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Escalated grades of complications correlate with incremental costs of video-assisted thoracoscopic surgery major lung resection for lung cancer in China

Ke Lan | Jian Zhou | Xizhao Sui | Jun Wang | Fan Yang

Department of Thoracic Surgery, Peking University People's Hospital, Beijing, China

Correspondence
Fan Yang, Department of Thoracic Surgery, Peking University People's Hospital, No. 11 Xizhimen South Street, Xicheng District, Beijing 100044, China.
Email: yangfan@pkuph.edu.cn

Abstract

Objective: Few studies have focused on factors associated with the incremental cost of video-assisted thoracoscopic surgery (VATS) in China. We aim to systematically classify the complications after VATS major lung resection and explore their correlation with hospital costs.

Methods: Patients with pathologically stage I–III lung cancer who underwent VATS major lung resections from January 2007 to December 2018 were included. The Thoracic Mortality and Morbidity (TM&M) Classification system was used to evaluate postoperative complications. Grade I and II complications, defined as minor complications, require no therapy or pharmacologic intervention only. Grade III and IV complications, defined as major complications, require surgical intervention or life support. Grade V results in death. A generalized linear model was used to explore the correlation of incremental hospital costs and complications, as well as other clinicopathologic parameters between 2013 and 2016.

Results: A total of 2881 patients were enrolled in the first part, and the minor and major complications rates were 24.3% (703 patients) and 8.3% (228 patients), respectively. Six hundred and eighty-two patients were enrolled in the second part. The complications grade II (odds ratio [OR] 1.12, 95% confidence interval [CI] 1.05–1.2, $p = 0.0005$), grade III (OR 1.55, 95% CI 1.26–1.9, $p < 0.0001$), grades IV and V (OR 1.09, 95% CI 1.04–1.13, $p = 0.0002$), diffusion capacity of carbon dioxide (OR 0.998, 95% CI 0.997–1.000, $p = 0.004$), and duration of chest drainage (OR 1.03, 95% CI 1.02–1.04, $p < 0.001$) and were independent risk factors for the increase in in-hospital costs of VATS major lung resections.

Conclusions: The severity of complications graded by the TM&M system was an independent risk factor for increased in-hospital costs.

KEYWORDS
complications, cost, lung cancer, video-assisted thoracoscopy surgery

INTRODUCTION

Lung cancer resection performed via video-assisted thoracoscopy surgery (VATS) has been consistently demonstrated to lead to enhanced recovery associated with fewer complications and shorter length of hospital stay compared with traditional open thoracotomy lung resections.[1–3] Economic analyses have also determined that post-discharge and in-hospital costs are lower after VATS than after open thoracotomy lung resections.[4]

Few studies have documented the cost impact of graded complications following VATS major lung resections, both major and minor, over a 90-day postoperative interval. However, to date, there is a lack of data quantifying factors associated with the incremental costs of VATS in China.

The purpose of the present study was to systematically quantify the incidence of commonly encountered complications following the most common operation for lung cancer, and to estimate the relative incremental direct hospital costs of graded

complications. To our knowledge, this is the largest single-center complications report of VATS for Chinese lung cancer patients, and we improved our understanding of the detailed cost implications of surgical complications after major lung resections. These data have the potential to be very useful for Chinese physicians, administors, and policy-makers who wish to understand the economic effect of perioperative complications better. Specifically, this analysis may help identify future areas of improvement efforts to optimize patient outcomes and target specific complications for cost reduction.

METHODS

Study population and clinical data collection

We retrospectively reviewed the electronic medical records of all patients with stage I–III lung cancer who underwent VATS lobectomy, VATS bilobectomy, VATS sleeve lobectomy, or VATS pneumonectomy at Peking University People's Hospital from 2007 to 2018 (January 2007 to December 2018). We also collected in-hospital cost data for all former operations performed between 2013 and 2016 (January 2013 to December 2016). VATS major lung resections that were converted to open thoracotomy or wedge resections were excluded. Approval for this study was obtained from the Institutional Review Board of Peking University People's Hospital, which exempted the study from the typical requirement for informed consent given the nature of the study. Although our analysis was performed from a hospital costs perspective, in a setting of limited societal resources, the hospital perspective clearly has implications for Chinese society as a whole.

We collected demographic information and data on staging (American Joint Committee on Cancer Staging Manual, 8th edition), preoperative comorbidities, pulmonary function tests, operative variables, and postoperative outcomes.

