Original Article

Perioperative outcomes of upper lobectomy according to preservation or division of the inferior pulmonary ligament

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Background: The aim of this study was to investigate the relationship between inferior pulmonary ligament division and postoperative complications.

Methods: Medical records of 72 non-small cell lung cancer (NSCLC) patients who underwent video-assisted thoracic surgery (VATS) upper lobectomy between March 2012 and November 2013 performed by a single thoracic surgeon at our center were reviewed retrospectively. Patients were categorized into two groups: the division group, who underwent division of the inferior pulmonary ligament, and the preservation group, who did not. The division group included 43 patients (27 right, 16 left), while the preservation group included 29 (11 right, 18 left). Postoperative outcomes such as the presence of pleural effusion, chest tube duration, and changes in the angle and diameter of remnant bronchus were compared; bronchial diameter and angle were measured on three-dimensional (3D) reconstruction chest CT images.

Results: Chest tube duration, duration of chest tube drainage >200 mL, and the presence of pleural effusion on chest X-rays taken 1 month after surgery were not significantly different between the two groups (P=0.07, 0.33, and 1.00, respectively). There were also no significant differences between groups in the presence of apical dead space or in change in bronchial angle (P=0.22 and 0.74, respectively). In 3D reconstruction images, changes in the diameter of the right middle, right lower, and left lower lobar (LLL) bronchi were similar between groups (P=0.72, 0.12 and 0.29, respectively). Change in the angle between the right bronchus intermedius (RBI) and the right middle lobar (RML) bronchus and between the RBI and the right lower lobar (RLL) bronchus were significantly different between the division and preservation groups (P=0.02 and 0.05, respectively).

Conclusions: Inferior pulmonary ligament division had no clear benefits. Complications related to excessive dislocation of remnant bronchi might be associated with inferior pulmonary ligament division, but further research is needed to elucidate this relationship.

Keywords: Thoracic; lung cancer surgery; complications

Submitted Oct 12, 2015. Accepted for publication Nov 05, 2015.
doi: 10.3978/j.issn.2072-1439.2015.11.41
View this article at: http://dx.doi.org/10.3978/j.issn.2072-1439.2015.11.41

Introduction

Inferior pulmonary ligament division in upper lobectomy is believed to be helpful for reducing free space in the upper thorax, and thus for preventing postoperative complications such as pooling of pleural effusion, empyema, insufficient expansion of the remaining lung, and prolonged air leak (1). Although some textbooks state that this procedure should be performed to release the middle or lower lobes, there is no scientific evidence of the clinical advantage of this procedures (2).

Several studies have discussed the potential association between excessive bronchial displacement and inferior pulmonary ligament division, which can lead to disastrous complications (2-4). The beneficial effects of this procedure are controversial, and its performance during upper lobectomy is largely based on surgeon preference. Upper lobectomy is frequently associated with bronchial kink, and this could worsen postoperative pulmonary function (5,6), but there is a lack of evidence of this relationship.

We analyzed perioperative outcomes including the presence of dead space and changes in bronchial angles between patients with lung cancer who underwent division of the inferior pulmonary ligament during upper lobectomy and those who did not.

Materials and methods

Patients

Between March 2012 and November 2013 a total of 207 patients were underwent lobectomies by a single surgeon (K. Kim) in our institute. Among those, 72 patients who underwent video-assisted thoracic surgery (VATS) surgeries for non-small cell lung cancer (NSCLC) were enrolled in this study. Inclusion criteria were as follows: (I) patients who were diagnosed with NSCLC; (II) patients who had cancers in their right or left upper lobes; (III) patients who underwent VATS surgeries for their cancer lesions.

Patients who underwent open thoracotomy or conversion to open (n=9), patients whose diagnoses were other than NSCLC (n=21), and patients who underwent surgeries on their lower or middle lobes (n=102) were excluded.

Enrolled patients were categorized into two groups: the division group, who underwent division of the inferior pulmonary ligament, and the preservation group, who did not. The amount of chest tube drainage and chest tube duration was measured via retrospective review of medical records. The presence of dead space was detected via postoperative chest X-ray. Change in lower lobe angle was measured on chest CT taken 1 month postoperative. This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB number; B-1412/280-112).

