

Cite this article as: Koike S, Eguchi T, Matsuoka S, Takeda T, Miura K, Shimizu K *et al.* Impact of counterclockwise rotation of the right middle lobe following right upper lobectomy. *Interact CardioVasc Thorac Surg* 2022;34:1062–70.

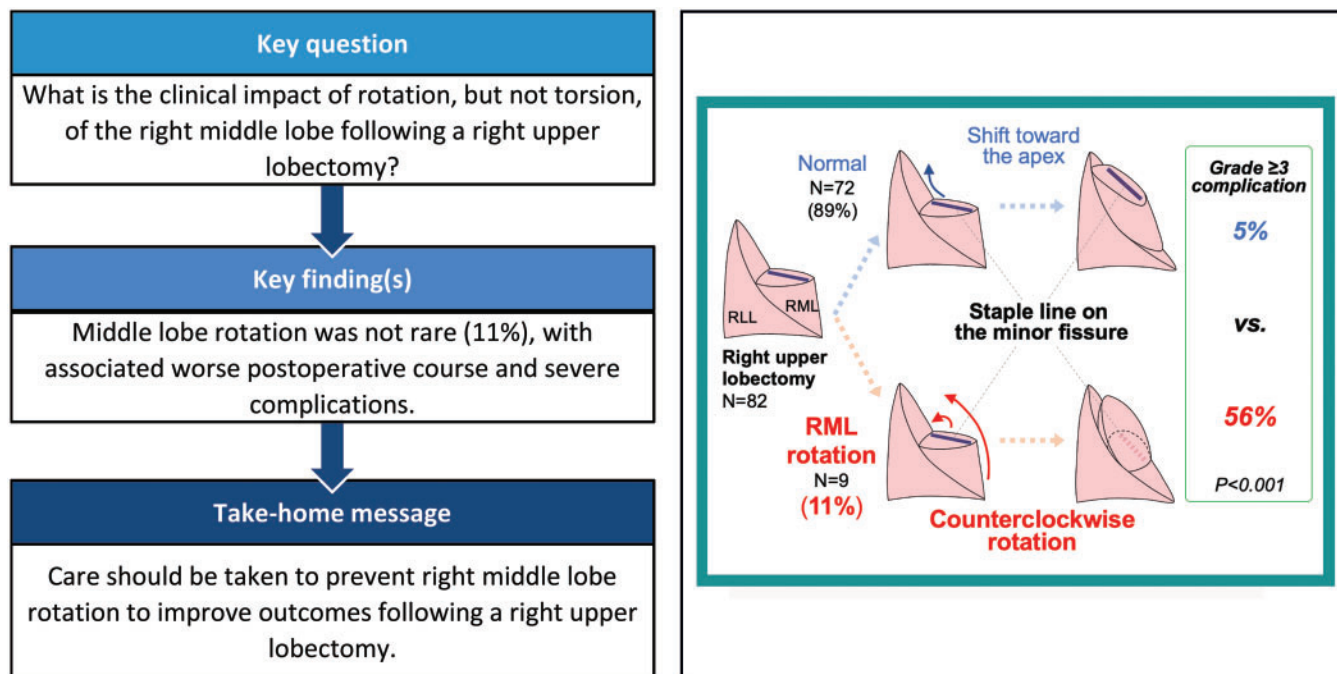
Impact of counterclockwise rotation of the right middle lobe following right upper lobectomy

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Received 1 July 2021; received in revised form 2 November 2021; accepted 20 November 2021



Abstract

OBJECTIVES: Following right upper lobectomy, the right middle lobe may shift towards the apex and rotate in a counterclockwise direction with respect to the hilum. This study aimed to investigate the incidence and clinical impact of middle lobe rotation in patients undergoing right upper lobectomy.

METHODS: From January 2014 to November 2018, 82 patients underwent right upper lobectomy at our institution for lung cancer using a surgical stapler to divide the minor fissure. Postoperative computed tomography scans evaluated the counterclockwise rotation of the middle lobe, in which the staple lines placed on the minor fissure were in contact with the major fissure of the right lower lobe (120° counterclockwise rotation). Clinicoradiological factors were evaluated and compared between patients with and without

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middle lobe rotation. We also reviewed surgical videos in patients with middle lobe rotation to evaluate the position of the middle lobe at the end of surgery.

RESULTS: Nine patients had a middle lobe rotation (11%), where 1 patient required surgical derotation. Patients with middle lobe rotation were significantly associated with more frequent right middle lobe atelectasis and severe postoperative complications compared with those without rotation. A surgical video review detected potential middle lobe rotation at the end of the surgery.

CONCLUSIONS: Middle lobe rotation without torsion following right upper lobectomy is not rare, and it is associated with adverse postoperative courses. Careful positioning of the right middle lobe at the end of surgery is warranted to improve postoperative outcomes.

Keywords: Right upper lobectomy • Right middle lobe rotation • Right middle lobe torsion • Bronchial kink • Postoperative complication

ABBREVIATIONS

CT	Computed tomography
CXR	Chest X-ray
POD	Postoperative day

INTRODUCTION

Lobectomy is the standard surgical procedure for early stage lung cancer [1]. The right upper lobe is the most commonly affected lobe resected by thoracic surgeons [2, 3]. Lobar torsion is rare but one of the major complications following thoracic surgery, which is generally defined as parenchymal rotation on the bronchovascular pedicle accompanied by vascular compromise and obstruction of the resultant airway, which may require emergent surgery [4]. Right middle lobe torsion following right upper lobectomy is the most frequent lobar torsion [5].

