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Original Article

Evaluation of the Prognostic Nutritional Index in Conjunction with Lung Cancer Stage and PET-CT SUVmax

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ABSTRACT

OBJECTIVE: Lung cancer is among the malignancies with the highest mortality rates globally, where nutritional and immune status significantly influence disease progression and prognosis. The study aimed to investigate the relationship of the prognostic nutritional index (PNI) with both the maximum standardized uptake value (SUVmax), measured by positron emission tomography-computed tomography, and the clinical stage of lung cancer.

MATERIAL AND METHODS: Patients who underwent fiberoptic bronchoscopy and were diagnosed with lung cancer at the Department of Pulmonology, Kütahya Health Sciences University, between January 1, 2022 and May 31, 2025, were retrospectively evaluated. A total of 241 patients diagnosed with lung cancer via bronchoscopy were evaluated; of these, 205 patients diagnosed with non-small-cell lung cancer (n = 205) were assessed according to stage.

RESULTS: A total of 241 lung cancer patients were included; the mean age was 68.35±8.52 years and 95.0% were male. The mean PNI was 41.41±9.50 and the mean primary tumor SUVmax was 10.53±5.22. PNI and primary tumor SUVmax showed a very weak negative association that did not reach statistical significance (Spearman ρ = -0.127; $P = 0.055$). Clinical stage was positively associated with SUVmax (ρ = 0.253; $P < 0.001$) and negatively associated with PNI (ρ = -0.186; $P = 0.007$).

CONCLUSION: Higher clinical stage was associated with higher primary tumor SUVmax and lower PNI. The association between PNI and SUVmax was weak and not statistically significant; therefore, it should not be considered clinically discriminative on its own. PNI may serve as an adjunctive indicator of nutritional and immune status, but prospective studies with survival outcomes and multivariable adjustment are required before it can be used as a prognostic or staging tool.

KEYWORDS: Lung cancer, prognostic nutritional index, nutrition, PET-CT, SUVmax, staging

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INTRODUCTION

Lung cancer represents a major public health concern, ranking as the most frequently diagnosed malignancy and the leading cause of cancer-related mortality worldwide. According to World Health Organization data, approximately 2.2 million new cases of lung cancer are diagnosed annually, and the disease accounts for more than 1.8 million deaths per year.[1]

In Türkiye, lung cancer remains the most common cancer among men and the leading cause of cancer-related deaths.[2] Advanced stage at diagnosis is among the most critical factors adversely affecting prognosis; a substantial proportion of cases present with metastatic disease.

The determinant role of nutritional and immunological status in the clinical course of cancer is increasingly recognized. Malnutrition and immunosuppression accelerate tumor progression, impair treatment response, and shorten overall survival.[3,4] In this context, there is growing interest in indices that use simple laboratory parameters to assess nutritional

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and immune status. The prognostic nutritional index (PNI) was originally developed by Onodera et al.[5] in 1984 to predict postoperative complications in gastrointestinal surgery patients. It is calculated using the following formula: PNI = 10 × serum albumin (g/dL) + 0.005 × peripheral lymphocyte count (cells/mm^3). The index reflects nutritional status through albumin levels and immune competence through lymphocyte count.

Positron emission tomography-computed tomography (PET-CT) is the standard imaging modality used for staging, assessment of treatment response, and detection of recurrence in lung cancer. The maximum standardized uptake value (SUVmax), measured by ^{18}F-fluorodeoxyglucose (FDG) PET-CT, reflects the metabolic activity of the tumor and has been shown to correlate with distant metastasis and prognosis.[6,7] High SUVmax values are known to be associated with advanced stage, rapid tumor progression, and poor prognosis.[8]

Research investigating the effects of PNI on clinical stage, tumor metabolic activity, and survival in lung cancer patients has markedly increased in recent years. Nevertheless, the number of studies examining the relationship between PNI and SUVmax, as measured by PET-CT, remains relatively limited. This study aimed to evaluate PNI alongside primary tumor SUVmax measured on PET-CT and clinical stage in patients diagnosed with lung cancer by fiberoptic bronchoscopy.

MATERIAL AND METHODS

Study Design and Patient Selection

This retrospective observational study was conducted in the Department of Pulmonology at Kütahya Health Sciences University Evliya Çelebi Training and Research between January 1, 2022, and May 31, 2025. The study was approved by the Kütahya Health Sciences University Rectorate Non-Interventional Clinical Research Ethics Committee (decision no: 2025/07-08, date: 29.05.2025) and was performed in accordance with the Declaration of Helsinki. Adults who underwent fiberoptic bronchoscopy for diagnostic purposes and had lung cancer confirmed by bronchoscopic biopsy were eligible. During review, the cohort was independently re-audited at the individual-patient level by cross-matching bronchoscopy records, final pathology records, laboratory records, and PET-CT records. A total of 241 unique eligible patients constituted the final analytic cohort.

