International Journal of Medical and Health Research
ISSN: 2454-9142
www.medicalsciencejournal.com
Volume 4; Issue 8; August 2018; Page No. 37-45

Comparative analysis of pneumonectomy and bronchial sleeve lobectomy operations in patients with non-small cell lung carcinoma

Dr. Murat Kapdagli[1*], Dr. Murat Saricam[2], Dr. Berker Ozkan[3], Dr. Adalet Demir[4], Dr. Alper Toker[5]
[1] Department of Thoracic Surgery, American Hospital, Istanbul, Turkey
[2] Assistant Professor, Department of Thoracic Surgery, Namik Kemal University, Tekirdag, Turkey
[3] Associate, Professor, Department of Thoracic Surgery, Istanbul University, Istanbul, Turkey
[4, 5] Professor, Department of Thoracic Surgery, Istinye University, Istanbul, Turkey

Abstract
Bronchial sleeve lobectomy (BSL) is a lung-saving procedure indicated for central tumors as an alternative to pneumonectomy (PN). Our study compares operative results of both operations. We inducted a study including a total of 273 patients of whom 139 underwent PN and 134 were treated with BSL between January 2007 and December 2017. Both groups were compared in terms of their demographic characteristics, morbidity, mortality, survival and recurrence. The patients in our study comprises 254 (89.7%) men and 28 (10.3%) women. The morbidity rate is higher in the BSL group than the PN group. There are no statistical differences in terms of 30-day mortality rate, local recurrence or distant metastasis between two groups. Overall 5-year survival rate is higher for the patients who underwent BSL. Moreover, BSL has significant survival advantage in patients with N1 disease, neoadjuvant therapy and age less than 60 years. BSL can be performed safely in selected patients without increasing mortality, local recurrence or distant metastases, also offering better long-term survival rates compared to PN.

Keywords: lung carcinoma, bronchial sleeve lobectomy, pneumonectomy

Introduction
Lung cancer is one of the most common cancer types in the world and is the leading cause of cancer-related deaths (1). Despite advancing technology, surgical techniques and oncologic therapies, the 5-year survival rate in lung cancer is as low as 15% [1, 2].
Surgery is the primary and most effective form of treatment non-small cell lung cancers (NSCLC) that constitutes the majority of lung cancers [3]. The basic principle in surgical treatment is to perform complete resection and to reveal the mediastinal lymph node status. With surgical treatment, the aim is to complete the staging of the patient's lung cancer, to plan appropriate additional treatment and follow-up, and to achieve the highest survival.
Herein we compare pneumonectomy (PN), a radical surgical treatment for NSCLC, with bronchial sleeve lobectomy (BSL) which is considered as an alternative resection technique.

Materials and methods
Patients who underwent PN or BSL operations due to non-small cell lung cancer in our institution between January 2007 and December 2017 were retrospectively analyzed through data bank records.
Patients who underwent carinal sleeve pneumonectomy or developed positive surgical margins and lymph node involvement at the level of multiple N2 were excluded from the study.
All of our patients underwent lymph node nodule staging via mediastinoscopy in the same or different session. Patients were staged based on 8th TNM (4). For cases who took neoadjuvant treatment, restaging was repeated and their new stage scores were recorded. Those who were reported as having no tumor cells as a result of full response to treatment were classified as T0. Those who had macroscopic residual tumor left behind since the whole tumor could not be removed during the operation and those who had macroscopic (R2) or microscopic (R1) tumor in any surgical margin as a result of pathological examination were evaluated as patients with incomplete resection and were also excluded from the study.
Patients were called for routine outpatient clinic checkup four times in their first year after resection and were followed up in 12 month-intervals after postoperative 2nd year. In these checkups all the patients were followed up in terms of complications and recurrence. Tumor recurrences at the site of bronchial anastomosis, bronchial stump, ipsilateral lung, hilar, or mediastinal lymph nodes were recorded as local recurrences while tumor recurrences at the contralateral lung and other distant organs were recorded as metastatic developments.
Information regarding the survival of the patients who skipped their checkups in the outpatient clinic was obtained by calling the patients themselves or their relatives and the calculations were performed based on these data. To construct a database, Windows Office Excel and Word 97, 2003, 2007 and 2010 versions, and for statistical calculations, IBM SPSS Statistics Version 21 were used.
Patients were classified as the PN and BSL groups. In intergroup comparisons, for categorical variables, Pearson Chi-Square Test, Fisher's Exact Test and for non-categorical variables Independent Sample T-test and Mann-Whitney U

test were used. A P value less than 0.05 was considered statistically significant. In survival and prognostic factor analyses, Kaplan-Meier (Logrank test) test was performed and for parameters with a p value <0.1was accepted as significant. Multivariate analyzes were performed via Cox-regression tests.

Results

The mean age of a total of 273 patients, of whom 139 underwent PN and 134 underwent BSL, was 59.57 ± 8.70 (Range: 39-80). The mean age of the patients who underwent PN was 58.78 ± 8.53 (Range: 39-78) and the mean age of the patients who underwent BSL was 60, 39 ± 8,84 (Range: 40-80), and no statistical differences were detected (p=0.12). Of the patients, 254 (89.7%) were male and 28 were female (10.3%).