On the other hand, following right upper lobectomy, the position of the residual middle lobe may shift towards the apical pleural space without perfusion impairment due to a counterclockwise rotation of the middle lobe. This may cause cranial traction of the middle lobe and a kink or occlusion of the bronchus, resulting in postoperative atelectasis of the middle lobe. Yanagihara *et al.* reported that a staple line that completed the minor fissure or the horizontal fissure might be relocated in parallel with the major fissure or the oblique fissure because of a counterclockwise rotation of the middle lobe. This can be recognized as staple lines on the minor fissure in contact with the major fissure of the right lower lobe on postoperative computed tomography (CT) [6]. Although a kink of the right middle lobe bronchus has been reported as a complication following right upper lobectomy [4, 5, 7–11], the clinical significance of a counterclockwise rotation of the right middle lobe has not been investigated.

At the end of 2018, we experienced 2 cases who underwent right upper lobectomy, and at the last part of the procedure, we recognized the counterclockwise rotation of the middle lobe, which was corrected intraoperatively by a simple derotation procedure using a suction instrument (Videos S1 and S2). These experiences of avoiding middle lobe rotation prompted us to retrospectively investigate the incidence and clinical impact of counterclockwise rotation of the right middle lobe in patients who underwent right upper lobectomy.

PATIENTS AND METHODS

Ethics statement

This study was approved by the Institutional Review Board of Shinshu University Hospital, Matsumoto, Japan (No. 5003). We utilized an opt-out approach instead of obtaining written informed consent from each patient.

Patients

Three hundred seventy-seven patients underwent lobectomy for primary lung cancer at Shinshu University Hospital from January 2014 to November 2018. In this study, we retrospectively investigated 82 patients who underwent right upper lobectomy with the use of surgical staplers and at least 1 CT scan at any time point after surgery. A schema of the patient selection is shown in Fig. 1.

Radiological evaluation of the completeness of the fissure and postoperative position of the right middle lobe

Preoperative and postoperative CT scans were reviewed in all patients by 2 thoracic surgeons (Sachie Koike and Kazutoshi Hamanaka). The grade of the completeness of the fissure between the right middle and lower lobes was determined on preoperative CT using the criteria proposed by Craig and Walker [12]. The grading criteria were as follows: grade 1, complete fissure; grade 2, partially fused fissure with the complete visceral cleft; grade 3, partially fused fissure with incomplete visceral cleft; and grade 4, completely fused fissure without evidence of the fusion line. To determine the postoperative position of the right middle lobe, the location and direction of staple lines placed on the minor fissure were evaluated on postoperative CT scans, which includes both the CT scans performed during postoperative hospitalization and those performed in the outpatient clinic as postoperative follow-up imaging. If >1 postoperative CT scan was performed during the study period, the earliest scan after surgery was reviewed. In most patients, the staple lines that were placed on the minor fissure to complete the fissure during right upper lobectomy were in contact with the mediastinum on the postoperative CT scan. This was considered the normal position of the middle lobe after a right upper lobectomy.



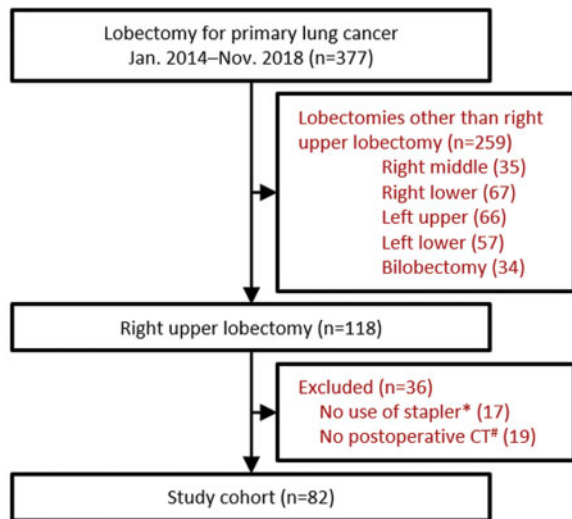


Figure 1: Schema of the study cohort. CT: computed tomography. *Patients in whom stapler was not used on the minor fissure because of the complete minor fissure. #Patients who were followed up in the other institutions and postoperative computed tomography images were not available in this study.

However, we observed a particular position of the middle lobe where the staple lines on the minor fissure existed adjacent to the right lower lobe in parallel with the major fissure in several patients. We considered that this particular position of the right middle lobe was caused by a 120° counterclockwise rotation of the bronchovascular pedicle of the middle lobe (Figs 2 and 3). To investigate the clinical significance of this phenomenon, we compared patients with and without counterclockwise rotation of the middle lobe in terms of the completeness of the fissure and the other perioperative findings as described below. Medical records were reviewed for all patients to evaluate: (i) background demographics including age, sex, smoking

status and comorbidities; (ii) pathological findings including tumour size, stage and histology; and (iii) perioperative findings including operation time, intraoperative blood loss, postoperative complications, blood gas analysis on postoperative day (POD) 1, C-reactive protein on POD 6–8 and postoperative chest X-ray (CXR) during hospitalization. Abnormal opacification on CXR was defined as opacification in the right upper lung field on postoperative CXR (Fig. 4). Atelectasis of the right middle lobe was defined as consolidation of the whole or partial right middle lobe on postoperative chest CT scan (Fig. 4).