Patients with benign biopsy results, insufficient pre-bronchoscopy laboratory data, active infection or inflammatory disease, or no PET-CT imaging were excluded.

Main Points

- In 241 bronchoscopically confirmed lung cancer patients, higher clinical stage was significantly associated with higher primary tumor maximum standardized uptake value (SUVmax) ($\rho = 0.253$, $P < 0.001$) and lower prognostic nutritional index (PNI) ($\rho = -0.186$, $P = 0.007$).
- The direct correlation between PNI and SUVmax was weak and not statistically significant ($\rho = -0.127$, $P = 0.055$), indicating these parameters are not interchangeable measures of tumor burden.
- PNI may serve as a complementary marker of nutritional and immune status, but prospective studies with survival outcomes and multivariable adjustment are required before it can be used as a prognostic or staging tool.

Data Collection

Patient age, sex, smoking history (active smoker, former smoker, never smoker), pack-year exposure, comorbid conditions, histological subtype, and clinical stage were recorded. Clinical staging was performed according to the International Association for the Study of Lung Cancer eighth edition tumor, node, metastasis (TNM) classification.[9] For analytic comparability, TNM stage groups I–IV were used for all tumors; the limited-stage/extensive-stage category for small cell lung cancer was retained only as a clinical descriptor and was not used in the stage-correlation analyses.

Serum albumin levels (g/dL) and peripheral lymphocyte counts (cells/mm^3) were obtained from routine blood tests performed before bronchoscopy. Laboratory albumin values, originally exported in g/L, were divided by 10 before PNI calculation and reporting in g/dL. PNI was calculated as follows: PNI = 10 × albumin (g/dL) + 0.005 × lymphocyte count (cells/mm^3).[5] Primary tumor SUVmax values were obtained from nuclear medicine PET-CT reports.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation and median; categorical variables were presented as number and percentage. Kolmogorov-Smirnov tests showed significant departures from normality for both PNI and SUVmax ($P < 0.05$ for both). Because clinical stage was ordinal and the continuous variables were non-normally distributed, the Spearman rank correlation was used. Stage-group comparisons were performed using the Kruskal-Wallis test. Statistical significance was set at $P < 0.05$.

RESULTS

Demographic and Clinical Characteristics

Of the 308 patients who underwent bronchoscopy during the study period, 241 received a diagnosis of lung cancer and were included in the analysis. The patient selection diagram was shown in Figure 1. Of these, 229 (95.0%) were male and 12 (5.0%) were female. The mean age was 68.35±8.52 years (range: 43–92 years). Smoking status was available for 195 patients: 71 (36.4%) were active smokers, 115 (59.0%) were former smokers, and 9 (4.6%) had never smoked; smoking data were unavailable for 46 patients. Mean tobacco exposure among patients with available smoking data was 50.23±22.44 pack-years (Table 1).

Histological evaluation identified squamous cell carcinoma in 52.9%, adenocarcinoma in 24.3%, and small-cell lung cancer in 14.93% of patients. The remaining 7.87% consisted of other

or not otherwise specified lung cancer histologies. Except for descriptive data, the analysis included cases of non-small cell lung cancer (NSCLC). Among the 205 staged patients, 17 (8.3%) had stage I disease, 27 (13.2%) had stage II disease, 69 (33.7%) had stage III disease, and 92 (44.9%) had stage IV disease.

Prognostic Nutritional Index, Albumin, and Lymphocyte Values

The mean serum albumin concentration was 3.40±0.73 g/dL (range: 1.4–5.3 g/dL), the mean peripheral lymphocyte count was 1491.09±788.27 cells/mm^3. The mean PNI was 41.41±9.50 (range: 17.30–61.30).

Mean PNI values by clinical stage were 45.94±6.52 for stage I, 43.45±9.28 for stage II, 41.01±9.10 for stage III, and 39.34±9.70 for stage IV. PNI differed significantly across stage groups (Kruskal-Wallis $P = 0.027$) (Table 2).

SUVmax Values and Correlation with NSCLC Stage

The mean primary tumor SUVmax was 10.53±5.22 (range: 1.7–42.4). Mean SUVmax values by clinical stage were 7.53±3.31 for stage I, 9.66±4.18 for stage II, 10.56±4.53 for stage III, and 11.94±5.96 for stage IV. SUVmax differed significantly across stage groups (Kruskal-Wallis $P < 0.001$) (Table 2).