In the PN group, 65 patients (46.8%) underwent right-sided and 74 patients (53.2%) underwent left-sided PN. In the BSL group, 88 patients (65.7%) underwent right-sided surgery, 46 patients (34.3%) underwent left-sided resections. Considering that more of our BSL operations are right-sided, statistically significant difference was detected between the two groups in terms of the side (p=0.002).

There was statistically significant difference between the two groups in terms of pathological N status (p=0.01)**.** It was found that N0 was statistically significantly more in the BSL group had more NO while PN group had more N1 patients **(** p=0.01 and p=0.03, respectively**)**. No statistically significant difference was detected between the two groups in terms of the distribution of N2 (p=0.242).

In the evaluation based on the stages of the lung cancer, stage 3 disease was the most common stage, with 62 patients (44.6%) in the PN group. In the BSL group, the most common stage was 0 and 1, with 39 patients (29.1%). Stage 3 was the second most common stage with 38 patients (28.4%) in the BSL group. There was statistically significant difference between the two groups in terms of the distribution of stage (p=0.006).

In terms of the neoadjuvant and adjuvant treatment, PN group had 32 patients (23%) and BSL group had 26 patients (19.4%) receiving neoadjuvant therapy. No statistically significant difference was detected between the groups in terms of receiving neoadjuvant therapy (p=0.46). The number of patients receiving adjuvant therapy was 86 (61.9%) in the PN group and 86 (64.2%) in the BSL group, and there was no significant difference between the two groups (p=0.92).

General demographic characteristics of the patients and the comparative analyses of the PN and BSL groups are given in detail in Table 1.

Table 1: General characteristics of patients and inter-group comparative analysis

Table 1	All patients (n= 273)	Sleeve Lobectomy (n= 134)	Pneumonectomy (n= 139)	'p' value
Age (mean± SD)	59.57 ± 8.706	60.39 ± 8.84	57.78 ± 8.53	0.12
<60	137 (50.2%)	64 (47.8%)	73 (52.5%)	0.43
≥60	136 (49.8%)	70 (52.2%)	66 (47.5%)	
Gender				
Female	28 (10.3%)	14 (10.4%)	14 (10%)	0.91
Male	245 (89.7%)	120 (89.6%)	125 (90%)	
Side				
Right	153 (56%)	88 (65.7%)	65(46.8%)	0.002
Left	120 (44%)	46 (34.3%)	74 (53.2%)	
FEV1 (mean ml ± SD)	2330 ± 641.8	2281.65 ± 671.7	2377.50 ± 610.6	0.224
% FEV1				
< 70%	71 (27.3%)	34 (26.5%)	37 (28%)	0.79
≥ 70%	189 (72.7%)	94 (73.5%)	95 (72%)	
Cell type				
SCC	212 (77.7%)	108 (80.6%)	104 (74.8%)	0.06
Adeno	46 (16.8%)	23 (17.2%)	23 (16.5%)	
Other	15 (5.5%)	3 (2.2%)	12 (8.60%)	
Neoadjuvant treatment				
Yes	58 (21.2%)	26 (19.4%)	32 (23%)	0.46
No	215 (78.8%)	108 (80.6%)	107 (77%)	
T status				
T0	8 (2.9%)	6 (4.5%)	2 (1.4%)	0.07
T1	6 (2.2%)	4 (3%)	2 (1.4%)	
T2	144 (52.7%)	75 (56%)	69 (49.6%)	
T3	89 (32.6%)	42 (31.3%)	47 (33.8%)	
T4	26 (9.5%)	7 (5.2%)	19 (13.7%)	
N status				
N0	113 (41.4%)	66 (49.3%)	47 (33.8%)	0.01
N1	128 (46.9%)	58 (43.3%)	70 (50.4%)	
N2	32 (11.7%)	10 (7.5%)	22 (15.8%)	

Pathological Stage				
0	8 (2.9%)	6 (4.5%)	2 (1.4%)	0.006
IA	2 (0.7%)	2 (1.5%)	0	
IB	45 (16.5%)	31 (23.1%)	14 (10.1%)	
IIA	65 (23.8%)	35 (26.1%)	30 (21.6%)	
IIB	53 (19.4%)	22 (16.4%)	31 (22.3%)	
IIIA	97 (35.5%)	37 (27.6%)	60 (43.2%)	
IIIB	3 (21.1%)	1 (0.7%)	2 (1.4%)	
Stage				
0-1	55	39 (29.1%)	16 (11.5%)	0.001
2A	65	35(26.1%)	30(21.6%)	
2B	53	22(16.5%)	31(22.3%)	
3	100	38(28.4%)	62(44.6%)	
Drainage (days ± SD)	5.49 ± 6.07	8.37 ± 7.40	2.56 ± 1.3	< 0.001
Hospitalization (days ± SD)	10.89 ± 8.54	13.07 ± 10.23	8.78 ± 5.83	< 0.001
Complication	92 (33.7%)	59 (44.0%)	33 (23.7%)	< 0.001
Mortality	10 (3.7%)	4 (2.8%)	6 (4.3%)	0.51
Adjuvant treatment				
Yes	172 (68.5%)	86 (69%)	86 (68.3%)	0.92
No	79 (31.5%)	39 (%31)	40 (31.7%)	
Local recurrence	36/232 (13.7%)	17 (14.5%)	19 (16.5%)	0.67
Metastatic Development	38/232(13.9%)	18 (15.3%)	20 (17.3%)	0.68

(SD: standard deviation, SCC: squamous cell carcinoma, Adeno: adenocarcinoma)

The mean duration of drainage was 2.56 ± 1.3 days in patients in the PN group and 8.37 ± 7.4 days in patients in the BSL group revealing a significant difference between the two groups in terms of the duration of drainage (p<0.001). The mean duration of hospitalization was 8.78 ± 5.83 days in the PN group and 13.07 ± 10.23 days in the BSL group. There was statistically significant difference between the groups in terms of duration of hospitalization (p<0.001) noting that patients who underwent PN stayed longer in the postoperative period.

