RESEARCH ARTICLE

Sleeve lobectomy versus lobectomy for primary treatment of non-small–cell lung cancer: A single-center retrospective analysis

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Abstract

Background and Objectives: It is unclear how much additional perioperative risk a sleeve lobectomy could pose in comparison to lobectomy. The objective of this analysis was to compare the complication rate, 30-day mortality, and overall survival between lobectomy and sleeve lobectomy without prior neoadjuvant treatment in non-small–cell lung cancer (NSCLC).

Methods: This is a retrospective study using our prospective database for quality assurance in our hospital. Inclusion criteria for our study was a completed lobectomy or sleeve lobectomy for primary treatment of NSCLC.

Results: In 506 patients, the tumor was treated by means of standard lobectomy. In 252 patients with central tumor localization, sleeve lobectomy was performed. Postoperative complications occurred in n:148 (29.24%) patients of the lobectomy group and in n = 76 (30.15%) of the sleeve group. The mortality rate difference between the two groups was statistically significant and favored the lobectomy group (0.78% vs. 4.76%, p = .007). Five year survival was 69.97% for the lobectomy and 65.59% for the sleeve group (p = .829).

Conclusion: Sleeve lobectomy for primary surgical treatment of NSCLC has comparable perioperative complications with lobectomy. Sleeve lobectomy does not seem to negatively influence survival. Postoperative mortality was higher in the sleeve group.

KEYWORDS
lobectomy, lung cancer, sleeve

1 | INTRODUCTION

Nowadays, lobectomy remains the gold standard for surgical treatment of non-small–cell lung cancer (NSCLC). In cases of centrally located tumors, sleeve-lobectomy can be an oncological equivalent therapy if not better than pneumonectomy while preserving substantially more lung parenchyma.1,2 Sleeve lobectomy may also present the only surgical option in patients with limited cardiopulmonary function in contrast to pneumonectomy. The treatment alternative for these patients would be definitive chemoradiation or stereotactic radiation with not always equal...
oncological outcomes. The ratio of sleeve lobectomy to lobectomy or bilobectomy in Germany varies between 4% and 26% according to the annual 2019 report for certified lung cancer centers. Although the functional advantages of sleeve lobectomy are well-documented and incomplete resection of bronchus margins usually leads to non-favorable oncological results, the intraoperative willingness or judgment of the thoracic surgeon to perform a sleeve lobectomy may be negatively influenced by concerns regarding anastomosis-related complications.

There is, however, a lack of high-volume studies comparing standard lobectomy with sleeve lobectomy. It is unclear how much additional perioperative risk a sleeve lobectomy could pose in comparison to standard lobectomy. The objective of this retrospective analysis was to compare the complication rate and 30-day mortality between lobectomy and sleeve lobectomy without prior neoadjuvant treatment in a high-volume reference center for bronchoplastic procedures in Cologne, Germany.

2 | MATERIALS AND METHODS

This is a retrospective study using our prospective database for quality assurance in our hospital. Preoperative, intraoperative, and postoperative data are continuously documented for intra- and extra-clinical benchmarking. The study was approved by the ethics committee of the University of Witten Herdecke (protocol number 51/2017).

2.1 | Inclusion and exclusion criteria

Inclusion criteria for our study was a completed lobectomy or sleeve lobectomy for primary treatment of NSCLC. Exclusion criteria were small-cell lung cancer, carcinoid, or sarcoma histology. Patients undergoing anatomical segmental resection, palliative resection, chest wall resection or carinal reconstructions were also excluded. No patients with neoadjuvant treatment were included in this trial.

2.2 | Staging

In tumors larger than 3 cm in diameter and/or mediastinal lymph nodes larger than 1 cm, invasive mediastinal and whole-body staging was performed. The mediastinal staging was performed by means of transbronchial ultrasound-controlled fine needle biopsy or a mediastinoscopy. Whole-body staging was performed by means of magnetic resonance tomography, or alternatively by positron emission tomography (PET). The endobronchial staging of the candidates for sleeve lobectomy was performed by bronchial biopsies during initial bronchoscopy.

