (arrow) (SUVmax = 5.09).
B. Ultrasonography image shows an oval shaped isoechoic nodule in the right thyroid lobe (arrow). FNA confirmed nodular hyperplasia.
FDG = ^{18}F-deoxyglucose, FNA = fine needle aspiration, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

Hashimoto's Thyroiditis

Hashimoto's thyroiditis is an autoimmune disease leading to hypothyroidism through destruction of the thyroid gland (5). Karantanis et al. (7) observed increased diffuse FDG uptake in PET/CT scans of the thyroid glands in 2.9% (138/4732) of Hashimoto's thyroiditis patients, with or without the presence of hypothyroidism. Moreover, 47% of these patients with diffuse thyroidal FDG uptake had a prior diagnosis, and 14.3% of them had a subsequent diagnosis of hypothyroidism or autoimmune thyroiditis. As mentioned previously, diffuse symmetrical FDG uptake in both lobes of the thyroid gland is likely to indicate a benign disease such as diffuse goiters or autoimmune thyroiditis, whereas increased focal FDG uptake indicates a malignancy (3). Moderate to intense uptake in both lobes of the thyroid is typically secondary to hypothyroidism associated with elevated thyroid stimulating hormone (thyroiditis) or hyperthyroidism and Graves' disease. These conditions may produce increased blood flow, enhanced glucose metabolism, and inflammation, all of which are factors that increase FDG uptake by the thyroid (8). It has also been reported that a moderate to intense FDG uptake is not indicative of either the degree of hypothyroidism or the levels of thyroid peroxidase antibodies (7). The typical sonographic appearance of Hashimoto's thyroiditis is diffuse glandular enlargement of the thyroid with lobulated margins and fibrous septa. The presence of multiple, discrete, hypoechoic micronodules (1–6.5 mm) is also a strong indication of chronic thyroiditis (5). At our institution, a 54-year-old woman underwent PET/CT for screening, and an incidental diffuse FDG uptake was observed in both lobes of the thyroid gland (SUVmax = 4.2) (Fig. 2A). A thyroid function test revealed mild hypothyroidism. On ultrasonography, heterogeneous parenchymal echogenicity with ill-defined oval heterogeneous hypoechoic nodules was observed in both lobes of the thyroid gland (Fig. 2B). FNA confirmed Hashimoto's thyroiditis.

Subacute Thyroiditis

Subacute thyroiditis is an inflammation of the thyroid gland that occurs after viral infection, and most commonly occurs in middle-aged women (5). Subacute thyroiditis can exhibit diffuse FDG uptake involving a single lobe or both lobes of the thyroid gland on PET/CT. However, a rare observation of focal FDG uptake by the thyroid gland may also occur in subacute thyroiditis. Yeo et al. (6) reported the first case of subacute thyroiditis with focal hypermetabolism on PET/CT, mimicking thyroid malignancy. Additional imaging modalities were necessary because of the limitations of PET/CT. On ultrasonography, subacute thyroiditis characteristically appears as a markedly hypoechoic area with ill-defined, irregular margins. Using color Doppler ultraso-

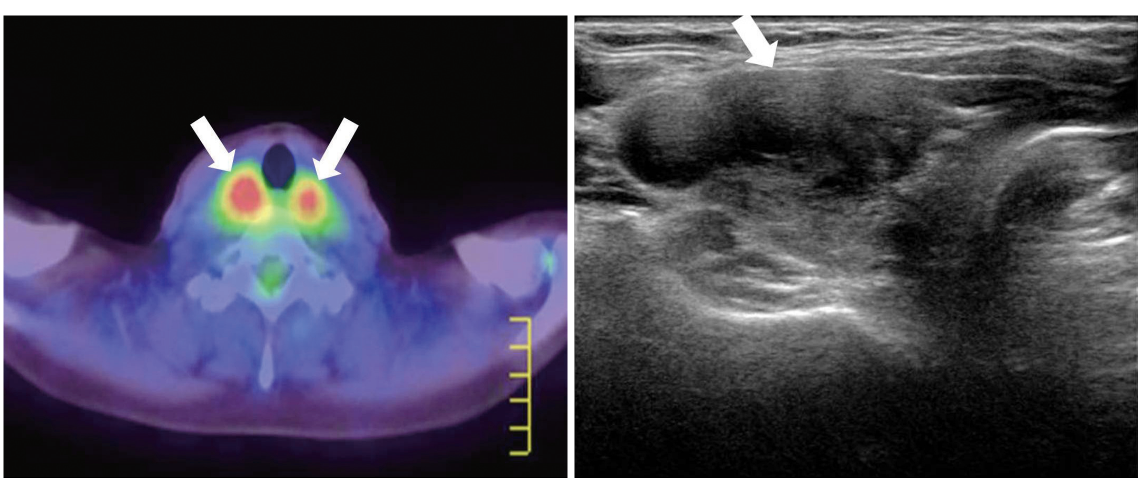

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Fig. 2. Hashimoto's thyroiditis, a 54-year-old woman, screening.
A. PET/CT transaxial fusion image shows increased diffuse FDG uptake in both lobes of thyroid gland (arrows) (SUVmax = 4.2).
B. Ultrasonography image shows heterogeneous parenchymal echogenicity with ill-defined oval hypoechoic nodules in the right lobe of the thyroid gland (arrow). FNA confirmed Hashimoto's thyroiditis.
FDG = [18]F-deoxyglucose, FNA = fine needle aspiration, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

