Video-Assisted Thoracic Surgery Lobectomy: Single Institutional Experience With 704 Cases

Kwhanmien Kim, MD, PhD, Hong Kwan Kim, MD, Joon Suk Park, MD, Sung Wook Chang, MD, Yong Soo Choi, MD, PhD, Jhingook Kim, MD, PhD, and Young Mog Shim, MD, PhD

Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea

Background. **During the past decade, video-assisted thoracic surgery (VATS) lobectomy has been performed with increasing frequency in patients with early-stage non–small cell lung cancer (NSCLC). However, questions remain as to whether VATS lobectomy reduces local recurrence and improves long-term survival in patients with NSCLC.**

Methods. **We retrospectively reviewed short-term and midterm outcomes, including postoperative morbidity, mortality, recurrence rate, and survival, in patients undergoing VATS lobectomy.**

Results. **Between 2003 and 2008, 704 patients underwent VATS lobectomy for the following indications: NSCLC (n = 548), carcinoid tumors (n = 7), pulmonary metastases (n = 22), and benign diseases (n = 127). One hundred eleven of 548 clinical stage I NSCLC patients (20.3%) experienced pathologic upstaging postoperatively. There were 9 in-hospital deaths (1.3%); all of these patients died of acute respiratory distress syndrome. Sixty-four patients experienced postoperative complications (9.1%). The median follow-up was 20 months for patients with NSCLC. During follow-up, 54 patients had a recurrence, and 13 patients died. Disease-free survival for patients with pathologic stage I disease was 92.7% at 1 year and 87.6% at 3 years. For patients with pathologic N1 (n = 55) and N2 diseases (n = 41), disease-free survival at 3 years was 79.3% and 57.1%, respectively.**

Conclusions. **Video-assisted thoracoscopic surgery lobectomy is a technically feasible and safe operation with excellent survival for early-stage lung cancer. For patients with pathologic N1 or N2 diseases after VATS lobectomy, survival was not compromised by this minimally invasive approach.**

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During the past decade, video-assisted thoracic surgery (VATS) lobectomy has been performed with increasing frequency [1–12]. The Cancer and Leukemia Group B (CALGB) 39802 prospective, multiinstitutional study evaluated the technical feasibility and safety of VATS lobectomy for the treatment of early-stage non–small cell lung cancer (NSCLC) and revealed that the procedure can be performed with low morbidity and mortality rates [13]. A recent meta-analysis of randomized and nonrandomized trials investigating the safety and efficacy of VATS lobectomy demonstrated that VATS lobectomy is an appropriate procedure for select patients with early-stage NSCLC when compared with open surgery [14]. However, some thoracic surgeons have questioned whether VATS lobectomy reduces local disease recurrence and improves long-term survival in patients with NSCLC [15–17]. Therefore, more evidence supporting the oncologic efficacy of VATS lobectomy in patients with NSCLC needs to be accumulated to gain widespread acceptance of this procedure in clinical practice.

We have performed VATS lobectomy for patients with early-stage NSCLC as well as benign lung diseases at our institution. The objectives of this study were to (1) report our experience regarding the safety and feasibility of VATS lobectomy and (2) evaluate whether this technique is oncologically effective in patients with NSCLC, focusing on disease recurrence and midterm survival.

Patients and Methods

Medical records were retrospectively reviewed from a cohort of 704 consecutive patients who underwent VATS lobectomy at Samsung Medical Center between December 2003 and December 2008. This study was reviewed and approved by the Institutional Review Board of Samsung Medical Center. As long as lesions were amenable to anatomic resection and patients were anticipated to be able to tolerate single-lung ventilation, as determined by preoperative pulmonary function tests, we have applied VATS lobectomy to various pulmonary diseases, including primary lung cancer, pulmonary metastases, carci-

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Address correspondence to Dr K. Kim, Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, 50 Ilwon-dong, Gangnam-gu, Seoul, 135–710, Korea; e-mail: kmkim0070@skku.edu.

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noid tumors, and benign lung diseases such as pulmonary tuberculosis, aspergilloma, bronchiectasis, and congenital lung diseases.

Under single-lung anesthesia, VATS lobectomy was performed using two ports and a utility incision without rib spreading. A 15-mm trocar for the 10-mm, 30-degree thoracoscope was placed through the seventh or eighth intercostal space in the posterior axillary line. A 4-cm utility incision was made through the fourth or fifth intercostal space in the anterior axillary line. An additional 5-mm trocar was placed through the sixth or seventh intercostal space in the posterior scapular line. The vessels and bronchi of the target lobe were individually dissected. For patients with NSCLC, a systematic lymph node dissection was mandatory. All specimens were placed into an impermeable bag and removed through the utility incision.