Surgical video review in patients with postoperative rotation of the right middle lobe

To evaluate the position of the middle lobe at the last moment of surgery after the removal of the right upper lobe in 9 patients who were found to have counterclockwise rotation of the middle lobe through postoperative chest CT scan, we reviewed the surgical video and evaluated the location and direction of the staple lines that were placed on the minor fissure at the moment of re-expansion of the right lung after the sealing test and chest tube insertion. Among the 9 patients, the surgical video was not available in 1 patient and we could not evaluate the position of the middle lobe in 2 patients because the middle lobe was not visualized at the last moment of surgery.

Statistical analysis

Statistical analyses were performed using the SPSS statistical software (version 26.0; SPSS, IBM, USA). Differences between groups A and B were assessed using Mann-Whitney *U*-test for continuous variables and the Chi-squared test and Fisher's exact test for categorical variables. Differences were considered statistically significant at $P < 0.05$.

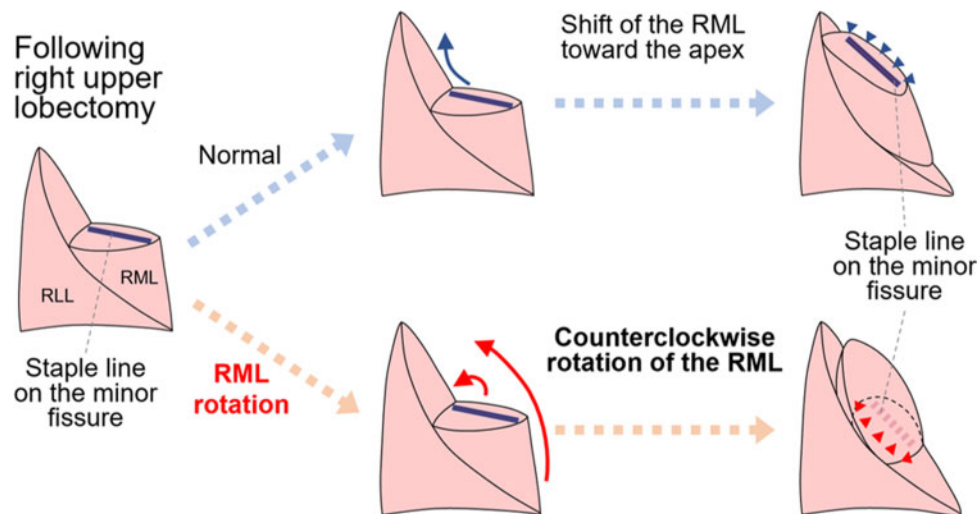


Figure 2: Schema of position of the middle lobe following right upper lobectomy. In the normal position of the middle lobe following right upper lobectomy, the entire right middle lobe shifts towards the apex without rotation (blue arrow), resulting in the staple line placed in the minor fissure in contact with the mediastinum (blue arrowheads). In contrast, in patients with counterclockwise rotation of the right middle lobe, right middle lobe is rotated 120° counterclockwise centring around the hilum (red arrows), resulting in the staple line placed in the minor fissure in contact with the major fissure of the right lower lobe (red arrowheads). RLL: right lower lobe; RML: right middle lobe.

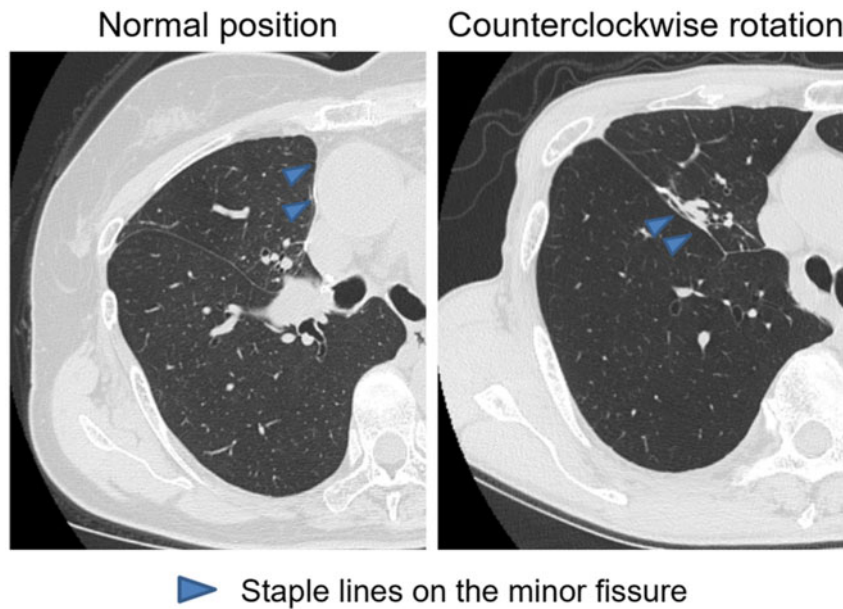


Figure 3: Representative computed tomographic images of the right middle lobe following right upper lobectomy. Left: in a patient with a normal position in the right middle lobe, staple lines placed on the minor fissure (blue arrowheads) touch the mediastinum. Right: in patients with counterclockwise rotation of the right middle lobe, staple lines placed on the minor fissure (blue arrowheads) touch the major fissure of the right lower lobe.

