

Review

Diagnostic and Prognostic Applications of PET/CT in Small-cell Lung Cancer

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Abstract

Background/Aim: In small-cell lung cancer, treatment differs between extensive disease (ED) and limited disease (LD). Chemotherapy plus immune checkpoint inhibitors is used in patients with ED. In patients with LD, chemoradiotherapy or chemoradiotherapy plus immune checkpoint inhibitors is used. Therefore, initial staging is important. Some reports exist on the utility of positron emission tomography-computed tomography (PET/CT); in particular, PET/CT can change the diagnosis between LD and ED. This review aimed to summarize the utility of PET/CT in small-cell lung cancer.

Materials and Methods: We identified relevant articles published on PUBMED between 2010 and 2025 using selected keywords. We categorized the contents into disease staging, prognosis prediction, and topics, and then summarized section-by-section.

Results: In addition to cancer staging between ED and LD, PET/CT can be used to evaluate semiquantitative indicators such as the maximum standard uptake value (SUVmax), total lesion glycolysis (TLG), and metabolic tumor volume (MTV). This is important as SUVmax, TLG, and MTV have been shown to predict treatment response.

Conclusion: PET/CT is useful for staging small-cell lung cancers. However, reports on its usefulness for prognostic prediction are mixed, with some finding it useful and others not. Further research is needed as treatment approaches for small-cell lung cancer are evolving.

Keywords: Small-cell lung cancer, positron emission tomography-computed tomography imaging, maximum standardized uptake value, total lesion glycolysis, metabolic tumor volume, review.

Introduction

Small-cell lung cancer is highly aggressive and has a poor prognosis (1). It comprises the following features: early

metastatic spread, aggressive biology, and high frequency of disease relapse (1). The inactivation of RB1 and overexpression of the MYC family are related to its characteristics (2). In clinical practice, the classification of



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small-cell lung cancer as limited-stage (LD) and extensive-stage (ED) is important. In ED, chemotherapy and immune checkpoint inhibitors are the standard first-line therapies (3). In contrast, chemotherapy plus radiotherapy, especially accelerated fractionation, is the standard first-line therapy for LD (4, 5). Concurrently, the effect of including immune checkpoint inhibitors after chemoradiotherapy in LD has been reported (6). Based on these reports, accurate initial staging, particularly distinguishing between LD and ED, is important. Positron emission tomography (PET), especially PET-computed tomography (CT), is widely used for the diagnosis and staging of small-cell lung cancer. In PET/CT, fluorodeoxyglucose F18 (18F-FDG) is used as the radiopharmaceutical, reflecting glucose-like metabolic activity. The accumulated value of 18F-FDG is often evaluated using the standard uptake value (SUV) and its maximum value, SUVmax. Additionally, the metabolic tumor volume (MTV), which reflects the volume showing accumulation above a certain SUV value, and total lesion glycolysis (TLG), which shows the volume by radiopharmaceutical uptake, are used. This review aims to synthesize articles on PET/CT for small-cell lung cancer to aid in future research.

Materials and Methods

We used PUBMED to identify relevant articles. We employed the keywords “small-cell lung cancer” and “PET” and identified an original article and review articles published between 2010 and 2025. We selected an original article by the first author, O. Y. (7), and included review articles (8-12). The contents were categorized into disease staging, prognosis prediction, and topics, and then summarized section-by-section.

Results

Disease staging.

Utility of PET/CT in staging. One report described the utility of PET/CT for staging. Specifically, in 250 patients with small-cell lung cancer, PET/CT changed the staging (13).

Diagnostic changes. In 46 cases of small-cell lung cancer (24 men, 22 women, mean age 63.5 years), CT and PET were used for diagnosis: 22 cases were classified as LD by both CT and PET, four were classified as ED by CT but LD by PET, 12 were classified as ED by both CT and PET, and eight were classified as ED by CT but LD by PET (14). In 33 small-cell lung cancer cases (13 men and 20 women; median age, 61 years), PET/CT was performed in 12 cases for initial staging and 11 cases for restaging. Among the 43 PET examinations, 19% resulted in a change in management based on PET findings (15). In 25 cases of small-cell lung cancer (24 men, 1 woman; 14LD,11ED; age 50-70 years), PET/CT led to upstaging in nine cases and downstaging in two (16). In a study of 73 patients with LD (60 men, 13 women; median age, 62 years), PET/CT revealed unexpected metastatic accumulation in 13 cases, leading to a change in the treatment plan (17). In 23 cases of small-cell lung cancer (19 men, 4 women; age 58±9 years), PET/CT elevated the Tumor-Node-Metastasis (TNM) staging in 12 cases (18). These results are shown in Table I.