nography, subacute thyroiditis typically exhibits decreased vascularity because of diffuse edema of the gland (5). In one of our cases, a 62-year-old woman with stomach cancer underwent PET/CT for metastatic evaluation. We detected increased diffuse FDG uptake in both lobes of the thyroid gland (SUVmax = 3.47) (Fig. 3A). Because the patient also complained of neck tenderness, color Doppler ultrasonography was also performed. This revealed a heterogeneous hypoechoic area with an irregular margin in the anterior portion of both lobes of the thyroid gland, and decreased vascularity (Fig. 3B). Ultrasonography-guided FNA was also performed, and combined with the clinical symptoms and histology, subacute thyroiditis was finally confirmed.

Benign Inflammation – Tuberculous Lymphadenopathy, Reactive Lymphadenopathy

Tuberculosis is a systemic disease caused by *Mycobacterium tuberculosis* that can affect any organ of the body. Various imaging modalities, including conventional radiography, CT, magnetic resonance imaging (MRI), and PET/CT, are used for detecting pulmonary and extrapulmonary tuberculosis. On PET/CT, tuberculosis can exhibit increased FDG uptake because FDG accumulates in inflammatory cells, such as neutrophils, activated macrophages, and lymphocytes, at the site of inflammation or infection. Therefore, diagnostic imaging is occasionally challenging because image findings of tuberculosis may mimic those

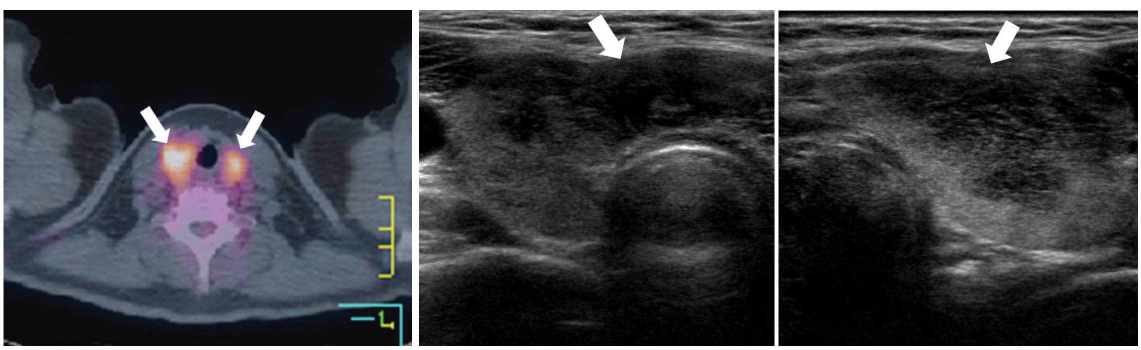

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Fig. 3. Subacute thyroiditis, a 62-year-old woman with stomach cancer.
A. PET/CT transaxial fusion image shows increased diffuse FDG uptake in both lobes of the thyroid gland (arrows) (SUVmax = 3.47).
B. Ultrasonography images show irregular margin and heterogeneous hypoechoic area in anterior portion of both lobes of the thyroid gland (arrows) with decreased vascularity on color Doppler ultrasonography (not shown). FNA confirmed subacute thyroiditis.
FDG = ^{18}F-deoxyglucose, FNA = fine needle aspiration, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

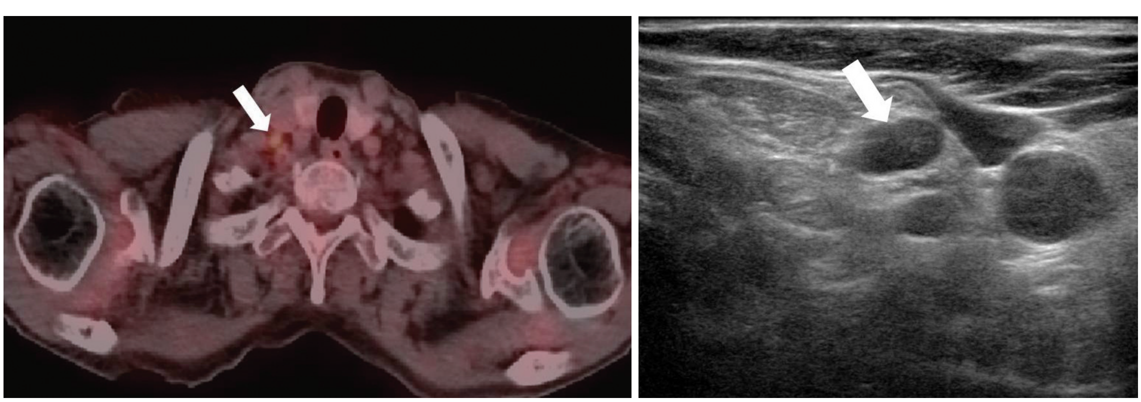

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Fig. 4. Benign inflammation (tuberculous lymphadenopathy), a 75-year-old woman with cervical cancer.
A. PET/CT transaxial fusion image shows increased focal nodular FDG uptake in right neck level IV (arrow) (SUVmax = 2.4).
B. Ultrasonography image shows a small lymph node in the right neck with loss of fatty hilum (arrow). Biopsy confirmed tuberculosis.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