Pleural effusion

We checked the number of days that daily chest tube drainage was >200 mL, chest tube duration and the chest X-ray at 1 month postoperatively. The indications for chest tube removal included a total amount of daily chest tube drainage <200 mL and no air leakage.

Expansion of the remaining lung

We used the method described by Matsuoka *et al*. (2) to check the expansion of the remaining lung. The chest X-rays (posterior-anterior) performed preoperatively at end-inspiration, and 1 month postoperatively were reviewed and compared; thereafter the existence of the dead space at the apex was evaluated.

Change in bronchial angle

We used a previously described method (6) to calculate bronchial angle. We used coronal view CT preoperatively and 1 month postoperatively and measured the angles formed by the main bronchus and the bronchus intermedius on the right side, and by the main bronchus and the lower bronchus on the left side. Bronchial angle change was defined as the angle difference between postoperative and preoperative CT images (*Figure 1*).

Three-dimensional (3D) reconstruction of chest CT

Reconstruction of 3D chest CT images was performed using a reconstruction program (Lung Quest™, SuperDimension, Inc., Minneapolis, MN, USA) to analyze changes in bronchial diameter and angle more precisely. The same chest CT images we used to measure change in angle were used in analysis. Not all CT images could be reconstructed into 3D images because of the lack of digital information necessary for this program. Chest CT images of 27 patients who underwent right upper lobectomy (19 in the division group and 8 in the preservation group) and 19 who underwent left upper lobectomies (8 in the division group and 11 in the preservation group) were reconstructed and included in

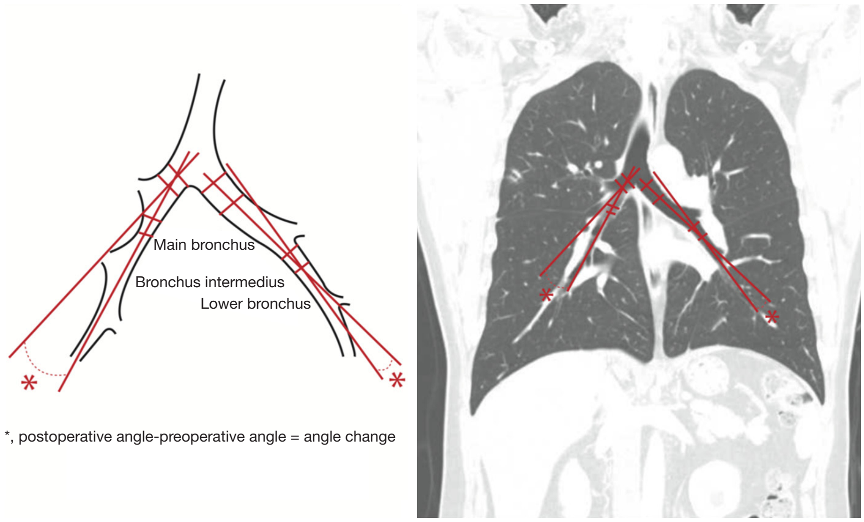

Figure 1 Assessment of measured change in bronchial angle. We adopted the same methods as used in Matsuoka's study to measure change in bronchial angle and diameter on three-dimensional reconstruction images.

Figure 2 Computed tomography-based three-dimensional reconstruction images on the coronal and transverse planes. (A) Three-dimensional reconstruction images of the bronchus after right upper lobectomy; (B) three-dimensional reconstruction images of the bronchus after left upper lobectomy. Measurement of change in bronchial diameter and angle on three-dimensional images was based on the methods used in Matsuoka's study.

analysis. Changes in the diameter of remnant bronchus were measured. Changes in the angle between the main bronchus and the remaining lobar bronchus were measured on coronal and sagittal views (*Figure 2*).

Statistical analysis

We used χ^2 and Fisher's exact test to assess differences in categorical variables. Unpaired Student's *t*-test and the Mann-Whitney test were used for discrete and continuous

Table 1 Patient and operative characteristics

Variable	Division group (N=43)	Preservation group (N=29)	P value
Age	63.8±8.9	65.0±10.0	0.41
Sex			0.31
Male	23	19	
Female	20	10	
Smoking			0.95
Never-smoker	25	17	
Ex-smoker	13	8	
Current smoker	5	5	
Histology			0.28
Squamous	6	6	
Adenocarcinoma	34	23	
Other	3	0	
Pathologic stage			1.00
I	33	23	
II	5	3	
III	4	3	
IV	1	0	
OP side			0.04
Right	27	11	
Left	16	18	
MLD			0.99
Yes	37	25	
No	6	4	

OP, operation; MLD, mediastinal lymph node dissection.

variables. Statistical significance was defined as P values less than 0.05. All statistical analyses were performed using IBM SPSS 20.0 software (IBM Co., Chicago, IL, USA).