2.3 | Surgical technique

Standard lobectomy was performed by means of anterolateral thoracotomy in 86% cases. Video-assisted thoracoscopy (14%) was performed for tumors less than 4 cm in size. In open lobectomy, bronchial closure was performed by double row continuous absorbable 4-0 PDS suture. A linear Endo-GIA stapling device was used during thoracoscopic lobectomy for vascular and bronchial closure. The anastomoses after sleeve resection were sutured with PDS 4-0 monofil absorbable continuous double-armed suture. In every case, complete hilar and mediastinal lymph node dissection was performed with the dissection of levels 2, 4, 7, 8, 9, and 10 on the right side and of levels 4, 5, 6, 7, 8, 9, and 10 on the left side. Angioplastic or intrapericardial resections were added when necessary.

2.4 | Postoperative management

All patients undergoing sleeve lobectomy were treated with inhalative tobramycin for 7 days as infection prophylaxis according to our internal standard management. A bronchoscopic anastomosis evaluation after sleeve lobectomy was performed routinely on the 7th postoperative day. The results were divided into five grades according to our formerly published classification of bronchial anastomosis healing. In case of bronchial insufficiency, further diagnostic and antibiotic or surgical treatment were indicated. In the standard lobectomy group, postoperative bronchoscopy was performed only when clinical suspicion of bronchial stump insufficiency arose.

2.5 | Statistical analysis

The statistical analysis was performed using the MedCalc program, version 14.8.1.0. Overall survival was calculated as the time between surgery and death from any cause. Survival was estimated using the Kaplan–Meier method, and survival comparison between groups was performed using log-rank analysis. Univariate logistic regression analyses were used to determine the impact of patient characteristics on in-hospital complications. A p-value < .05 was considered statistically significant.

3 | RESULTS

3.1 | Patients characteristics

Between 2006 and 2014, 1456 NSCLC patients were treated surgically in our institution. 1178 were diagnosed with a primarily operable non-small-cell lung carcinoma in postoperative stage I to IIIB. In 506 patients, the tumor was treated by means of standard lobectomy. In 252 patients with central tumor localization or central lymph node infiltration, sleeve lobectomy was performed.

Patients characteristics, tumor localization, and histology are illustrated in Table 1. There was no statistical difference in sex, age, and preoperative lung function between the lobectomy and...
TABLE 1  Patient characteristics, histology, adjuvant therapy, and recurrence types

|                          | Lobectomy (n = 506) | Sleeve L. (n = 252) | p Value |
|--------------------------|----------------------|---------------------|---------|
| Sex                      |                      |                     |         |
| Male                     | 324                  | 179                 | .0001   |
| Female                   | 182                  | 73                  | .001    |
| Age                      | 67                   | 66                  | .56     |
| Active smokers           | 441                  | 317                 | .0005   |
| Localization             |                      |                     |         |
| Right upper lobe         | 162                  | 101                 | .0001   |
| Middle lobe              | 21                   | 3                   | .001    |
| Right lower lobe         | 90                   | 41                  | .025    |
| Left upper lobe          | 165                  | 38                  | .0001   |
| Left lower lobe          | 68                   | 43                  | .204    |
| Right main bronchus      | 0                    | 21                  | .0001   |
| Left main bronchus       | 0                    | 5                   | .0001   |
| Histology                |                      |                     |         |
| Adenocarcinoma           | 335                  | 85                  | .0001   |
| Squamous cell carcinoma  | 128                  | 139                 | .0001   |
| Large cell carcinoma     | 28                   | 6                   | .0001   |
| Not otherwise specified NSCLC | 15              | 22                  | .0001   |
| FEV1%                    | 74                   | 70                  | .028    |
| Kco%                     | 79                   | 72                  | .058    |
| p-stage                  |                      |                     |         |
| IA                       | 231                  | 5                   | .0001   |
| IB                       | 205                  | 1                   | .040    |
| IIA                      | 18                   | 128                 | .39     |
| IIB                      | 16                   | 26                  | .032    |
| IIIA                     | 35                   | 81                  | .001    |
| IIIB                     | 0                    | 11                  | .037    |
| T1                       | 260                  | 42                  | .0001   |
| T2                       | 241                  | 139                 | .0001   |
| T3                       | 5                    | 52                  | .0001   |
| T4                       | 0                    | 19                  | .0001   |
| N0                       | 443                  | 114                 | .0001   |
| N1                       | 33                   | 122                 | .0001   |
| N2                       | 30                   | 16                  | .0001   |
| Radicability             |                      |                     |         |
| R0                       | 499                  | 227                 | .23     |
| R1                       | 7                    | 25                  | .0001   |
| Adjuvant therapy         |                      |                     |         |
| Chemotherapy             | 106                  | 83                  | .0015   |
| Radiotherapy             | 4                    | 17                  | .0001   |
| Radiochemotherapy        | 18                   | 16                  | .084    |
| Recurrence               |                      |                     |         |
| None                     | 115                  | 109                 | .0077   |
| Local                    | 391                  | 227                 | .58     |
| Distant                  | 45                   | 23                  | .031    |
| Local and distant        | 26                   | 19                  | .19     |