of other diseases such as neoplasms (9). SUV measurements from both tuberculous and malignant lesions tend to be high and share considerable overlap. Thus, Vorster et al. (10) stated that FDG PET is unable to distinguish tuberculous lymphadenitis from metastatic lymph node involvement based on the SUV alone. However, Nair et al. (11) suggested that dual-time-point PET/CT (3–5 h delayed) is of paramount importance in confidently differentiating inflammatory or infective lesions from malignancies because FDG remains in malignant cells for a long time period, whereas FDG washes out of inflammatory or infective over a short period. CT imaging can also demonstrate the characteristic features of tuberculous lymphadenopathy, such as a lymph node with a low-density center and surrounding peripheral enhancing rim reflecting caseous necrosis and granulomatous inflammatory tissue, respectively (9). In one of our cases, a 75-year-old woman who had a history of cervical cancer underwent PET/CT for metastatic evaluation. No abnormal increased FDG uptake was observed on the initial PET/CT. However, after one year, we detected a newly developed increased focal nodular FDG uptake in the right side of the neck (SUVmax = 2.4) (Fig. 4A), and metastatic lymphadenopathy was suspected. An ultrasonography-guided core biopsy was performed (Fig. 4B) which confirmed a diagnosis of tuberculosis.

Infection is a common cause of lymph node enlargement. Infected macrophages in the draining lymph nodes and the pathogen-stimulated cellular immune response explain why increased FDG uptake is seen on PET/CT in patients with infective lymphadenopathy. Activated macrophages have been shown to have increased glucose utilization. Accumulation of FDG by inflammatory and infectious processes occasionally results in false-positive identification of malignancy (12). According to Payabvash et al. (13), the maximum SUV measurement can help to differentiate malignant cervical lymph nodes in patients with head and neck cancer. They stated that malignant lymph nodes had a higher maximum SUV value ($p < 0.001$) and short axis diameter ($p = 0.015$) compared with benign nodes. A maximum SUV ≥ 2.5 was 100% sensitive, and a maximum SUV ≥ 5.5 was 100% specific for malignant lymphadenopathy. We treated a case of reactive lymphadenopathy, which mimicked metastasis with high FDG uptake on PET/CT. There was an enlarged lymph node in the right supraclavicular area with increased FDG uptake seen on PET/CT (SUVmax = 3.5) (Fig. 5A). Ultrasonography guided core biopsy was performed and reactive hyperplasia was confirmed (Fig. 5B).

Traumatic Neuroma

Traumatic neuroma is the result of a proliferative and hyperplastic response to nerve injury, usually during a surgical procedure or after trauma (14). The typical symptom of traumatic neuroma is painful hypersensitivity or paresthesia, although asymptomatic patients are not rare. Usually, the patient immediately complains of pain when the needle tip touches the mass. Traumatic neuroma is usually seen on ultrasonography as a firm and well-defined hypoechoic nodule that is located adjacent to vascular structures. CT findings show a hyperattenuating rim which

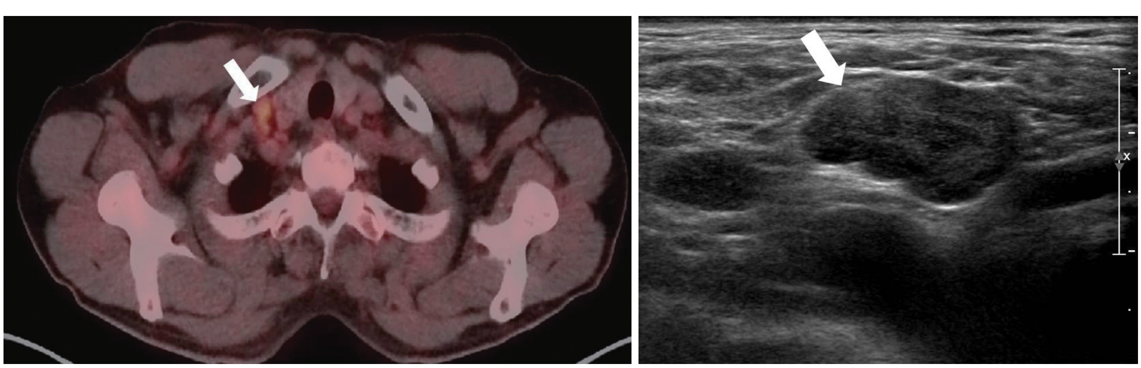

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Fig. 5. Benign inflammation (reactive lymphadenopathy), a 69-year-old man with stomach cancer.
A. PET/CT transaxial fusion image shows a lymph node in right supraclavicular area with increased FDG uptake (arrow) (SUVmax = 3.5).
B. Ultrasonography image shows an enlarged lymph node in the right supraclavicular area with loss of fatty hilum (arrow). Biopsy confirmed reactive hyperplasia.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