There were 33 (23.7%) perioperative complications in the PN group while this rate was 44% (n=59) in the BSL group. The difference between the two groups in terms of complications was statistically significant (p< 0.001) (Figure 1).

In terms of postoperative 30 day-mortality rate, PN group had 6 cases (4.3%) and the BSL group had 4 cases (2.8%). No statistically significant difference was detected between the two groups in terms of mortality (p=0.51) (Figure 1).

In the postoperative follow-ups, when the presence of local recurrence or development of distant metastasis were evaluated, it was found that 19 patients (16.5%) in the PN group had local recurrence and 20 patients (17.3%) had distant metastasis. In the BSL group, 17 patients (14.5%) had recurrence and 18 patients (15.3%) had distant metastasis. In the postoperative follow-up, no significant difference was detected between the two groups in terms of recurrence and metastasis (p=0.67 and p=0.68) (Figure 1).

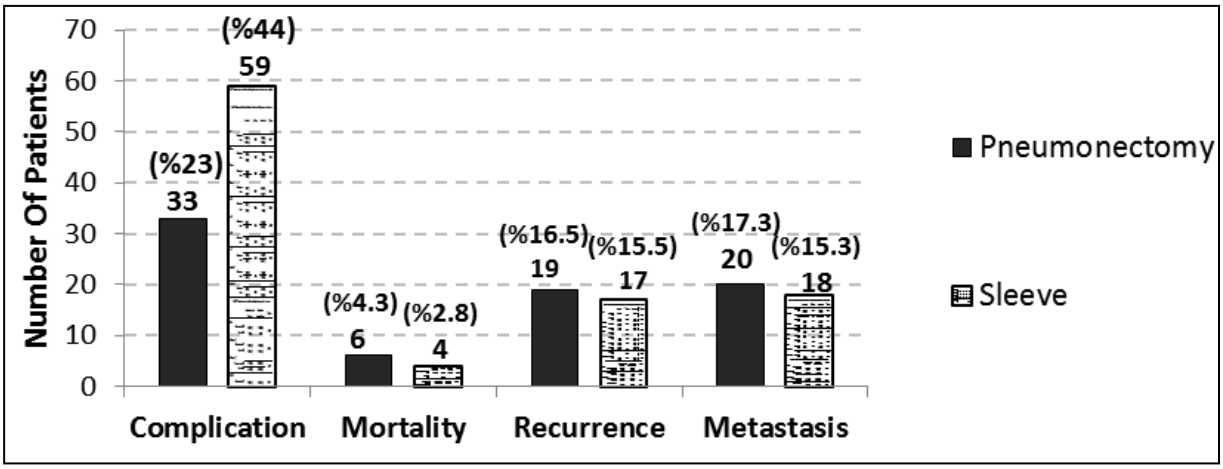

Fig 1: Distribution of complication, mortality, recurrence and metastasis in pneumonectomy and sleeve lobectomy

There were no significant differences regarding the neoadjuvant therapy, stage of malignancy or subgroups of N

status in terms of local recurrence and distant metastasis (Table 2).

Between patient subgroups of those receiving neoadjuvant therapy and those who are not, the rate of complications was statistically significantly higher in the BSL operations than the PN operations. (p=0.043 and p=0.02, respectively) (Table 2).

Table 2: Comparison between pneumonectomy / sleeve lobectomy in terms of local recurrence and distant site metastasis

Table 2		Local recurrence	' p ' value	Distant metastasis	' p ' value
General Sleeve	Pneumonectomy	19 (16.5%)	0.675	20 (17.4%)	0.68
	Sleeve	17 (14.5%)		18 (15.4%)	
N0 status	Pneumonectomy	6 (15.4%)	0.539	2 (5.1%)	0.114
	Sleeve	6 (10.5%)		10 (17.5%)	
N1 status	Pneumonectomy	11(19.0%)	0.859	12 (20.7%)	0.211
	Sleeve	9(17.6%)		6 (11.8%)	
N2 status	Pneumonectomy	2(11.1%)	0.582	1 (7.1%)	0.676
	Sleeve	2(22.2%)		6 (17.6%)	
Stage 0-1	Pneumonectomy	1(7.1%)	0.654	1 (7.1%)	0.656
	Sleeve	2(5.9%)		6 (17.6%)	
Stage 2A	Pneumonectomy	6(25%)	0.66	5 (20.8%)	0.489
	Sleeve	6(20%)		4 (13.3%)	
Stage 2B	Pneumonectomy	5(18.5%)	0.60	3 (11.1%)	0.691
	Sleeve	3(16.7%)		2 (11.1%)	
Stage 3	Pneumonectomy	7(14.0%)	0.69	11 (22.0%)	0.582
	Sleeve	6(17.1%)		6 (17.1%)	
Neoadjuvant (-)	Pneumonectomy	17 (19.8%)	0.424	16 (18.6%)	0.698
	Sleeve	14 (15.2%)		15 (16.3%)	
Neoadjuvant (+)	Pneumonectomy	17 (19.8%)	2 (6.9%)	4 (13.8%)	0.585
	Sleeve	14 (15.2%)		3 (12.0%)	

Statistically significant difference was not detected in terms of complications between the PN and BSL groups among the subgroup of patients under 60 years old (p=0.212). In patients aged 60 or over, it was found that there were statistically significantly more complications in BSL than PN (p<0.001) (Table 3).