For benign lung diseases, lobectomy was planned only when sublobar resection was considered difficult owing to nearly total destruction of the pulmonary parenchyma or close proximity of the lesions to the central bronchovascular structure. When preoperative computed tomography (CT) findings revealed a definite pleural calcification, tight calcification stuck to the pulmonary vessel, thoracic cage deformity, or decreased volume of the ipsilateral lung, this implied severely dense adhesion, and VATS lobectomy was not attempted for those patients.

For NSCLC, candidates for VATS lobectomy were patients with clinical stage I disease, peripherally located lesions (no endobronchial lesions), and a tumor 6 cm or smaller. The preoperative workup for patients with NSCLC included pulmonary function tests, CT scans, and integrated positron emission tomography and CT (PET/CT) scans. For patients with preoperatively proven NSCLC, cervical mediastinoscopy was routinely performed regardless of the findings of CT or PET/CT scans. Mediastinal lymph node dissection consisted of en bloc resections of all nodes at stations 2R, 4R, 7, 8, 9, and 10R for right-sided tumors and nodes at stations 4L, 5, 6, 7, 8, 9, and 10L for left-sided tumors. For patients who experienced pathologic upstaging postoperatively, adjuvant chemotherapy or radiotherapy was performed. Patients undergoing surgery were regularly evaluated by CT every 3 to 4 months for the first 2 years after surgery, and then every 6 months thereafter.

Descriptive statistics were used to describe the patients' demographic characteristics and outcomes. Normally distributed continuous data were expressed as mean ± standard deviation. Categorical data were expressed as count and proportion. Student's *t* test and the χ^2 test or Fisher's exact test were used to compare continuous and categorical variables, respectively. Overall survival (OS) was defined as the time from the date of surgery until the last date of follow-up for patients who remained alive or until death. Disease-free survival (DFS) was defined as the time from the date of surgery to recurrence or death. Survival curves were prepared using the Kaplan-Meier method and were compared univariately using the log-rank test. All statistical tests were two-sided with a significance level set at 0.05 and were performed using Stata software version 10.0 (StataCorp LP, College Station, TX).

Table 1. Reasons for Conversion to Thoracotomy

Reason	NSCLC	Benign Diseases	Total
Calcified LN around the bronchus	11	2	13
Bleeding of a PA branch	8	2	10
Incomplete fissure	4	3	7
Cancer involvement of the LN	2	NA	2
Cancer involvement of the hilum	1	NA	1
Pleural adhesions	1	1	2
Mainstem bronchus injury	1	0	1

LN = lymph nodes; NA = not applicable; NSCLC = non-small cell lung cancer; PA = pulmonary artery.

Results

Between December 2003 and December 2008, VATS lobectomy was attempted in 740 patients at our institution; the procedure was converted to a thoracotomy in 36 patients (4.9%; Table 1). Accordingly, VATS lobectomy was successfully performed in 704 patients (344 men and 360 women) for the following indications: NSCLC (n = 548), carcinoid tumor (n = 7), pulmonary metastases (n = 22), and benign diseases (n = 127). The pathologic diagnoses are summarized in Table 2. The mean age was 57 years (range, 12 to 86 years) with 105 patients age 70 years or older. For NSCLC, 1,366 patients with clinical stage I NSCLC underwent curative-intent surgery between December 2003 and December 2008. Of those, VATS lobectomy was attempted in 576 patients and open lobectomy in 790 patients. Of 576 patients in whom VATS lobectomy was tried, the procedure was converted to a thoracotomy in 28 patients (4.9%). The pathologic staging for patients with NSCLC is listed in Table 3. One hundred eleven of 548 clinical stage I NSCLC patients (20.3%) experienced pathologic upstaging postoperatively. The median duration of chest tube placement was 4 days (range, 1 to 59 days). The median length of hospital stay was 6 days (range, 2 to 102 days).

