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Clinical Research

Prognostic Analysis of Stage I Non-Small Cell Lung Cancer Abutting Adjacent Structures on Preoperative Computed Tomography

Soohwan Choi, MD., Ph.D.[1,2], Sun Kyun Ro, M.D., Ph.D.[2,*], Seok Whan Moon, M.D., Ph.D.[1,*]

[1]Department of Thoracic and Cardiovascular Surgery, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul; [2]Department of Thoracic and Cardiovascular Surgery, Hanyang University Guri Hospital, Hanyang University College of Medicine, Guri, Korea

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Corresponding author
Sun Kyun Ro
Tel 82-31-560-2305
E-mail skro@hanyang.ac.kr
ORCID
https://orcid.org/0000-0003-1472-0845

Seok Whan Moon
Tel 82-2-2258-2858
E-mail swmoon@catholic.ac.kr
ORCID
https://orcid.org/0000-0003-3348-6011

*These authors contributed equally to this work as corresponding authors.

Background: Early non-small cell lung cancer (NSCLC) that abuts adjacent structures requires careful evaluation due to its potential impact on postoperative outcomes and prognosis. We examined stage I NSCLC with invasion into adjacent structures, focusing on the prognostic implications after curative surgical resection.
Methods: We retrospectively analyzed the records of 796 patients who underwent curative surgical resection for pathologic stage IA/IB NSCLC (i.e., visceral pleural invasion only) at a single center from 2008 to 2017. Patients were classified based on tumor abutment and then reclassified by the presence of visceral pleural invasion. Clinical characteristics, pathological features, and survival rates were compared.
Results: The study included 181 patients with abutting NSCLC (22.7% of all participants) and 615 with non-abutting tumors (77.3%). Those with tumor abutment exhibited higher rates of non-adenocarcinoma (26.5% vs. 9.9%, p<0.01) and visceral/lymphatic/vascular invasion (30.4%/33.1%/12.7% vs. 8.5%/22.4%/5.7%, respectively; p<0.01) compared to those without abutment. Multivariable analysis identified lymphatic invasion and male sex as risk factors for overall survival (OS) and disease-free survival (DFS) in stage I NSCLC measuring 3 cm or smaller. Age, smoking history, vascular invasion, and recurrence emerged as risk factors for OS, whereas the presence of non-pure ground-glass opacity was a risk factor for DFS.
Conclusion: NSCLC lesions 3 cm or smaller that abut adjacent structures present higher rates of various risk factors than non-abutting lesions, necessitating evaluation of tumor invasion into adjacent structures and lymph node metastasis. In isolation, however, the presence of tumor abutment without visceral pleural invasion does not constitute a risk factor.

Keywords: Abutting, Non-small-cell lung carcinoma, Visceral pleural invasion, Disease-free survival

Introduction

Surgical resection remains the cornerstone of treatment for non-small cell lung cancer (NSCLC). It is typically considered the definitive treatment approach, particularly for patients with early-stage NSCLC. Even in advanced stages of the disease, surgical resection plays an important and evolving role [1-3]. According to the eighth edition of the tumor-node-metastasis (TNM) classification of malignant tumors, visceral pleural invasion (VPI) confers a T2 categorization, which corresponds to stage IB NSCLC if the tumor is 3 cm or smaller and no nodal involvement is observed [4]. VPI is a documented risk factor for poor outcomes and recurrence in NSCLC following curative surgical resection [5,6]. When a lesion infiltrates the chest wall, diaphragm, mediastinum, or other adjacent structures beyond the visceral pleura, it is classified as T3 or T4 and considered stage II or III, provided no distant metastasis is found. In such instances, immediate anatomical resection of the involved lobe, along with radical resection of the adjacent structures, is required. Reports have indicated satisfactory outcomes following such cases of anatomical lung resec-

tion [7-9]. However, the staging of adjacent lobe invasion is still a matter of debate, with some researchers suggesting T3 as the proper classification [10-12]. Therefore, surgeons should carefully review preoperative computed tomography (CT) scans of lesions abutting adjacent structures, as these findings can considerably influence the surgical plan. However, the invasion of adjacent structures can only be confirmed through histological examination or during surgery, not by preoperative assessment alone. Given this limitation, it may be valuable to consider whether radiological signs of abutment are indicative of pathological invasion and to investigate how these features impact clinical outcomes, including survival and recurrence rates. To date, the clinical significance of tumors abutting potential invasion sites has not been documented. Moreover, even among patients with early-stage (IA or IB) cancer who have undergone curative surgical resection, recurrence has been observed, with 5-year survival rates ranging from 65.8% for stage IB to 87% for stage IA [13,14]. Consequently, efforts must be made to identify additional risk factors for poor outcomes in this population to understand when adjuvant treatments are warranted [13-19].