The Thoracic Mortality and Morbidity (TM&M) Classification system[5] was used to grade the severity of complications, which summarized 42 complications in eight categories: pulmonary, pleural, anastomosis, cardiovascular, gastrointestinal tract, urinary tract, wound, and nervous system. According to the Claviden–Dindo classification system,[6] the TM&M system grades each postsurgical complication in a scale from I to V according to the complexity of its management. Grades I and II include minor complications requiring no therapy or pharmacologic intervention only. Grades III and IV are major complications that require surgical intervention or life support. Grade V complications result in postoperative death. In cases where a patient had multiple concurrent complications, the highest complications were considered.

Outcomes and end points

Outcomes measured in this study included the frequency of specific complications, the hospital costs of major versus

TABLE 1 Patient characteristics and perioperative outcomes (n = 2881)

Variable	Value
Gender, male	1470 (51.0)
Age, year	61.0 ± 10.1
BMI (kg/m^2)	24.48 ± 11.36
Smoker	1046 (36.3)
ASA score	
1	449 (15.6)
2	2289 (79.4)
3	141 (4.9)
4	2 (0.1)
CCI	
0	2215 (76.9)
1	487 (16.9)
2	143 (5.0)
≥3	5 (0.2)
Diameter of main lesion (cm)	2.46 ± 1.49
Lobe resected	
Right upper lobe	1001 (34.8)
Right middle lobe	271 (9.4)
Right lower lobe	571 (19.8)
Left upper lobe	597 (20.7)
Left lower lobe	441 (15.3)
FEV1, %	96.0 ± 17.5
DLCO, %	87.7 ± 28.5
Type of procedure	
Lobectomy	2761 (95.8)
Bilobectomy	64 (2.2)
Sleeve lobectomy	30 (1.0)
Pneumonectomy	26 (1.0)
Pathology	
Squamous cell	386 (13.4)
Adenocarcinoma	2311 (80.2)
Small cell	44 (1.5)
Others	140 (4.9)
Pathologic stage	
I	2020 (72.9)
II	319 (11.5)
III	432 (15.6)
Dissected nodal stations	6 (6–7)
Dissected lymph nodes	14 (10–19)
Operative time (min)	155 (130–190)
Blood loss (ml)	50 (30–100)
Duration of chest drainage	4 (3–6)
Length of stay (days)	12 (10–15)

Note: Values are mean ± SD or median (IQR) or *n* (%) unless otherwise noted.
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson comorbidity index; DLCO, diffusing capacity of carbon monoxide; FEV1, forced expiratory volume in 1 s; IQR, interquartile range; SD, standard deviation.

minor complications, and risk factors for the increase in in-hospital through generalized linear model analysis. In the analysis of costs, hospital billing department records were queried for total direct hospital costs, which were summarized for all encounters occurring in-hospital duration. This includes both fixed direct costs and variable direct costs. Fixed direct costs refer to the expenses arising from the use, depreciation, and rent of equipment or instruments. Variable costs refer to medical consumables, drugs, and service wages directly consumed in the provision of medical services. Indirect costs, usually involving the loss of resources due to disease, including wage loss caused by work suspension and death, were not included in the analysis. Complication frequency was assessed by dividing the cohort incidence of each complication by the total number of patients in the cohort.

Data analysis

Results are reported as means and standard deviation for numeric variables if they are normally distributed or median and interquartile range if not. Categorical variables are reported as frequency of occurrence. Because the in-hospital costs did not follow the normal distribution after testing for normality, a generalized linear model was used to explore the correlation of incremental in-hospital costs and complications, as well as other clinicopathologic parameters. The generalized linear model is an extension of the linear model, which establishes the relationship between the mathematical expectation of the dependent variable and the linear combination of predictive variables through the

connection function. When the dependent variable y does not satisfy the normal distribution, such as the Bernoulli distribution, multinomial distribution, Poisson distribution, gamma distribution, exponential distribution and β distribution, then, through a function (connection function) of the dependent variable y, a bridge is built between the result of linear prediction and the value of the dependent variable y to transform the nonlinear model into a linear model problem.[7] A p value less than 0.05 was considered to indicate statistical significance. All analyses were conducted in Excel (Microsoft), GraphPad Prism (GraphPad Software), or Stata software (StataCorp).

RESULTS

A total of 2881 patients were analyzed in the first part; demographic and clinicopathologic parameters, and pulmonary function test results of VATS patients are summarized in Table 1. For the cost analysis, to limit the impact of economic inflation and national health care reform, 682 patients from 2013 to 2016 were included to explore the correlation of incremental hospital costs and complications (see Figure 1).

