Pulmonary completion lobectomy after segmentectomy: An integrated analysis of perioperative outcomes

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Abstract
Background: Completion lobectomy (CL) after anatomical segmentectomy is technically challenging and rarely performed. Here, we aimed to report perioperative outcomes of a single center real-world CL data.

Methods: Seven patients who underwent CL after segmentectomy were retrospectively evaluated between 2015–2021. Additionally, 34 patients were included in the review based on relevant studies in the literature until March 2022. A total of 41 patients were finally analyzed and classified into groups, according to surgical approach (video-assisted thoracic surgery [VATS] and thoracotomy; 12 and 29 patients, respectively) or interval-to-CL following initial segmentectomy (≤8 weeks [short] and >8 weeks [long]; 11 and 29 patients, respectively).

Results: There were no significant differences in estimated blood loss, postoperative hospital stay, or complications between the predefined groups. However, a longer operative time was observed in the long interval-to-CL group than in the short interval-to-CL group (267 vs. 226 min, \( p = 0.02 \)). The rate of severe hilar adhesions was higher in the thoracotomy versus VATS groups (72 vs. 42%, \( p = 0.06 \)) and in the long versus short interval-to-CL groups (70 vs. 45%, \( p = 0.15 \)). On multivariable logistic regression analysis of a subgroup (n = 30), completion lobectomy of upper lobes may be associated with severe hilar adhesions (\( p = 0.02 \), odds ratio: 13.98; 95% confidence interval [CI]: 1.36–143.71).

Conclusion: Completion lobectomy after segmentectomy can be performed securely by either VATS or thoracotomy. Although the thoracotomy and long interval-to-CL groups retained a greater percentage of severe hilar adhesions, the perioperative outcomes were similar to those of VATS and short interval-to-CL groups, respectively.

Keywords: completion lobectomy, lung cancer, perioperative outcome, segmentectomy

INTRODUCTION

Reoperations for multiple lung cancers have been performed for non-small cell lung cancer (NSCLC) and metastatic lung tumors, and their prognostic advantage has been reported.1,2 However, these operations often require additional time for management of intrapleural adhesions that develop after initial surgery, when surgical treatment is performed ipsilaterally. Recently, several studies described successes in performing video-assisted thoracic surgery (VATS) reoperations when treating ipsilateral pulmonary lesions without increasing postoperative complications.3,4 Among the wide array of reoperation options, completion lobectomy (CL) after segmentectomy in the same lobe is particularly difficult because of dense adhesions that are generated from hilar dissections and destroyed hilar structures. So far, few studies have reported surgical outcomes on CL after segmentectomy.5–10
However, it is unknown whether this challenging procedure affects patient safety and recovery. In this study, we aimed to retrospectively investigate the single-institutional experience of patients undergoing CL after VATS segmentectomy. Second, a systematic literature search was carried out for data of relevant cases that received CL after segmentectomy and a pooled analysis of perioperative outcomes regarding surgical approach (VATS vs. thoracotomy) or time interval between CL and segmentectomy (short vs. long).

**METHODS**

**Study design**

Between January 2015 and December 2021, 434 patients underwent anatomical segmentectomy at a single medical center. Among them, 21 patients who underwent reoperation for ipsilateral thoracic disease were enrolled. Further, seven patients undergoing CL after segmentectomy in the same lobe were included. Data on demographic characteristics and perioperative outcomes were collected from electronic medical records. Additionally, a systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Figure 1 visually summarizes the flowchart of the study selection. PubMed was queried by two authors (YWL and CNK) for relevant articles published between January 1990 and March 2022. The search terms included all subject headings and/or keywords associated with “completion lobectomy” [and] “segmentectomy.” After independently screening titles and abstracts and excluding irrelevant studies by the two authors (YWL and CNK), articles that clearly described pulmonary CL after anatomical segmentectomy were eligible for inclusion. Studies that included complete perioperative data were considered for inclusion in the integrated analysis. Discrepancies were resolved by consensus and discussion with an independent senior author (SHC). Eventually, 34 patients were identified in the included five articles. Taken together with our own seven patients retrieved from a single center database, an integrated analysis of 41 patients with regard to the surgical approach and time interval-to-CL was performed (Figure 1).