Correlation Analyses

Kolmogorov-Smirnov test with Lilliefors correction indicated that PNI (D = 0.072, $P = 0.008$) and SUVmax (D = 0.121, $P < 0.001$) were non-normally distributed; clinical stage was treated as an ordinal variable. Therefore, all reported associations were evaluated using Spearman's rank correlation, with pairwise available-case sample sizes. PNI and primary tumor SUVmax showed a very weak negative association that did not reach conventional statistical significance (Spearman ρ = –0.127; $P = 0.055$; n = 205) (Figure 2, Table 3). The small effect size indicates substantial overlap across PNI values and limits clinical interpretability.

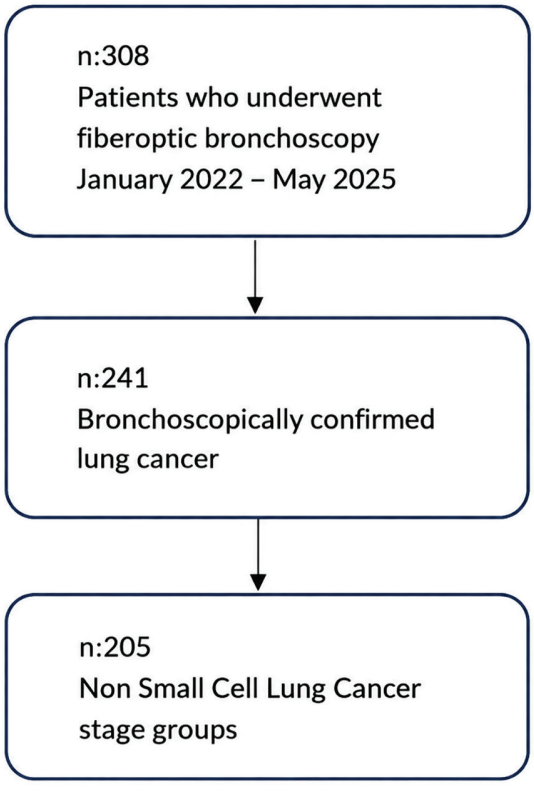

Figure 1. Patient-selection flow diagram. The full bronchoscopy pool, the bronchoscopically confirmed lung cancer cohort, and the non-small-cell lung cancer stage groups are shown separately

Clinical stage was positively associated with primary tumor SUVmax (Spearman ρ = 0.253; $P < 0.001$; n = 205), indicating a weak-to-moderate monotonic trend toward higher metabolic activity with advancing stage.

Clinical stage was negatively associated with PNI (Spearman ρ = –0.186; $P = 0.007$; n = 205), indicating a weak monotonic tendency toward lower nutritional and immune status at more advanced stages.

DISCUSSION

This retrospective study included 241 patients with bronchoscopically confirmed lung cancer; 205 NSCLC patients had complete staging data. Clinical stage was positively associated with primary tumor SUVmax and negatively associated with PNI.

Studies investigating the prognostic value of PNI in lung cancer patients have markedly increased in recent years. A meta-analysis demonstrated that lower PNI scores were associated with worse survival outcomes.[10]

Shoji et al.[11] reported that lower preoperative PNI predicted postoperative recurrence in surgically resected pathological stage I NSCLC. That population is not directly comparable with the present bronchoscopy-based cohort, which was heterogeneous, predominantly advanced-stage, frequently inoperable, and included 14.93% small-cell lung cancer cases. Accordingly, the Shoji et al.[11] study supports the general biological relevance of PNI, but should not be used for direct effect-size or prognostic comparisons with our cohort. In the present study, PNI declined across clinical stage groups and showed a weak negative association with stage (ρ = –0.186; $P = 0.007$).

Albumin is the primary component of the PNI calculation. Hypoalbuminemia serves as an indicator of protein-calorie malnutrition, inflammation, and hepatic dysfunction and is frequently encountered in cancer patients. Low serum albumin levels are associated with poor performance status and reduced treatment tolerance.[3] Lymphocytes, on the other hand, are the principal effectors of cellular immunity and play a critical role in sustaining antitumor immune responses within the tumor microenvironment.[12] Lymphopenia in cancer patients can be interpreted as evidence of immune suppression by the tumor and an indication of disease progression. The PNI, which integrates both parameters, provides more comprehensive prognostic information than albumin or lymphocyte measurements alone.