In this study, we aimed to compare the clinical outcomes of stage I NSCLC measuring 3 cm or smaller based on the presence of tumor abutment. Additionally, we sought to identify risk factors for recurrence within this patient population.

Methods

Patients and study design

We conducted a retrospective review of the medical records of patients who underwent surgical resection for lung cancer at a single center between October 2008 and April 2017. Each patient was given a preoperative diagnostic workup, including CT imaging, followed by postoperative pathological examination to ensure accurate staging. The lung cancer staging adhered to the criteria set forth in the eighth edition of the TNM classification of malignant tumors [4]. A total of 839 patients underwent surgical resection of NSCLC measuring 3 cm or smaller and without nodal or distant metastasis. We excluded cases with inadequate pathological data (n=31); T2 lesions that involved the main bronchus but not the carina or that were associated with atelectasis or obstructive pneumonitis extending to the hilar region (n=8); and tumors with invasion into adjacent lobes or structures (n=4). T2 lesions with VPI were included in the study. Ultimately, 796 patients with stage IA and IB lung cancer (specifically, lesions 3 cm or smaller with VPI) were included in the analysis (Fig. 1).

The patients were grouped based on the presence or absence of tumor abutment. An abutting tumor was defined as a lesion that maintains constant contact with surrounding structures, such as other lobes, the parietal pleura, the mediastinal pleura, and/or the diaphragm. This contact is characterized by more than 1 point of attachment along the lung boundary, as observed on preoperative CT. Fig. 2

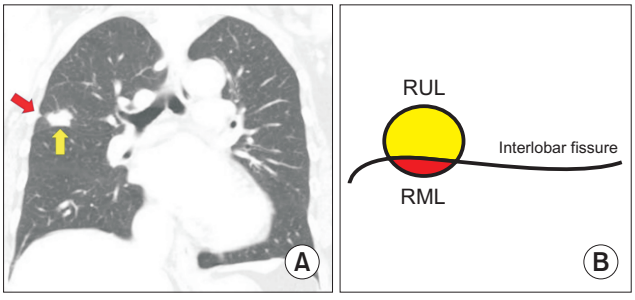

Fig. 2. Example of abutting lung cancer on computed tomography. (A) Right upper lobe (RUL) lung cancer abutting the right middle lobe (RML) via the minor fissure (arrows). (B) Schematic illustration of abutment.

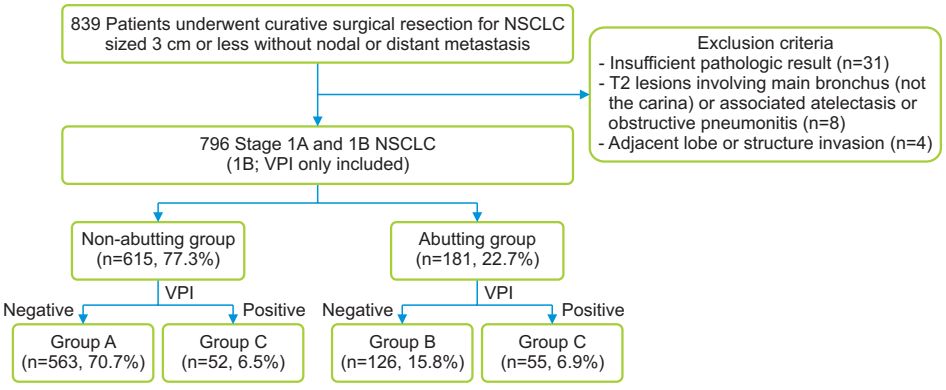

Fig. 1. Inclusion and exclusion criteria, along with a comparison between non-abutment and abutment groups as well as among the 4 subgroups determined based on the presence of abutment and visceral pleural invasion. NSCLC, non-small cell lung cancer; VPI, visceral pleural invasion.