Data on the following perioperative outcomes were obtained and evaluated: interval between initial segmentectomy and CL, reasons for CL, targeted lobe for CL, surgical pathology of the first and second operations, surgical approach, operative time, estimated blood loss, extent and degree of intraoperative adhesions, intraoperative securing of the pulmonary artery (PA), and perioperative complications. Additionally, the reasons for CL were classified as complications in the remaining lobe, unexpected lymph node metastasis, and local recurrence, while degree of adhesion were classified as none, mild, or severe, respectively. Specifically, based on the suggestions from Omasa et al., severe adhesion was characterized as tight adhesions requiring >5 min to divide, whilst mild adhesion was defined as minimal adhesions that could be divided easily.

![Flow diagram of patient recruitment](image-url)
(approximately less than 5 min). The aforementioned details can be found in the literature.\(^5,6\) Previous studies speculated that the transition of adhesion can be regarded as a wound healing model, where the postoperative anabolic phase is sustained for 5–8 weeks, which accelerates wound healing that induces scarring\(^5,12\); therefore, more severe adhesions might be encountered until 8 weeks after previous segmentectomy. Hence, we divided it into short (≤8 weeks) or long (>8 weeks) interval-to-CL based on the aforementioned presumption, in order to evaluate factors that may make CL challenging. This retrospective study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital, and the requirement for written informed consent was waived (KMUHIRB-E[I]-20200228).

### Operative procedures of initial segmentectomy and CL

At our institution, segmentectomy is indicated and performed for early stage lung cancer and metastatic lung cancer based on the surgeons’ discretion, features of targeted lung lesions, and National Comprehensive Cancer Network (NCCN) guidelines.\(^13\) All seven initial segmentectomies were completed using the right VATS approach (Table 1). Patients who underwent VATS segmentectomy were placed in the lateral decubitus position. One-lung anesthesia via a double-lumen endotracheal tube has also been routinely performed. Two-port VATS (one 3–5 cm utility port over the fifth intercostal space at the anterior axillary line and another 2-cm camera port over the seventh intercostal space at the posterior axillary line) were mostly performed. Additional utility ports may be added as necessary, depending on the surgeon’s preference. With regard to the CL, we performed resections via the previous wound with extension to 6–8 cm via the VATS. However, four of seven patients ultimately required conversion to thoracotomy for accomplishing CL due to severe adhesion or injury to the intrathoracic organs. Intraoperatively, main PA taping was seldom performed regardless of the surgical approach or severity of adhesion (Table 2).

### Statistical analysis

Categorical variables are expressed as numbers with percentages and compared using the chi-square test or Fisher’s exact test. Non-normally distributed data are described as medians with interquartile ranges and were analyzed using the Mann-Whitney U test. Multivariable logistic regression analysis was performed to identify the possible predictors for severe hilar adhesions from the independent variables. A \(p\)-value from two-tailed significance was set at 0.05. All statistical analyses were performed using MedCalc Statistical Software version 19.2.6 (MedCalc Software bv, Ostend, Belgium; https://www.medcalc.org, 2020).

### RESULTS

Tables 1 and 2 show our single center data on patient characteristics and perioperative outcomes. Segmentectomy was indicated if there was a suspicion of early-stage or metastatic lung cancer. Definitive pathologies revealed consistent findings of the presumed malignancy except for one case, which was determined to be inflammation following resection. All seven patients underwent right-sided VATS anatomical segmentectomy with R0 resection. The reasons for requiring CL were as follows: staple line recurrence (\(n = 3\)), remaining lobe plus staple line recurrence (\(n = 2\)), remaining lobe atelectasis (\(n = 1\)), and short surgical margins (\(n = 1\)). One case (No. 7) in which VATS was used to perform CL has been reported in a previous study.\(^9\) Herein, we describe another case of thoracotomy for CL (No. 5).