SUVmax is a semiquantitative measure of tumor glucose uptake on FDG-PET. Increased glycolysis, commonly described as the Warburg[13] effect, is a hallmark of malignant metabolism. The positive association between primary tumor SUVmax and

Table 1. Demographic and clinical characteristics of patients who bronchoscopically confirmed lung cancer (n = 241)

Variable	n (%) or mean ± SD	Min–max
General characteristics		
Total number of patients	241	-
Age (years)		
Mean ± SD	68.35±8.52	43–92
Median	69	
Sex		
Male	229 (95.0%)	-
Female	12 (5.0%)	-
Smoking history		
Active smoker	71 (36.4%)	-
Former smoker (ex-smoker)	115 (59.0%)	-
Never smoker	9 (4.6%)	-
Smoking pack-years (mean ± SD)	50.23±22.44	0–130
Laboratory values		
Serum albumin (g/dL), mean ± SD	3.40±0.73	1.4–5.3
Peripheral lymphocyte count (cells/mm^3), mean ± SD	1491.09±788.27	60–5000
PNI, mean ± SD*	41.41±9.50	17.30–61.30
PET-CT primary tumor SUVmax, mean ± SD	10.53±5.22	1.7–42.4

*PNI = 10 × albumin (g/dL) + 0.005 × lymphocyte count (cells/mm^3)
SD: standard deviation, PNI: prognostic nutritional index, PET-CT: positron emission tomography-computed tomography, SUVmax: maximum standardized uptake value, Min: minimum, max: maximum

Table 2. Comparison of PNI, SUVmax, albumin, and lymphocyte values according to NSCLC stage groups (n = 205)

Parameter	Stage I (n = 17)	Stage II (n = 27)	Stage III (n = 69)	Stage IV (n = 92)	*P* value
PNI					
Mean ± SD	45.94±6.52	43.45±9.28	41.01±9.10	39.34±9.70	0.027†
Median	45.05 (42.05–51.55)	44.25 (39.40–51.27)	41.20 (35.62–47.74)	41.32 (30.73–45.90)	
PET-CT primary tumor SUVmax					
Mean ± SD	7.53±3.31	9.66±4.18	10.56±4.53	11.94±5.96	<0.001†
Median	7.50 (5.80–8.80)	9.90 (7.05–10.95)	9.70 (7.22–12.53)	10.80 (8.03–14.10)	
Serum albumin (g/dL)					
Mean ± SD	3.82±0.58	3.55±0.64	3.32±0.68	3.25±0.76	0.002†
Median	3.90 (3.60–4.20)	3.60 (3.40–3.95)	3.30 (2.90–3.98)	3.40 (2.70–3.85)	
Peripheral lymphocyte count (cells/mm^3)					
Mean ± SD	1548.18±535.81	1588.14±847.90	1569.56±762.93	1373.26±823.31	0.283†
Median	1510 (1010–1810)	1310 (1115–2160)	1500 (952–2072)	1360 (690–1945)	

†Kruskal-Wallis test
PNI: prognostic nutritional index, SUVmax: maximum standardized uptake value, SD: standard deviation, NSCLC: non-small cell lung cancer, PET-CT: positron emission tomography-computed tomography

clinical stage in our cohort (ρ = 0.253; $P < 0.001$) is consistent with studies linking higher primary tumor FDG uptake to greater extent or metastatic potential in NSCLC.[6,8,14] Nevertheless, the observed coefficient indicates only a weak-to-moderate monotonic association and does not imply that SUVmax can substitute for formal anatomic staging.

In 186 patients with advanced NSCLC treated with PD-1 blockade, Ito et al. found associations between FDG-derived metabolic tumor burden and several inflammatory or nutritional indices, including PNI.[15] Dolan et al.[16] evaluated 119 patients with lung cancer undergoing radiotherapy and reported that higher PET-CT-derived tumor metabolic activity was associated with more advanced stage, greater nutritional risk, systemic inflammation, and poorer survival. These studies support a relationship between tumor metabolism and host inflammatory-nutritional status, although their populations, PET metrics, treatments, and outcomes differ from those in the present study.