is characteristic of traumatic neuroma (14). To our knowledge, there are no previous reports of PET/CT observations of traumatic neuroma in the neck. Kim et al. (15) reported a case of traumatic neuroma after modified radical mastectomy, which showed no focal FDG uptake on PET/CT. Liu (16) reported a case of post-amputation sciatic neuroma with increased focal FDG uptake on PET. We treated a patient with a traumatic neuroma in the neck that demonstrated mild FDG uptake on PET/CT. At our institution, a 32-year-old man underwent PET/CT for metastatic evaluation. He had a history of total thyroidectomy due to papillary thyroid cancer. On PET/CT, there was a lesion with mild FDG uptake in the right neck (SUVmax = 2.1) (Fig. 6A). On ultrasonography, a spindle-shaped heterogeneous isoechoic nodule was seen (Fig. 6B). An 18G core needle biopsy of the nodule was performed, with the patient complaining of severe pain when the needle tip touched the nodule. Traumatic neuroma was confirmed histologically.

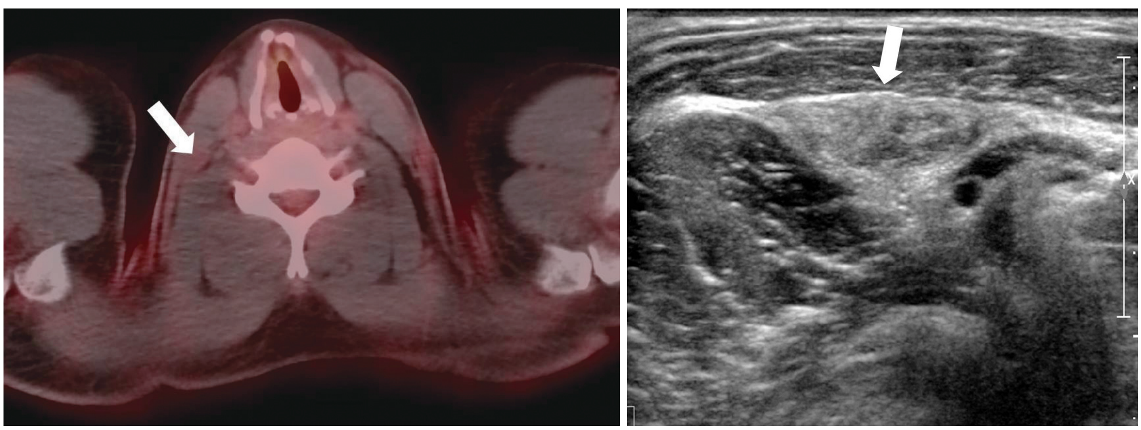

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Fig. 6. Traumatic neuroma, a 32-year-old man with total thyroidectomy for papillary thyroid cancer.
A. PET/CT transaxial fusion image shows increased FDG uptake in the right neck (arrow) (SUVmax = 2.1).
B. Ultrasonography image shows a spindle-shaped circumscribed heterogeneous isoechoic nodule in the right neck (arrow). An 18G core needle biopsy was performed and traumatic neuroma was confirmed.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

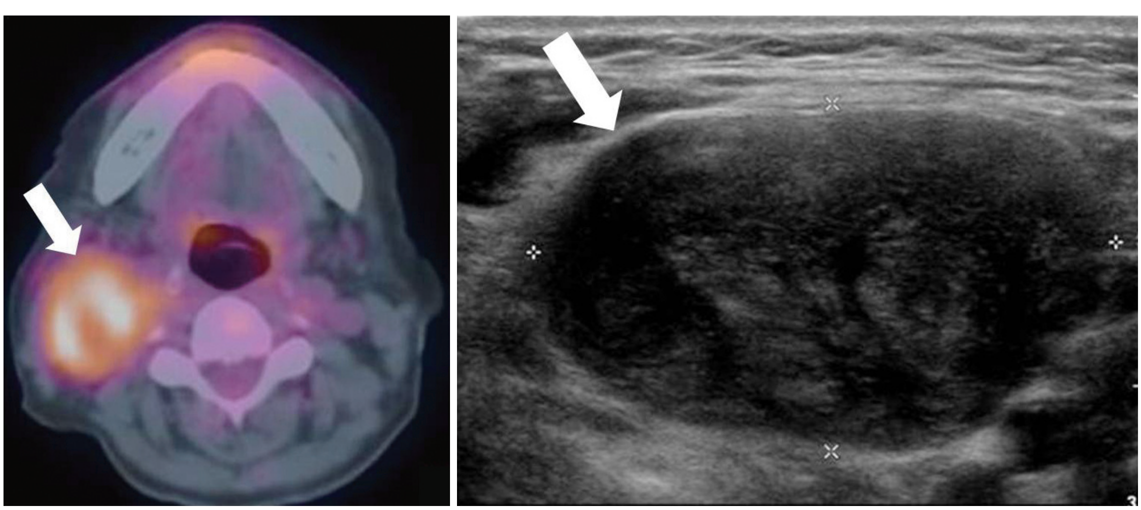

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Fig. 7. Schwannoma, a 64-year-old woman with breast cancer.
A. PET/CT transaxial fusion image shows increased focal nodular FDG uptake in the right neck (arrow) (SUVmax = 5.5).
B. Ultrasonography image shows a circumscribed, oval, heterogeneous, hypoechoic nodule in the right neck (arrow). An 18G core needle biopsy confirmed schwannoma.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