### TABLE 1  Demographic data of patients who underwent a previous segmentectomy

| No (age/gender) | FEV1 (Pred) before segmentectomy, liter (%) | FEV1 (Pred) before CL, liter (%) | Previous segmentectomy | MLD | Surgical approach | Feature of the targeted nodule | Diagnosis of segmentectomy | Surgical margin | Use of PGA sheet | Use of fibrin glue |
|-----------------|-------------------------------------------|---------------------------------|------------------------|-----|----------------|-------------------------------|---------------------------|----------------|------------------|-------------------|
| 1 (72/male)     | 1.98 (87%)                                | 1.66 (82%)                      | RS\(^1\)               | Yes | VATS          | Solid, 1.8 cm                 | Metastatic cancer          | R0     | Yes              | No                |
| 2 (71/male)     | 2.72 (97%)                                | 2.68 (94%)                      | RS\(^9,10\)            | Yes | VATS          | Part-solid, 1.5 cm            | Lung cancer               | R0     | Yes              | No                |
| 3 (24/female)   | 3.53 (107%)                               | 3.2 (99%)                       | RS\(^4\)               | Yes | VATS          | GGO, 1.0 cm                   | Lung cancer               | R0     | Yes              | No                |
| 4 (56/female)   | 2.25 (105%)                               | 2.1 (107%)                      | RS\(^6\)               | Yes | VATS          | GGO, 0.6 cm                   | Inflammation              | R0     | No               | No                |
| 5 (68/female)   | 1.3 (72%)                                 | 1.39 (77%)                      | RS\(^3\)               | Yes | VATS          | Solid, 1.2 cm                 | Metastatic cancer          | R0     | Yes              | No                |
| 6 (77/female)   | 1.41 (80%)                                | 1.31 (94%)                      | RS\(^6\)               | Yes | VATS          | Solid, 2 cm                   | Lung cancer               | R0     | Yes              | No                |
| 7 (47/male)     | 3.43 (103%)                               | 3.10 (93%)                      | RS\(^7,8\)             | Yes | VATS          | GGO, 0.6 cm                   | Lung cancer               | R0     | Yes              | No                |

Abbreviations: FEV1 (Pred), forced expiratory volume in the first second of expiration (predicted %); CL, completion lobectomy; MLD, mediastinal lymph node dissection; PGA, polyglycolic acid; RS, right pulmonary segment; VATS, video-assisted thoracic surgery; GGO, ground-glass opacity.
The patient (No. 5) underwent a right VATS S3 segmentectomy to confirm metastatic lung nodules from breast cancer. Fifty weeks later, a new lesion abutted the previous staple lines in the remaining right upper lobe (RUL) (Figure 2). In the second operation, initially using a 6-cm incision via VATS approach, dense adhesions in the pleural cavity were observed and the procedure converted to 12-cm mini-thoracotomy for complete adhesiolysis was performed. We were able to divide the RUL bronchus, A1, and A2 sequentially with careful manipulation. We attempted to divide the superior pulmonary vein (PV) into the pericardium, but this was unsuccessful, owing to tight adhesions around the hilum. Therefore, the remaining lung parenchyma and superior PV were simultaneously transected using a stapler (Figure 3).

Surgical outcomes of the CL were comparable to those of previous studies in terms of operative time, blood loss, complications, and length of postoperative hospital stay. Table 2 summarizes the perioperative data of patients who underwent CL reported in the literature. A total of 34 patients who underwent CL in the literature after a systematic review were included in the study for further analysis. As shown in Table 4, a total of 41 patients were analyzed based on the surgical approach. Patient characteristics in the two groups with regard to the targeted lobe for CL, reasons for CL, or interval to CL were found to be similar. Regarding the severity of hilar adhesions, a slight majority was seen in the thoracotomy group (72 vs. 42% for thoracotomy vs. VATS, respectively, \( p = 0.06 \)). However, other variables, such as operative time, blood loss, PA taping, postoperative hospital stay, and complications were comparable. As shown in Table 5, perioperative outcomes based on the interval between segmentectomy and CL were analyzed again. We found that greater percentage of complications occurred in the short interval-to-CL group (64%) compared to those in the long interval-to-CL group (40%), \( p = 0.0001 \). The operative time and estimated blood loss were greater in the long interval-to-CL group than in the short interval-to-CL group (median 260 vs. 226 min, \( p = 0.02 \) and 360 vs. 253 ml, respectively, \( p = 0.55 \)). Although no significant differences were identified, more severe hilar adhesions occurred in the long interval-to-CL group (51%, 45%) than in the short interval-to-CL group (25%, 23%). This finding may be explained by the association with longer operative time and greater blood loss, which was observed in the former group. Regardless of the classification by surgical approach or interval-to-CL, there were no significant differences in the length of postoperative hospital stay, PA taping, and complications between the predefined subgroup comparisons.