Incidence of complications classified by the TM&M system

A total of 2881 patients with lung cancer were enrolled, the distribution of which is summarized in Table 2 and presented in Figure 2, including 1942 with no complications, 71 with
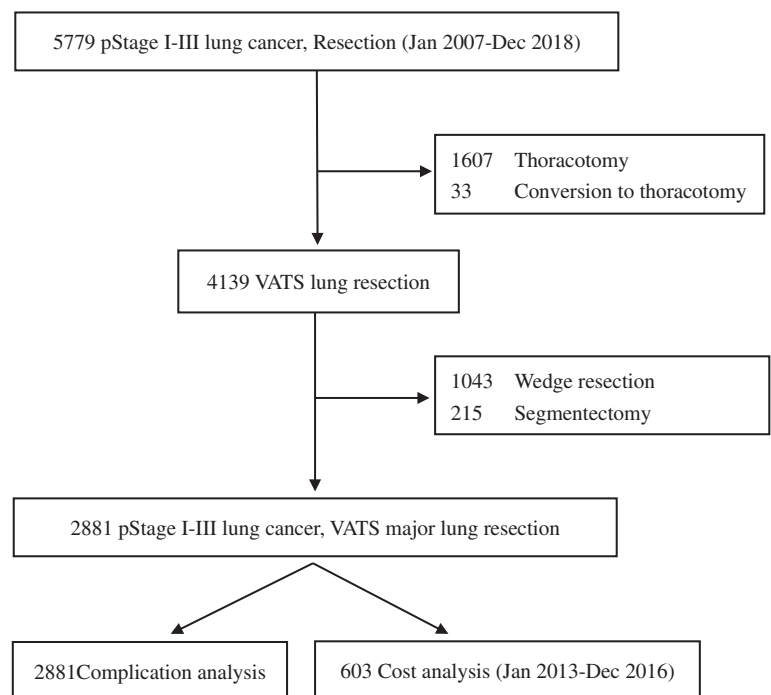

FIGURE 1 Flow diagram documenting the recruitment of patients with lung cancer

TABLE 2 Postoperative complications classified by the TM&M system

Complications	None (%)	Grade I (%)	Grade II (%)	Grade IIIa (%)	Grade IIIb (%)	Grade IVa (%)	Grade IVb (%)	Grade V (%)	All (%)
All procedures	1943 (67.44)	71 (2.46)	632 (21.94)	205 (7.12)	20 (0.69)	1 (0.03)	1 (0.03)	8 (0.28)	2881 (100)
Inflammatory lung injury	2879 (99.93)	0 (0)	0 (0)	1 (0.03)	0 (0)	0 (0)	1 (0.03)	0 (0.28)	2 (0.07)
Pneumonia	2851 (98.96)	0 (0)	23 (0.8)	4 (0.14)	0 (0)	1 (0.03)	0 (0)	2 (0.07)	30 (1.04)
Atelectasis	2857 (99.17)	0 (0)	5 (0.17)	18 (0.62)	1 (0.03)	0 (0)	0 (0)	0 (0)	24 (0.83)
Effusion	2865 (99.44)	7 (0.24)	4 (0.14)	5 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	16 (0.56)
Pneumothorax	2849 (98.89)	9 (0.31)	20 (0.69)	3 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	32 (1.11)
Subcutaneous emphysema	2776 (96.36)	51 (1.77)	18 (0.62)	36 (1.25)	0 (0)	0 (0)	0 (0)	0 (0)	105 (3.64)
Empyema	2880 (99.97)	0 (0)	0 (0)	1 (0.03)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)
Hemothorax	2867 (99.51)	0 (0)	7 (0.24)	0 (0)	6 (0.21)	0 (0)	0 (0)	1 (0.03)	14 (0.49)
Chylothorax	2813 (97.64)	0 (0)	52 (1.8)	8 (0.28)	8 (0.28)	0 (0)	0 (0)	0 (0)	68 (2.36)
Prolonged pleural drainage	2574 (89.34)	0 (0)	260 (9.02)	47 (1.63)	0 (0)	0 (0)	0 (0)	0 (0)	307 (10.66)
Prolonged alveolar air leak (>5 d)	2726 (94.62)	0 (0)	84 (2.92)	69 (2.4)	2 (0.07)	0 (0)	0 (0)	0 (0)	155 (5.38)
Bronchopleural fistula	2879 (99.93)	0 (0)	0 (0)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	2 (0.07)
Atrial fibrillation	2742 (95.18)	4 (0.14)	135 (4.69)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	139 (4.82)
Venous thrombosis	2879 (99.93)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)
Pulmonary embolism	2876 (99.83)	0 (0)	0 (0)	1 (0.03)	0 (0)	0 (0)	0 (0)	4 (0.14)	5 (0.17)
Myocardial ischemia	2880 (99.97)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)	1 (0.03)
Chronic heart failure	2879 (99.93)	0 (0)	1 (0.03)	1 (0.03)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)
Hypertension	2879 (99.93)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)
Urinary retention	2870 (99.62)	0 (0)	5 (0.17)	6 (0.21)	0 (0)	0 (0)	0 (0)	0 (0)	11 (0.38)
Urinary tract infection	2879 (99.93)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)
Gastrointestinal bleeding	2879 (99.93)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)
Ileus	2877 (99.86)	0 (0)	4 (0.14)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (0.14)
Delayed emptying	2878 (99.9)	0 (0)	1 (0.03)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	3 (0.1)
Hematoma	2880 (99.97)	0 (0)	1 (0.03)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)
Wound infection	2876 (99.83)	0 (0)	1 (0.03)	3 (0.1)	1 (0.03)	0 (0)	0 (0)	0 (0)	5 (0.17)
Confusion/delirium	2880 (99.97)	0 (0)	1 (0.03)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.03)
Cerebro-vascular accident	2879 (99.93)	0 (0)	2 (0.07)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.07)