presents 2 images for comparison. Image (A) depicts lung cancer of the right upper lobe that abuts the right middle lobe through the minor fissure. The yellow arrow indicates a finding typical of abutment on CT. Concurrently, the cancer lesion exhibits pleural retraction, indicated by the red arrow, which is distinct from the abutment seen on the CT scan. Image (B) provides a schematic illustration of abutment. Within the circle, some areas marked in yellow have turned red, signifying that parts of the cancer lesion have been supplanted by the surrounding structures through the interlobar fissure. In the absence of surrounding structures, the cancer lesion may display concentric growth. However, as depicted in this schematic, the cancer lesion presents with a red defect within the cancer mass, illustrating the typical signs of abutment. Furthermore, this definition was confined to the lesion, with no evidence of direct invasion into adjacent structures on either surgical inspection or pathological evaluation. Subsequently, each group was additionally divided based on the presence or absence of VPI, resulting in 4 subgroups: non-abutting and non-VPI (termed group A), abutting and non-VPI (group B), non-abutting and VPI (group C), and abutting and VPI (group D).

After curative surgical resection, each case was reviewed by a multidisciplinary team that included oncologists, pulmonologists, radiologists, pathologists, and thoracic surgeons. The decision to administer adjuvant therapy was made following an interdisciplinary discussion.

Data collection

All data on patient demographics, operative outcomes, clinical and pathological findings, recurrence, and survival were obtained from the patients' medical records.

Statistical analysis

Categorical variables were compared using the chi-square test or the Fisher exact test, with the latter selected when the expected frequency in 1 or more cells was less than 5. For continuous variables, comparisons between the 2 groups were conducted using the Student t-test or the Wilcoxon rank-sum test, while comparisons among the 4 subgroups employed 1-way analysis of variance or the Kruskal-Wallis test, as appropriate. Overall survival (OS) and disease-free survival (DFS) were analyzed with Kaplan-Meier survival curves, and differences between the curves were assessed for statistical significance using 2-tailed log-rank tests. Univariable analysis for OS and DFS was carried out using the Cox proportional hazards model. Variables with statistical significance (represented by p-values ≤0.1) in the univariable analysis were subsequently included in multivariable analysis. A p-value of less than 0.05 was considered to indicate statistical significance. All statistical analyses were conducted using IBM SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA).

Ethical statement

The authors are responsible for all aspects of the work in ensuring that any questions regarding the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki, as revised in 2013. Approval for this study was granted by the institutional review board of St. Mary's Hospital (Seoul, South Korea) under the approval number KC19RASI0794 on November 18, 2019. Due to the retrospective nature of this study, the requirement for informed consent was waived.

Results

Comparison based on presence of abutment

A total of 796 patients (mean age, 63.0±10.1 years) were enrolled, including 384 (48.2%) male and 412 (51.8%) female participants. The patients were divided into those with non-abutting NSCLC (n=615, 77.3%) and those with NSCLC exhibiting tumor abutment (n=181, 22.7%). Structures adjacent to abutting tumors included adjacent lobes, mediastinal pleura or structures, parietal pleura (rib or chest wall), and the diaphragm. Some tumors abutted more than 1 adjacent structure. The number of patients with tumors abutting the adjacent lung, mediastinal pleura, parietal pleura, and diaphragm were 84 (10.6%), 19 (2.4%), 65 (8.2%), and 2 (0.3%), respectively. Two lesions (0.3%) simultaneously abutted the lung and mediastinal pleura. Additionally, 6 lesions (0.8%) abutted both the lung and parietal pleura, 1 lesion (0.1%) abutted the lung and diaphragm, and 2 lesions (0.3%) abutted the mediastinal and parietal pleura. Significant differences in several clinical and pathological characteristics were observed between the groups. The participants with tumor abutment showed a male predominance (55.2%) that was not observed in the non-abutment group, which was 46.2% male (p=0.03). Those with abutting tumors also had a higher rate of positive smoking history (76.8% versus 64.6%, p<0.01). Pure ground-glass nodules (GGNs) were more commonly found

in the non-abutment group (19.2% versus 4.4%, p<0.01). According to both preoperative CT and pathological analysis, those with abutting tumors had lesions with a longer diameter (2.1 cm and 2.0 cm, respectively) than those in the non-abutting tumor group (1.8 cm and 1.7 cm, respectively, p<0.01). Pathological analysis revealed distinct characteristics between the groups. The patients with tumor abutment had higher frequencies of non-well-differentiated and non-adenocarcinoma tumors (26.5% and 22.3%, respectively) compared to those not exhibiting abutment (9.9% and 13.6%, respectively; p<0.01). The abutting tumor group also displayed higher rates of visceral, lymphatic, and vascular invasion (30.4%, 33.1%, and 12.7% versus 8.5%, 22.4%, and 5.7%, respectively; p<0.01). Adjuvant treatments, such as chemotherapy and radiotherapy, were more frequently administered to patients with abutting tumors (8.3% versus 1.3%, p<0.01). Finally, the recurrence rate was higher among those with abutment (14.4% versus 8.1%, p=0.01). The details are presented in Table 1.

