A risk score for predicting postoperative complications in non-intubated thoracic surgery

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Research

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Abstract

Background

The risk factors for postoperative complications in non-intubated video-assisted thoracoscopic surgery (VATS) has not been observed before. Here to develop a simple risk score to predict the risk of postoperative complications for patients who scheduling non-intubated VATS, which is beneficial to guide the clinical interventions.

Methods

1837 patients who underwent non-intubated VATS were included from January 2011 to December 2018. A development data set and a validation data set were allocated according to an approximate 3:2 ratio of total cases. The stepwise logistic regression was used to establish a risk score model, and the methods of bootstrap and split-sample were used for validation.

Results

Multivariable analysis revealed that the forced expiratory volume in the first second in percent of predicted, the anesthesia method, blood loss, surgical time, and preoperative neutrophil ratio were risk factors for postoperative complications. The risk score was established with these 5 factors, varied from 0–53, with the corresponding predicted probability of postoperative complications occurrence ranged from 1%–92%, and was calibrated (Hosmer-Lemeshow $\chi^2 = 6.261$; $P = 0.618$). Good discrimination was acquired in the development and validation data sets (C-statistic 0.705 and 0.700). A positive correlation was between the risk score and postoperative complications (P for trend < 0.01). Three levels of low-risk (0–15 points], moderate-risk (15–30 points], and high-risk (> 30 points] were established based on the score distribution of postoperative complications.

Conclusions

This simple risk score model based on risk factors of postoperative complications can validly identify the high-risk patients with postoperative complications in the non-intubated VATS, and allow for early interventions.

Background

At the end of the 1800s, the first attempts of anesthesia in thoracic surgery were made by non-intubated patients with spontaneous breathing air-ether through a mask.¹ With the development of pulmonary isolation techniques and mechanical ventilation, the intubated thoracic anesthesia became mainstream.

However, in recent years, the non-intubated video-assisted thoracoscopic surgery (VATS) had been successfully performed in different types of procedures.²⁻⁶

VATS surgery under non-intubated anesthesia decreased the duration of surgery and postoperative hospital stay,⁷ and improved recovery with less postoperative complications.^{2-4,8} At present, the surgical procedures and anesthesia techniques of non-intubated VATS had been described clearly,⁹⁻¹¹ but it still lacks specific observations for perioperative complications. The postoperative clinical complications are the most concerning issues to postoperative rehabilitation. However, risk factors of postoperative complications in non-intubated VATS had not been reported before. Moreover, this question can not be easy to answer, due to not only the majority of publications on non-intubated VATS came from scattered and different medical centers, with inevitable different selection criteria for patients, but also most of them were the small sample observations. Hence, since non-intubated VATS has gradually gained popularity in the past two decades, and no clinical risk model of predicting postoperative complications has been established at present. It is necessary to explicit the risk factors of postoperative complications and accurately allows for timely interventions for the high-risk patients.

Hereupon, through this observation, the primary outcome was to find out the risk factors for postoperative complications and develop a convenient and accurate risk score to identify the high-risk patients with postoperative complications in non-intubated VATS.

Methods

Study design

We conducted a post hoc reanalysis of a large single-center retrospective cohort. The data collectors were blind to the primary outcome. The analysis included patients who successfully underwent VATS with non-intubated anesthesia from January 1st, 2011, to December 30th, 2018 at the Guangzhou Institute of Respiratory Diseases. The inclusion for non-intubated VATS is the same as described before¹²⁻¹⁴, which patients were age ≥ 18 years, with body mass index (BMI) ≤ 25 , the American Society of Anesthesiologists (ASA) physical status III or less, with no abnormal airway and spinal anatomy, no compromised coagulation, no serious cardiopulmonary dysfunction, and no extensive pleural adhesion. Patients were excluded from this observation if they proceeded to overlapping operations besides lungs, thoracotomy, tracheal surgery, and esophagus surgery. Patients who had invalid or unavailable preoperative basic examination results and incomplete intraoperative and postoperative medical records were also excluded (Fig. 1).

Main operating procedures

All patients received VATS under non-intubated anesthesia.^{12,15} Two anesthesia methods were initiated in our institution, one was plasma concentration target-controlled infusion (TCI) of propofol and remifentanyl, combined with intravenous dexmedetomidine and placed with laryngeal mask airway

(LMA), the other method was epidural anesthesia (EA), which maintained anesthesia with ropivacaine with placing the epidural catheter in the fifth or seventh epidural space. It was up to the patients, the experience of surgeons and anesthesiologists to decide which anesthesia method to choose.