Results

Patient and operative characteristics

The mean age of patients was 64.5±9.32 years (range, 35 to 81 years). No significant differences were found between the division and preservation groups in age, sex, smoking history, pathology or staging. Patient characteristics are summarized in *Table 1*.

Pleural effusion

Chest tube duration, duration of chest tube drainage >200 mL, and presence of pleural effusion on follow-up chest X-ray taken 1 month after surgery was not significantly different between the division group and the preservation group (P=0.07, 0.33 and 1.00, respectively). Patients who underwent right and left upper lobectomy did not show significant differences in chest tube duration, duration of chest tube drainage >200 mL, or pleural effusion on postoperative chest X-rays (*Table 2*).

Expansion of the remaining lung

The presence of apical dead space was evaluated on chest X-rays taken one month after surgery and was observed in 11 patients, but there was no significant difference between division and preservation groups (6 and 5 patients, respectively, P=0.22). Right and left upper lobectomy groups also showed similar apical dead space presence (right, division group: 4, preservation group: 3, P=0.39) (left, division group: 2, preservation group: 2, P=1.00) (*Table 2*).

Change in bronchial angle in chest X-rays

Bronchial angle change in the division group was 64.1±17.1° and that in the preservation group was 65.4±24.0°, with no significant difference between the groups (P=0.74). In right upper lobectomy patients, the change in bronchial angle in the division group was 65.4±16.4° and that in the preservation group was 59.1±18.0°, with no significant difference between groups (P=0.31). In left upper lobectomy patients, the change in bronchial angle in the division group was 59.4±23.6° and that in the preservation group was 71.2±22.7°, with no significant difference between groups (P=0.15) (*Table 3*).

Change in bronchial diameter and angle in 3D reconstruction images

No significant differences were found between the division and preservation groups in RML and LLL bronchial diameter change (P=0.72 and 0.12, respectively). There were also no significant differences in the change in the left main bronchus and left lower lobar (LLL) bronchus angle (0.90 on the coronal view and 0.94 on the sagittal view). Changes in right main bronchus and bronchus intermedius angle were not significantly different in the coronal or transverse plane (P=0.31 and 0.80, respectively); however, there were significant differences in the change in the

Table 2 Comparison of indicators of pleural effusion and apical dead space after VATS upper lobectomy

Variables	Division group (all=43; right=27; left=16)	Preservation group (all=29; right=11; left=18)	P value
All			
Chest tube duration (days)	3.63±1.96	2.76±1.41	0.07
Chest tube drainage >200 mL (days)	2.30±1.25	2.03±0.99	0.33
Pleural effusion (on chest X-ray)			1
Yes	2	1	
No	41	28	
Dead space			0.22
Yes	6	5	
No	37	24	
Right upper lobectomy			
Chest tube duration (days)	3.48±1.81	3.00±1.27	0.43
Chest tube drainage >200 mL (days)	2.30±1.33	2.27±1.35	0.96
Pleural effusion (on chest X-ray)			1
Yes	2	0	
No	25	11	
Dead space			0.39
Yes	4	3	
No	23	8	
Left upper lobectomy			
Chest tube duration (days)	3.81±2.56	2.67±0.97	0.42
Chest tube drainage >200 mL (days)	2.00±0.82	2.17±1.00	0.61
Pleural effusion (on chest X-ray)			1
Yes	0	1	
No	16	17	
Dead space			1
Yes	2	2	
No	14	16	

VATS, video-assisted thoracic surgery.

Table 3 Comparison of bronchial angle change after VATS upper lobectomy

Variables	Division group [N]	Preservation group [N]	P value
All	64.0±17.1 [43]	65.4±24.0 [29]	0.74
Right upper lobectomy	65.4±16.4 [27]	59.1±18.0 [11]	0.31
Left upper lobectomy	59.4±23.6 [16]	71.2±22.7 [18]	0.15

VATS, video-assisted thoracic surgery.

bronchus intermedius and remnant lobar bronchi angle [P=0.02 for the right middle lobar (RML) bronchus and P=0.046 for the right lower lobar (RLL) bronchus]. The results are summarized in *Tables 4,5*.