Table 3: Comparison between pneumonectomy and sleeve lobectomy in terms of complications

Table 3		Number of patients who had complications	Number of patients without complications	' p ' value
General	Pneumonectomy (n=139)	33 (23.7%)	106 (76.3%)	< 0.001
	Sleeve (n=134)	59 (%44)	75 (%66)	
Neoadjuvant (+)	Pneumonectomy (n=32)	10 (31.3%)	22 (68.8%)	0.043
	Sleeve (n=26)	15 (57.7%)	11 (42.3%)	
Neoadjuvant (-)	Pneumonectomy (n=107)	23 (21.5%)	84 (78.5%)	0.02
	Sleeve(n=108)	44 (40.7%)	64 (59.3%)	
Age < 60	Pneumonectomy (n=73)	18 (24.7%)	55 (75.3%)	0.212
	Sleeve (n=64)	22 (34.4%)	42 (65.6%)	
General	Pneumonectomy (n=139)	15 (22.7%)	51 (77.3%)	<0.001
	Sleeve (n=134)	37 (52.9%)	33 (47.1%)	

The most common complication in the PN group was atrial fibrillation (10.1%) followed by bronchopleural fistula developing in 3 patients (2.2%), whereas prolonged air leak (13.4%) was the most common complication in the BSL group was. Moreover 1 patient (0.7%) of this group had bronchopleural fistula.

Among all patients, median survival was 96 months and 5-year survival rate was 57.3%. The 5-year survival rate was 51.8% in the PN group and 62.2% in the BSL group. Median survival was 67 months for the PN group and 96 months for the BSL group. There was statistically significant difference between the two groups in terms of survival (p=0.027) regarding that the rate and span of survival in the BSL group was higher (Figure 2) (Table 4).

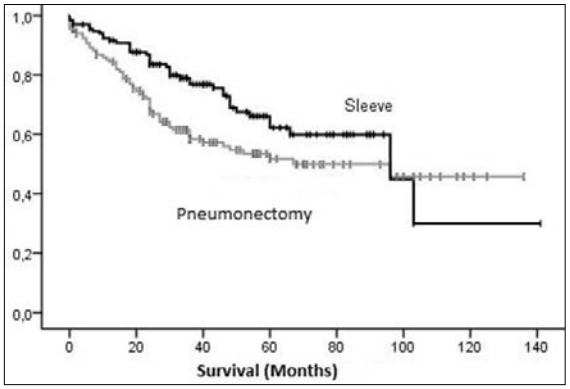

Fig 2: Survival rate in pneumonectomy and sleeve resection

In survival analysis based on lymph node involvement, it was

found that 5-year survival in the N1 patients in the PN group was 45% while this was 63.2% in the BSL group, and there was statistically significant difference between the N1 patients of the two groups (p=0.048) (Table 4).

In terms of the surgical side, it was found that 5-year survival rate for right-sided surgery in PN was 55.5% while it was 71.1% in BSL, and there was statistically significant difference between the two groups in terms of survival (p=0.031) (Table 4).

While no statistical difference in terms of survival was detected between the two groups for adenocarcinoma cells, for squamous cell carcinoma cells, 5-year survival rate was 52.4% in the PN and 66.2% in the BSL group and the difference was statistically significant (p=0.016) (Table 4).

5-year survival rate in PN patients who received neoadjuvant therapy was 42% and 76% in BSL, and there was significant difference in terms of survival (p=0.013) (Table 4).

In terms of the survival of patients aged 60 or younger, it was found that the 5-year survival of patients was 56.1% in the PN group and 78.8% in the BSL group and these values were statistically significant (p=0.027) (Table 4).

Table 4: Comparison between pneumonectomy and sleeve lobectomy in terms of survival