Furthermore, we performed a logistic regression multivariable analysis of factors associated with severe hilar adhesions in a subgroup of patients who underwent thoracotomy. As shown in the supplementary Table 1, the findings revealed that completion lobectomy of upper lobes may be associated with severe hilar adhesions.

### Table 2: Perioperative data of patients who underwent complete lobectomy

| No | ASA score | Reason for CL | Lobe for CL | Diagnosis after CL | Interval to CL (weeks) | Surgical approach | Operative time (min) | Blood loss (ml) | Degree of adhesions | PA taping | Perioperative complication | Postoperative stay (days) |
|----|-----------|---------------|-------------|-------------------|------------------------|-------------------|---------------------|-------------------|------------------|-----------|--------------------------|--------------------------|
| 1  | 3         | Staple line recurrence | RUL         | Metastatic cancer | 180                    | Thoracotomy        | 340                 | 700               | Severe           | Yes       | Azygos vein injury, PAL | 9                         |
| 2  | 3         | Staple line recurrence | RLL         | Hemangioma        | 57                     | Thoracotomy        | 320                 | 200               | Severe           | No        | Diaphragm injury         | 6                         |
| 3  | 2         | Remaining lobe atelectasis | RML         | Granuloma         | 5                      | VATS               | 160                 | 120               | Mild             | No        | No                       | 7                         |
| 4  | 3         | Staple line recurrence | RLL         | Organized pneumonia | 120                  | VATS               | 180                 | 100               | Mild             | No        | No                       | 6                         |
| 5  | 3         | Remaining lobe and staple line recurrence | RUL         | Metastatic cancer | 50                    | Thoracotomy        | 350                 | 400               | Severe           | No        | PAL                      | 10                        |
| 6  | 3         | Remaining lobe and staple line recurrence | RLL         | Lung cancer       | 52                    | Thoracotomy        | 250                 | 200               | Severe           | No        | PAL                      | 9                         |
| 7  | 2         | Short surgical margin   | RLL         | Granuloma         | 9                      | VATS               | 340                 | 470               | Severe           | No        | No                       | 5                         |

Abbreviations: ASA, American Society of Anesthesiologists; CL, completion lobectomy; PA, pulmonary artery; RUL, right upper lobe; RLL, right lower lobe; RML, right middle lobe; MC, metastatic cancer; PAL, prolonged air leakage; VATS, video-assisted thoracic surgery.
**FIGURE 2** Computed tomography (CT) of the representative case who underwent completion lobectomy of the right upper lobe (RUL) after a right VATS S3 segmentectomy. (a) CT imaging revealed two nodules in right pulmonary segment 3. (b) Three-dimensional reconstruction imaging revealed the relative location between targeted nodules and bronchovascular structures of segment 3. (c) CT scan showing recurrent nodule abutting previous staple lines at 50 weeks after right S3 segmentectomy. (d) CT scan demonstrated previous staple lines tightly attached to the mediastinum.

RUL, right upper lobe; CT, computed tomography; VATS, video-assisted thoracic surgery.

**FIGURE 3** Intraoperative view of the representative case who underwent completion lobectomy of the right upper lobe (RUL) after a right VATS S3 segmentectomy. (a) Right lateral mini-thoracotomy incision (12 cm). (b) Pneumolysis for the dense adhesions over posterior pleural cavity. (c) Pneumolysis for the dense adhesions over anterior pleural cavity. (d) Division of right upper lobe (RUL) bronchus. (e) Isolation and division of the right pulmonary artery 1. (f) Isolation and division of the right pulmonary artery 2. (g) Simultaneous stapling of RUL lung parenchyma and pulmonary vein using a stapler with black cartridge. (h) View of remaining hilar structure after completion lobectomy of RUL. RUL, right upper lobe; VATS, video-assisted thoracic surgery.
### Table 3: Perioperative data of patients who underwent complete lobectomy