The thoracoscopic procedures were consistent with the guidelines of the American Association for Thoracic Surgery.¹⁶ Whether to place a chest-drainage tube or not depends on the patient's condition and surgical procedures. All thoracic procedures were divided into four types, such as the nonanatomic wedge resection, including wedge resection, bullectomy, and lung volume reduction surgery; the anatomic resection, including lobectomy and segmentectomy; the mediastinal mass resection; and others procedures, including bilateral sympathectomy, thoracoscopic exploration, lung biopsy, pericardial cyst resection, etc. Surgical time was defined as the interval from skin cutting to wound suturing and a surgical dressing covering. After the operation, the patients were removed LMA or epidural catheter and sent back to the ward, or transfer to the intensive care unit (ICU). If the patient did not place a drainage tube or enter the ICU, the duration of chest drainage and ICU stay were recorded as zero.

Primary endpoint and candidate predictors

The primary endpoint was postoperative complications (PC). PC definition included: pleural effusion, mechanical ventilation, dyspnea, arrhythmia, air leakage, fever, reoperation, cardio-dysfunction, chylothorax, pulmonary embolism, and death. The candidate predictors included preoperative characteristics and intraoperative variables, such as age, gender, BMI, the level of ASA physical status, the previous medical history, revised cardiac risk index (RCRI), stair climbing, values of the forced vital capacity in percent of predicted (FVC% predicted), and the forced expiratory volume in the first second in percent of predicted (FEV₁% predicted), left ventricular ejection fraction (LVEF), thoracic procedures, surgical location, preoperative values of leukocyte and neutrophil ratio, anesthesia methods, surgery time, blood loss, intraoperative values of minimum pulse oxygen saturation (SpO₂) and arterial partial pressure of carbon dioxide (PaCO₂).

Statistical analysis

Statistical analyses of patient distribution were performed with SAS software version 9.2. All analyses were based on the input of complete cases.

All eligible patients were allocated on the ratio of 3:2, and a development data set and a validation data set were established respectively. A risk model and a risk score model were established according to the development data set. In univariate analysis, $P < 0.05$ candidate predictors were included in the development of the risk model. The best subset of risk factors was selected by the bootstrap method to avoid over-fitting. The scoring method of the risk score model was similar to Sullivan's¹⁷ and was based on the development of the risk model. Continuous variables were classified as clinical significant categories for scoring purposes. Pearson's contingency coefficient evaluated the degree of correlation between the score levels and the PC risk, and the Cochran-Armitage test was used to examine the trend.

The predictive accuracy of the risk model and the risk score model was assessed by both discriminations measured by the C-statistic and calibration evaluated by the Hosmer- Lemeshow χ^2 statistic and calibration plot. Furthermore, the risk scoring model was validated by split-sample to evaluate the stability of the model. The area under the receiver operating characteristic (ROC) curve was compared by the nonparametric approach of DeLong.¹⁸

Results

A total of 1837 patients who underwent non-intubated thoracic surgery were included (Supplemental Table S1).

Risk model and risk score development

157 (9%) experienced PC among the 1837 patients. 101 of 1097 patients experienced PC in the development data set, while 56 of 740 patients experienced PC in the validation data set (Supplemental Table S2 and S3). After variables selected by a bootstrap technique, the FVE₁% predicted, anesthesia method, blood loss, surgical time, and preoperative neutrophil ratio were selected as the best subset of risk factors to establish a risk model (Table 1). The scores of all predictors were shown in Table 2.

Risk score validation

The risk score model was applied to the development data set for discrimination, with a C-statistic of 0.705 (95% CI: 0.650-0.759) and high calibration with a χ^2 statistic of 6.261 ($P = 0.618$) (Fig. 2). The validation results of split-sample, which based on the validation data set, were similar to those of the development data set, with an average C-statistic of 0.700 (95% CI: 0.619-0.781) and high calibration with a χ^2 statistic of 7.963 ($P = 0.437$) (Fig. 2). The ROC (Fig. 2) and the PC proportions (Fig. 3) from the development and validation data sets were consistent with each other. The predicted incidence of PC was nicely corresponding to the observed (Fig. 3).

Clinical implications of the risk score model

Based on the risk score model, the risk scores were classified into three levels for clinical use (Fig. 4). The definitions of three levels were low-risk (0-15 points], moderate-risk (15-30 points], and high-risk (>30 points], which based on the score distribution of PC (Fig. 3). The total risk score varied from the minimum 0 (lowest risk) to the maximum 53 (highest risk) (Table 2), and the corresponding predicted probability of PC occurrence ranged from 1%-92%. The relationship of risk level and predicted risk of PC were low-risk (1-6%), moderate-risk (7-33%), high-risk (36-92%) (Table 3).