sleeve lobectomy groups. The most common tumor localization was the right upper lobe with 162 (32.02%) patients in the lobectomy group and 101 (40.8%) patients in the sleeve lobectomy group.

Patients of the lobectomy group had predominately early-stage tumors: n = 436 (86.16%) UICC Stage I, n = 260 (51.38%) pT1a-c, and n = 443 (87.55%) pN0. In the sleeve lobectomy group, more advanced tumor stages were documented: n = 154 (61.01%) UICC Stage IIAB,
\[ n = 92 \ (36.51\%) \ ] UICC Stage IIIA,B, \[ n = 139 \ (55.16\%) \ ] \( pT2a-b \) and \[ n = 122 \ (48.41\%) \ ] pN1. R0-resection was documented at 98.62% in the lobectomy group and at 90.08% in the sleeve lobectomy group respectively.

### 3.2 | Morbidity and mortality

Postoperative complications occurred in \( n = 148 \) (29.24%) patients of the lobectomy group and in \( n = 76 \) (30.15%) of the sleeve group. All complications are depicted in Table 2. The difference between the two groups was statistically significant in respect of respiratory insufficiency and postoperative ventilation rates. While respiratory insufficiency was a more common complication in the lobectomy group (105 [20.75%] vs. 27 [10.78%]) in the sleeve lobectomy group, postoperative ventilation was more frequently necessary in the sleeve lobectomy group (27 [10.78%] vs. 18 [3.56%]). Three (0.59%) patients had a bronchial stump insufficiency after lobectomy. Anastomotic leakage after sleeve lobectomy was diagnosed in 2 (0.79%) patients. Four (0.79%) patients died within 30 days after lobectomy and 12 (4.76%) after sleeve lobectomy. The mortality rate difference between the two groups was statistically significant and favored the lobectomy group (0.78% vs. 4.76%, \( p = .007 \)). All mortality causes are depicted in Table 2. The most frequent causes (4 [1.59%] patients) of a fatal outcome were acute respiratory distress syndrome (ARDS) and systemic inflammatory response syndrome (SIRS). Bronchial anastomotic insufficiency was the trigger of the further complicated clinical course which led to the death of one patient in the sleeve lobectomy group.

### 3.3 | Long-term survival

Local or distant recurrence was more frequent in the sleeve lobectomy group (32.94%) than in the standard lobectomy group (22.73%) (\( p = .0001 \)). Recurrence status (tumor metastasis, local recurrence or both) are depicted in Table 1 and recurrence rates comparatively in Figure 1. The recurrence status could not be determined reliably for three patients from the lobectomy group. 5-year survival was 69.97% for the lobectomy group and 65.59% for the sleeve group (\( p = .829 \)) (Figure 2). Due to the distribution difference between the two groups regarding tumor stage, we calculated the long-term survival (5-year survival probability) for Stages I and II (early stages) patients, such as for Stage IIIA,B patients (advanced stages) (Figures 3 and 4). There was no statistically significant difference between the two groups.