Diagnostic accuracy by site. In 19 cases of small-cell lung cancer (10 men and 9 women; median age 67 years), PET demonstrated a sensitivity of 91% and specificity of 87% for lymph node metastasis (19). Of the 95 small-cell lung cancer cases (71 men, 24 women, age 68±9 years), 30 (age 66±9 years) were positive for bone metastases by other methods, and 65 were negative. The sensitivity and specificity of PET/CT for bone metastases were reported as 100% and 100%, respectively, whereas bone scintigraphy showed a sensitivity of 37% and a specificity of 92% (20). In 62 small-cell lung cancer cases (54 men, 8 women; age, 69.8±7.8 years), comparing other imaging methods + head magnetic resonance imaging (MRI) vs. PET/CT + head MRI for each TNM classification factor yielded the following diagnostic accuracy rates: T factor 78.0% (46/59) vs. 84.7% (50/59), N factor 67.8% (40/59) vs. 89.8% (53/59), M factor 91.5% (54/59) vs. 96.6% (57/59), TNM: 72.9% (43/59) vs. 88.1% (52/59), and VALSG stage: 91.5% (54/59) vs. 96.6% (57/59). PET/CT

Table I. Positron emission tomography-computed tomography (PET-CT) and change in tumor staging.

Reference number	Number of patients	PET-CT and staging
14	46	Changed the staging LD to ED: 4 cases ED to LD: 8 cases
15	33	19% resulted in a change in management
16	25	Upstaging in 9 cases Downstaging in 2 cases
17	73	Changed the treatment plan in 13 cases
18	23	Elevated the TNM staging in 12 cases

ED: Extensive disease; LD: limited disease.

Table II. Positron emission tomography-computed tomography (PET-CT) and sensitivity/specificity for metastatic site.

Reference number	Number of patients	Metastatic site	PET-CT and imaging quality
19	19	Lymph node	Sensitivity: 91%, specificity: 87%
20	95	Bone	Sensitivity: 100%, specificity: 100%

has been reported to be superior for N factors and TNM staging (21). These results are shown in Table II.

Impact on prognosis. In 968 small cell lung cancer cases (76.8% male, 23.2% female, age 65.6±10.6 years) the use of PET-CT for staging improved diagnostic accuracy for limited-disease small cell lung cancer, resulting in improved overall survival (22). Furthermore, in a study of 54 cases of limited-disease small cell lung cancer (40 cases with PET-CT, 9 male, 31 female, median age 67 years; 14 cases without PET-CT, 3 male, 11 female, median age 59 years), multivariate analysis showed that the presence of PET-CT staging was associated with a hazard ratio of 0.25 [95% confidence interval (CI)=0.11-0.56] for overall survival, ECOG performance status (0 vs. 1 vs. 2) had a hazard ratio of 1.87 (95%CI=1.01-3.48), and the presence of lymph node metastasis had a hazard ratio of 4.75 (95%CI=1.89-11.94) (23). Furthermore, in 147 cases of small cell lung cancer (69 male, 78 female), the presence or absence of pre-treatment PET-CT was reported to affect prognosis with a hazard ratio of 0.39 (95%CI=0.21-0.74) (24).

Comparison with other imaging modalities. In 164 cases of small-cell lung cancer (109 men and 55 women), PET/CT

demonstrated increased uptake in the primary tumor (118 cases), lymph nodes (97 cases), and distant metastases (41 cases). When comparing contrast-enhanced CT with PET/CT, findings matched in 52 patients (43.7%). PET/CT detected lesions that contrast-enhanced CT missed in 35 cases (29.4%), whereas contrast-enhanced CT detected lesions not identified by PET/CT in 32 cases (26.9%) (25). These results suggest that combining PET/CT with contrast-enhanced CT may be necessary to achieve more accurate staging.

Combination with blood tests. In 119 small-cell lung cancer cases (105 men, 14 women, median age 64 years), the ratio of MTV/monocyte-to-lymphocyte (MTV/MLR) showed an odds ratio of 8.67 [95%CI=3.51-21.42] for distinguishing between LD and ED, indicating its usefulness for differentiation (26).