There were 9 postoperative deaths (1.3%). All of these patients underwent VATS lobectomy for NSCLC. The cause of death was acute respiratory distress syndrome in all cases. Of these, 5 patients had a history of diffuse interstitial lung disease. Seventy-six complications occurred in 64 patients (9.1%; Table 4). The most common complication was prolonged air leak (n = 33). There were 15 episodes of acute respiratory distress syndrome, 5 episodes of atrial fibrillation, 2 episodes of bleeding, and 1 episode of myocardial infarction. Blood transfusions were administered in 22 patients (3.1%). Postoperatively, 121 patients received adjuvant chemotherapy (n = 94), radiotherapy (n = 9), or chemoradiation (n = 18). The median interval between discharge from surgery and the start of adjuvant treatment was 32 days. No patients

Table 2. Pathologic Diagnoses for Which 704 Patients Underwent Video-Assisted Thoracoscopic Surgery Lobectomy

Diagnosis	Number
Primary lung cancer	548 (77.8%)
Adenocarcinoma	435
Bronchioloalveolar carcinoma	26
Squamous cell carcinoma	48
Large cell carcinoma	12
Others	27
Carcinoid	7 (1.0%)
Pulmonary metastasis	22 (3.1%)
Inflammatory lung disease	83 (11.8%)
Pulmonary TB (MDR-TB)	16 (9)
NTM disease	7
Aspergilloma	22
Bronchiectasis	22
Abscess	6
Others	10
Congenital lung disease	23 (3.3%)
CCAM	10
Pulmonary sequestration	12
Others	1
Benign lung neoplasm	21 (3.0%)
Sclerosing hemangioma	6
Hamartoma	4
Leiomyoma	2
Others	9

CCAM = congenital cystic adenomatoid malformation; MDR-TB = multidrug-resistant tuberculosis; NTM = nontuberculous mycobacterial; TB = tuberculosis.

failed to complete the schedule owing to treatment-related toxicities or morbidities during adjuvant therapy.

Survival analyses were done for patients with NSCLC, and the median follow-up time was 20 months. During follow-up, 54 patients had a recurrence, and 13 patients died. The pattern of recurrence was locoregional in 15 patients, distant in 34, and both in 5 (Table 5). The location of locoregional recurrences was ipsilateral pleura in 7 patients, ipsilateral lung in 3, mediastinal lymph nodes in 3, hilar lymph nodes in 1, and stump in 1. Postoperatively, 55 patients and 41 patients were found to have pathologic N1 and N2 diseases, respectively. Among 55 patients with pathologic N1 disease, 35 underwent adjuvant chemotherapy (n = 30), radiotherapy (n = 2), or chemoradiation (n = 3). Of those, 7 patients had recurrences in the contralateral lung (n = 4), cervical or supraclavicular lymph nodes (n = 2), and ipsilateral pleura (n = 1). Among 41 patients with pathologic N2 disease, 29 underwent adjuvant chemotherapy (n = 11), radiotherapy (n = 3), or chemoradiation (n = 15). Of those, 10 patients had recurrences in distant organs (n = 4), hilar or mediastinal lymph nodes (n = 2), supraclavicular lymph nodes (n = 2), and ipsilateral pleura (n = 2). For patients with pathologic stage I disease, OS was 96.8% at 1 year and 94.8% at 3 years, and DFS was 92.7% at 1 year and 87.6% at 3 years. For patients who turned out to have pathologic N1 disease, OS was 98.1% at 1 year and 98.1% at 3 years, and DFS was 88.4% at 1 year and 79.3% at 3 years. For patients who turned out to have pathologic N2 disease, OS was 97.4% at 1 year and 97.4% at 3 years, and DFS was 81.7% at 1 year and 57.1% at 3 years. Operative survival and DFS were shown in Figures 1 and 2, respectively.

Table 4. Postoperative Complications

Complication	Number
Prolonged air leak	33[a]
Acute respiratory distress syndrome	15
Postoperative arrhythmia	7[b]
Chylothorax	7
Prolonged effusion	3
Vocal cord palsy	3
Postoperative bleeding	2
Acute myocardial infarction	1
Pneumonia	1
Empyema	1
Renal infarction	1
Delirium	1
Diaphragmatic hernia	1

[a] Of these, 30 patients required chemical pleurodesis. [b] Of these, 5 patients had atrial fibrillation.