RESULTS

A counterclockwise 120° rotation of the right middle lobe was identified in 9 patients (11%). Details and postoperative radiological findings of these 9 patients are shown in Table 1 and Fig. 4. Among the 9 patients with middle lobe rotation, 1 patient underwent surgical reoperation due to suspicion of middle lobe torsion. The patient was a 53-year-old female former smoker with a history of hypertension and hyperlipidaemia who underwent video-assisted thoracoscopic surgery right upper lobectomy for clinical stage I lung cancer. She developed high fever and prolonged postoperative elevation of white blood cell count and C-reactive protein levels. Postoperative CXR showed opacification in the upper right field, and chest CT scan with contrast on POD 7 revealed atelectasis of the middle lobe with narrowing of the middle lobe pulmonary vein. Pulmonary rehabilitation and antibiotics were initiated without improvement of the clinical presentations. To rule out a potential middle lobe torsion and to improve middle lobe atelectasis if there was no torsion, we performed a reoperation through video-assisted thoracoscopic surgery on POD 11. We found that the right middle lobe was rotated counterclockwise without perfusion impairment and simply performed derotation of the middle lobe. The middle lobe was fixed by suturing the middle lobe to the lower lobe. None of the other 8 patients with middle lobe rotation required reoperation. Although abnormal findings such as opacification on chest radiography, atelectasis of the right middle lobe, cough or dyspnoea were observed in several patients, we did not consider that they were clinically significant that requires surgical intervention.

Comparison of patient characteristics, radiological/surgical/pathological findings, laboratory data, and symptoms between patients with and without middle lobe rotation are shown in Table 2. In terms of fissure completeness, 56% of patients with middle lobe rotation had a complete fissure, whereas 36% of patients without rotation had a complete fissure (Table 2, statistically not significant). The incidence of severe postoperative

complications (Clavien-Dindo grade III or higher) was 5 (55.6%) out of 9 patients with middle lobe rotation and 4 (5.5%) out of 73 patients without middle lobe rotation. The frequency was significantly higher in patients with middle lobe rotation than in those without ($P < 0.001$). Severe postoperative complications in patients with middle lobe rotation included pneumonia treated with intravenous antibiotics that required with bronchoscopy (case 8), delayed postoperative pneumothorax treated with re-drainage (case 5), acute respiratory distress syndrome intubated in intensive care unit (case 7), cerebral infarction treated using endovascular management (case 9) and right middle lobe rotation diagnosed as middle lobe torsion, which was operated (case 3). In patients without middle lobe rotation, severe complications included pneumonia treated with intravenous antibiotics requiring bronchoscopy, 2 prolonged air leaks treated with chest tube drainage and deep venous thrombosis treated using inferior vena cava filter insertion. Abnormal opacification on postoperative CXR was more frequently observed in patients with middle lobe rotation (44%) than in those without (4%) ($P = 0.002$). Middle lobe atelectasis (including partial atelectasis) on postoperative CT was significantly more frequent in patients with middle lobe rotation (55%) than in those without (2.7%) ($P < 0.001$).

In the surgical video review in 9 patients who had right middle lobe rotation, the position of the middle lobe at the last moment of surgery was sufficiently evaluated in 6 patients. The staple lines on the minor fissure already shifted towards the major fissure of the right lower lobe but not towards the mediastinum in all the 6 patients.

DISCUSSION

In our study, we did not include patients with pulmonary torsion. However, counterclockwise rotation of the middle lobe was observed in 11% of patients who underwent right upper

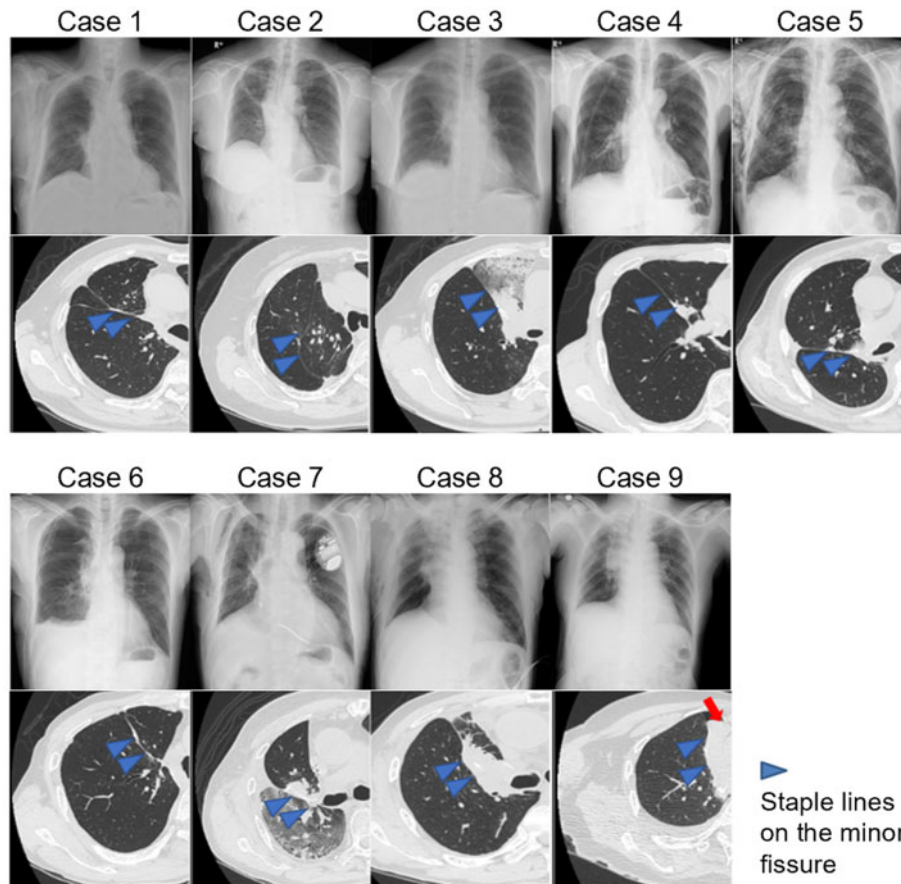


Figure 4: Postoperative chest X-ray and computed tomographic images in 9 patients with the counterclockwise rotation of the right middle lobe. Abnormal opacification on chest radiography is shown in cases 3, 7, 8 and 9. The atelectasis of the whole or partial right middle lobe on the computed tomographic scan is shown in cases 3, 4, 7, 8 and 9. In case 9, the atelectasis of the entire right middle lobe is shown (red arrow).