Utility of PET/CT in prognostic prediction.

LD. Chemoradiotherapy is the standard treatment for LD. Among the 59 patients with LD (46 men, 13 women, median age 67 years), some (n=41) received chemoradiotherapy with cisplatin or carboplatin+etoposide plus thoracic

irradiation at 45 Gy/30 fractions/15 days, some (n=9) received chemotherapy alone, and some (n=5) received radiotherapy alone. Multivariate analysis showed that the SUVmax of the primary tumor was a factor affecting OS, with a hazard ratio of 1.133 (95%CI=1.042-1.231) (27). In 344 cases of small-cell lung cancer (292 men, 52 women, median age 61 years; 153 Stage I-III, 191 Stage IV), pre-treatment SUVmax=11.6 in Stage I-III patients was a prognostic factor with a hazard ratio of 1.88 (95%CI=1.15-3.08) (28). In 46 patients with Stage II-III small-cell lung cancer with lymph node metastasis (35 men, 11 women, median age 62 years), the following factors were associated with OS after chemoradiotherapy with cisplatin+etoposide plus chest irradiation with ≥ 60 Gy/30 fractions: i) presence of mediastinal lymph node metastasis, ii) lymph node MTV ≥ 39 , hazard ratio 3.824 (95%CI=1.528-8.794), and iii) lymph node TLG ≥ 137 , hazard ratio 3.543 (95%CI=1.662-7.386) (29). In 30 LD cases (29 men, 1 woman; median age 65 years) and chest irradiation of 54 Gy/30 fractions, the group with MTV ≤ 166.6 ml had a median survival of 76 months, whereas that with MTV > 166.6 ml had a median survival of 22 months. Multivariate analysis showed a hazard ratio of 16.7 (3.26-85.1) for OS, indicating that MTV is a prognostic factor (30). In 41 cases of LD (37 men, 4 women, median age 63 years), after chemoradiotherapy with cisplatin/etoposide and thoracic irradiation (50 Gy/25 fractions to 60 Gy/30 fractions), the following factors were associated with OS: sex, lactate dehydrogenase (LDH) ≥ 400 IU/l, treatment response (PR/CR vs. SD/PD), and liver SUVmax (liver SUVmax) with a hazard ratio of 0.194 (95%CI=0.05-0.72); this result indicates that liver accumulation is a prognostic factor (31). In 125 cases of LD (110 men, 15 women, mean age 66.8 \pm 9 years), a liver SUVmean/Bone Marrow (BM) mean ratio (BM/L) of one is associated with a 1.6-fold increased risk of post-treatment mortality, and a primary tumor SUVmax/brain SUVmax ratio of > 1 was associated with a 2-fold increased risk. This finding was consistent across multiple analyses. Increased bone marrow uptake indicates a poor prognosis (32). In 46 patients with LD (42 men, 4 women, median age 59 years), the SUVmax in the lymph node (> 5.8) and age (> 65 years) were poor prognostic factors (33).

However, some studies have suggested that PET/CT uptake is not a prognostic factor. In 120 LD cases (52 men, 68 women; median age 65.5 years), SUVmean, SUVmax, MTV, and TLG were not prognostic factors for OS (34). In 50 LD cases (28 men and 22 women), SUVmax was not reported to be a prognostic factor for OS (35). These results are shown in Table III.

ED. Chemotherapy is the primary treatment for ED. In 154 cases of ED (123 men and 31 women; mean age, 60 years), MTV, and TLG were reported as indicators of response to initial anticancer drug therapy with cisplatin plus etoposide or carboplatin plus etoposide (36). Furthermore, in 46 ED cases (38 men, 8 women; median age, 74 years), MTV and TLG were reported to be factors influencing survival duration, exceeding 180 days when chemotherapy plus immune checkpoint inhibitors were used (37). However, other reports have suggested that the MTV, TLG, and PET/CT uptake are not prognostic factors. In 68 ED cases (50 men, 18 women; median age, 67 years), MTV and TLG were not reported to be prognostic factors (38). These results are shown in Table IV.

LD and ED. Visual assessment: Among 29 patients with small-cell lung cancer (19 men, 10 women; ages 43-80; 13 patients with LD, 16 with ED), who received chemotherapy (primarily cisplatin+etoposide) and radiotherapy (chest irradiation: mean 54 Gy), eight later demonstrated complete metabolic response (CMR) on PET/CT, showing a relatively favorable prognosis with a relative risk of 0.10 (95%CI=0.0198-0.5356) compared to other cases (27).