Schwannoma

Benign peripheral nerve sheath tumors include neurofibroma and schwannoma. Typically, schwannomas arise from the spinal nerve roots and the cervical, symptomatic, vagus nerves in the head and neck (17). On PET, schwannomas can show a variable range of FDG uptake that can be explained by different degrees of cellularity. Even in cases in which the maximum SUV is greater than 6.0, schwannomas cannot be excluded. No correlation has been found between FDG uptake and tumor size or tumor proliferation rate. The reason high FDG uptake is seen in benign tumors, such as schwannomas, remains unclear. However, overexpression of glucose transporter proteins by tumor cells could provide a possible explanation. Because there are several reports of schwannomas with a high level of FDG uptake, it is difficult to distinguish benign lesions from malignant lesions before performing a biopsy or surgery (17). However, findings from other imaging modalities can be helpful. On CT, schwannomas tend to be well circumscribed, solitary, round to oval-shaped, hypo- to iso-attenuated, and medial to the vessels of the carotid sheath. They routinely displace the internal carotid artery anteriorly or anterolaterally (18). We treated a patient with a schwannoma that demonstrated increased focal nodular FDG uptake on PET/CT (SUVmax = 5.5) (Fig. 7A). On ultrasonography, a circumscribed oval heterogeneous hypoechoic nodule was seen on the right side of the neck (Fig. 7B). Schwannoma was confirmed by an 18G core needle biopsy.

Foreign Body Granuloma

Any hypoechoic mass detected in the postoperative thyroid bed on ultrasonography is suggestive of tumor recurrence. However, several benign lesions can mimic tumor recurrence in the thyroid bed, such as foreign body granuloma. A suture granuloma is a benign, granulomatous inflammatory lesion, which results from a histiocytic reaction by foreign body giant cells to non-absorbable sutures (19). Foreign body granuloma can show increased focal FDG uptake on PET. According to Miyake et al. (20), a foreign body granuloma typically shows a ring-shaped pattern of FDG uptake due to a granulation tissue-type stromal reaction with neovascularization. Therefore, these lesions can mimic malignant tumors with massive necrosis or degeneration. However, Miyake et al. (20) also reported one case of foreign body granuloma without FDG uptake, and important illustration that the degree of FDG uptake can be variable or even absent. On ultrasonography, suture granulomas are typically ill-defined, heterogeneous, and irregular hypo- to isoechoic lesions, with multiple central or paracentral internal echogenic foci. Kim et al. (19) described the characteristic sonographic findings of foreign body granulomas and their evolutional change. On early ultrasonography, foreign body granulomas show hyperechoic linear lesions with posterior acoustic shadowing, but without vascularity on color Doppler images. Over time, these granulomas decrease in size and change into well-defined oval iso- to slightly hypoechoic lesions (19). In one of our cases, we detected

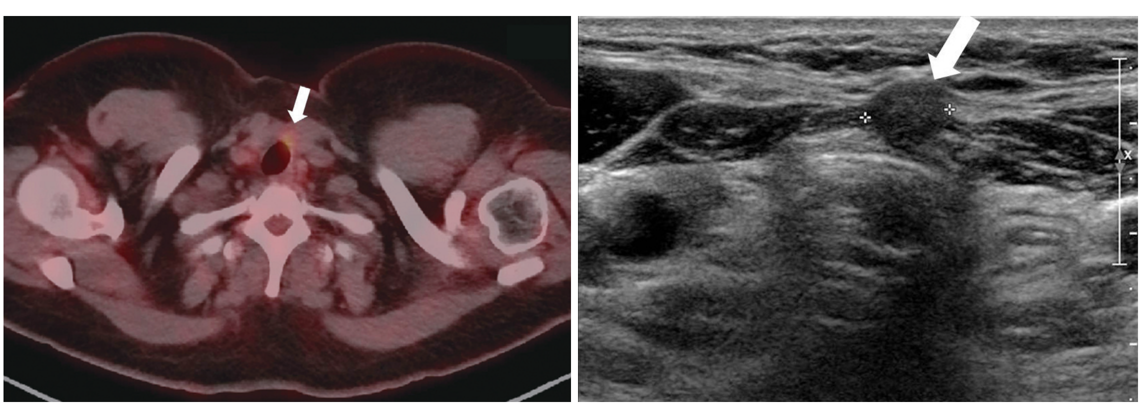

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Fig. 8. Foreign body granuloma, a 43-year-old woman with left hemithyroidectomy for left thyroid cancer.
A. PET/CT transaxial fusion image shows increased focal nodular FDG uptake in the postoperative bed of the left anterior neck (arrow) (SUVmax = 2.9).
B. Ultrasonography image shows a well-defined, round, isoechoic nodular lesion in the postoperative bed of the left anterior neck (arrow). An 18G core needle biopsy was performed, confirming foreign body granuloma.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

increased focal nodular FDG uptake in the postoperative bed in the left anterior neck (SUVmax = 2.9) (Fig. 8A). On ultrasonography, a well-defined round isoechoic nodule was observed (Fig. 8B). An 18G core needle biopsy was performed and foreign body granuloma was confirmed.