Table 3. Pathologic Staging of the 548 Patients Who Underwent Video-Assisted Thoracoscopic Surgery Lobectomy for Non–Small Cell Lung Cancer

Stage	Number (%)
IA	248 (45.3%)
IB	188 (34.3%)
IIA	13 (2.4%)
IIB	44 (8.0%)
IIIA	38 (6.9%)
IIIB	12 (2.2%)
IV	5 (0.9%)

Table 5. The Pattern of Recurrence of the 548 Patients Who Underwent Video-Assisted Thoracoscopic Surgery Lobectomy for Non–Small Cell Lung Cancer According to Pathologic Stage

Pathologic Stage	Locoregional	Distant	Both
IA	4	8	. . .
IB	6	14	3
IIA	. . .	2	. . .
IIB	1	4	1
IIIA	2	8	1
IIIB	1	2	. . .
IV	. . .	1	. . .

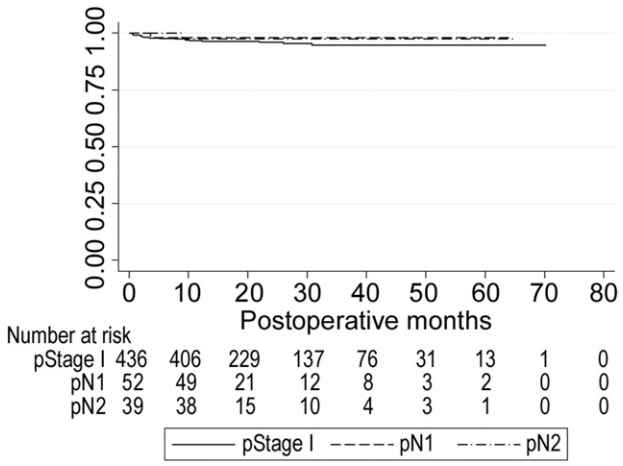

Fig 1. Overall survival of patients who underwent video-assisted thoracoscopic surgery lobectomy for non–small cell lung cancer.

Comment

Since the use of VATS for pulmonary lobectomy was first reported in 1992 [1], this minimally invasive procedure has been performed with increasing frequency [1–12]. Advocates of VATS lobectomy emphasize the benefit in terms of less tissue trauma, reduced cytokine release, decreased postoperative pain, lower complication rates, and shorter hospital stay. McKenna and colleagues [9] reported the largest single-institutional experience with 1,100 patients undergoing VATS lobectomy and suggested that VATS lobectomy can be performed with low morbidity and mortality rates. The CALGB 39802 prospective, multiinstitutional study evaluated the technical feasibility and safety of VATS lobectomy for early-stage NSCLC and demonstrated that the procedure is associated with a low complication rate and a short duration of chest tube placement [13]. A recent meta-analysis of randomized and nonrandomized trials evaluating the safety and efficacy of VATS lobectomy also demonstrated that VATS lobectomy may become a valid alternative to open surgery if performed in qualified centers [14].

Our results are comparable to those from previous reports. In our series, postoperative mortality and morbidity rates were 1.3% and 9.1%, respectively. We have performed 704 VATS lobectomies during a relatively short period at a single institution; this may have resulted in a relatively homogeneous quality of perioperative management. Furthermore, 18% of our patients underwent VATS lobectomy for inflammatory lung diseases such as pulmonary tuberculosis and aspergilloma. Given that severe pleural adhesions and calcified lymph nodes around the bronchus are usually encountered in such inflammatory diseases, our results may strengthen the assertion that VATS lobectomy can be safely performed with technical feasibility. In our experience, patients who had severely dense adhesion on CT scans were excluded from being candidates of VATS lobectomy for benign lung diseases. Therefore, even if there is a loose adhesion in the pleural cavity, it does not seem to be an obstacle to performing a VATS lobectomy as long as patients are carefully selected. Although the mortality rate in our series was quite low, all patients died of acute respiratory distress syndrome, and of those, 5 patients had a history of diffuse interstitial lung disease. This does not necessarily mean that these patients would have avoided serious complications if the lobectomy had been performed by means of a thoracotomy. In fact, open lobectomy may be safer if less time is required to accomplish the resection, thus diminishing the amount of time under general anesthesia. Therefore, special attention should be paid to such patients as they have a high risk of experiencing postoperative respiratory failure after VATS lobectomy.