Utility of MTV and TLG: In 106 cases of small-cell lung cancer (45 LD, 61 ED; 89 men, 17 women; median age 69 years), multivariate analysis showed that the group with a whole-body MTV exceeding 127 had a poor OS, with a hazard ratio of 2.11 (95%CI=1.31-3.39) (39). In 202 small-cell lung cancer cases (age 64.0 \pm 8.8 years, 179 men, 23 women, 95 LD, 107 ED), chemotherapy with cisplatin or carboplatin+etoposide or irinotecan and chest irradiation of approximately 52.5 Gy in 25 fractions were delivered. A total MTV ≥ 100 was associated with a hazard ratio for death of

Table III. Positron emission tomography-computed tomography (PET-CT) indicator and subsequent prognosis in limited disease small cell lung cancer.

Reference number	Number of patients	Indicator (PET-CT)	Prognostic factor (PET-CT)
27	59	SUVmax	YES
28	153 (Stage I-III)	SUVmax	YES
29		MTV (lymph node)	YES
30	30	MTV	YES
31	41	SUVmax (liver)	YES
32	125	Liver SUV mean/BM mean primary tumor	YES
33	46	SUVmax/brain SUVmax	YES
34	120	SUVmax (lymph node)	YES
		SUVmax	NO
		SUVmean	
		MTV	
35	50	TLG	NO

SUV: Standard uptake value; MTV: metabolic tumor volume; TLG: total lesion glycolysis.

Table IV. Positron emission tomography-computed tomography (PET-CT) indicator and subsequent prognosis in extended disease small cell lung cancer.

Reference number	Number of patients	Indicator (PET-CT)	Prognostic factor (PET-CT)
36	154	MTV	YES
		TLG	
37	46	MTV	YES
		TLG	
38	68		NO

SUV: Standard uptake value; MTV: metabolic tumor volume; TLG: total lesion glycolysis.

1.779 (95%CI=1.072-2.959), and a total TLG ≥ 555 was associated with a hazard ratio for death of 1.815 (95%CI=1.094-3.012) (40). In 55 cases of small-cell lung cancer (36 men, 19 women; 24 with LD and 31 with ED), disease progression occurred in six (10.9%). For TLG > 443.8 , the hazard ratio for OS was 2.1 (95%CI=1.14-3.871), with reported OS of 13.4 months vs. 25.7 months (41).

Utility of SUV: In 59 patients with small-cell lung cancer (39 men, 29 women; median age 67 years; 27 LD, 32 ED), PET/CT was performed before and after treatment. The group with an SUVpeak change ratio of -46.8% had poorer survival, with a hazard ratio for mortality of 2.6 (95%CI=1.4-4.8 for OS) (42). In 114 cases of small-cell lung cancer (105 men, 9 women, median age 67 years; 26 LD, 88 ED), multivariate analysis indicated that age ≥ 65 years, ≤ 3 cycles of chemotherapy, SD or PD at initial treatment, plus SUVmax of ≥ 24.6 had a hazard

ratio of 3.970 for OS (95%CI=1.471-10.715) (43). In 98 patients with small-cell lung cancer (71 men, 27 women, median age 58 years; 41 LD, 57 ED), MTV and integrated standardized uptake value (iSUV) are prognostic factor for overall survival rate (44). In 256 men with small-cell lung cancer (mean age 63.8 years), age (< 63 vs. ≥ 63 years), T stage, lymph node metastasis, distant metastasis, chemotherapy, radiation therapy, and MTV were reported as survival factors with a hazard ratio of 1.51 (95%CI=1.15-1.99) (45). In 38 small-cell lung cancer cases (34 men, 4 women; age, 65.76 ± 8.18 years), MTV ≥ 147 cm was reported as a prognostic factor (46). In 112 cases of small-cell lung cancer (92 men, 20 women, median age 58 years; 26 cases LD, 86 cases ED), poor survival was reported for NLR ≥ 4 , MTV ≥ 60.1 , whole body MTV ≥ 120 , and whole body TLG $\geq 1,000$ points. NLR has been reported to correlate with SUVmean ($r=0.36$),

Table V. Positron emission tomography-computed tomography (PET-CT) indicator and subsequent prognosis in both limited and extended disease small cell lung cancer.