Comparison based on presence of abutment and VPI

To investigate whether differences based on abutment type were associated with VPI, we compared groups A and B (the subgroups representing tumors without VPI) with groups C and D (those representing tumors with VPI). Regarding patient characteristics, group B—which included patients with tumor abutment but no VPI—had a higher proportion of male participants (57.1% versus 45.3%, p=0.02) and a greater prevalence of positive smoking history (76.2% versus 65.0%, p=0.02) compared to group A, which was characterized by the absence of both abutment and VPI. In preoperative CT findings, group B exhibited a lower frequency of pure ground-glass opacity (GGO) nodules (5.6% versus 20.8%, p<0.01) and a larger average CT diameter (2.1 cm versus 1.8 cm, p<0.01) than group A. Pathologic analysis revealed that group B had larger tumors (1.9 cm versus 1.7 cm, p<0.01), a higher incidence of non-adenocarcinoma (25.4% versus 9.9%, p<0.01), more

Table 1. Comparison of groups based on the presence of tumor abutment

Characteristic	Non-abutting	Abutting	p-value
No. of patients	615 (77.3)	181 (22.7)	
Age (yr)	62.6±10.2	64.2±9.8	0.07
Sex			0.03
Male	284 (46.2)	100 (55.2)	
Female	331 (53.8)	81 (44.8)	
Smoking history	397 (64.6)	139 (76.8)	<0.01
Mean hospital stay (day)	6.8±7.5	7.0±4.6	0.73
Anatomical resection + additional resection	43 (7.0)	20 (11.0)	0.08
Pure GGN	118 (19.2)	8 (4.4)	<0.01
CT diameter (cm)	1.8±0.7	2.1±0.9	<0.01
Laterality			0.36
Right	378 (61.5)	118 (65.2)	
Left	237 (38.5)	63 (34.8)	
Specimen diameter (cm)	1.7±0.6	2.0±0.6	<0.01
Non-adenocarcinoma	61 (9.9)	48 (26.5)	<0.01
Visceral pleural invasion	52 (8.5)	55 (30.4)	<0.01
Lymphatic invasion	138 (22.4)	60 (33.1)	<0.01
Vascular invasion	35 (5.7)	23 (12.7)	<0.01
Perineural invasion	2 (0.3)	3 (1.7)	0.08[a]
Non-well-differentiated tumor	82 (13.6)	40 (22.3)	<0.01
Adjuvant treatment rate	8 (1.3)	15 (8.3)	<0.01
CTx	6 (1.0)	12 (6.6)	
RTx	2 (0.3)	2 (1.1)	
CTx+RTx	0	1 (0.6)	
Recurrence rate	50 (8.1)	26 (14.4)	0.01
Mortality rate	33 (5.4)	15 (8.3)	0.15

Values are presented as number (%) or mean±standard deviation.
GGN, ground-glass opacity nodule; CT, computed tomography; CTx, chemotherapy; RTx, radiotherapy; CTx+RTx, chemotherapy and radiotherapy.
[a]The p-value was calculated using the Fisher exact test.

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non-well-differentiated lesions (20.8% versus 13.0%, p=0.03), and more frequent perineural invasion (2.4% versus 0.2%, p=0.02 by Fisher exact test) than group A. Additionally, patients in group B were more often treated with adjuvant therapy (4.8% versus 1.4%, p=0.03) than those in group A. In terms of patient characteristics, group D (which was characterized by both VPI and abutment) had a higher rate of positive smoking history (78.2% versus 59.6%, p=0.04) than group C, which had VPI but no abutment. Pathological analysis showed that group D had a greater incidence of non-adenocarcinoma (29.1% versus 9.6%, p=0.01) and vascular invasion (27.3% versus 9.6%, p=0.02) than group C. Moreover, patients in group D were more frequently treated with adjuvant therapy (16.4% versus 0.0%, p<0.01) than those in group C. The details are presented in Table 2.

