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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 30 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.[11] 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, whist mild adhesion was defined as minimal adhesions that could be divided easily

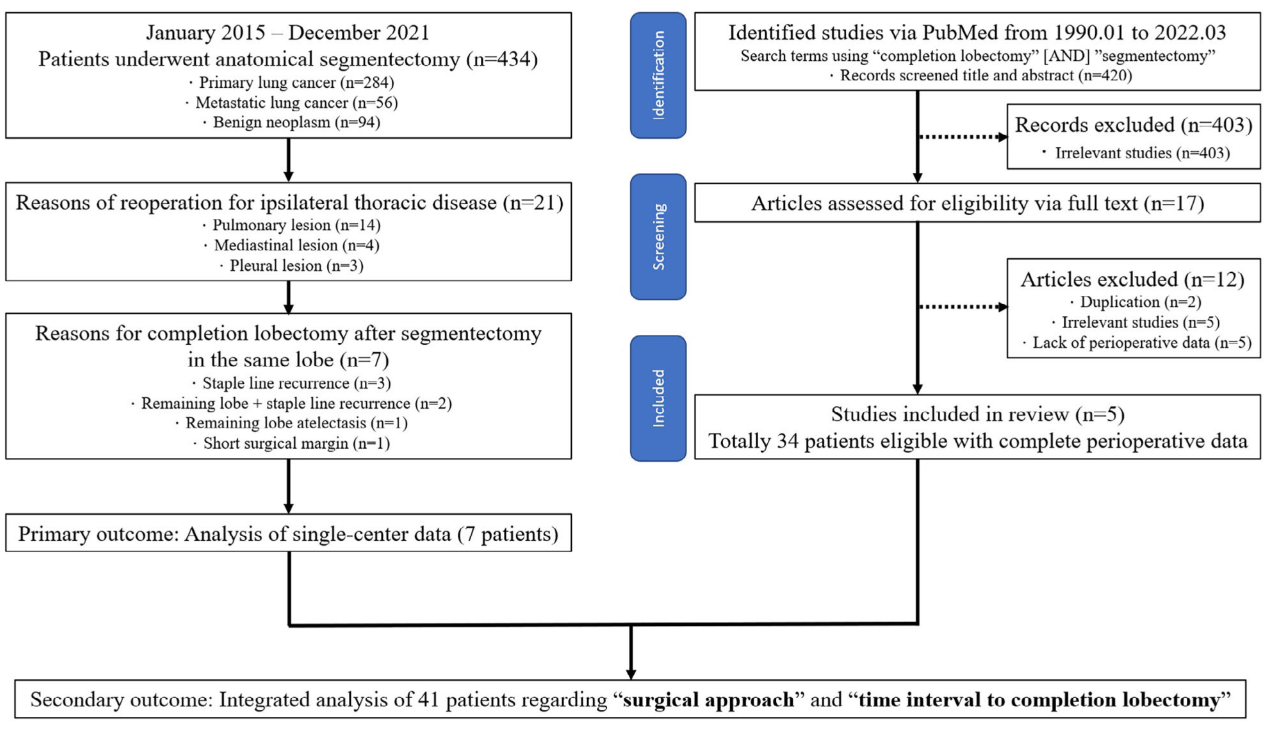

FIGURE 1 Flow diagram of patient recruitment

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[8]	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.

(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 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	2	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.

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 3 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 severe hilar adhesions among the patients in both groups, 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 (64%) occurred in the short interval-to-CL group, while higher rate of local recurrence (93%) appeared in the long interval-to-CL group ($p = 0.0001$) in terms of three predefined reasons for performing CL. 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, 267 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 (21/30, 70%) than in the short interval-to-CL group (5/11, 45%). This finding may delineate 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 this study (excluding the study by Omasa et al. due to lack of data). As shown in the supplemental Table 1, the findings revealed that completion lobectomy of upper lobes may be associated with severe hilar