lobectomy. Importantly, middle lobe rotation was significantly associated with a higher risk of postoperative complications compared to those without middle lobe rotation. The novelty and significance of our study were as follows: (i) this is the first study to investigate the incidence and clinical impact of postoperative rotation of the middle lobe following right upper lobectomy; (ii) the middle lobe rotation has adverse clinical impact with relatively frequent incidence (11% in our cohort); (iii) patients with incomplete fissures still have a risk of rotation; and (iv) our study suggested that careful positioning of the middle lobe at the end of surgery might prevent middle lobe rotation.

In general, the complete major fissure is considered to be a cause of pulmonary torsion of the middle lobe. Several techniques of middle lobe fixation have been proposed in patients undergoing right upper lobectomy with complete major fissure [13, 14]. In our study, however, nearly half of the patients (44%) with counterclockwise rotation of the middle lobe had incomplete fissures (Craig criteria grade II) on the preoperative CT scan, and there was no statistical difference in terms of grade of fissure completeness between patients with middle lobe rotation and those without. This result warns about the possibility that middle lobe rotation can occur even if the major fissure is incomplete. However, the completeness of the major fissure was determined by the preoperative CT scan in this study and a previous study suggested that there was no statistical correlation between the completeness of the major fissure predicted by preoperative CT

and that confirmed at surgery [15]. Since we cannot evaluate the true completeness of the major fissure using surgical videos, we cannot conclude whether an association between the completeness of the major fissure and the occurrences of the middle lobe rotation exists.

A systemic review of pulmonary torsion by Dai *et al.* [5] reported that the degree of rotation of the lung was $>180^\circ$ in most patients. During our study period, we did not include patients with pulmonary torsion with vascular compromise. However, 1 patient from our study cohort required reoperation because of persistent fever and elevated inflammatory changes in laboratory data with middle lobe atelectasis and narrowing of the middle lobe vein, suggesting potential congestive changes in the right middle lobe. Derotation of the middle lobe resulted in resolution of the symptoms and findings. We suggest that some cases with a rotation of $<180^\circ$ without obvious vascular compromise might require surgical detorsion.

Although it was expected, we found that the risk of atelectasis of the right middle lobe was significantly higher in patients with middle lobe rotation than in those without. In some cases, the degree of atelectasis changes with the associated changes in oxygenation. Among the 5 patients with partial or whole lobar atelectasis of the right middle lobe in our study cohort, 2 patients demonstrated an altered degree of atelectasis of the right middle lobe (cases 4 and 8, Fig. 5). The requirement for home oxygen therapy in one of them changed according to the degree of atelectasis (case 8).

Table 1: Pre- and postoperative findings in 9 patients with counterclockwise rotation of the right middle lobe after right upper lobectomy

	Age	Sex	Smoking history	Surgical approach	Histology/pStage	RML rotation at the end of surgery	Postoperative complication (grade)	Postoperative course
Case 1	76	M	Yes	VATS	ADC/I	Video not available	No	Uneventful
Case 2	68	F	No	VATS	ADC/I	Yes	No	Uneventful
Case 3	53	F	No	VATS	ADC/I	Yes	RML atelectasis (IIIb)	RML atelectasis with high fever required surgical derotation (described in the result section)
Case 4	77	M	No	RATS	ADC/I	Yes	No	RML atelectasis developed 3 years after surgery (Fig. 4)
Case 5	74	M	Yes	VATS	SCC/I	RML not visualized	Delayed pneumothorax (IIIb)	Delayed pneumothorax treated with chest tube drainage
Case 6	64	M	Yes	VATS	ADC/I	RML not visualized	Prolonged air leak (II)	Prolonged chest tube drainage period
Case 7	71	M	Yes	VATS	ADC/I	Yes	RML atelectasis, ARDS (IVa)	ARDS developed on POD 13, which required mechanical ventilation, ICU stay, high-dose corticosteroid therapy
Case 8	65	M	Yes	VATS	SCC/I	Yes	RML atelectasis, pneumonia, HOT (IIIa)	Repeated RML atelectasis (Fig. 4)
Case 9	71	F	No	VATS	ADC/I	Yes	RML atelectasis, cerebral infarction (IVa)	Cerebral infarction developed on POD 2, which required endovascular intervention (no PV thrombosis on enhanced chest CT scan)

ADC: adenocarcinoma; ARDS: acute respiratory distress syndrome; CT: computed tomography; F: female; HOT: home oxygen therapy; ICU: intensive care unit; M: male; POD: postoperative day; PV: pulmonary vein; RATS: robotic-assisted thoracic surgery; RLL: right lower lobe; RML: right middle lobe; SCC: squamous cell carcinoma; VATS: video-assisted thoracoscopic surgery.