Despite these favorable safety and feasibility outcomes, the adequacy of VATS lobectomy for oncologic control still needs to be proven compared with standard open lobectomy. Concerns about the possibility of procedure-related recurrence in VATS lobectomy when compared with open surgery may be related to the possibilities of cancer dissemination during VATS manipulation, leaving residual tumor at the resection margin, and performing an insufficient lymph node dissection [14–17]. However, the CALGB study demonstrated that the probability of failure-free survival was 91% at 1 year and 78% at 2 years for patients determined to have T1N0 NSCLC [13]. Furthermore, the recent meta-analysis demonstrated that VATS lobectomy is not inferior to open surgery based on similar locoregional recurrence rates and 5-year survival outcomes [14]. Also, in our series, DFS for patients with pathologic stage I disease was 92.7% at 1 year and 87.6% at 3 years. This suggests that survival outcomes after VATS lobectomy compare favorably with those for standard open lobectomy, at least at early follow-up times.

It is still controversial whether to convert VATS to open surgery when intraoperative frozen-section biopsy of lymph nodes is positive for malignancy. Watanabe and colleagues [18] reported the outcomes of patients with

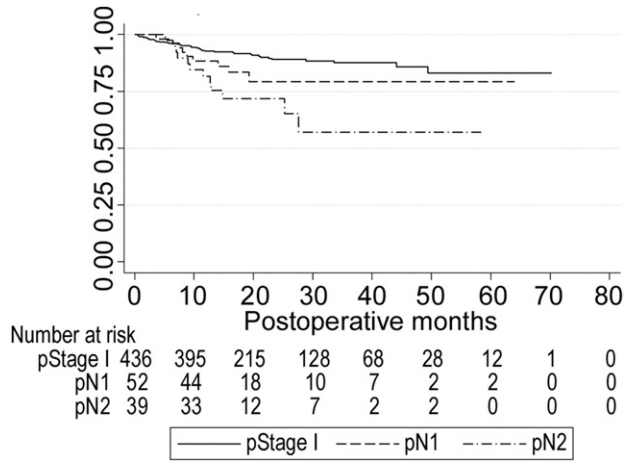

Fig 2. Disease-free survival of patients who underwent video-assisted thoracoscopic surgery lobectomy for non–small cell lung cancer.

clinical N0 and pathologic N2 NSCLC and compared the recurrence and survival rates between patients undergoing VATS lobectomy and open thoracotomy. In their study, there were no significant differences in recurrence-free survival rates between the two groups; they suggested that it is unnecessary to convert VATS to thoracotomy for systematic node dissection even if pathologic N2 disease is revealed during VATS lobectomy [18]. In the present study, pathologic upstaging occurred in approximately 20% of our patients. Likewise, even for patients who had pathologic N2 disease, DFS was 81.7% at 1 year and 57.1% at 3 years. These survival rates appear to be quite favorable considering the presence of pathologic N2 disease. This may be related to the fact that we routinely perform PET/CT scans and cervical mediastinoscopies for accurate staging at our institution. As VATS lobectomy was performed in selected patients who were staged clinically as N0 on PET/CT or mediastinoscopy, unexpected N2 disease was likely to represent microscopic involvement of lymph nodes. Therefore, even for patients who turned out to have pathologic N2 disease after VATS lobectomy, survival did not appear to be compromised by a minimally invasive approach. As long as mediastinal lymph node dissection can be performed as completely as in open surgery, we suggest that when intraoperative frozen-section biopsy of the mediastinal lymph nodes is positive for malignancy during VATS lobectomy, there is no need to convert to conventional thoracotomy.

Our study has several limitations. Because this is a retrospective and noncomparative study, our results should be interpreted with caution. Prospective randomized trials are required for more conclusive results. We chose to perform VATS lobectomy in selected patients with favorable prognostic characteristics. This may have predisposed the study population undergoing VATS lobectomy to experience favorable outcomes compared with those undergoing open surgery. It should also be noted that patients who were converted to open surgery during VATS lobectomy were not included in this study. For these reasons, this study is subject to selection bias. Also, the follow-up duration was relatively short, making it difficult to conclude whether recurrence-free survival rates were truly favorable for patients undergoing VATS lobectomy. Considering that most recurrences occur in the early stages of follow-up, especially within the first 2 years, the oncologic equivalence of the VATS lobectomy may not be durable owing to the short follow-up duration of our study. Further studies are needed to confirm the current results.

In summary, our results suggest that VATS lobectomy is technically feasible and safe with low postoperative morbidity and mortality. For patients with early-stage NSCLC, VATS lobectomy is an appropriate procedure in terms of local control of cancer and survival. Even for patients who underwent VATS lobectomy and had pathologic N2 disease, survival was comparable with that of open surgery in the literature. From these findings, we suggest that when intraoperative frozen-section biopsy of the mediastinal lymph nodes is shown to be positive for malignancy during VATS lobectomy, there is no need to convert to conventional thoracotomy.