| First author | Year of publication | Age/gender | Reason for CL | Lobe of CL or previous segment | Interval to CL (weeks) | Surgical approach | Operative time (min) | Blood loss (ml) | Severe adhesions | PA taping | Perioperative complication | Postoperative stay (days) |
|--------------|---------------------|------------|---------------|-------------------------------|------------------------|-------------------|---------------------|------------------|------------------|----------|--------------------------|--------------------------|
| Omasa [5]    | 2016                | 3 pts (N/A)| Complication  | N/A                           | 0.8                    | Thoracotomy       | 95                  | 57               | No               | No       | 5/11 (45%)               | N/A                      |
|              |                     | 3 pts (N/A)| LN metastasis | N/A                           | 4.9                    | Thoracotomy       | 274                 | 410              | 3                | 1/3 (33%)      | N/A                   |                          |
|              |                     | 5 pts (N/A)| Recurrence    | N/A                           | 105                    | Thoracotomy       | 253                 | 381              | 5                | 4/5 (80%)      | N/A                   |                          |
| Takahashi [6] | 2019               | 66/M       | Recurrence    | LS⁵                          | 72                     | VATS              | 295                 | 500              | No (mild)        | No       | No                       | 9                        |
|              |                     | 70/F       | Recurrence    | RS⁷⁺⁻¹⁰                      | 208                    | VATS              | 389                 | 200              | Yes              | Yes      | PA injury                | 16                       |
|              |                     | 72/M       | Recurrence    | RS⁵                          | 180                    | VATS              | 280                 | 300              | Yes              | No       | No                       | 12                       |
|              |                     | 74/F       | Recurrence    | RS⁴⁻⁹                        | 16                     | VATS              | 279                 | 950              | No (mild)        | No       | No                       | 12                       |
|              |                     | 73/M       | Recurrence    | RS⁴                          | 160                    | VATS              | 342                 | 350              | Yes              | No       | Postoperative Af         | 14                       |
|              |                     | 61/F       | Recurrence    | LS¹⁺²⁺³                      | 432                    | Thoracotomy       | 458                 | 6870             | Yes              | No       | PA injury                | 14                       |
|              |                     | 69/F       | Recurrence    | RS⁴                          | 308                    | Thoracotomy       | 201                 | 200              | Yes              | No       | Azygos vein injury       | 8                        |
|              |                     | 64/M       | Recurrence    | LS¹⁺²⁺³                      | 8                      | Thoracotomy       | 339                 | 1020             | Yes              | Yes      | No                       | 13                       |
|              |                     | 80/F       | Recurrence    | LS¹⁺²                        | 192                    | Thoracotomy       | 391                 | 500              | Yes              | No       | PA injury                | 18                       |
|              |                     | 65/M       | Recurrence    | LS⁶⁺⁻¹⁰                      | 84                     | Thoracotomy       | 301                 | 160              | No (mild)        | No       | No                       | 8                        |
| Suzuki [7]   | 2021                | 65/F       | Recurrence    | RS⁶                          | 148                    | Thoracotomy       | 167                 | 75               | No (mild)        | No       | No                       | 9                        |
|              |                     | 82/F       | Recurrence    | RS⁶                          | 156                    | Thoracotomy       | 255                 | 220              | No (mild)        | No       | No                       | 7                        |
|              |                     | 81/F       | Recurrence    | LS⁶                          | 164                    | Thoracotomy       | 316                 | 100              | No (mild)        | No       | No                       | 18                       |
|              |                     | 67/F       | Recurrence    | RS⁵                          | 64                     | Thoracotomy       | 284                 | 370              | Yes              | No       | PV injury                | 21                       |
| Takamori [8] | 2021                | N/A        | Second LC     | LS¹⁺²                        | 306                    | Thoracotomy       | 194                 | 543              | Yes              | Yes      | No                       | 10                       |
|              |                     | N/A        | Second LC     | RS³⁺⁻³⁺⁺²⁺⁺⁻¹⁰              | 98                     | VATS              | 234                 | 61               | No (mild)        | Yes      | Arrhythmia               | 5                        |
|              |                     | N/A        | Pathological change | RS³⁺⁻³⁺⁺²⁺⁺⁻¹⁰ | 1                     | VATS              | 138                 | 253              | No (mild)        | No       | No                       | 6                        |
|              |                     | N/A        | Recurrence    | RS¹⁺⁻¹⁰                      | 109                    | Thoracotomy       | 165                 | 230              | Yes              | No       | No                       | 5                        |
|              |                     | N/A        | Pathological change | RS⁶⁺⁻¹⁰                | 4                      | Thoracotomy       | 226                 | 906              | Yes              | Yes      | PAL                      | 6                        |
|              |                     | N/A        | Pathological change | LS⁶⁺⁻¹⁰                | 19                     | VATS              | 216                 | 206              | Yes              | No       | No                       | 6                        |
| Komatsu [10] | 2021                | N/A        | Second LC     | RS⁵⁺⁻⁶⁺⁻⁶⁺⁻¹⁰               | 120                    | Thoracotomy       | 175                 | 248              | No (mild)        | Yes      | No                       | 8                        |
|              |                     | N/A        | Second LC     | LS¹⁺²⁺³⁺⁺⁻¹⁰               | 133                    | Thoracotomy       | 407                 | 2194             | Yes              | No       | No                       | 7                        |
|              |                     | N/A        | Second LC     | LS⁸⁺⁻⁹⁺⁺⁻¹⁰               | 2                      | VATS              | 266                 | 200              | No (mild)        | No       | No                       | 13                       |