Note: Values are n (%).

grade I complications, 632 with grade II, 225 with grade III, three with grade IV, and eight with grade V death. The major complication rate was 7.9% and the minor complication rate was 24.3%. Ninety-day mortality was eight out of 2881 (0.28%) patients. The most common complications were prolonged pleural drainage, prolonged alveolar air leak, atrial fibrillation, subcutaneous emphysema, and other pulmonary and pleural complications (including pneumothorax, atelectasis, pleural effusion, pneumonia, chylothorax, and other pulmonary events not otherwise specified). Prolonged pleural drainage occurred in 307 patients (10.7%) and these were all minor complications. Prolonged alveolar air leak (>5 days) occurred in 155 patients (5.4%) and most of these were minor complications. Atrial fibrillation occurred in 139 patients (4.8%) and the grade II incidence was 4.7% in the cohort. Subcutaneous emphysema occurred in 105 patients (3.64%), and grade IIIa occurred most frequently (1.3%) of all this cohort observed. Other system complication rates were no more than 5%.

Intraoperative data and outcomes

Six hundred and eighty-two patients were enrolled in the secondary analysis (see Table 3). A total of 264 (38.7%) patients encountered at least one complication. The minor and major complication rates were 28.3% (193 patients) and 10.3% (70 patients), respectively. Three patients died within 90 days of surgery. The median costs in patients without and with complications were significantly different (median 46913 [10 280, 96 390] vs. 56 451 [31 468, 159 712] Ren Min Bi (RMB), $p < 0.001$). The higher costs of the patients with minor complications were mainly associated with their longer hospital stays. These patients had a median postoperative stay of 3 days longer than those without complications (median 12 [6, 36] vs. 15 [7, 39] days, $p < 0.0001$). The median costs in patients with minor and major complications were significantly different (median 54486 [47 530，63 433]