OS and DFS

The median follow-up period was 46.5 months. Survival differences between the abutting and non-abutting groups are illustrated with OS and DFS curves (p=0.048 and p<0.01, respectively). Upon subgroup analysis, between the non-VPI subgroups (A and B), the OS and DFS curves revealed no statistically significant differences (p=0.24 and p=0.41, respectively). Similarly, when comparing the VPI groups (C and D), the OS and DFS curves indicated no significant differences (p=0.67 and p=0.44, respectively). These findings are detailed in Fig. 3.

Analysis of risk factors for OS and DFS

Age (hazard ratio [HR], 1.06; 95% confidence interval [CI], 1.03–1.10; p<0.01), male sex (HR, 2.92; 95% CI, 1.35–

Table 2. Comparison of groups based on the presence of tumor abutment and VPI

Variable	VPI					
	Negative (n=689)		p-value	Positive (n=107)		p-value
	Group A	Group B		Group C	Group D	
No. of patients	563 (81.7)	126 (18.3)		52 (48.6)	55 (51.4)	
Age (yr)	62.5±10.2	63.7±9.7	0.22	64.1±10.5	65.3±10.1	0.55
Sex			0.02			0.62
Male	255 (45.3)	72 (57.1)		29 (55.8)	28 (50.9)	
Female	308 (54.7)	54 (42.9)		23 (44.2)	27 (49.1)	
Smoking history	366 (65.0)	96 (76.2)	0.02	31 (59.6)	43 (78.2)	0.04
Mean hospital stay (day)	6.8±7.6	6.8±4.5	0.98	6.9±5.7	7.4±5.0	0.61
Anatomical resection+additional resection	38 (6.7)	13 (10.3)	0.17	5 (9.6)	7 (12.7)	0.61
Pure GGN	117 (20.8)	7 (5.6)	<0.01	1 (1.9)	1 (1.8)	>0.99
CT diameter (cm)	1.8±0.7	2.1±1.0	<0.01	2.2±0.7	2.2±0.7	0.77
Laterality			0.77			0.41
Right	345 (61.3)	79 (62.7)		33 (63.5)	39 (70.9)	
Left	218 (38.7)	47 (37.3)		19 (36.5)	16 (29.1)	
Specimen diameter (cm)	1.7±0.6	1.9±0.6	<0.01	2.1±0.6	2.2±0.5	0.43
Non-adenocarcinoma	56 (9.9)	32 (25.4)	<0.01	5 (9.6)	16 (29.1)	0.01
Lymphatic invasion	114 (20.2)	31 (24.6)	0.28	24 (46.2)	29 (52.7)	0.50
Vascular invasion	30 (5.3)	8 (6.3)	0.65	5 (9.6)	15 (27.3)	0.02
Perineural invasion	1 (0.2)	3 (2.4)	0.02[a]	1 (1.9)	0	0.49[a]
Non-well-differentiated tumor	72 (13.0)	26 (20.8)	0.03	10 (19.2)	14 (25.9)	0.41
Adjuvant treatment rate	8 (1.4)	6 (4.8)	0.03	0	9 (16.4)	<0.01
CTx	6 (1.1)	5 (4.0)		0	7 (12.7)	
RTx	2 (0.4)	1 (0.8)		0	1 (1.8)	
CTx+RTx	0	0		0	1 (1.8)	
Recurrence rate	39 (6.9)	11 (8.7)	0.48	11 (21.2)	15 (27.3)	0.46
Mortality rate	28 (5.0)	8 (6.3)	0.53	5 (9.6)	7 (12.7)	0.61

Values are presented as number (%) or mean±standard deviation. Group A: no abutment and no VPI (-/-). Group B: abutment present, but no VPI (+/-). Group C: no abutment, but VPI present (-/+). Group D: both abutment and VPI present (+/+).
VPI, visceral pleural invasion; GGN, ground-glass opacity nodule; CT, computed tomography; CTx, chemotherapy; RTx, radiotherapy; CTx+RTx, chemotherapy and radiotherapy.
[a]The p-value was calculated using the Fisher exact test.