Table 4		5-year survival rate (%)	Median survival (months)	‘ p ’ value
General	Pneumonectomy (n=134)	51.8	67	0.027
	Sleeve (n=133)	62.2	96	
N0 status	Pneumonectomy (n=44)	62	-	0.323
	Sleeve (n=65)	75.3	103	
N1 status	Pneumonectomy (n=69)	45.0	52	0.048
	Sleeve(n=58)	63.2	-	
N2 status	Pneumonectomy(n=21)	52	-	0.522
	Sleeve(n=10)	20	46	
Right-sided surgery	Pneumonectomy(n=63)	55.4	96	0.031
	Sleeve(n=87)	77.1	96	
Left-sided surgery	Pneumonectomy (n=71)	48.4	60	0.686
	Sleeve(n=46)	45.2	60	
Stage 0-1	Pneumonectomy (n=15)	59.3	-	0.110
	Sleeve(n=39)	77.6	-	
Stage 2A	Pneumonectomy (n=29)	45.5	52	0.446
	Sleeve(n=35)	49.6	60	
Stage 2B	Pneumonectomy (n=30)	56.6	67	0.456
	Sleeve (n=21)	69.5	96	
Stage 3	Pneumonectomy (n=60)	49.8	60	0.364
	Sleeve (n=38)	53.1	-	
Squamous cell carcinoma	Pneumonectomy (n=100)	52.4	67	0.016
	Sleeve (n=107)	66.2	96	
Adenocarcinoma	Pneumonectomy (n=22)	36.8	48	0.361
	Sleeve (n=23)	53.2	-	
Neoadjuvant (-)	Pneumonectomy (n=103)	55.0	96	0.257
	Sleeve (n=107)	59.0	96	
Neoadjuvant (+)	Pneumonectomy (n=31)	42.0	36	0.013
	Sleeve (n=26)	76.0	-	
Age < 60	Pneumonectomy (n=71)	56.1	-	0.027
	Sleeve (n=64)	78.8	103	
Age ≥ 60	Pneumonectomy (n=63)	47.4	60	0.342
	Sleeve (n=69)	43.5	60	

The age, side, N status and surgical procedure (PN/BSL) parameters with a p value less than 0.1 in the univariate analysis were evaluated with the multivariate analysis and statistically significant difference was detected in terms of age [(p=0.027), HR(95% CI): 1.582 (1.054-2.374)] and N status [(p=0.032) HR(95% CI): 1.385 (1.029-1.864)]. Age and lymph node involvement were identified as the predictive factors in survival (Table 5).

Table 5: Survival and prognostic factor analysis in all patients

Table 5	Median Survival (months)	5-year survival rate (%)	Univariate ‘p’ value	Multivariate ‘p’ value	Hazard ratio (95% CI)
Age			0.001	0.027	1.582 (1.054-2.374)
<60		67.2			
≥60	60	64.5			
Gender			0.51		
Female	96	57.4			
Male		57.3			

Side			0.02	0.093	1.416 (0.944-2.125)
Right		64.6			
Left	60	47.6			
Cell type			0.54		
SCC	96	59.8			
Adenoca	48	44.5			
Other		61.7			
T status			0.88		
T0		75			
T1	60				
T2	96	58.7			
T3	96	57.1			
T4		51.4			
N status			0.03	0.032	1.385 (1.029-1.864)
N0		69.9			
N1	60	49.8			
N2	46	42.2			
Stage			0.16		
0-1		72.5			
2A	60	48.7			
2B	96	62.2			
3		51.1			
% Fev1			0.64		
< 70%	96	52.6			
≥ 70%	96	58.2			
Surgery			0.02	0.128	0.722 (0.476-1.096)
Pneumonectomy	67	51.8			
Sleeve	96	62.2			
Complication			0.83		
Yes		54.6			
No	96	58.2			
Neoadjuvant					
Yes		57.0	0.633		
No	96	57.3			

Discussion

Sleeve lobectomies developed as alternative techniques to pneumonectomy due to their parenchyma-saving features. Frequency of sleeve lobectomy is approximately 5% [5-7] while the rate of BSL is between 3.4% to 13% among all pulmonary resections for cases with primary lung cancer [5-8].

The mean age of the patients in our study was 58.7 years in the PN group and 60.3 in the BSL group and their difference was not significant. These data are similar to the mean ages of the cases reported in the literature [9, 10].

In terms of the surgical side, based on the literature, it was found that left-sided surgery was performed more frequently in pneumonectomy while right-sided surgery was more frequent in sleeve lobectomy. In our study, 65.7% of the BSL and 53.2% of the PN were left-sided and there was statistically significant difference between the groups in terms of the surgical side. This difference indicated that since right-sided pneumonectomy is avoided more because of higher rates of complication and mortality while right-sided sleeve lobectomies were performed more frequently because of the technical ease due to anatomic properties [11-13].

In our study, significant difference was detected between the PN and BSL groups in terms of the distribution by pathological stage. While patients in more advanced stages such as stage 2 and 3 comprised the majority in the PN group with 66.9%, patients in stages less than 2B comprised the majority in the BSL group, with 55.2%. Significant differences between the groups in terms of distribution by stage have been shown in the meta-analysis by Ma *et al*. in 2007 comprising 12 studies and in a more comprehensive and up to date meta-analysis by Shi *et al*. in 2012, which also comprises the forementioned 12 studies. In these studies, similar to our study, the number of patients in the advanced stage was higher in the PN group than the BSL group and this was correlated with poor survival rates in PN [9, 10, 14].

In recent series where two procedures are compared in the literature, complication rates were between 16-45% in PN and 11-51% in BSL [5-7, 11, 15-25]. In our study, PN group had significantly fewer complications than the BSL group. Complication rate was 23.7% in the pneumonectomy group while this rate was 44% in the sleeve resection group. This finding in our study, where fewer complications were detected in the pneumonectomy group and the difference was statistically significant, was different from the overall trend in the literature. We assume that prolonged air leak that is not seen in PN operations but has a higher incidence in sleeve resections, and pulmonary complications such as atelectasia and pneumonia which have a tendency to develop more frequently after BSL, are the main causes behind this difference. Also it is certain that complication rates for patients receiving neoadjuvant therapy in both groups increased, although this increase was not statistically

significant. Complication rates for patient receiving neoadjuvant therapy were significantly higher in the BSL group than the PN group, which was the general trend in our study. While there are limited number of studies in the literature in which pneumonectomy and sleeve resection outcomes are compared in patients receiving neoadjuvant treatment, in the study by Maurizi *et al.* comparing 43 pneumonectomy and 39 sleeve patients under neoadjuvant treatment, complication rate was 33.3% in the PN group and 28.2% in the BSL group and this difference was not statistically significant [26].