Moreover, in our study cohort, severe postoperative life-threatening complications, including acute respiratory distress syndrome and cerebral infarction, frequently occurred in patients with middle lobe rotation. The exact relationship between rotation and these complications was unknown in our study cohort; however, a potential association between pulmonary torsion and these complications has been reported [9, 16, 17]. Care should be taken that the middle lobe 120° rotation might be associated with the occurrence of severe postoperative complications, and prophylaxis is warranted.

Through our review of surgical video in patients with middle lobe rotation detected by postoperative CT scans, we found that the rotation of the middle lobe was detected by thoracoscopic view at the end of surgery in 6 patients who were available for surgical video review. We suggest that the rotation would already be completed at the end of surgery, and one of the causes of the rotation would be direct pressure and compression of the middle lobe towards the hilum to observe the hilar structure during the water-sealing test. We might be able to reposition the rotated right middle lobe into the appropriate position with/without subsequent fixation (Fig. 6). Based on our findings, we changed our practice to all patients undergoing right upper lobectomy. We

carefully observed the position of the right middle lobe during and after pleural irrigation and a water-sealing test for air leakage. If we observe potential middle lobe rotation with minor fissure staple lines in parallel contact with the lower lobe, we restore the rotation and may add fixation by suturing, fibrin glue and/or polyglycolic acid sheet depending on the situation (Fig. 6).

Limitations

This study has several limitations. The relatively small cohort size, single institutional study, and retrospective nature might have affected the results and generalizability. Among patients who underwent right upper lobectomy, 36 patients (31%) were excluded because of no use of stapler on the minor fissure or no available postoperative CT scan images, which might have caused a selection bias. Also, we did not review the surgical videos in patients without middle lobe rotation on postoperative CT scans. The volume and shape of the middle lobe, which might affect the occurrence of middle lobe rotation, were not evaluated in this study. In addition, the remaining volume of the intrathoracic space, the shift of the mediastinum, and the elevation of the diaphragm could affect the occurrence of middle lobe rotation. The completeness of the major

Table 2: Demographical information and outcomes in comparison between patients with and without counterclockwise rotation of the right middle lobe

	Total (n = 82)	RML rotation		P-value
		Yes (n = 9; 11%)	No (n = 73, 89%)	
Background/preoperative findings				
Age	69 (63, 75)	71 (65, 75)	69 (62, 75)	0.85
Sex				
Male	52 (63.4)	6 (66.7)	46 (63.0)	>0.99
Female	30 (36.6)	3 (33.3)	27 (37.0)	
Smoking status				
Never	30 (36.6)	4 (44.4)	26 (35.6)	0.72
Former/current	52 (63.4)	5 (55.5)	47 (64.4)	
Comorbidity				
DM	17 (20.7)	0 (0.0)	17 (23.3)	0.19
CVD	22 (26.8)	1 (11.1)	21 (28.8)	0.43
COPD	23 (28.0)	2 (22.2)	21 (28.8)	>0.99
ILD	2 (2.4)	0 (0.0)	2 (2.7)	>0.99
FEV1.0 (L)	2.3 (2.0, 2.7)	1.9 (1.7, 2.7)	2.3 (2.0, 2.7)	0.38
FEV1.0/FVC (%)	73 (61, 78)	72 (62, 77)	74 (66, 79)	0.43
Fissure completeness				
Grade I	31 (37.8)	5 (55.5)	26 (35.6)	0.29
Grade II	51 (62.2)	4 (44.4)	47 (64.4)	
Grade III	0 (0.0)	0 (0.0)	0 (0.0)	
Grade IV	0 (0.0)	0 (0.0)	0 (0.0)	
Operative findings				
Surgical approach				
Thoracotomy	12 (14.6)	0 (0.0)	12 (16.4)	0.34
MIS	70 (85.4)	9 (100.0)	61 (83.6)	
Operation time (min)	240 (193, 303)	381 (166, 368)	238 (193, 293)	0.34
Blood loss (ml)	50 (30, 160)	100 (26, 160)	50 (30, 113)	0.81
Pathologic findings				
Tumour size (mm)	15 (10, 20)	17 (9, 20)	15 (10, 22)	0.95
pStage				
pStage 0–I	63 (76.8)	9 (100.0)	54 (74.0)	0.22
pStage II	11 (13.4)	0 (0.0)	11 (15.1)	
pStage III	8 (9.8)	0 (0.0)	8 (11.0)	
Histology				
ADC	67 (81.7)	7 (77.8)	60 (82.2)	0.68
SCC	12 (14.6)	2 (22.2)	10 (13.7)	
Others	3 (3.7)	0 (0.0)	3 (4.1)	
Postoperative findings				
CXR opacification	7 (8.5)	4 (44.4)	3 (4.1)	0.002
RML atelectasis	7 (8.5)	5 (55.6)	2 (2.7)	<0.001
PaO ₂ (mmHg) (POD 1)	128 (102, 150)	121 (89, 123)	133 (103, 152)	0.23
PaCO ₂ (mmHg) (POD 1)	34 (38, 41)	41 (38, 44)	40 (38, 41)	0.79
C-reactive protein (mg/l) (POD 6–8)	1.9 (0.9, 3.4)	3.1 (0.8, 8.0)	1.8 (0.9, 3.3)	0.53
Postoperative complications				
Any complications (≥CD grade II)	30 (36.6)	6 (66.7)	24 (32.9)	0.068
Any severe complications (≥CD grade III)	9 (10.9)	5 (55.6)	4 (5.5)	<0.001
Pneumonia	2 (2.4)	1 (11.1)	1 (1.3)	
Prolonged air leak (including CD grade II)	10 (12.2)	2 (22.2)	8 (11.0)	
Atrial fibrillation (including CD grade II)	10 (12.2)	0 (0.0)	10 (13.7)	
PE/DVT	2 (2.4)	0 (0.0)	2 (2.7)	
ARDS	1 (1.2)	1 (11.1)	0 (0.0)	
Cerebral infarction	1 (1.2)	1 (11.1)	0 (0.0)	

Data are shown as number (%) or median (25th, 75th percentiles). Differences were considered statistically significant at $P < 0.05$ and are shown in bold.