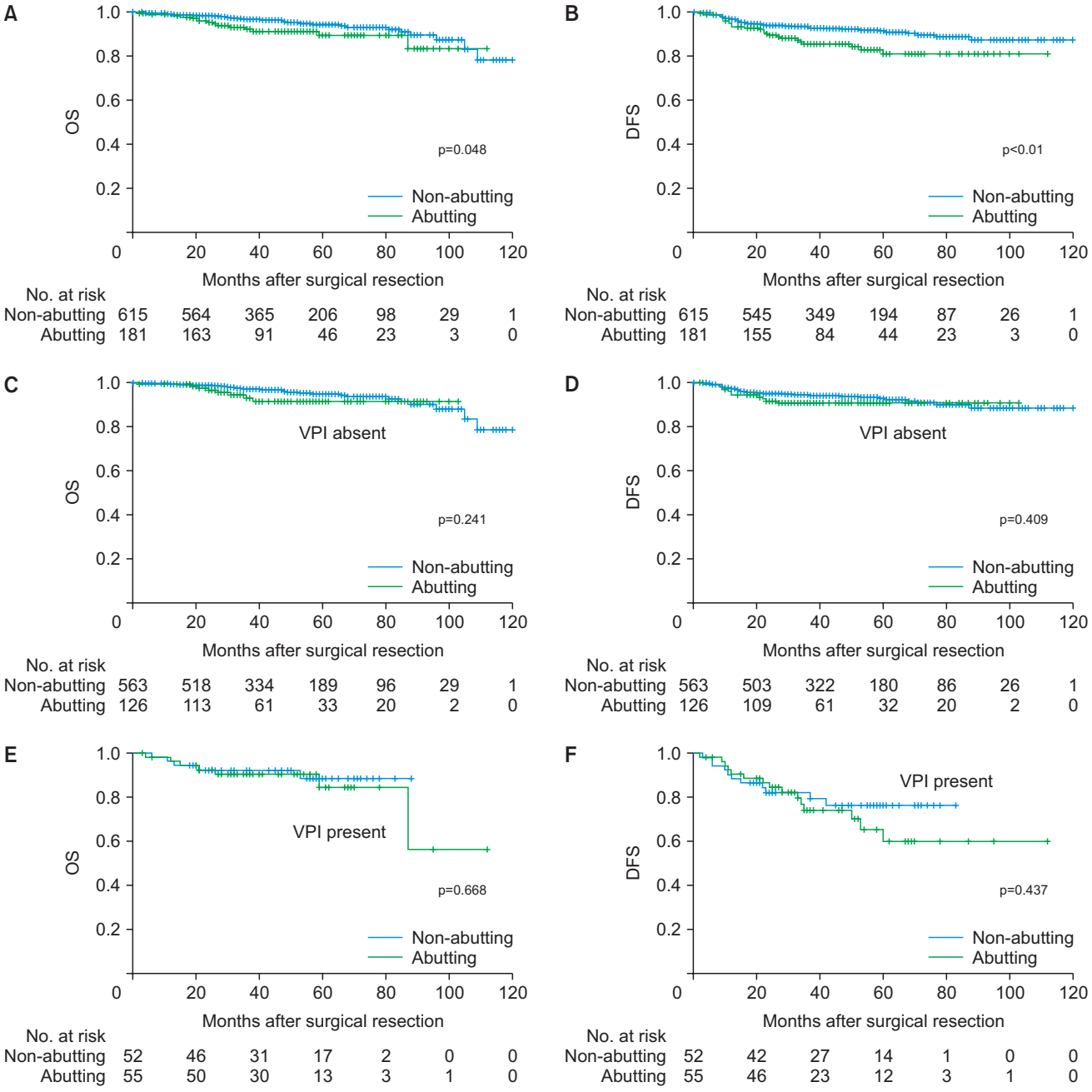

Fig. 3. Overall survival (OS) and disease-free survival (DFS) as depicted by Kaplan-Meier curves. (A) OS comparison between non-abutment and abutment groups. (B) DFS comparison between non-abutment and abutment groups. (C) OS comparison between groups A and B (VPI absent). (D) DFS comparison between groups A and B (VPI absent). (E) OS comparison between groups C and D (VPI present). (F) DFS comparison between groups C and D (VPI present). Group A: no abutment and no visceral pleural invasion (VPI) (-/-). Group B: abutment present, but no VPI (+/-). Group C: no abutment, but VPI present (-/+). Group D: both abutment and VPI present (+/+).