Discussion

Although major pulmonary resection is essential for lung cancer cure, sometimes it causes inevitable complications

Table 4 Change in bronchial diameter

Variables	Division group mean ± SD [N]	Preservation group mean ± SD [N]	P value
Change in RML bronchus	2.03±1.19 [19]	2.21±1.18 [8]	0.72
Change in RLL bronchus	1.35±1.51 [19]	2.44±1.85 [8]	0.12
Change in LLL bronchus	1.58±0.80 [8]	2.01±0.90 [11]	0.29

The diameter of the right middle, right lower and LLL bronchus on three-dimensional reconstruction images from pre- and postoperative chest CT scan images were measured and the difference was calculated. Comparison of diameter change between the division and preservation groups was performed using the student's *t*-test. A significance level below 0.05 was considered significantly different. RML, right middle lobar; RLL, right lower lobar; LLL, left lower lobar; SD, standard deviation.

Table 5 Changes in bronchial angles measured in three-dimensional reconstruction images

Variables	Division group mean ± SD (right=19; left=8)	Preservation group mean ± SD (right=8; left=11)	P value
Right upper lobectomy			
Coronal plane			
Δ Trachea-Rt. main bronchus	23.2±24.93	11.4±7.27	0.26
Δ Rt. main bronchus-RBI	25.0±24.11	13.7±11.1	0.31
Δ RBI-RML bronchus	21.4±24.82	25.5±19.71	0.67
Δ RBI-RLL bronchus	24.0±15.7	19.4±17.16	0.56
Transverse plane			
Δ Trachea-Rt. main bronchus	16.7±14.19	19.6±11.58	0.61
Δ Rt. main bronchus-RBI	20.0±18.57	22.5±21.17	0.80
Δ RBI-RML bronchus	24.3±13.44	10.1±7.06	0.02
Δ RBI-RLL bronchus	30.2±25.51	7.8±21.43	0.05
Left upper lobectomy			
Coronal plane			
Δ Trachea-Lt. main bronchus	11.1±8.72	10.0±6.83	0.78
Δ Lt. main bronchus-LLL bronchus	27.0±16.27	25.9±20.37	0.90
Transverse plane			
Δ Trachea-Lt. main bronchus	19.1±12.73	13.5±18.34	0.44
Δ Lt. main bronchus-LLL bronchus	20.1±15.32	20.7±18.53	0.94

Chest CT images were reconstructed into three-dimensional images in two ways, coronal and transverse planes. Changes in bronchial angles between RBI and RML bronchus, between RBI and RLL bronchus in transverse plane showed statistically significant differences in comparison of division and preservation groups (P=0.023 and 0.046 respectively). SD, standard deviation; Δ, changes between; Rt., right; RBI, right bronchus intermedius; RML, right middle lobar; RLL, right lower lobar; Lt., left; LLL, left lower lobar.

resulting from reduced lung volumes. Division of the inferior pulmonary ligament during upper lobectomy has been performed based on the belief that it can prevent complications caused by free space such as pleural effusion, empyema, and dead spaces (1,2).

However, some surgeons suspect that this procedure could lead to postoperative complications with poor or even fatal outcomes (1,3,4), including bronchial stenosis and bronchial obstruction, resulting from kinking of the bronchus (1,3). The inferior pulmonary ligament may secure the lower lobes; therefore, preservation of this structure could prevent upward displacement of the remaining lower lobe following upper lobectomy, which otherwise could lead bronchial kinking, bronchial stenosis or bronchial obstruction (6).

Decisions regarding inferior pulmonary ligament division tend to be largely based on physician experience because of the lack of research-based evidence. Surgeons who are in favor of this procedure think that it can prevent the formation of apical dead space and pooling of pleural effusion. However, Matsuoka *et al*. (2) reported that division of the inferior pulmonary ligament does not significantly decrease the dead space ratio on chest X-ray in either right or left upper lobectomy. Our study showed similar results. We compared the presence of apical dead space in chest X-rays taken one month after surgery, and found no significant difference between the division group and the preservation group in both right and left upper lobectomy.