Recent papers report that mortality rate in sleeve lobectomy is 0-7.5% while it is 1.2-15% in pneumonectomy [6, 8-11, 14, 18]. Moreover, many studies have reported sleeve lobectomy as a more safe procedure since its mortality is significantly lower than the pneumonectomy [6-10, 12, 19, 22, 23]. However, we did not detect any significant differences between pneumonectomy and sleeve lobectomy in terms of mortality. Mortality rate was 4.3% in pneumonectomy and 2.8% in sleeve lobectomy, both of which were acceptable according to the literature, and were concordant with the rates that favor sleeve lobectomy in the literature.

A controversial issue regarding sleeve resection is that its parenchyma-saving feature can be associated with high post-operative recurrence rates. When pneumonectomy and sleeve resections are compared in terms of general tumor recurrences such as local or distant site recurrence, it was found that sleeve resection has a higher incidence of recurrences varying between 4.3 - 57%, while this incidence is between 4.8-47% in pneumonectomy [5, 9, 10, 11, 14, 15, 21, 22]. When the details of the study are analyzed, it can be seen that there is no significant difference between pneumonectomy and sleeve resection in terms of incomplete surgery rates, while pneumonectomy comprises more advanced stage diseases and more patients in N2 and N1 stages compared to sleeve lobectomy [12]. In the comparisons performed in our study in terms of tumor recurrence, local recurrence rate was 14.5% and distant site metastasis rate was 15.3% for sleeve lobectomy. In the pneumonectomy group, local recurrence rate was 16.5% and distant metastasis rate was 17.3%**.** With these rates, no difference was detected between pneumonectomy and sleeve lobectomy in terms of local and distant site recurrences and the results were considered consistent with the majority of the literature. In this context, we propose that, despite its parenchyma-saving properties, sleeve resection can be performed without causing an increase in the tumor recurrence compared to pneumonectomy.

Based on the survival analyses in the literature where pneumonectomy and sleeve resections are compared, it can be seen that 5-year survival rate in sleeve resection varies between 37.5%-72.5%, while it varies between 27%-53.7% in pneumonectomy [5, 9, 10, 14, 15, 17, 27]. The great majority of these comparative studies which also include meta-analyses report the superiority of sleeve resection over pneumonectomy in terms of survival [6, 9, 10, 12, 14, 15, 28]. In our literature review, there were no publications in the comparative series reporting outcomes regarding long term survival which favor pneumonectomy. Our results regarding long-term survival were concordant with the overall trend in the literature and sleeve resection was found to be superior to pneumonectomy. Five-year survival rate was 62.2% in sleeve lobectomy while it was 51% in pneumonectomy and the difference was statistically significant. We may argue that, greater number of advanced stage patients in the pneumonectomy group and performing pneumonectomy in more advanced tumor cases where sleeve resection is not surgically suitable are the causes behind the significant difference between the two procedure in terms of survival.

When the survival is analyzed in terms of lymph node involvement, both Okada *et al*. and Deslauriers *et al*. have found that the survival rate of sleeve resection in N0 and N1 lymph node involvement is better, but there is no significant difference in terms of survival between pneumonectomy and sleeve lobectomy in N2 lymph node involvement [6, 12]. Contrary to this result, Kim and Parissis have performed separate survival comparisons for N0, N1, N2 and found no significant difference between pneumonectomy and sleeve resectomy [15, 23]. In our study, in the survival comparison based on the status of lymph node involvement, it was found that N1 has better survival in sleeve resection than pneumonectomy and the difference was statistically significant. In the case of N0 where survival rates are higher, and in the case of N2 where the number of patients is quite low, there were no statistically significant differences between pneumonectomy and sleeve resection in terms of survival.

Our study reveales no significant difference in recurrence, and especially in the case of N1, ended up with no results favoring pneumonectomy in terms of survival. In a study in the literature which corroborated this hypothesis, it was shown that pneumonectomy is not more advantageous than lobectomy in interlobar lymph node involvement [29]. In light of these results, we propose that, preferring sleeve resection over pneumonectomy in cases where complete resection can be achieved, particularly in N1 lymph node involvement, would be appropriate. Another view which asserts the same outcome is that, in cases of lymph node involvement, distant site recurrences are more predictive than local recurrence in long term survival, and thus, sleeve resection, which is a parenchyma-saving surgery, can be preferred over pneumonectomy. While this view is maintained particularly for N1 involvement, uncertainty in N2 cases and the need for further studies continue [6, 12, 30, 31]. Although the survival rates in sleeve lobectomy for N2 cases did not achieve statistical significance, they showed a more significant decrease compared to pneumonectomy, but there were no significant differences between the two surgical procedures in terms of tumor recurrence, which could have explained this decrease. These findings leave the choice of surgical procedure in N2 case as a controversial and ambiguous area.