Discussion

In this observation, we established and validated a risk score model based on 5 available factors (FEV₁% predicted, preoperative neutrophil ratio, surgical time, blood loss, and anesthesia method), to predict the

risk of postoperative complications in non-intubated VATS. And we provided three classifications of low, moderate, and higher-risk levels of post-operative complications for the clinicians to use. This recommended convenient risk score allows for the identification of high-risk patients immediately and makes the right risk allocation.

Non-intubated VATS has been applied to a large number of patients in a series of observations, such as the Klijian's report under awake VATS,¹⁹ Chen's experience in lung resection and Huang's studies in thoracoscopic lobectomy.^{11,20-22} However, no specific perioperative complications have been proposed in these observations. In our previous studies, eligibility criteria for non-intubated VATS were strictly identified, but the occurrence of postoperative complications still existed.¹²⁻¹⁴ Based on this observation, the incidence of postoperative complications was 9%, and we could speculate that the FEV₁% predicted, the anesthesia method, the blood loss, the surgical time and the preoperative neutrophil ratio were the risk factors of postoperative complications. It has been proved that the poor pulmonary function and the longer surgical time can increase the postoperative complications,²³⁻²⁵ and epidural anesthesia with high plane block can retardant the movement of intercostal muscles and reduce the inspiratory capacity,^{26,27} which can lead to hypercapnia and hypoxia. Therefore, it requires to initiate timely interventions for high-risk patients and proceed with personality procedure in non-intubated VATS.

Of note, postoperative complications prolonged the hospital stay and increased unfavorable clinical outcomes, which are contrary to the rapid rehabilitation paraded by non-intubated VATS. A practical and efficacious method for avoiding complications is its early identification and prevention. Therefore, the establishment of a risk score model to detect postoperative complications earlier are immediately needed in non-intubated VATS. In this observation, the proposed risk score revealed a high degree of differentiation and good calibration both in the development and validation data sets, and the predictive power of the risk score for postoperative complications was higher. Moreover, the quantitative variables in our risk model may be more objective, which comes from a large number of clinical cases of non-intubated VATS in our institution.

Non-intubated VATS are usually practiced in simple surgical procedures for which intubated anesthesia is deemed more complex and thus unnecessary, such as treatment of spontaneous pneumothorax, recurrent pleural effusion, pleural, pulmonary and mediastinal biopsy, and sympathectomy, etc;^{2,4,8} on the other, non-intubated VATS are preferred in some cases which are deemed at higher risk for standard intubated anesthesia, such as patients with compromised pulmonary function, older age, associated cardiovascular comorbidity.^{5,10,28} It's in brief that the advantage of non-intubated VAST outweighs the disadvantage for some high-risk patients, and the intraoperative factors can significantly affect the postoperative rehabilitation of patients. Licker proposes that prolonged surgery is an independent risk factor for predicting postoperative complications,²⁹ and that was why we included intraoperative factors to establish the risk score model. In our risk score, the ability to predict was more comprehensive by combining with four other factors. If the score is less than 15, the risk level of postoperative complications is low-risk, the patients may need no special treatment after the operation. If the score is >

15–30, the risk level of postoperative complication is medium risk, and we should initiate atomization and expectoration immediately after the operation, initiate a more appropriate postoperative analgesia, and carry out rehabilitation training of lung function as early as possible. If the score is more than 30, the risk level of postoperative complication is high risk, the patient not only initiates the therapies the same as in medium risk level, but also should be placed chest-tube drainage longer, receive intensive care and monitoring, and need more chest-radiography and laboratory examination.

Limitations

Undoubtedly, this study has several limitations. First, this investigation proceeded in a single-center, and its results may be limited to the intubated populations. But it can avoid the study bias coming from different training programs of surgeons and different protocols of management and therapy in multi-center. Second, patients without values of pulmonary function and LVEF (such as patients with pneumothorax or intolerance of pulmonary function test) were excluded from this study, which resulted in a lack of data analysis for such non-intubated VATS patients. However, pulmonary function and LVEF are important indexes for preoperative evaluation of thoracic surgery, thus the established risk score model should be included the patients with these results. Third, this model was verified by the split-sample method. It is a simple way to examine the overfitting, and can not determine the generalizability of independent cohorts. Fourth, this risk model was based on different types of surgical procedures which may result in a heterogeneity of comparison, but it would make the risk model more accordance with the actual clinical practice, since non-intubated VATS has been applied in a wide range of thoracoscopic procedures.