Parotid Gland Tumor

It is important to distinguish between malignant and benign parotid gland tumors preoperatively in order to determine the proper treatment and improve the outcome of patients. There are several modalities for evaluating parotid gland tumors, such as CT, MRI, and FNA, but their accuracy is not always reliable (21). Hadiprodjo et al. (21) suggested FDG PET/CT, maximum SUV, metabolic tumor volume, and total glycolytic activity as imaging parameters to differentiate between benign and malignant tumors of the parotid gland. They stated that there are four levels of FDG uptake in the parotid glands: normal physiologic uptake, increased diffuse uptake, benign tumor uptake, and malignant tumor uptake. To differentiate between normal physiologic and tumor uptake by the parotid gland, they suggested an optimal SUVmax cutoff of 3.7. According to their study, the median SUVmax of increased diffuse uptake (2.55) was significantly lower than the median SUVmax of tumors (8.48). The median SUVmax of malignant tumors (11.8) was significantly higher than that of benign tumors (6.4). Although malignant parotid tumors showed significantly higher FDG uptake than either benign tumors or inflammation, SUV values of Warthin's tumor and malignant parotid tumors demonstrated some overlap (22). In this situation, combining salivary gland scintigraphy with FDG PET would better characterize parotid tumors, because Warthin's tumors show increased radiotracer uptake on salivary gland scintigraphy while malignant tumors show cold defects. In one of our patients, we detected increased focal nodular FDG uptake in the left parotid gland (SUVmax = 5.26) (Fig. 9A), in which a well-defined hypoechoic nodular lesion was observed on ultrasonography (Fig. 9B). Warthin's tumor was confirmed by an 18G core biopsy.

Inflammation after Recent Surgery

Post-surgical inflammatory edema, scarring, and granulation tissue can cause increased FDG uptake making PET/CT interpretation difficult (3). This inflammation may result in increased glycolysis which might therefore be associated with increased FDG uptake (4). Granulation tissue is the first step in wound healing and mainly contains inflammatory cells, fibroblasts, myofibroblasts, and small vessels. Transformation of granulation

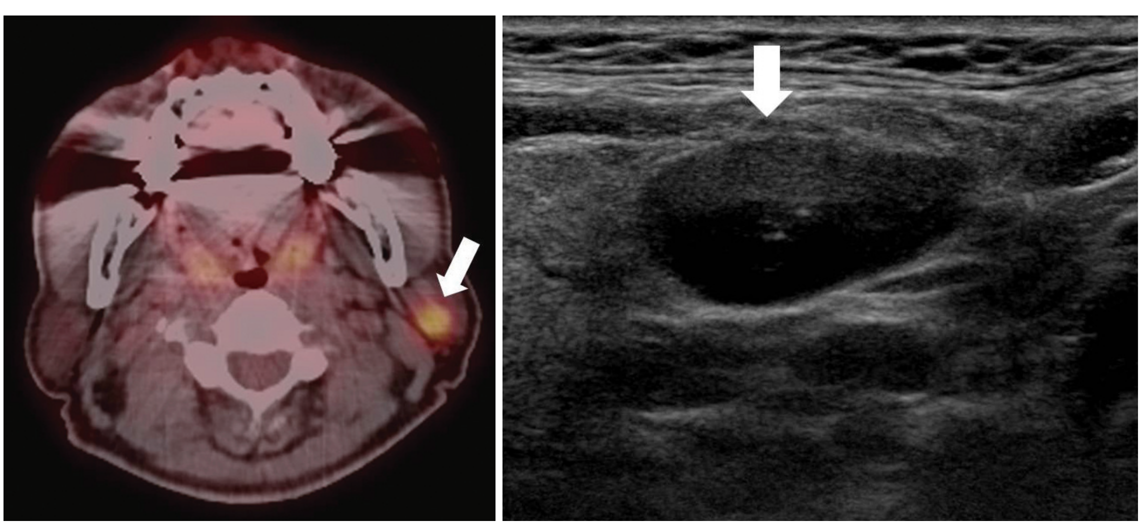

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Fig. 9. Warthin's tumor, a 72-year-old man with supraglottic cancer.
A. PET/CT transaxial fusion image shows increased focal nodular FDG uptake in the left parotid gland (arrow) (SUVmax=5.26).
B. Ultrasonography image shows a well-defined, hypoechoic nodular lesion in the left parotid gland (arrow). An 18G core needle biopsy confirmed Warthin's tumor.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

tissue into scar tissue usually occurs within the first 2 months of injury, and major FDG uptake is typically seen during the first weeks to months after surgery. Therefore, PET performed after recent surgery may yield a false positive finding. However, follow-up PET/CT at least 4–6 weeks after surgery helps to avoid diagnostic errors, because FDG uptake by post-surgical inflammation tends to decrease gradually over time (3). At our institution, we treated a patient with post-surgical inflammatory changes that exhibited increased FDG uptake mimicking a recurred malignancy (Fig. 10).