### 4 | DISCUSSION

The indication for sleeve resection is determined by the central localization and extension of the tumor into the main bronchus or parabronchial lymph node metastases with bronchial or mucosal infiltration. Although it has been reported that pneumonectomy patients probably have more advanced disease, long-term survival and local control are significantly better when complete resection can be achieved by sleeve lobectomy.8,9

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**TABLE 2** Postoperative complications and mortality

| Complications                        | Lobectomy (\( n = 506 \)) | Sleeve L. (\( n = 252 \)) | \( p \) Value |
|--------------------------------------|---------------------------|---------------------------|--------------|
| Respiratory insuff., type I          | 105 (20.75%)              | 27 (10.71%)               | <.0001       |
| Artificial respiration               | 18 (3.56%)                | 27 (10.71%)               | .0002        |
| Pneumonia                            | 69 (13.64%)               | 22 (8.73%)                | .043         |
| Wound infection/empyema              | 6 (1.19%)                 | 13 (5.16%)                | .0021        |
| Atrial fibrillation                  | 45 (8.89%)                | 18 (7.14%)                | .40          |
| Thromboembolism                      | 12 (2.37%)                | 9 (3.57%)                 | .34          |
| Other                                | 71 (14.03%)               | 49 (19.44%)               | .069         |
| Bronchial/anastomotic insuff.        | 3 (0.59%)                 | 12 (4.76%)                | .74          |
| 30-Day mortality                     | 4 (0.78%)                 | 13 (4.76%)                | .0079        |
| ARDS SIRS                            |                           | 4 (1.59%)                 | .16          |
| Heart attack                         | 1 (0.19%)                 | 2 (0.79%)                 | .24          |
| Pneumonia, sepsis                    | 1 (0.19%)                 | 1 (0.40%)                 | .62          |
| Empyema, sepsis                      | 1 (0.19%)                 | 1 (0.40%)                 | .48          |
| Bronchial anastomotic insufficiency  | 1 (0.40%)                 | 1 (0.40%)                 | .48          |
| Thrombosis of vascular anastomosis   |                           | 1 (0.40%)                 | .48          |
| Pulmonary embolism                   | 1 (0.19%)                 | 1 (0.40%)                 | .48          |
| Multiorgan failure                   | 1 (0.19%)                 | 1 (0.40%)                 | .62          |

Abbreviations: ARDS, acute respiratory distress syndrome; SIRS, systemic inflammatory response syndrome.
Thus, the advantages of sleeve lobectomy in comparison to pneumonectomy are well documented; the scientific evidence regarding its comparison with standard lobectomy is rare. D’Andrilli et al reported in 2016 that functional and oncologic results of a sleeve lobectomy are comparable to those of a standard lobectomy in patients with NSCLC.\textsuperscript{10,11} However, the study was limited by the relatively low number of sleeve lobectomies. The objective of our study was to compare perioperative complications between standard lobectomy and sleeve lobectomy in a high-volume German center for bronchoplastic procedures.

Although pneumonectomy is the oncological alternative to sleeve resection in terms of complete resection, the question to perform un-expected sleeve resection intraoperatively can also arise in patients scheduled for standard lobectomy according to our single-center experience. Tumors larger than 4–5 cm or centrally located lesions without endobronchial involvement cause usually undetected N1 disease (often also PET negative) and/or parabronchial lymphangitic infiltration of the lobar bronchus.\textsuperscript{12} Therefore, it is logical to investigate the additional perioperative risk indicating a sleeve lobectomy not only in comparison to