Reference number	Number of patients	Indicator (PET-CT)	Prognostic factor (PET-CT)
39	106	Whole body MTV	YES
40	202	Total MTV Total TLG	YES
41	55	TLG	YES
42	59	SUVpeak change	YES
43	114	SUVmax	YES
44	98	MTV SUVmax of all lesions	YES
45	256	MTV	YES
46	38	MTV	YES
47	112	MTV TLG	YES
48	145	SUVmax values for all lesions	YES
49	54		NO
50	142		NO
51	77		NO
52	91		NO
53	82		NO
54	90		NO
55	349		NO

SUV: Standard uptake value; MTV: metabolic tumor volume; TLG: total lesion glycolysis.

SUVmax ($r=0.34$), TLG ($r=0.39$), MTV ($r=0.51$), WBMTV ($r=0.40$), and WBTLG ($r=0.46$) (47). In 145 cases of small-cell lung cancer (122 men, 23 women, median age 67 years), the sum of SUVmax values for all lesions was calculated. Using a median total value of 21.9 as the cutoff, this was reported to be an independent prognostic factor, with a hazard ratio of 2.676 (95%CI=1.674-4.277) (48).

PET/CT measurements are not useful for predicting prognosis: Reports have also indicated that PET/CT measurements are not useful for predicting the prognosis of small-cell lung cancer. In 54 cases of small-cell lung cancer (50 men, 4 women; median age, 57 years; 30 ED, 24 LD), performance status and extent of disease spread were reported as prognostic factors, whereas PET factors were unrelated to prognosis (49). In 142 cases of small-cell lung cancer (124 men, 18 women, median age 58.2 ± 10.1 years), PET/CT SUV was reported not to be a prognostic factor (50). In 77 cases of small-cell lung cancer (67 men and 10 women), SUVmax was not reported to be a prognostic factor (51). In 91 cases of small-cell lung cancer (75 men, 16

women), the status of extrapleural lesions was a prognostic factor for chemotherapy, whereas the MTV in intrapleural lesions was not related to prognosis (52). In 82 cases of small-cell lung cancer (75 men and 7 women), SUV was not a prognostic factor (53). In 90 cases of small-cell lung cancer, SUV was also reported not to be a prognostic factor (54). SUVmax was not a prognostic factor in 349 cases of small-cell lung cancer (294 men, 55 women, age 63 years; 224 ED, 125 LD) (55). These results are shown in Table V.

Topics.

Differences in pathology by location. Among 69 cases of small-cell lung cancer there were 28 central-type cases (23 men, 5 women; median age, 78 years) and 41 peripheral-type cases (34 men, 7 women; median age, 72 years). The MTV was 100.6 ± 93.6 for the central type and 53.4 ± 68.1 for the peripheral type, with the peripheral type showing a statistically significant lower value (56). TLG was 823.6 ± 916.5 in a central type and 394.5 ± 607.2 in the peripheral type, with the peripheral type showing

a statistically significant decrease (56). Furthermore, it has been reported that the best prognosis is observed in peripheral-type cases with low TLG and MTV (56).

Correlation with tumor markers. In 21 cases of recurrent small-cell lung cancer (17 men, 4 women, age 37-79 years), NSE correlated with MTV (correlation coefficient 0.789) and TLG (correlation coefficient 0.872) in the group with NSE above the reference value (57). In addition, in the group with LDH levels above the reference range, LDH and MTV showed a correlation coefficient of 0.656, whereas TLG showed a correlation coefficient of 0.697 (57).

Correlation with Ki67. In 94 cases of small-cell lung cancer (75 men, 19 women; median age, 68 years), Ki67 showed no correlation with SUVmax but a correlation coefficient of 0.254 with MTV and 0.239 with TLG (58).

Circulating tumor cells. In total, 112 patients with cancer (67 men, 45 women; median age 59 years) were included. Overall, 87 cases tested positive for two or more circulating tumor cells (CTC). After cisplatin/carboplatin-etoposide chemotherapy, CTC positivity showed a hazard ratio of 4.73 (95%CI=1.05-13.90), and MTV showed a hazard ratio of 5.32 (95%CI=2.10-11.93), indicating that both are significant prognostic factors (59).