**Abbreviations:** CL, completion lobectomy; PA, pulmonary artery; pts, patients; LN, lymph node; LC, lung cancer; RS, right pulmonary segment; LS, left pulmonary segment; PAL, prolonged air leakage; VATS, video-assisted thoracic surgery; N/A, not available.
adhesions ($p = 0.02$, odds ratio [OR]: 13.98; 95% confidence interval [CI]: 1.36–143.71).

**DISCUSSION**

In recent decades, segmentectomy has been thought to better preserve lung function than lobectomy, and has become a treatment option for early stage lung cancer. Its use is likely to expand widely because of the increase in the early detection of suspicious ground-glass nodules by low-dose chest computed tomography screening. Additionally, the increased incidence of second primary lung cancer or local recurrence has resulted in a greater number of repeated ipsilateral thoracic operations after lung cancer surgery.

Recently, the JCOG0802 study showed the benefits of...

**TABLE 4** Summarized perioperative outcome based on surgical approach for patients undergoing completion lobectomy

| Variables | VATS ($n = 12$) | Thoracotomy ($n = 29$) | $p$-value |
|-----------|----------------|------------------------|-----------|
| Targeted lobe for CL, n (%) | | |
| RUL | 3 (25) | 6 (20.7) | 0.32 |
| RML | 1 (8.3) | 0 (0) | |
| RLL | 4 (33.4) | 11 (37.9) | |
| RML + RLL | 1 (8.3) | 0 (0) | |
| LUL | 0 (0) | 8 (27.6) | |
| LLL | 3 (25) | 4 (13.8) | |

| Targeted lobe for CL, n (%) | | |
| Upper lobe | 3 (25) | 14 (48) | 0.17 |
| Nonupper lobe | 9 (75) | 15 (52) | |

| Reasons for CL, n (%) | | |
| Complication | 5 (42) | 4 (14) | 0.28 |
| Unexpected LN metastasis | 0 (0) | 3 (10) | |
| Local recurrence | 7 (58) | 22 (76) | |

| Interval to CL, week (IQR) | 45 (7–140) | 105 (7.2–150) | 0.58 |
| Operation time, min (IQR) | 272 (198–317) | 253 (199–317) | 0.89 |
| Estimated blood loss, ml (IQR) | 229 (160–410) | 381 (200–432) | 0.37 |
| Postoperative hospital stay, day (IQR) (*) | 8 (6–12) | 9 (7–13) | 0.43 |
| Severe hilar adhesion, n (%) | 5 (42) | 21 (72) | 0.06 |
| PA taping, n (%) | 2 (17) | 10 (34) | 0.26 |
| Perioperative complication, n (%) | 3 (25) | 14 (48) | 0.29 |

(*), only 30 patients available for analysis (13 vs. 17, respectively).

Abbreviations: CL, completion lobectomy; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; LN, lymph node; VATS, video-assisted thoracic surgery; IQR, interquartile range; PA, pulmonary artery.