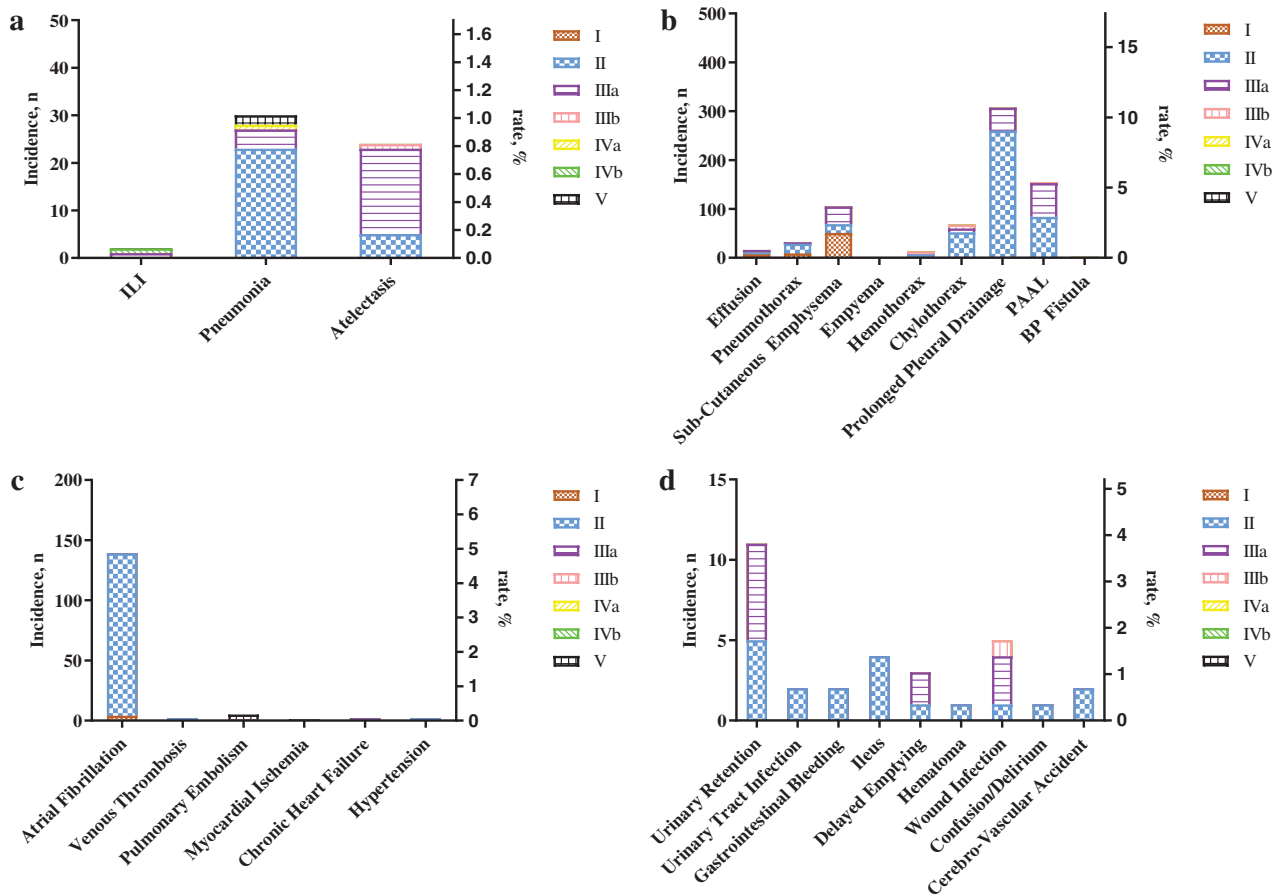
FIGURE 2 Incidence number and rate of different systems: (a) pulmonary complications, (b) pleural complications,(c) cardiovascular system complications, and (d) other system complications

vs. 58 119 [51 023，64 617] RMB, *p* = 0.019). The median hospital stay in patients with minor and major complications were significantly different (median 15 [13, 15] vs. 19 [15, 22] days, *p* < 0.001; Table 4).

Correlation between grade of complications and in-hospital costs

With the increase in complication grade, the in-hospital costs and length of stay increased (Figure 3). Generalized linear model analysis of in-hospital costs and clinical data of 682 patients showed that complication grade II (odds ratio [OR] 1.12, 95% confidence interval [CI] 1.05–1.2, *p* = 0.0005), grade III (OR 1.55, 95% CI 1.26–1.9, *p* < 0.0001), grades IV and V (OR 1.09, 95% CI 1.04–1.13, *p* = 0.0002), diffusion capacity of carbon dioxide (DLCO, OR 0.998, 95% CI 0.997–1.000, *p* = 0.004), and duration of chest drainage (OR 1.03, 95% CI 1.02–1.04, *p* < 0.001) were independent risk factors for the increase in in-hospital costs of VATS major lung resections (Table 5).

DISCUSSION

This study demonstrated that TM&M can systemically report complications of VATS compared with the Common Terminology Criteria for Adverse Events (CTCAE)[8] and Claviden–Dindo classification.

CTCAE is a part of the cancer clinical trial evaluation program proposed by the National Cancer Institute (NCI) in 1983. It mainly focuses on adverse events (AEs) in clinical trials. Although the standard comprehensively reports the adverse reactions of various systems, it still cannot fully cover the postoperative complications of thoracic surgery, such as prolonged drainage time and alveolar pleural fistula. Moreover, many adverse reactions of drug trials rarely occur after thoracic surgery, such as pulmonary fibrosis, allergic rhinitis, laryngitis, etc.