ADC: adenocarcinoma; ARDS: acute respiratory distress syndrome; CD: Clavien-Dindo; COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease; CXR: chest X-ray; DM: diabetes mellitus; DVT: deep venous thrombosis; FEV1.0: forced expiratory volume in 1 s; FVC: forced vital capacity; ILD: interstitial lung disease; MIS: minimally invasive surgery; PE: pulmonary embolism; POD: postoperative day; RML: right middle lobe; SCC: squamous cell carcinoma.

fissure was evaluated by preoperative CT scan but not by intraoperative evaluation since the anterior major fissure between the middle lobe and lower lobe was not sufficiently visualized to evaluate the fissure completeness in most of the cases in this retrospective study cohort. Lastly, the duration between the operation and the first postoperative chest CT scan varied between the cases.

CONCLUSION

In conclusion, middle lobe rotation without torsion following right upper lobectomy is not rare and is associated with adverse postoperative courses. Careful positioning of the right middle lobe during surgery is necessary to prevent rotation.

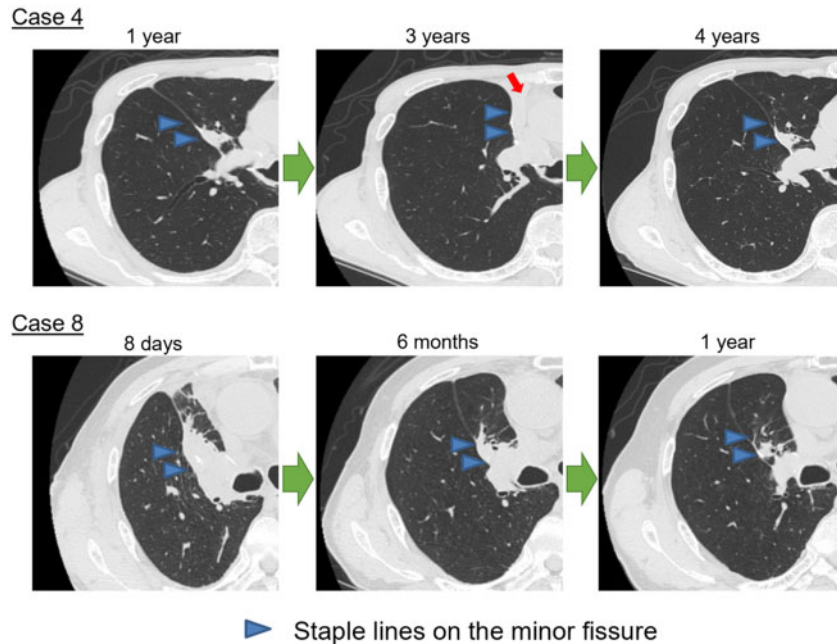


Figure 5: Two representative courses of altering degree of the middle lobe atelectasis. In case 4, partial atelectasis of the middle lobe was observed on postoperative follow-up in computed tomography 1 year after surgery (upper left). The right middle lobe was completely collapsed (whole atelectasis, red arrow) at 3 years after surgery without any symptoms (upper middle), which was almost resolved at 4 years after surgery (upper right). In case 8, a partial but nearly complete atelectasis of the right middle lobe was observed on postoperative computed tomography performed due to hypoxia on postoperative day 8 (lower left), and home oxygen therapy was started. Gradual improvement of the right middle lobe atelectasis was observed at 6 months (lower middle) and 1 year (lower right) after surgery, and home oxygen therapy was discontinued at 1 year after surgery.

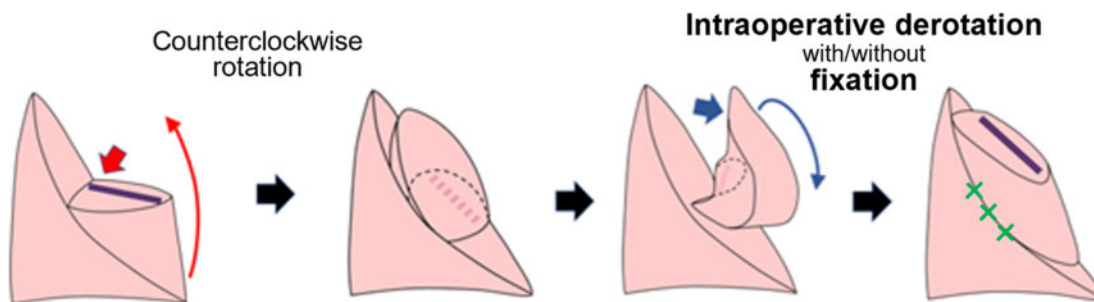


Figure 6: Schema of the counterclockwise rotation and derotation of the middle lobe. Holding the middle lobe down to observe the hilum during the water-sealing test (thick red arrow) may cause 120° counterclockwise rotation of the right middle lobe (thin red arrow). Careful derotation of the right middle lobe (blue arrows) with or without fixation (green mark) by suturing, fibrin glue, and/or polyglycolic acid sheet.