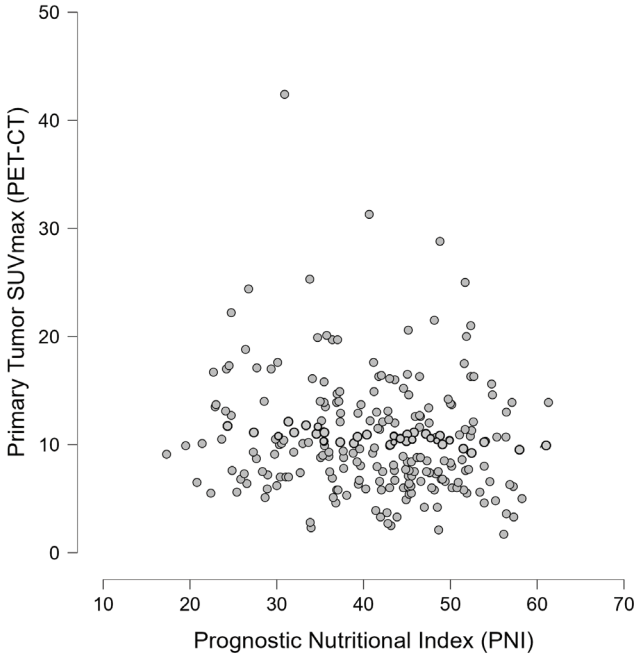

Figure 2. Scatter plot of prognostic nutritional index and primary tumor SUVmax on PET-CT (Spearman ρ = −0.127; *P* = 0.055). Each circle represents one patient. No parametric regression line is displayed because the reported analysis is rank-based

SUVmax: maximum standardized uptake value, PET-CT: positron emission tomography-computed tomography

Table 3. Pairwise Spearman rank correlations among clinical stage, PNI, and primary tumor SUVmax (n = 205)

Comparison	Spearman ρ	*P* value
PNI vs. primary tumor SUVmax	−0.127	0.055
Clinical stage vs. primary tumor SUVmax	0.253	<0.001*
Clinical stage vs. PNI	−0.186	0.007*

*Statistically significant ($P < 0.05$). Pairwise available-case sample sizes are shown

ρ: Spearman rank correlation coefficient, PNI: prognostic nutritional index, SUVmax: maximum standardized uptake value

In our corrected analysis, the association between PNI and SUVmax was very weak and did not reach conventional levels of statistical significance (ρ = -0.127; *P* = 0.055). Therefore, this finding should not be interpreted as evidence that SUVmax meaningfully predicts PNI, or vice versa, at the individual-patient level. The unadjusted association may be influenced by shared determinants such as stage, histology, inflammation, comorbidity, and tumor burden. A biologically plausible link between metabolically active tumors and lower albumin or lymphocyte levels remains possible, but causality cannot be inferred from this cross-sectional retrospective analysis.

Study Limitations

This study has several limitations. First, the retrospective, single-center design may introduce selection bias and limit generalizability. Histological heterogeneity, including NSCLC and small-cell lung cancer, also complicates direct comparisons with homogeneous surgical cohorts. Second, the patient cohort is limited to a single center, which may restrict the generalizability of the findings. Furthermore, standardization of the timing of albumin and lymphocyte measurements used in PNI calculation presents a challenge, as active infection, corticosteroid use, and other inflammatory conditions may influence lymphocyte counts. Survival analysis was not incorporated into the present study; therefore, the long-term impact of PNI on mortality could not be assessed. Despite these limitations, the study makes a contribution through its real-world cohort and observed relationship between PNI and SUVmax.

CONCLUSION

A higher clinical stage was associated with a higher primary tumor SUVmax and a lower PNI in patients with bronchoscopically diagnosed lung cancer. After patient-level correction of PNI components, the PNI-SUVmax association was very weak and not statistically significant, and it should not be interpreted as clinically discriminative on its own. PNI may be considered an adjunctive marker of nutritional and immune status, but it cannot replace formal staging or validated prognostic assessment. Prospective studies with standardized laboratory timing, survival outcomes, and multivariable adjustment are required before PNI can be used as a prognostic or staging tool.

Ethics

Ethics Committee Approval: The study was approved by the Kütahya Health Sciences University Rectorate Non-Interventional Clinical Research Ethics Committee (decision no: 2025/07-08, date: 29.05.2025) and was performed in accordance with the Declaration of Helsinki.

Informed Consent: The requirement for informed consent was waived by the local ethics committee because of the retrospective design of the study and the use of anonymized data.

Footnotes

Authorship Contributions

Surgical and Medical Practices: İ.K., Ü.E., Ş.E.P., F.M., M.D., Ş.K., J.K., Concept: İ.K., Ü.E., M.D., Design: İ.K., Ş.E.P., Ş.K., J.K., Data Collection or Processing: İ.K., Ü.E., Ş.E.P., F.M., Ş.K., J.K., Analysis or Interpretation: İ.K., F.M., M.D., Literature Search: İ.K., Writing: İ.K., J.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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