There have been no studies to date that have reported the preventative effects of inferior pulmonary ligament division on the pooling of pleural effusion. In our study, we examined chest tube duration, duration of chest tube drainage >200 mL and the presence of pleural effusion on postoperative chest X-rays to evaluate the pooling of pleural effusion. We found no significant difference in these aspects between the division and preservation groups. Looking at all patients, chest tube duration was longer in the division group, but this difference was not statistically significant. This may be due to our hospital's recent practice of performing earlier pleurodesis for postoperative air leakage, as the duration of chest tube placement is determined not only by the amount of drainage, but also by the presence of air leakage. Therefore, we believe that the duration of chest tube drainage >200 mL is more important than chest tube duration when analyzing pooling of pleural effusion.

Surgeons who prefer to preserve the inferior pulmonary ligament think that this is an effective method of preventing complications such as bronchial stenosis and bronchial obstruction related to kinking rotation of the remaining bronchi after ligament division. Preservation of the inferior pulmonary ligament may also suppress upward deviation of the remaining lobe (1). In our study, we measured the angle between the main bronchus and the remaining bronchus (6). The advantage of this method is that it is a simple and quick method of measurement on chest CT. However, a limitation of this method is that it cannot confirm whether actual bronchial stenosis or obstruction has occurred. Nevertheless, a key cause of bronchial stenosis and obstruction is excessive bronchial kinking, so the measurement of bronchial angulation could be relevant.

When we measured changes in bronchial angles using the same methods used in Matsuoka's study; we did not find any significant differences between the division and preservation groups. This might be due to the fact that the degree of bronchial angulation is affected not only by division of the inferior pulmonary ligament, but also by hilar release from lymph node dissection (1,7).

We found significant differences in the change in bronchus intermedius and remnant right lobe angle when we reconstructed chest CT images into 3D images. The changes in bronchus intermedius and RML bronchus angle and in bronchus intermedius and RLL bronchus angle were significantly different between the division and preservation groups when measured in the transverse plane. This finding may suggest that inferior pulmonary ligament division could cause displacement of remnant bronchus, thus leading to bronchial kinking or stenosis.

There are some limitations to this study. First, this study is a retrospective study with a small number of subjects. Second, we did not compare the apical dead space ratio, but, rather, the existence of apical dead space. We may have observed significant differences between groups if we analyzed the apical dead space ratio. However, when calculating the apical dead space ratio it is important that chest X-rays are taken at the exact end of inspiration, and inconsistencies may lead to variation between individuals (8). Other factors such as postoperative pain can limit full inspiration, so we believe that analysis of the presence of apical dead space is a suitable alternative. Finally, although we performed 3D reconstruction using chest CT data, this could not be achieved for all patients. Some chest CT data could not be reconstructed in 3D form, due to a lack of sufficient data necessary for reconstruction.

We detected a possible association between complications caused by bronchial over-dislocation and inferior pulmonary ligament division in upper lobectomy. Because some loss of pulmonary function is inevitable during the treatment of lung cancer, careful consideration of surgical details such as inferior pulmonary ligament division is needed to avoid additional functional loss (9).

The limitation of this study is that it is retrospective research, and that the division of inferior pulmonary ligament was performed at the surgeon's own decision. We have no exact standard for the division or preservation of inferior pulmonary ligament. Therefore, there might exist selection bias for the decision whether preservation or not. More precisely designed randomized controlled trials should be proceeded to demonstrate more accurate relationship between the complications and the division of inferior pulmonary ligaments.

Conclusions

In conclusion, there is no evidence of advantages of inferior pulmonary ligament division. Rather, we discovered an association between this procedure and excessive dislocation of remnant bronchi. The potential disadvantages of division of the inferior pulmonary ligament during upper lobectomy in lung cancer patients should be carefully considered.

Acknowledgements

Funding: This work was supported by Research Fund of Seoul National University College of Medicine Education Research Foundation (grant number: 800-20130174).

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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Cite this article as: Seok Y, Yi E, Cho S, Jheon S, Kim K. Perioperative outcomes of upper lobectomy according to preservation or division of the inferior pulmonary ligament. J Thorac Dis 2015;7(11):2033-2040. doi: 10.3978/j.issn.2072-1439.2015.11.41