**FIGURE 1** 5-year recurrence-rate (distant and local), green line: sleeve lobectomy group, blue line: lobectomy group, x-axis: time in months, y-axis: recurrence probability in % [Color figure can be viewed at wileyonlinelibrary.com]

**FIGURE 2** Overall survival, green line: sleeve lobectomy group, blue line: lobectomy group, x-axis: time in months, y-axis: survival probability in % [Color figure can be viewed at wileyonlinelibrary.com]

**FIGURE 3** Overall survival for pathological Stages I and II patients, green line: sleeve lobectomy group, blue line: lobectomy group, x-axis: time in months, y-axis: survival probability in % [Color figure can be viewed at wileyonlinelibrary.com]

**FIGURE 4** Overall survival for pathological Stages IIIA,B patients, green line: sleeve lobectomy group, blue line: lobectomy group, x-axis: time in months, y-axis: survival probability in % [Color figure can be viewed at wileyonlinelibrary.com]
the undoubtedly risk-associated pneumonectomy but also to the standard of surgical care for NSCLC, the lobectomy.

Maurizi et al summarized postoperative complication rates after sleeve lobectomy ranging between 7.4% and 50%. In our collective, the total number of postoperative complications after sleeve lobectomy was comparable and sometimes even lower than after a lobectomy. Lower pneumonia and respiratory insufficiency rates in the sleeve lobectomy group could be also attributed to routine postoperative tobramycin inhalation in our institution. The average 30-day mortality after sleeve lobectomy ranges from 2.14% to 12.6% and is reported at about 3% for lobectomy in high-volume thoracic surgery centers. In our collective, 30-day mortality after sleeve resection was documented at 4.76% and at 0.78% after standard lobectomy. Both ratios are interestingly low compared to other reports. These numbers support the known fact that, even with well-established perioperative care, sleeve lobectomy is more challenging than standard lobectomy. It presents more severe and fatal complications when they arise. An additional potentially fatal complication after sleeve lobectomy is Anastomotic insufficiency. In our collective, anastomotic complications were rare, but ARDS and SIRS played a significant role as main mortality factors. Local anastomotic complications are usually dependent on neoadjuvant treatment, such as chemoradiotherapy as our study group reported earlier. Thus, no neoadjuvant therapy patients were initially included in our collective.

Inci et al investigated in a similar study protocol complication rates and overall survival comparing standard lobectomy with standard sleeve lobectomy and complex sleeve lobectomy in n = 755 patients. 30-Day mortality, anastomotic complications and long-term survival were similar to our report.

Overall survival was similar in both groups of our study, although tumor stage distribution favored the lobectomy group for earlier stages as expected. Local or distant recurrence was more frequent in the sleeve lobectomy group as expected, due to higher tumor stages. To further clarify the difference between standard and sleeve lobectomy, we performed subsequent analysis in subgroups. A stage-based differentiation revealed comparable survival in Stage I plus II and Stage IIIA,B groups without a significant difference between the lobectomy and sleeve lobectomy group. It could be assumed that more complicated surgery does not negatively influence long-term survival in patients with similar tumor stage. The standard lobectomy group mainly consisted of UICC Stages I and II patients and the sleeve lobectomy group of UICC Stage III patients. The groups differ significantly in terms of their oncological preoperative situation. Tumors in the sleeve lobectomy group were more advanced. The nodal status in the sleeve lobectomy group was also higher. Such a comparison is, however, inevitable due to a lack of prospective randomized data and is also being reported in pneumonectomy versus sleeve lobectomy as well as lobectomy versus sleeve lobectomy studies from other institutions.

5 | CONCLUSION

Sleeve lobectomy for primary surgical treatment of NSCLC without prior neoadjuvant treatment has comparable perioperative complications with standard lobectomy. Even though 30-day mortality after sleeve lobectomy was higher in our patient collective, sleeve lobectomy is comparable to lobectomy in terms of oncological radicality and overall survival.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT

Raw data were generated at Cologne-Merheim Hospital. Derived data supporting the findings of this study are available from the corresponding author D.Z. on request.

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