ACKNOWLEDGEMENT

We would like to thank Editage (www.editage.com) for English language editing.

Conflict of interest: none declared.

Data Availability Statement

The data underlying this article cannot be shared publicly for protecting privacy of individuals that participated in this study. The data may be shared on reasonable request to the corresponding author after an additional approval by the Institutional Review Board of Shinshu University Hospital, Matsumoto, Japan.

Author contributions

Sachie Koike: Data curation; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. **Takashi Eguchi:** Conceptualization; Data curation; Methodology; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing. **Shunichiro Matsuoka:** Data curation; Investigation. **Tetsu Takeda:** Data curation; Investigation. **Kentaro Miura:** Data curation; Investigation. **Kimihiko Shimizu:** Project administration; Supervision; Writing—review & editing. **Kazutoshi Hamanaka:** Conceptualization; Investigation; Methodology; Project administration; Supervision; Visualization; Writing—review & editing.

Reviewer information

Interactive CardioVascular and Thoracic Surgery thanks Muammer Cumhuri Sivriköz, Shun-Mao Yang and the other, anonymous reviewer(s) for their contribution to the peer review process of this article.

REFERENCES

- [1] Ginsberg RJ, Rubinstein LV. Randomized trial of lobectomy versus limited resection for T1 N0 non-small cell lung cancer. Lung Cancer Study Group. *Ann Thorac Surg* 1995;60:615–22. discussion 22–3.
- [2] Hristov B, Eguchi T, Bains S, Dycoco J, Tan KS, Isbell JM *et al.* Minimally invasive lobectomy is associated with lower noncancer-specific mortality in elderly patients: a propensity score matched competing risks analysis. *Ann Surg* 2019;270:1161–9.
- [3] Okami J, Shintani Y, Okumura M, Ito H, Ohtsuka T, Toyooka S *et al.*; Japanese Joint Committee of Lung Cancer Registry. Demographics, safety and quality, and prognostic information in both the seventh and eighth editions of the TNM classification in 18,973 surgical cases of the Japanese Joint Committee of Lung Cancer Registry Database in 2010. *J Thorac Oncol* 2019;14:212–22.
- [4] Cable DG, Deschamps C, Allen MS, Miller DL, Nichols FC, Trastek VF *et al.* Lobar torsion after pulmonary resection: presentation and outcome. *J Thorac Cardiovasc Surg* 2001;122:1091–3.
- [5] Dai J, Xie D, Wang H, He W, Zhou Y, Hernández-Arenas LA *et al.* Predictors of survival in lung torsion: a systematic review and pooled analysis. *J Thorac Cardiovasc Surg* 2016;152:737–45.e3.
- [6] Yanagihara T, Ichimura H, Kobayashi K, Sato Y. Computed tomography detection of stapled interlobar fissure facilitates diagnosing postoperative lobar torsion: a case report. *Int J Surg Case Rep* 2017; 41:86–8.
- [7] Epplen F, Jacobson A. Twisted pedicle of accessory lobe of the lung. *JAMA* 1930;94:1135.
- [8] Keagy BA, Lores ME, Starek PJ, Murray GF, Lucas CL, Wilcox BR. Elective pulmonary lobectomy: factors associated with morbidity and operative mortality. *Ann Thorac Surg* 1985;40:349–52.
- [9] Larsson S, Lepore V, Dernevik L, Nilsson F, Selin K. Torsion of a lung lobe: diagnosis and treatment. *Thorac Cardiovasc Surg* 1988;36:281–3.
- [10] Masuda Y, Marutsuka T, Suzuki M. A risk factor for kinked middle lobar bronchus following right upper lobectomy. *Asian Cardiovasc Thorac Ann* 2014;22:955–9.
- [11] Ueda K, Tanaka T, Hayashi M, Tanaka N, Li TS, Hamano K. Clinical ramifications of bronchial kink after upper lobectomy. *Ann Thorac Surg* 2012;93:259–65.
- [12] Craig SR, Walker WS. A proposed anatomical classification of the pulmonary fissures. *J R Coll Surg Edinb* 1997;42:233–4.
- [13] Higashiyama M, Takami K, Higaki N, Kodama K. Pulmonary middle lobe fixation using TachoComb in patients undergoing right upper lobectomy with complete oblique fissure. *Interact CardioVasc Thorac Surg* 2004;3:107–9.
- [14] Uramoto H, Takenoyama M, Hanagiri T. Simple prophylactic fixation for lung torsion. *Ann Thorac Surg* 2010;90:2028–30.
- [15] Schieman C, MacGregor JH, Kelly E, Graham A, McFadden SP, Gelfand G *et al.* Can preoperative computed tomography of the chest predict completeness of the major pulmonary fissure at surgery? *Can J Surg* 2011;54: 252–6.
- [16] Apostolakis E, Koletsis EN, Panagopoulos N, Prokakis C, Dougenis D. Fatal stroke after completion pneumonectomy for torsion of left upper lobe following left lower lobectomy. *J Cardiothorac Surg* 2006;1:25.
- [17] Hendriks J, Van Schil P, De Backer W, Hauben E, Vanmaele R, Van Marck E. Massive cerebral infarction after completion pneumonectomy for pulmonary torsion. *Thorax* 1994;49:1274–5.