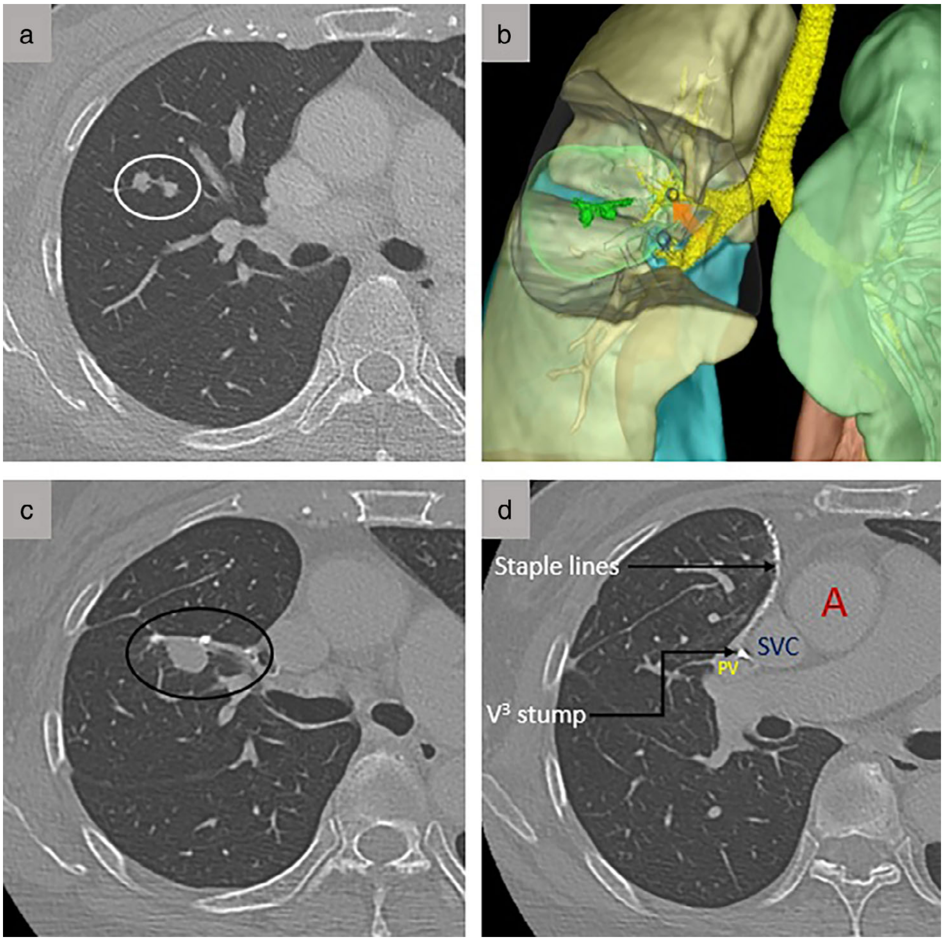

FIGURE 2 Computed tomography (CT) of the representative case who underwent completion lobectomy of the RUL after a right VATS S3 segmentectomy. (a) CT imaging revealed two nodules in right pulmonary segment 3. (b) Three-dimensional reconstruction imaging revealed the relative location between targeted 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 medial mediastinum. RUL, right upper lobe; CT, computed tomography; VATS, video-assisted thoracic surgery.