Inflammation after Chemoradiotherapy

Chemoradiotherapy causes inflammation, edema, hyperemia, fibrosis, and loss of tissue planes. Post-treatment inflammatory tissue can cause increased FDG uptake mimicking residual or recurrent malignancy. False positive findings on PET/CT after chemoradiotherapy include radiation-induced mucositis, reactive nodes, soft tissue necrosis, and radionecrosis of the bone (3). Previous studies showed that PET/CT performed within the first month of therapy may yield false positive findings (4). Therefore, it is recommended that PET/CT be performed at

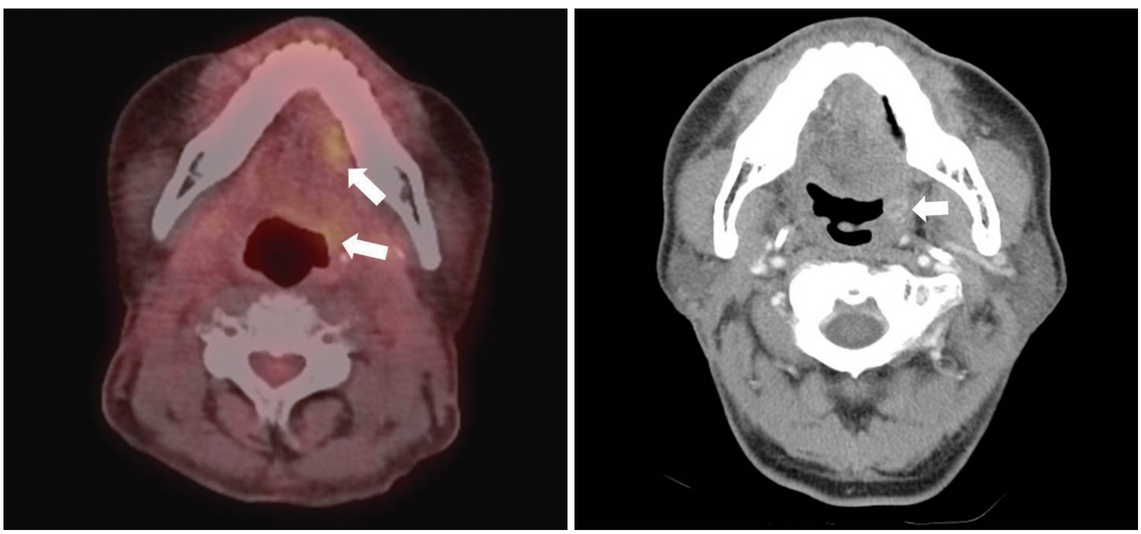

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Fig. 10. Inflammation after recent surgery, a 55-year-old man following wide excision and chemoradiotherapy for tongue cancer.
A. PET/CT transaxial fusion image shows focal FDG uptake in the operation bed and left oropharynx (arrows) (SUVmax = 4.1).
B. Contrast-enhanced axial CT image shows a peripherally enhanced lesion in the left oropharynx (arrow). Physical examination and pathology confirmed the absence of malignancy.
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

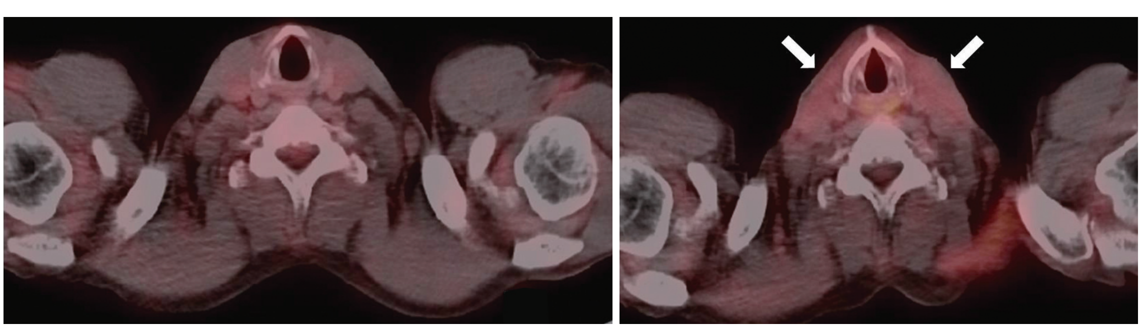

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Fig. 11. Inflammation after radiotherapy, a 61-year-old man following radiotherapy for glottic cancer.
A. Initial PET/CT transaxial fusion image shows no definite FDG uptake in the anterior neck muscles.
B. A 10-month follow-up PET/CT transaxial fusion image shows a newly developed increased diffuse FDG uptake in the muscles of the anterior neck (arrows) (SUVmax = 3.05).
FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value

Table 1. Benign Thyroid Lesions with Increased FDG Uptake on PET/CT

	Diagnosis	FDG Uptake Pattern	SUV	Mechanism	USG	Other Study
Case 1	Nodular hyperplasia	Focal	5.09	Increased blood flow and vascularity (24)	Well-circumscribed oval-shaped isoechoic nodule	Normal thyroid hormone level on thyroid function test
Case 2	Hashimoto thyroiditis	Diffuse	4.2	Inflammation (8)	Heterogeneous parenchymal echogenicity with ill-defined oval hypoechoic nodules	Hypothyroidism on thyroid function test
Case 3	Subacute thyroiditis	Diffuse	3.47	Inflammation (8)	Heterogeneous hypoechoic area in anterior portion of both thyroid glands with decreased vascularity on color Doppler	Neck pain on physical examination

FDG = ^{18}F-deoxyglucose, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value, USG = ultrasonography