**TABLE 5** Summarized perioperative outcome based on interval between segmentectomy and completion lobectomy

| Variables | Short (interval to CL ≤8 weeks) ($n = 11$) | Long (interval to CL >8 weeks) ($n = 30$) | $P$-value |
|-----------|------------------------------------------|------------------------------------------|-----------|
| Reasons for CL, n (%) | | | 0.0001 |
| Complication | 7 (64) | 2 (7) | |
| Unexpected LN metastasis | 3 (27) | 0 (0) | |
| Local recurrence | 1 (9) | 28 (93) | 1.0 |
| Surgical approach with VATS, n (%) | 3 (27) | 9 (30) | |
| Operation time, min (IQR) | 226 (105–274) | 267 (234–340) | 0.02 |
| Estimated blood loss, ml (IQR) | 253 (72–410) | 360 (200–470) | 0.55 |
| Postoperative hospital stay, day (IQR) (*) | 7 (6–13) | 9 (6.7–12.5) | 0.63 |
| Severe hilar adhesion, n (%) | 5 (45) | 21 (70) | 0.15 |
| PA taping, n (%) | 3 (27) | 9 (30) | 1.00 |
| Perioperative complication, n (%) | 4 (36) | 13 (43) | 0.69 |

(*), only 30 patients available for analysis (5 vs. 25, respectively).

Abbreviations: CL, completion lobectomy; LN, lymph node; VATS, video-assisted thoracic surgery; IQR, interquartile range; PA, pulmonary artery.
segmentectomy versus lobectomy in the overall survival of patients with small peripheral NSCLC (tumor diameter ≤2 cm; consolidation-to-tumor ratio >0.5). These findings suggest that segmentectomy is the standard surgical procedure for this patient population. Although segmentectomy may play a leading role in the aforementioned indications of lung resection, it is becoming paramount to be able to perform CL or resegmentectomy after a previous segmentectomy, regardless of whether it is performed on the ipsilateral side or the same lobe because of the growing number of early lung cancers detected through screening programs and advances in precision cancer medicine.15

Only a handful of studies have reported the surgical outcomes of CL after segmentectomy.5-10 Completion lobectomy after segmentectomy has been associated with rare adverse circumstances, including complications or local recurrences in the remaining lobe, as well as unexpected nodal involvement, which was first proposed by Omasa et al.5 In the current study, we used a similar classification for the included 41 patients. A greater percentage of complications (64%) occurred in the short interval-to-CL group, while a higher rate of local recurrence (93%) occurred in the long interval-to-CL group. It is conceivable that surgeons tend to operate on patients with complications following segmentectomy in the early postoperative period. Omasa et al. also reported more severe adhesions around the hilum 5 weeks after segmentectomy, thereby complicating CL.5 Although we used an eight-week interval-to-CL to compare the impact of adhesion on surgical outcomes, our results were consistent with their findings, where longer operative time and more severe adhesions were observed in the long interval-to-CL group. Takahashi et al. were the first to report and compare patients undergoing VATS or thoracotomy and VATS, recognition of the degree of adhesion, and exclusion of studies with incomplete data. Although we used an eight-week interval-to-CL to compare the impact of adhesion on surgical outcomes, our results were consistent with their findings, where longer operative time and more severe adhesions were observed in the long interval-to-CL group. Takahashi et al. were the first to report and compare patients undergoing VATS or thoracotomy and VATS, recognition of the degree of adhesion, and exclusion of studies with incomplete data.19,20

As mentioned in previous studies,6,8 it may be arduous to conduct a large-scale prospective cohort study on CL. Hence, we present this integrated analysis to obtain solid evidence to evaluate the perioperative outcomes of CL. To the best of our knowledge, our study is the first to collect analyzable data and compare the surgical outcomes between “thoracotomy and VATS,” as well as “long versus short interval-to-CL” in CL after segmentectomy. The main limitations of this study are its retrospective design and the inclusion of a small number of patients. Some selection bias does invariably exist, including the variation of institutional experience, operation method (open thoracotomy vs. VATS), recognition of the degree of adhesion, and exclusion of studies with incomplete data.19-23 Additionally, patient or surgeon sentiments toward CL or other alternative treatments, such as stereotactic ablative body radiotherapy are lacking.

In conclusion, CL after segmentectomy can be accomplished securely using either VATS or thoracotomy without major complications in selected patients. In particular, patients with completion upper lobectomy are more likely to have severe hilar adhesions. Although patients exhibiting a greater percentage of severe hilar adhesions tended to undergo thoracotomy and appeared in the long interval-to-CL group, the perioperative outcomes were equivalent to those shown in the other groups (VATS and short interval-to-CL, respectively). As an increase in segmentectomy is anticipated, knowledge of performing CL after segmentectomy is crucial, and more relevant investigations are needed.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interests.
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SUPPORTING INFORMATION
Additional supporting information can be found online in the Supporting Information section at the end of this article.

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