In 2004, Claviden and his colleague Dindo proposed an improved Claviden–Dindo complications classification system.[9] Compared with the previous version, the system was more detailed according to the treatment method: the standard of grade I complications was optimized and

TABLE 3 Characteristics of patients included in the generalized linear model ($n = 682$)

Variables	Values
Gender, male	352 (51.6)
Age, year	60.4 ± 10.6
BMI (kg/m^2)	24.1 ± 3.2
Smoker	269 (39.4)
CCI	
0	520 (76.2)
1	116 (17.0)
2	34 (5.0)
≥3	12 (1.8)
Diameter of main lesion (cm)	2.5 ± 1.5
Number of lesions	
Single	470 (68.9)
Multiple	212 (31.1)
FEV1, L	2.5 ± 0.7
FEV1/FVC	79.2 ± 9.5
DLCO, %	87.7 ± 15.1
Type of procedure	
Lobectomy	661 (96.9)
Bilobectomy	12 (1.8)
Sleeve lobectomy	9 (1.3)
Pathology	
Squamous cell	84 (12.3)
Adenocarcinoma	545 (80.0)
Small cell	11 (1.6)
Others	42 (6.1)
Pathologic stage	
I	469 (68.8)
II	98 (14.3)
III	115 (16.9)
Neoadjuvant, yes	14 (2.1)
Blood loss (ml)	80.6 ± 79.7
Duration of chest drainage	5.0 ± 2.7
Complication	
None	418 (61.29%)
Grade I	48 (7.04%)
Grade II	145 (21.26%)
Grade III	67 (9.82%)
Grade IV&V	4 (0.59%)

Note: Values are mean ± SD or median (IQR) or n (%) unless otherwise noted.
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson comorbidity index; DLCO, carbon monoxide lung diffusion capacity; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; IQR, interquartile range; SD, standard deviation.

complications without drug treatment were defined as grade I, while those requiring drug treatment or simple operation were defined as grade II. Grade III complications were divided into IIIa and IIIB according to general anesthesia, and grade IV complications were divided into IVA and IVB according to the number of organs involved. The Claviden–Dindo complications classification system has been proven to have good clinical application value in urology, pediatrics, and head and neck surgery.[10–12] However, it is worth noting that the grading system does not systematically grade the complications of thoracic surgery as the relevant grading is not detailed enough, and lacks the definition and grading standard widely accepted by thoracic surgeons. Hence, it is easy to produce deviation in the application of thoracic surgery.

The TM&M is based on the CTCAE and Claviden–Dindo classification. By focusing on the management of the complications rather than their cause and anatomic and physiologic nature, it achieves effectiveness, simplicity, and reproducibility. It overcomes the difficulties in using extensive, detailed, and complex descriptions of complications for quality analysis purposes.

According to the TM&M system, the overall morbidity rate after VATS major lung resection in our center is similar to that in other countries. A study[13] analyzed 374 VATS procedures among 503 patients in the United Kingdom and 272 patients (54%) did not experience any complications. The distribution of postoperative complications in the remaining patients according to the TMM system was as follows: 57 (25%) grade I, 108 (47%) grade II, 29 (12%) grade III, 17 (7%) grade IV, and 20 (9%) grade V. Another large nationwide registry dataset in Italy had 4191 VATS lobectomies in 4156 patients (2480 men, 1676 women) were analyzed. Grades I and II and grades III–V complications were observed in 20.1% and in 5.8%, respectively. Ninety-day mortality was 0.55%.[14] The reason for a higher complication rate may be our long-term analysis, which contains many surgeries performed during our initial VATS period.

Our second-part analysis shows that complication grade, DLCO, and postoperative drainage time were independent risk factors for the increase in in-hospital costs of VATS major lung resections. The presence of a low DLCO and prolonged postoperative drainage time were found to be associated with increasing financial costs in previous studies.[15,16] Their association with in-hospital cost appears logical because they are factors reputedly linked with increased risk of complications and they are generally related to prolonged length of stay (LOS). Hence, it is important for medical care providers and managers to strengthen the patient's perioperative preparation and management, and to reduce cost burden, shorten LOS, and lessen the incidence of complications.