Bone marrow uptake. In 70 cases of small-cell lung cancer (60 men, 10 women, median age 68 years), a bone marrow SUVmax of ≥ 1.6 vs. < 1.6 was reported to be a factor for progression-free survival with a hazard ratio of 2.28 (95%CI=1.27-4.28) (60).

Liver/muscle uptake and inflammation. In 155 cases of small-cell lung cancer (124 men, 31 women, 58 LD, 97 ED), the liver to muscle (rectus-femoris) uptake ratio (each SUV mean) was the prognostic factor for OS rate in patients with ED (uptake ratio ≥ 3.18 , OS 7.85 months; uptake ratio < 3.18 , OS 9.40 months). Moreover, the C-reactive-protein to albumin ratio was a prognostic factor for OS (C-reactive-protein to albumin ratio > 0.29 ,

OS 7.55 months; C-reactive-protein to albumin ratio < 0.29 , OS 13.74 months) (61).

Time-radioactivity curve. In 10 small-cell lung cancer cases (9 men, 1 woman), dynamic PET/CT imaging revealed that the response to drug therapy could be predicted based on the slope of the time-radioactivity curve at 10 and 30 min (62).

Relationship with the central nervous system. In a report by the lead author (Okada *et al.*) (7), 19 cases diagnosed with LD (3 men, 6 women; age, 70.1 ± 8.8 years) were examined with PET/CT. In the group with NSE values at or above the reference value of 16.3, the SUVmax in the hypothalamic-pituitary region was 4.10, while in the group with NSE below the cutoff value of 16.3 the SUVmax was 2.95 in the hypothalamic-pituitary region, showing a statistically significant difference (7). The SUVmax in the hypothalamic-pituitary region and NSE levels showed a correlation coefficient of $r=0.458$. When using an SUVmax cutoff value of 3.10, the sensitivity was 0.846, and the specificity was 0.833 for distinguishing between NSE values above and below the cutoff (7). The TLG in the hypothalamic-pituitary region and the primary tumor showed a correlation coefficient of $r=0.53$, whereas the TLG in the hypothalamic-pituitary region and the total tumor showed a correlation coefficient of $r=0.424$ ($p=0.07$) (7). Increased glucose metabolism in the hypothalamic-pituitary region was associated with small-cell lung cancer.

Artificial intelligence. In total, 98 small-cell lung cancer cases (66 men, 32 women) were classified into 98 training cases and 20 evaluation cases. Radiomic analysis was performed in 56 responders and 42 non-responders to platinum-based chemotherapy. Combining clinical data with radiomics yielded an area under the curve (AUC) of 0.832-0.833, enabling the prediction of treatment response (63).

Discussion

In small-cell lung cancer, there are different therapeutic options for LD and ED. Nonetheless, PET-CT is useful for

initial staging in both LD and ED and can help predict the treatment response. Some reports have discussed the utility of PET-CT parameters such as SUV, MTV, and TLG. While their utility has not been conclusively ascertained, these semi-quantitative parameters have potential. Moreover, 18F-FDG uptake in normal organs such as the liver, bone marrow and the hypothalamic-pituitary region indicates the pathological stage of the small-cell lung cancer.

The use of PET-CT in small-cell lung cancer has some limitations. First, semi-quantitative parameters such as SUV, MTV, and TLG may vary depending on the PET-CT machine. Second, the visual evaluation in PET-CT depends on operator experience. Third, the number of reports about the machine learning and radiomics are limited. Recently, in non-small cell lung cancer, the utility of machine learning and radiomics about the PET-CT are reported (64). Thus, further research under same conditions is necessary to validate the findings of this study.

Conclusion

PET/CT is considered useful for staging small-cell lung cancers. However, reports on its prognostic utility are mixed: some find it useful, whereas others do not. Further research is needed as treatment approaches for small-cell lung cancer are evolving.

Conflicts of Interest

Y.O. was a member of Expert Imaging and Interventional Support (EiIS), undertaking the medical imaging reading at Iga City General Hospital. All other Authors declare no conflicts of interest in relation to this study.

Authors' Contributions

Y.O: wrote the article; T.Z, T.I, R.M, M.O, S.S, S.W, T.K, Y.M, M.K: checked the article related to radiation oncology; M.I, M.Y, K.A, MA: checked the article as related to medical imaging and nuclear medicine; K.S: checked the article and provided suggestions regarding this research.

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Artificial Intelligence (AI) Disclosure

The Authors used artificial intelligence (ChatGPT by OpenAI) for the final article check.

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