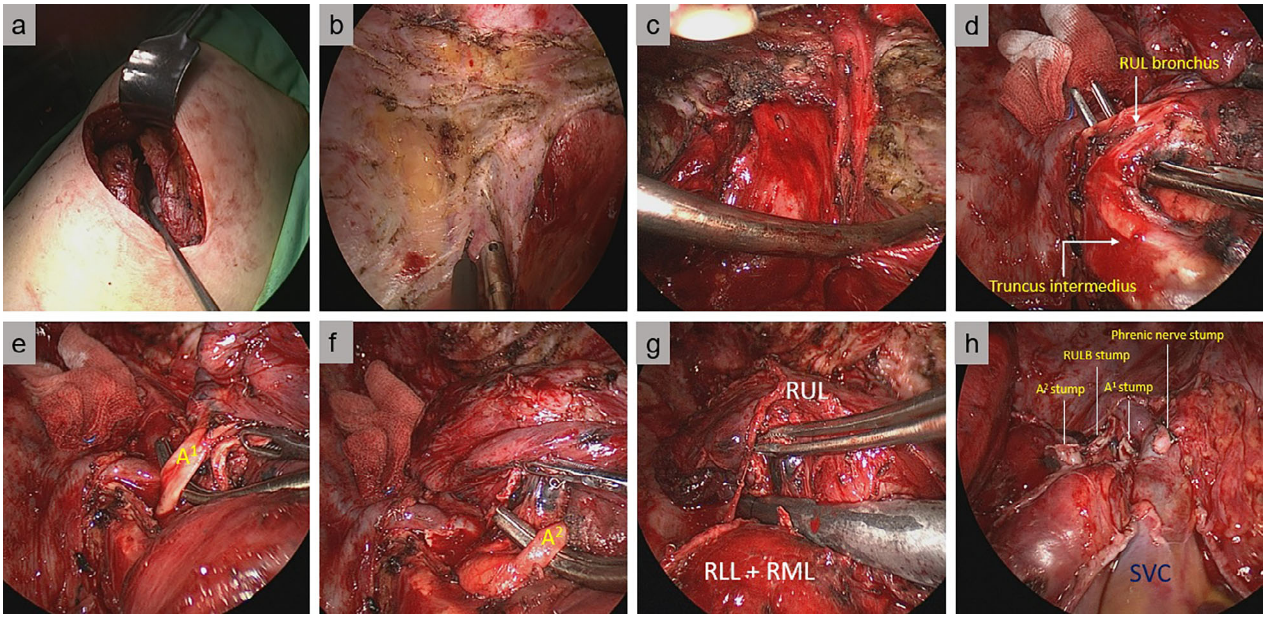

FIGURE 3 Intraoperative view of the representative case who underwent completion lobectomy of the right upper lobe (RUL) after a right VATS S3 segmentectomy. (a) Right lateral mini-thoracotomy incision (12 cm). (b) Pneumolysis for the dense adhesions over posterior pleural cavity. (c) Pneumolysis for 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	LS^{6}	72	VATS	295	500	No (mild)	No	No	9
		70/F	Recurrence	RS^{7+10}	208	VATS	389	200	Yes	Yes	PA injury	16
		72/M	Recurrence	RS^{2}	180	VATS	280	300	Yes	No	No	12
		74/F	Recurrence	RS^{8+9}	16	VATS	279	950	No (mild)	No	No	12
		73/M	Recurrence	RS^{3}	160	VATS	342	350	Yes	No	Postoperative Af	14
		61/F	Recurrence	LS^{1+2+3}	432	Thoracotomy	458	6870	Yes	No	PA injury	14
		69/F	Recurrence	RS^{2}	308	Thoracotomy	201	200	Yes	No	Azygos vein injury	8
		64/M	Recurrence	LS^{1+2+3}	8	Thoracotomy	339	1020	Yes	Yes	No	13
		80/F	Recurrence	LS^{1+2}	192	Thoracotomy	391	500	Yes	No	PA injury	18
		65/M	Recurrence	LS^{9+10}	84	Thoracotomy	301	160	No (mild)	No	No	8
Suzuki [7]	2021	65/F	Recurrence	RS^{6}	148	Thoracotomy	167	75	No (mild)	No	No	9
		82/F	Recurrence	RS^{6}	156	Thoracotomy	255	220	No (mild)	No	No	7
		81/F	Recurrence	LS^{6}	164	Thoracotomy	316	100	No (mild)	No	No	18
		67/F	Recurrence	RS^{1}	64	Thoracotomy	284	370	Yes	No	PV injury	21
Takamori [8]	2021	N/A	Second LC	LS^{1+2}	306	Thoracotomy	194	543	Yes	Yes	No	10
		N/A	Second LC	RS^{3a}	98	VATS	234	61	No (mild)	Yes	Arrhythmia	5
		N/A	Pathological change	RS^{8a}	1	VATS	138	253	No (mild)	No	No	6
		N/A	Recurrence	RS^{10}	109	Thoracotomy	165	230	Yes	No	No	5
		N/A	Pathological change	RS^{6}	4	Thoracotomy	226	906	Yes	Yes	PAL	6
		N/A	Pathological change	LS^{9+10}	19	VATS	216	206	Yes	No	No	6
		N/A	Second LC	RS^{8+6b}	120	Thoracotomy	175	248	No (mild)	Yes	No	8
		N/A	Second LC	LS^{1+2+3}	133	Thoracotomy	407	2194	Yes	No	No	7
Komatsu [10]	2021	20/M	Pathological change	LS^{8+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.

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 (%)			0.32
RUL	3 (25)	6 (20.7)	
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 (%)			0.28
Complication	5 (42)	4 (14)	
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)	
Surgical approach with VATS, n (%)	3 (27)	9 (30)	1.0
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.

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.[3,4] Recently, the JCOG0802 study showed the benefits of 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.[14] 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 CL for lung cancer.[6] Similarly, our results also disclosed comparable feasibility and safety regardless of the VATS or thoracotomy approach for CL. It should be noted that longer interval-to-CL (median 105 vs. 45 weeks, $p = 0.58$) and more severe adhesions (72% vs. 42%, $p = 0.06$) occurred in the thoracotomy group than in the VATS group, although the difference was not statistically significant. On multivariable logistic regression analysis of a subgroup, we found that completion upper lobectomy might be the predictor for severe hilar adhesions (OR: 13.98; 95% CI: 1.36–143.71). Based on our results in this integrated analysis, patients with completion lobectomy of upper lobes are more likely to exhibit severe hilar adhesions, and they tend to eventually require a thoracotomy approach.

Notably, despite the fact that it is often recommended to open the pericardium and secure the main PA to prevent catastrophic bleeding when it is difficult to expose and divide the PA due to adhesion in the hilum, only 29% (12/41 patients) received PA taping during the CL. As previous studies have reported, completion upper lobectomy is technically tougher than completion lower lobectomy because of anatomical features, presence of adhesions around the main PA at the hilum, and effect of previous superior mediastinal nodal dissection.[7] In terms of technical issues, some authors have addressed the use of simultaneous division of the PA and lung parenchyma with a stapler to manage tight adhesions.[8,9] Simultaneous stapling of the bronchus and PA is generally not preferred because of the risk of staple line bursts, bronchopleural fistula, and massive bleeding; however, no adverse events resulting from simultaneous stapling have been reported in the literature. Lewis et al. encountered no significant stapling-related complications in 400 consecutive lobectomies, all performed using simultaneous stapling.[16] Murakami et al. also described uneventful simultaneous stapling of the PA and bronchus in an animal study.[17] Furthermore, Qiang et al. presented a simultaneous stapling technique to successfully deal with dense fibrous adhesion of the upper PV and bronchus for treating primary lung cancer.[18] Although the decision to manage CL using simultaneous stapling is controversial. After isolating and severing as many hilar structures as possible, on rare occasions, simultaneous stapling of the pulmonary vessels and parenchyma during hilar division may be reliably used if the patient has dense adhesions following previous hilar dissection.

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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