In addition, this study found that referring to patients without complications, grade I complications did not increase the risk of hospitalization expenses, while grade II complications increased by 1.12 times (OR: 1.12, 95% CI: 1.05–1.2, $p = 0.0005$), grade III complications increased by 1.55 times (OR: 1.55, 95% CI: 1.26–1.9, $p < 0.0001$), but grade IV and V complications increased by 1.09 times (OR: 1.09, 95% CI: 1.04–1.13, $p = 0.0002$). Considering that grade II complication generally requires only drug intervention or simple operation intervention, while grade III requires

TABLE 4 The relationship between complications and in-hospital costs and length of stay

Complication	In-hospital costs (median, [IQR], RMB)	p value	Length of stay (median, [IQR], days)	p value
None	46 997 (40 928, 53 204)	<0.001*	12 (9, 14)	<0.001
Any	55 819 (48 385，64 170)		15 (13, 19)	
Minor	54 486 (47 530，63 433)	0.019	15 (13, 15)	<0.001
Major	58 119 (51 023，64 617)		19 (15, 22)	

Abbreviation: IQR, interquartile range; RMB, Ren Min Bi.

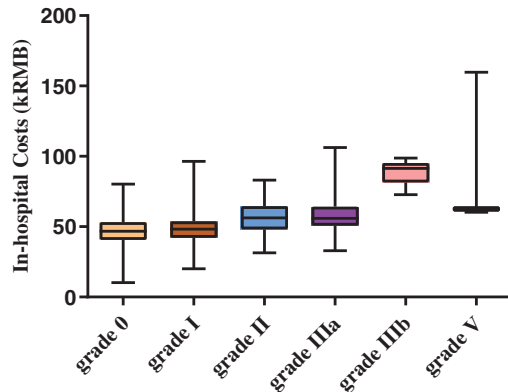*$p < 0.05$ is statistically significant.

FIGURE 3 Boxplot of in-hospital costs after video-assisted thoracoscopic surgery major lung resection by thoracic morbidity and mortality grades

surgery, endoscopy, intervention and other treatment, grade IV and V patients commonly have a poor prognosis and rapid death. So grade III patients will significantly increase in-hospital costs, while grade IV and V patients have a higher risk of relatively increasing in-hospital costs than grade III patients. In summary, using the TM&M system can further deepen the understanding of complications between doctors and patients, and drive them to take more standardized and active intervention measures in the perioperative period to reduce the incidence of complications and in-hospital costs.

Our findings are in line with previous evidence in our specialty. Brunelli and colleagues[13] studied the association between the TM&M classification system and hospital costs after lung resection. They found that the average postoperative cost of the uncomplicated patients was $3560 (95% CI $3440–$3680). The average postoperative costs of the patients with complications increased along with the grade of the TMM system: $4548 (95% CI $4134–$4962) for grade I, $4909 (95% CI $4537–$5281) for grade II, $6392 (95% CI $5303–$7483) for grade III, and $14 547 (95% CI $6334–$22760) for grade IV. The average postoperative cost for the patients who eventually died was $17 695 (95% CI $11 246–$24144). Our research has reached similar conclusions, and the results are more reliable due to the use of a more realistic modeling tool.

We were able to demonstrated that there was a consistent increase in financial costs and the severity grade of complications after VATS major lung resection. This study showed that the intensity of management of postoperative complications, which was comprehensively described by the TM&M system, translated into higher in-hospital costs. The TM&M grades accurately reflect the postoperative financial expenditures in lung cancer surgery. Knowledge that certain patient characteristics or certain types of operation, independently of the occurrence of complications, are associated with increased postoperative costs may have important clinical and managerial implications. It is clear that the association between adverse perioperative outcomes and cost variability should be highly considered by tariff regulators when constructing bundled payments for specific procedures.

According to the patient's age, gender, length of stay, clinical diagnosis, types of surgery, severity of disease, comorbidities, complications, outcomes, etc., the patients were divided into 500–600 diagnosis-related groups, and fixed prepayment was given based on scientific calculations of specific DRGs.[17] DRG payments are applied in China, this study have the potential in costs reduction for lung cancer resection via VATS under current medical insurance system reform in China.

Considering the increasing pressures to provide cost-effective healthcare, identifying the drivers of costs for commonly performed surgical procedures—such as this analysis targeting VATS major lung resection—will become increasingly important. Continuous efforts were made to reduce medical care costs by our National Health Commission, for instance the separation of expenditures on medical services and drugs. Our hospital has a high operation volume, allowing cheaper high-value medical consumables and reduction in stapling device usage. Otherwise, every effort was made to shorten LOS in our center, such as enhanced recovery after surgery (ERAS) protocols.[18]