Table 2. Benign Neck Lesions with Increased FDG Uptake on PET/CT

	Diagnosis	FDG Uptake Degree	SUV	Mechanism	Other Features
Case 4	Benign inflammation - tuberculous lymphadenopathy	Mild	2.4	Increased macrophage and neutrophil activity (10)	Dual-time-point PET/CT (3–5 h delayed): malignant cells retain FDG for a long period (11)
Case 5	Benign inflammation - reactive Lymphadenopathy	Moderate	3.5	Stimulated cellular immune response, activated macrophage, increased glucose utilization (12)	Maximum SUV ≥ 5.5: 100% specific for malignant lymphadenopathy (13)
Case 6	Traumatic neuroma	Mild	2.1	Non-neoplastic axonal proliferation (16) and neurogenic inflammation (25)	Typical symptom: painful when the needle tip touches the mass CT: hyperattenuating rim (14)
Case 7	Schwannoma	Strong	5.5	Unclear, perhaps overexpression of glucose transporter proteins type-3 (17)	Variable range of FDG uptake: low, intermediate, or high SUV (even greater than 6.0) (17) Typical location: medial to the vessels of the carotid sheath, displacing the ICA anteriorly or anterolaterally (18)
Case 8	Foreign body granuloma	Moderate	2.9	Granulation tissue-type stromal reaction with neovascularization (20)	The ring shaped pattern of FDG uptake (20) USG: evolutional change (19)
Case 9	Warthin's tumor	Strong	5.26	Two hypotheses: FDG may accumulate in the lymphoid stroma of tumor or epithelial cells in the ductal inner layer (26)	Salivary gland scintigraphy (Tc-99m pertechnetate): negative in malignant tumors vs positive in Warthin's tumor (22)
Case 10	Inflammation after recent surgery	Strong	4.1	Wound healing with inflammatory cells, increased glycolysis (4)	Follow up PET/CT at least 4–6 weeks after surgery: FDG uptake by post-surgical inflammation tends to decreased gradually over time (3)
Case 11	Post-radiation therapeutic change	Moderate	3.05	Soft tissue inflammation (3)	Short term follow-up PET/CT or MRI with diffusion-weighted sequence may be helpful: residual or recurrent malignancy shows significantly lower ADC values (23)

ADC = apparent diffusion coefficient, FDG = ^{18}F-deoxyglucose, ICA = internal carotid artery, MRI = magnetic resonance imaging, PET/CT = positron emission tomography-computed tomography, SUV = standardized uptake value, USG = ultrasonography least 2–3 months after the completion of therapy to reflect more accurately disease status and avoid misdiagnosis (3). In equivocal cases, short-term follow-up PET/CT or MRI with a diffusion-weighted sequence may be helpful in differentiating between chemoradiotherapy-induced change and residual/recurrent malignancy. It has been reported that residual or recurrent malignancy showed significantly lower ADC values than a benign post-treatment mass (23). In one of our cases, a 61-year-old man underwent follow-up PET/CT after radiotherapy due to glottic cancer. A 10-month follow up image after radiotherapy showed a newly developed increased FDG uptake in the muscles of the anterior neck (Fig. 11).

CONCLUSION

Because of the increased use of PET/CT for various diagnoses, incidental thyroid and neck lesions are frequently detected in patients. These lesions can exhibit increased focal or diffuse FDG uptake, mimicking malignancy. At our institution, we have detected numerous benign thyroid and neck lesions with increased FDG uptake on PET/CT (Tables 1, 2). Although increased focal FDG uptake and a high SUV strongly suggest neck and thyroid malignancy (1), numerous interpretation pitfalls exist (3). Therefore, correlation with additional imaging modalities is essential in a significant number of cases. It is critical to be aware of the various patterns of FDG uptake, and benign lesions must be considered in the differential diagnosis whenever incidental thyroid and neck lesions are observed with increased FDG uptake on PET/CT.

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양전자 방출 컴퓨터단층촬영(Positron Emission Tomography-Computed Tomography)에서 위양성을 보이는 양성 갑상선 및 경부 병변

윤예리[1] · 김신영[1]* · 이상미[2] · 이득영[3]

양전자 방출 컴퓨터단층촬영(positron emission tomography-computed tomography; 이하 PET/CT)의 이용이 증가함에 따라 ^{18}F-deoxyglucose (이하 FDG)의 섭취증가를 보이는 갑상선 및 경부 병변들이 우연히 발견되는 경우가 증가하였다. FDG 섭취가 증가한 병변이 보일 때 대부분 악성을 먼저 생각하지만 양성 병변들에서도 때때로 섭취 증가 소견을 보일 수 있다. 본 임상화보의 목적은 갑상선과 경부의 양성 병변들이 양전자 방출 컴퓨터단층촬영에서 위양성 소견을 보일 수 있다는 점을 잘 알고 판독하는 데 있어서 다양한 함정들을 파악하는 데 있다. 그리고 많은 경우 PET/CT 소견들만으로 이들의 감별이 어렵다는 점을 이해하고 오진을 피하기 위해 추가적인 영상 검사가 필수적이라는 사실을 잘 알아야 한다.

순천향대학교 천안병원 [1]영상의학과, [2]핵의학과, [3]연세 앙즈로 클리닉 외과