In a study by Bölükbaş *et al*. where comparative analysis was performed with patients aged 70 or older, it was found that sleeve resection is significantly more superior in long-term survival in elderly patients and it provides better respiratory reserve with its parenchyma-saving property. In the aforementioned study, it was also reported that the patients were similar in terms of comorbidity but preoperative Forced Expiratory Volume (FEV1) value was better in pneumonectomy patients [19]. In our study, 5-year survival rates in patients aged 60 or older were similar in sleeve resectomy and pneumonectomy, with 43.5% and 47.4%,

respectively. In the patient group aged 60 or younger, 5-year survival rate was 76% in sleeve resection and 42% in pneumonectomy, and the difference was statistically significant. While not investigated in our study, we think that additional preoperative comorbidities that are more commonly observed in elderly population caused a higher rate of deaths unrelated to cancer in sleeve resectomy group and thus increased the survival rates in elderly patients closer to those in pneumonectomy.

As another criteria for survival comparison, surgical side was also investigated in our study. In the literature, Bagan has compared upper right sleeve lobectomy with right sided pneumonectomy, which is known as a more radical procedure than the left-sided pneumonectomy, and found that 5-year survival rate was 53.2% for right-sided pneumonectomy and 72.5% for upper right sleeve lobectomy, and reported the superiority of sleeve lobectomy [5]. In the study by Deslauriers *et al*., it was shown that sleeve lobectomy provides a more significant survival advantage than pneumonectomy in both right and left sided surgery [12]. In our study 5-year survival rate in right sided surgery was 55.4% for pneumonectomy and 71.1% for sleeve lobectomy, and this significant difference provided significant survival advantage in right-sided surgery in favor of sleeve resection. In patients who underwent left-sided surgery, 5-year survival rate was 48.4% for pneumonectomy and 45.2% in sleeve resection, and no significant difference was detected. In the literature, after analyzing studies on independent factors that affect long term survival and compare pneumonectomy and sleeve resection, it was found that T factor, N factor and surgical procedure are usually noted as the significant factors [6, 15, 20, 27]. In the study by Okada *et al*., only three factors that are listed above were considered significant, while the study by Ludwig *et al*. also showed that being younger than 65 years is a good prognostic factor [6, 27]. Gomez-Caro *et al*. have shown that in addition to using sleeve resection as a surgical procedure, being younger than 70 years is another independent factor that positively affects survival [20]. In the study by Kim *et al*., surgical procedure did not have a significant effect but T and N status were identified as the significant prognostic factors [15].

When age, side, N status and surgical procedure parameters gave significant results in univariate analysis and were subjected to multivariate analysis, it was found that being younger than 60 years is a factor that positively affects survival. Similarly, it was found that lymph node involvement, particularly N2 involvement, has a significantly negative effect on long term survival. However, an equally significant result regarding the surgical procedure could not be obtained.

Conclusion

Sleeve resections are parenchyma-saving operations developed as an alternative to pneumonectomy. Our study reveals that sleeve resections can be safely performed with higher rate of complications but may be accepted as minor when compared to pneumonectomy, longer survival times, also lower mortality rates.

Sleeve lobectomies appear to be superior over pneumonectomy in long-term survival, without increasing local and distant tumor recurrence in the case of complete resection. For this reason, we recommend sleeve resections especially in young patient groups, in patients with N1 lymph node involvement, in right-sided surgery and in patients who received neoadjuvant treatment, since the difference in survival is significant in these patients.

References

1. Siegel R, Ward E, Brawley O, *et al*. Cancer statistics, 2011: the impact of eliminating socioeconomic and racial disparities on premature cancer deaths. CA Cancer J Clin. 2011; 61:212-36.
2. Jemal A, Bray F, Center MM, *et al*. Global cancer statistics.CA Cancer J Clin. 2011; 61(2):69-90.
3. Ponn Rb, LoCicero III J, Daly BDT. Surgical Treatment of Non-Small Cell Lung Cancer. In: Shields TW, LoCicero III J, Ponn Rb, Rusch VW, editors. General Thoracic Surgery. Lippincott Williams and Wilkins, Philedelphia, USA, 6th ed, 2005; 1549-87
4. Detterbeck FC, Boffa DJ, Kim AW, Tanoue LT. The Eighth Edition Lung Cancer Stage Classification. Chest. 2017; 151(1):193-203.
5. Bagan P, Berna P, Pereira JC, *et al*. Sleeve lobectomy versus pneumonectomy: tumor characteristics and comparative analysis of feasibility and results. Ann Thorac Surg. 2005; 80:2046-50.
6. Okada M, Yamagishi H, Satake S, *et al*. Survival related to lymph node involvement in lung cancer after sleeve lobectomy compared with pneumonectomy. J Thorac Cardiovasc Surg. 2000; 119:814-9.
7. Park JS, Yang HC, Kim HK, *et al*. Sleeve lobectomy as an alternative procedure to pneumonectomy for non-small cell lung cancer. J Thorac Oncol. 2010; 5:517-20.
8. Martin-Ucar AE, Chaudhuri N, Edwards JG, *et al*. Can pneumonectomy for non-small cell lung cancer be avoided? An audit of parenchymal sparing lung surgery. Eur J Cardiothorac Surg. 2002; 21:601-5.
9. Ma Z, Dong A, Fan J, *et al*. Does sleeve lobectomy concomitant with or without pulmonary artery reconstruction (double sleeve) have favorable results for non-small cell lung cancer compared with pneumonectomy? A meta-analysis. Eur J Cardiothorac Surg 2007; 32:20-8.
10. Shi W, Zhang W, Sun H, *et al*. Sleeve lobectomy versus pneumonectomy for non-small cell lung cancer: a meta-analysis.World J Surg Oncol. 2012; 10:265-9.
11. Takeda S, Maeda H, Koma M, *et al*. Comparison of surgical results after pneumonectomy and sleeve lobectomy for non-small cell lung cancer: trends over time and 20-year institutional experience. Eur J Cardiothorac Surg. 2006; 29:276–80.
12. Deslauriers J, Gregoire J, Jacques LF, *et al*. Sleeve lobectomy versus pneumonectomy for lung cancer: a comparative analysis of survival and sites of recurrence. Ann Thorac Surg. 2004; 77:1152-6.
13. Lee ES, Park SI, Kim YH, *et al*. Comparison of Operative Mortality and Complications Between Bronchoplastic Lobectomy And Pneumonectomy In Lung Cancer Patients. J Korean Med Sci. 2007; 22:43-7.
14. Stallard J, Loberg A, Dunning J, *et al*. Is A Significantly Better Than A Pneumonectomy? Interact Cardiovasc Thorac Surg. 2010; 11:660-6.