Beased on the current study and our experience, there are some recommendations for saving hospital costs. First, it is essential to perform a careful preoperative evaluation and preparation to screen the high-risk patients and strenthen their tolerance of thoracic surgery. As previously mentioned, the grade of complications and DLCO is associated with in-hospital costs, so every effort should be made to reduce the occurrence of complications and improve the lung function of high-risk patients. Then, safe and reasonable VATS should be performed by surgeons who are skilled in VATS and capable of handling acute events. Additionally, fewer and cheaper stapling devices should be used when dissecting

TABLE 5 Generalized linear model of in-hospital costs

Variables	OR, 95% CI	p value
Grade of complication		
None	Ref	–
Grade I	1.02 (0.95, 1.09)	0.5736
Grade II	1.12 (1.05, 1.2)	**0.0005***
Grade III	1.55 (1.26, 1.9)	**<0.0001**
Grades IV and V	1.09 (1.04, 1.14)	**0.0002**
Age, year	1.002 (1, 1.004)	0.0719
Diameter of main lesion (cm)	0.99 (0.98, 1.01)	0.2942
FEV1, L	1.02 (0.98, 1.06)	0.3644
FEV1/FVC	0.999 (0.997, 1.001)	0.5532
DLCO, %	0.998 (0.997, 1)	**0.0037**
Blood loss (ml)	1 (1, 1)	0.0393
Duration of chest drainage	1.03 (1.02, 1.04)	**<0.0001**
CCI		
0	Ref	–
1	1.02 (0.98, 1.05)	0.2986
2	1.02 (0.95, 1.09)	0.6482
3	1.28 (0.86, 1.91)	0.2195
Gender, male	1.01 (0.96, 1.06)	0.7194
Smoker	1 (0.96, 1.04)	0.9242
BMI, kg/m^2		
Normal	Ref	–
Underweight	0.96 (0.87, 1.06)	0.4527
Overweight	0.99 (0.95, 1.02)	0.3921
Obesity	1.01 (0.93, 1.1)	0.833
Number of lesions		
Single	Ref	–
Multiple	1.03 (1, 1.07)	0.0623
Neoadjuvant, yes	0.98 (0.88, 1.1)	0.7297
Type of procedure		
Lobectomy	Ref	–
Bilobectomy	1.09 (0.96, 1.24)	0.1785
Sleeve lobectomy	1.12 (0.96, 1.29)	0.1412
Pathology		
Squamous cell	Ref	–
Adenocarcinoma	0.99 (0.94, 1.05)	0.7746
Small cell	1.01 (0.93, 1.09)	0.8577
Others	0.97 (0.85, 1.11)	0.6779
Pathologic stage		
I	Ref	–
II	1 (0.95, 1.05)	0.9369
III	0.96 (0.92, 1.01)	0.1201

Abbreviations: BMI, body mass index; CCI, Charlson comorbidity index; DLCO, diffusing capacity of carbon monoxide; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; OR, odds ratio.
*$p < 0.05$ is statistically significant.

and cutting the edge of the lobe. Finally, there are many methods for shortening LOS, such as ERAS protocols and the use of a digital drainage system.

The current study has several limitations. As this analysis is a retrospective database analysis of a single institution, these results may be limited by bias inherent from unobserved variables and limit its generalizability.

Additionally, we excluded VATS lobectomies converted to open surgery as we wanted a financial estimation of a homogeneous sample of patients. We think, however, that the cost associated with this subgroup of patients warrants a separate investigation.

Finally, we utilized cost data from a single institution in this analysis, which may vary between and within institutions. Further investigation is warranted on this important aspect in more institutions. This study only focused on the direct hospital costs associated with VATS major lung resection. It did not capture the entire episode of lung cancer care, including readmissions, emergency room visits, postoperative clinic visits, and home care. Such financial information is complex to retrieve and easily misses data. Our data represent only a segment of the entire care episode, but that appears to be the most significant to governmental healthcare managers. The current study did not consider the composition of in-hospital costs, such as operating room, anesthesia, and postanesthesia care unit costs, thus further studies are needed to determine the cost composition associated with VATS major lung resection for lung cancer.

CONCLUSIONS

In conclusion, this analysis supports the notion that the severity of complications is associated with increasing in-hospital costs. We believe that the present study can contribute to the development of future best practice cost models of VATS major lung resection for lung cancer while addressing modifiable complications by using the TM&M system. Efforts to reduce healthcare costs while improving outcomes should focus on the leverage points, minimizing the incidence of specific complications while maximizing the most significant proportional cost impact reduction. Further analysis is needed to identify the costs of specific complications using larger multicenter cohorts.

CONFLICT OF INTEREST
None declared.

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