References

1. Lewis RJ, Caccavale RJ, Sisler GE, Mackenzie JW. Video-assisted thoracic surgical resection of malignant lung tumors. J Thorac Cardiovasc Surg 1992;104:1679–85.
2. Lewis RJ, Caccavale RJ, Bocage JP, Widmann MD. Video-assisted thoracic surgical non-rib spreading simultaneously stapled lobectomy: a more patient-friendly oncologic resection. Chest 1999;116:1119–24.
3. Kirby TJ, Mack MJ, Landreneau RJ, Rice TW. Lobectomy: video-assisted thoracic surgery versus muscle-sparing thoracotomy-a randomized trial. J Thorac Cardiovasc Surg 1995;109:997–1001.
4. Sugi K, Kaneda Y, Esato K. Video-assisted thoracoscopic lobectomy achieves a satisfactory long-term prognosis in patients with clinical stage IA lung cancer. World J Surg 2000;24:27–30.
5. Yim AP, Wan S, Lee TW, Arifi AA. VATS lobectomy reduces cytokine responses compared with conventional surgery. Ann Thorac Surg 2000;70:243–7.
6. Nomori H, Horio H, Naruke T, Suemasu K. What is the advantage of a thoracoscopic lobectomy over a limited thoracotomy procedure for lung cancer surgery? Ann Thorac Surg 2001;72:879–84.
7. Nagahiro I, Andou A, Aoe M, Sano Y, Date H, Shimizu N. Pulmonary function, postoperative pain, and serum cytokine level after lobectomy: a comparison of VATS and conventional procedure. Ann Thorac Surg 2001;72:362–5.
8. Shigemura N, Akashi A, Funaki S, et al. Long-term outcomes after a variety of video-assisted thoracoscopic lobectomy approaches for clinical stage IA lung cancer: a multi-institutional study. J Thorac Cardiovasc Surg 2006;132:507–12.
9. McKenna RJ Jr, Houck W, Fuller CB. Video-assisted thoracic surgery lobectomy: experience with 1,100 cases. Ann Thorac Surg 2006;81:421–6.
10. Shiraishi T, Shirakusa T, Hiratsuka M, Yamamoto S, Iwasaki A. Video-assisted thoracoscopic surgery lobectomy for c-T1N0M0 primary lung cancer: its impact on locoregional control. Ann Thorac Surg 2006;82:1021–6.
11. Petersen RP, Pham D, Burfeind WR, et al. Thoracoscopic lobectomy facilitates the delivery of chemotherapy after resection for lung cancer. Ann Thorac Surg 2007;83:1245–9.
12. Whitson BA, Andrade RS, Boettcher A, et al. Video-assisted thoracoscopic surgery is more favorable than thoracotomy for resection of clinical stage I non-small cell lung cancer. Ann Thorac Surg 2007;83:1965–70.
13. Swanson SJ, Herndon JE 2nd, D'Amico TA, et al. Video-assisted thoracic surgery lobectomy: report of CALGB 39802-A prospective, multi-institution feasibility study. J Clin Oncol 2007;25:4993–7.
14. Yan TD, Black D, Bannon PG, McCaughan BC. Systematic review and meta-analysis of randomized and nonrandomized trials on safety and efficacy of video-assisted thoracic surgery lobectomy for early-stage non-small-cell lung cancer. J Clin Oncol 2009;27:2553–62.
15. Fry WA, Siddiqui A, Pensler JM, Mastafavi H. Thoracoscopic implantation of cancer with a fatal outcome. Ann Thorac Surg 1995;59:42–5.
16. Jancovici R, Lang-Lazdunski L, Pons F, et al. Complications of video-assisted thoracic surgery: a five-year experience. Ann Thorac Surg 1996;61:533–7.
17. Yamashita J, Kurusu Y, Fujino N, Saisyoji T, Ogawa M. Detection of circulating tumor cells in patients with non-small cell lung cancer undergoing lobectomy by video-assisted thoracic surgery: a potential hazard for intraoperative hematogenous tumor cell dissemination. J Thorac Cardiovasc Surg 2000;119:899–905.
18. Watanabe A, Mishina T, Ohori S, et al. Is video-assisted thoracoscopic surgery a feasible approach for clinical N0 and postoperatively pathological N2 non-small cell lung cancer? Eur J Cardiothorac Surg 2008;33:812–8.