15. Kim YT, Kang CH, Sung SW, *et al*. Local control of disease related to lymph node involvement in non-small cell lung cancer after sleeve lobectomy compared with pneumonectomy. Ann Thorac Surg. 2005; 79:1153-61.
16. Gaissert HA, Mathisen DJ, Moncure AC, *et al*. Survival and function after sleeve lobectomy for lung cancer. J Thorac Cardiovasc Surg 1996; 11:948-53.
17. Ferguson MK, Lehman AG. Sleeve lobectomy or pneumonectomy: optimal magnagement strategy using decision analysis techniques. Ann Thorac Surg 2003; 76:1782-8.
18. Melloul E, Egger B, Krueger T, *et al*. Mortality, complications and loss of pulmonary function after pneumonectomy vs. sleeve lobectomy in patients younger and older than 70years. Interact Cardiovasc Thorac Surg 2008; 7:986-9.
19. Bolukbas S, Eberlein MH, Schirren J. Pneumonectomy vs. sleeve resection for non-small cell lung carcinoma in the elderly: analysis of short-term and long-term results. Thorac Cardiovasc Surg. 2011; 59:142–7.
20. Gomez-Caro A, Garcia S, Reguart N, *et al*. Determining the appropriate sleeve lobectomy versus pneumonectomy ratio in central non-small cell lung cancer patients: an audit of an aggressive policy of pneumonectomy avoidance. Eur J Cardiothorac Surg. 2011; 39:352-9.
21. Ghiribelli C, Voltolini L, Luzzi L, *et al*. Survival after bronchoplastic lobectomy for non small cell lung cancer compared with pneumonectomy according to nodal status. J Cardiovasc Surg 2002; 43:103-8.
22. Lausberg HF, Graeter TP, Tscholl D, *et al*. Bronchovascular versus bronchial sleeve resection for central lung tumors. Ann Thorac Surg. 2005; 79:1147-52.
23. Parissis H, Leotsinidis M, Hughes A, *et al*. Comparative analysis and outcomes of sleeve resection versus pneumonectomy. Asian Cardiovasc Thorac Ann 2009; 17:175-82.
24. Yoshino I, Tokoyama H, Yano T, *et al*. Comparison of the surgical results of lobectomy with bronchoplasty and pneumonectomy for lung cancer. J Surg Oncol 1997; 64:32-5.
25. Hanagiri T, Baba T, Ichiki Y, *et al*. Sleeve lobectomy for patients with non-small cell lung cancer. Int J Surg 2010; 8:39-43.
26. Maurizi G, D'Andrilli A, Anile M, *et al*. Sleeve lobectomy compared with pneumonectomy after induction therapy for non-small-cell lung cancer. J Thorac Oncol. 2013; 8:637-43.
27. Ludwig C, Stoelben E, Olschewski M, *et al*. Comparison of morbidty, 30-day mortality,and long - term survival after pneumonectomy and sleeve lobectomy for non small cell lung carsinoma.Ann Thorac Surg 2005; 79:968-73.
28. Suen HC, Meyers BF, Guthrie T, *et al*. Favorable results after sleeve lobectomy or bronchoplasty for bronchial malignancies. Ann Thorac Surg. 1999; 67:1557-62.
29. Gunluoglu MZ, Demir A, Turna A, *et al*. Extent of lung resection in non-small lung cancer with interlobar lymph node involvement. Ann Thorac Cardiovasc Surg. 2011; 17:229-35.
30. Spiguel L, Ferguson K. Sleeve lobectomy versus pneumonectomy for lung cancer in patients with good pulmonary function. In: Ferguson M K, ed. Difficult decisions in Thoracic surgery. London: Springer; 2007: 103-9.
31. Okada M, Tsubota N, Yoshimura M, *et al*. Extended sleeve lobectomy for lung cancer: the avoidance of pneumonectomy. J Thorac Cardiovasc Surg.1999; 118:710-4.