6.33; p<0.01), smoking history (HR, 2.16; 95% CI, 1.04–4.49; p=0.04), lymphatic invasion (HR, 1.89; 95% CI, 1.00–3.57; p=0.048), vascular invasion (HR, 2.59; 95% CI, 1.22–5.47; p=0.01), and recurrence (HR, 7.89; 95% CI, 4.40–14.16; p<0.01) were identified as independent risk factors for OS. Tumor abutment (HR, 1.84; 95% CI, 1.00–3.41; p=0.05) and tumor abutment with VPI (HR, 2.64; 95% CI, 1.18–5.89; p=0.02) were statistically significant risk factors for OS in the univariable analysis. However, their significance was not observed in the multivariable analysis. Simi-

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Table 3. Analysis of risk factors for OS and DFS

Variable	Univariable analysis		Multivariable analysis	
	HR (95% CI) for OS	p-value	HR (95% CI) for OS	p-value
OS				
Age	1.08 (1.04–1.11)	<0.01	1.06 (1.03–1.10)	<0.01
Male sex	4.71 (2.28–9.73)	<0.01	2.92 (1.35–6.33)	<0.01
Smoking history	2.85 (1.45–5.59)	<0.01	2.16 (1.04–4.49)	0.04
Non-pure GGN	2.16 (0.86–5.47)	0.10	0.99 (0.37–2.69)	0.99
Non-adenocarcinoma	4.29 (2.35–7.83)	<0.01	1.70 (0.87–3.32)	0.12
VPI	2.55 (1.32–4.93)	<0.01	1.58 (0.57–4.36)	0.38
Lymphatic invasion	3.47 (1.96–6.17)	<0.01	1.89 (1.00–3.57)	0.048
Vascular invasion	4.67 (2.36–9.23)	<0.01	2.59 (1.22–5.47)	0.01
Non-well-differentiated tumor	2.43 (1.22–4.83)	0.01	0.73 (0.33–1.64)	0.45
Adjuvant treatment	3.37 (1.33–8.53)	0.01	2.49 (0.78–8.00)	0.13
Recurrence	9.66 (5.48–17.03)	<0.01	7.89 (4.40–14.16)	<0.01
Abutment	1.84 (1.00–3.41)	0.05	1.21 (0.52–2.80)	0.66
Abutment with VPI	2.64 (1.18–5.89)	0.02	0.40 (0.09–1.84)	0.24
DFS				
Male sex	2.59 (1.59–4.23)	<0.01	2.55 (1.55–4.19)	<0.01
Non-pure GGN	5.58 (1.76–17.73)	<0.01	3.31 (1.02–10.70)	0.046
Specimen diameter	1.64 (1.14–2.37)	<0.01	1.02 (0.69–1.52)	0.91
Non-adenocarcinoma	2.52 (1.51–4.20)	<0.01	1.33 (0.74–2.37)	0.34
VPI	3.76 (2.34–6.05)	<0.01	2.32 (1.41–3.82)	<0.01
Lymphatic invasion	3.55 (2.26–5.57)	<0.01	2.59 (1.61–4.15)	<0.01
Vascular invasion	2.65 (1.43–4.91)	<0.01	0.96 (0.47–1.94)	0.91
Non-well-differentiated tumor	1.95 (1.13–3.36)	0.02	1.05 (0.57–1.92)	0.88
Adjuvant treatment	2.38 (0.96–5.89)	0.06	1.40 (0.54–3.64)	0.50
Abutment	1.90 (1.18–3.05)	<0.01	0.97 (0.49–1.92)	0.93
VPI without abutment	2.64 (1.39–5.01)	<0.01	0.90 (0.31–2.61)	0.84
VPI with abutment	3.74 (2.13–6.59)	<0.01	Reduced DF	

HR, hazard ratio; CI, confidence interval; OS, overall survival; DFS, disease-free survival; GGN, ground-glass opacity nodule; VPI, visceral pleural invasion; DF, degrees of freedom.

larly, male sex (HR, 2.55; 95% CI, 1.55–4.19; p<0.01), lymphatic invasion (HR, 2.59; 95% CI, 1.61–4.15; p<0.01), the presence of a solid component (non-pure GGO) (HR, 3.31; 95% CI, 1.02–10.70; p=0.046), and VPI (HR, 2.32; 95% CI, 1.41–3.82; p<0.01) were identified as risk factors for DFS in the multivariable analysis. Tumor abutment (HR, 1.90; 95% CI, 1.18–3.05; p<0.01), VPI without abutment (HR, 2.64; 95% CI, 1.39–5.01; p<0.01), and VPI with abutment (HR, 3.74; 95% CI, 2.13–6.59; p<0.01) were significant risk factors for DFS in the univariable analysis. However, either they were not significant in the multivariable analysis, or multivariable analysis could not be performed due to reduced degrees of freedom for a covariate (specifically, VPI with tumor abutment). The details are presented in Table 3.

Discussion

In this study, we observed several distinct differences between those with abutting and non-abutting tumors. The abutment group demonstrated a male predominance, a relatively high proportion of patients with a history of smoking, and a comparatively low proportion of patients with pure GGO nodules on preoperative CT and pathological analysis. Additionally, non-adenocarcinoma pathology occurred more frequently among those with abutment compared to those with non-abutting NSCLC. Previous studies [5,6,13-15,18] have identified risk factors such as visceral, lymphatic, and vascular invasion, along with poor differentiation, which were more commonly observed among patients with tumor abutment than in the non-abutting group. Regarding tumor size, those with abutment presented with larger tumors than those with non-abutting tumors, as determined based on both preoperative CT and pathological analyses. Consequently, most patients in the abutment group, which exhibited both larger tumors and known risk factors, were treated with adjuvant therapy. Nevertheless, the recurrence rate was higher among those with abutting tumors than among those without abutment.

Based on the study findings, the differences between the abutting and non-abutting tumor groups were primarily attributable to VPI. However, in the subgroup analysis of groups A and B (the VPI-negative subgroups), certain clinicopathological factors, such as smoking history and the presence of pure GGNs, remained different between those with and without tumor abutment. Abutting tumors (found in group A) tended to display a more aggressive nature, a higher rate of non-well-differentiated lesions, and a larger tumor diameter on CT. Nevertheless, in the survival analysis, the non-VPI groups A and B showed no statistically significant differences in OS or DFS. Similarly, the VPI-positive groups C and D showed no statistically significant differences in survival outcomes. Overall, we hypothesized that the survival differences between the abutting and non-abutting tumor groups may be due to VPI. These results suggest that taken alone, a preoperative CT finding indicating tumor abutment of adjacent structures is not associated with poor postoperative outcome. However, due to the aggressive nature of abutting tumors, a surgeon performing curative resection should approach the case with care and ensure meticulous follow-up.

In the Cox hazard model, the presence of abutment alone was not identified as a risk factor. However, when patients were categorized based on whether abutment was present, the groups exhibited differing rates of risk factors.

Our study results indicate that tumors abutting adjacent structures exhibit distinctive features compared to non-abutting tumors. These differences may be associated with the larger size of the abutting tumors or a higher rate of VPI. However, abutment itself was not confirmed as an independent risk factor, although the presence of abutment is associated with varying rates of other risk factors. When a surgeon identifies an abutting tumor on preoperative CT, standard curative resection should be performed. Subsequent adjuvant treatment should be applied based on the pathological findings.

This study had several limitations. First, it was retrospective in nature and the data were collected from a single center, which may have introduced selection bias and limited the generalizability of our findings. Second, the definition of "abutment" employed was somewhat ambiguous. We defined abutment as a situation in which lesions were in constant contact with surrounding structures, with more than 1 attachment point along the lung boundary. A recent study identified pleural attachment and indentation as risk factors for VPI [20]. Based on our definition, cases that exhibited only simple indentations or pleural attachments were not considered to display tumor abutment and were therefore excluded. Finally, invasion was subjectively determined by the respective surgeons. When excisions or biopsies of adjacent structures were not performed, the presence of invasion could not be definitively excluded. Thus, abutting lesions with microinvasions into adjacent structures would have been underestimated as noninvasive.

In conclusion, NSCLC lesions 3 cm or smaller that abut adjacent structures present higher rates of various risk factors than non-abutting lesions. Consequently, these cases require thorough evaluation for potential invasion into adjacent structures and lymph node metastasis. Taken alone, however, the presence of an abutting tumor without VPI does not represent a risk factor. To generalize our findings, further research involving larger datasets from multiple centers should be conducted.

Article information

ORCID

Soohwan Choi: https://orcid.org/0000-0001-5790-958X
Sun Kyun Ro: https://orcid.org/0000-0003-1472-0845
Seok Whan Moon: https://orcid.org/0000-0003-3348-6011

Author contributions

Conceptualization: SC, SWM. Data curation: SC, SWM. Formal analysis: SC, SKR, SWM. Investigation: SC, SKR, SWM. Methodology: SC, SWM. Supervision: SC, SKR, SWM. Writing–original draft: SC, SKR. Writing–review & editing: SC, SKR, SWM. Approval of final manuscript: all authors.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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