Conclusions

In summary, the preoperative evaluations should be rigorous on patients scheduled for non-intubated VATS. This simple risk score model, which based on five available factors ($FEV_1\%$ predicted, preoperative neutrophil ratio, surgical time, blood loss, and anesthesia method), is a valid tool for the identification of high-risk patients with postoperative complications in non-intubated thoracic surgery. This could help clinicians to distinguish the high-risk patients and initiate the appropriate and earlier interventions for them.

Abbreviations

1. VATS= Video-assisted thoracoscopic surgery
2. BMI= Body mass index
3. ASA= the American Society of Anesthesiologists
4. TCI= Target-controlled infusion
5. LMA= Laryngeal mask airway
6. EA= Epidural anesthesia

7. ICU= Intensive care unit
8. PC= Postoperative complications
9. RCRI= Revised cardiac risk index
10. FVC% predicted= the forced vital capacity in percent of predicted
11. FEV₁% predicted= the forced expiratory volume in the first second in percent of predicted
12. LVEF= Left ventricular ejection fraction
13. SpO₂= Pulse oxygen saturation
14. PaCO₂= Arterial partial pressure of carbon dioxide

Declarations

Ethics approval and consent to participate:

The observation was approved on November 5th, 2019 by the Medical Ethics Committee of the first affiliated hospital of Guangzhou Medical University (No.K-51) before data were accessed and waived patient's consent due to its retrospective characteristic.

Consent for publication:

Not applicable

Availability of data and materials:

The datasets used/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests :

The authors declare that they have no competing interests.

Funding:

None.

Author contribution:

Lan Lan's contribution: conceptualization and writing-review the manuscript. Long Jiang's contribution: methodology and investigation. *Chongyang Duan's* contribution: data curation and formal analysis. Weixiang Lu's contribution: project administration. *Canzhou Zhang's* contribution: project administration.

Yanyi Cen's contribution: supervision and resources. *Jianxing He's* contribution: guarantor, writing-review, and editing. All authors critically reviewed the manuscript, contributed to its revision, and approved the final version submitted. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. The corresponding author, Jianxing He, attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. He is the guarantor.

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Tables

Table. 1 Univariate and multivariable logistic regression analysis of risk factors that were selected to develop the risk model for predicting post-operative complications (developmental data set, n=1097).

Variable	Univariate analysis			Multivariable analysis		
	OR	95% CI	<i>P</i> value	OR	95%CI	<i>P</i> value
FVE ₁ % predicted	0.982	0.972 to 0.992	0.000	0.977	0.966 to 0.987	0.000
Anesthesia method (EA vs TCI+LMA)	2.165	1.396 to 3.356	0.001	2.092	1.316 to 3.326	0.002
Blood loss	1.003	1.001 to 1.004	0.000	1.002	1.001 to 1.003	0.006
Log surgical time*	2.080	1.437 to 3.011	0.000	1.885	1.263 to 2.815	0.002
Preoperative neutrophil ratio	1.025	1.005 to 1.045	0.015	1.021	1.001 to 1.042	0.041

*The natural logarithmic transformations of surgery time were made because of their extreme positive skewness. FEV₁ % predicted, the forced expiratory volume in the first second in percent of predicted; EA, Epidural anesthesia; TCI, Target controlled infusion; LMA, Laryngeal mask airway.

Table. 2 Risk scores for all predicting variables

Risk factors	Score
FVE₁ % predicted	
≥80 %	0
70-79 %	2.5
60-69 %	5
50-59 %	7.5
35-49 %	10
<35 %	15
Preoperative neutrophil ratio	
<40 %	0
40-50 %	2
50-60 %	4
60-70 %	6
70-80 %	8
≥80 %	10
Surgical time	
<30 min	0
30-59 min	4.5
60-119 min	9
120-239 min	13.5
≥240 min	18
Blood loss	
≤50 ml	0
51-100 ml	1
101-200 ml	3
>200 ml	6
Anesthesia method	
TCI+LMA	0
EA	4

TCl, Target controlled infusion; LMA, Laryngeal mask airway; EA, Epidural anesthesia.

Table. 3 The relationship between risk level and predicted risks of postoperative complications.

Risk level	Risk score level	Predicted risk %
Low-risk	0-15 points	1-6%
Moderate-risk	>15-30	7-33%
High-risk	>30	36-92%

Figures

Figure 1

The flow chart of this observation.

Figure 2

The area under the Receiver operator characteristic (ROC) curves and calibration plot with the Hosmer-Lemeshow test for goodness-of-fit result for the risk score.

Figure 3

The correlation of post-operative complications (PC) with the risk score. Increasing the risk of PC with increasing risk score is showed in the development and validation data sets. The observed incidence of PC was consistent with the predicted ones based on the data set risk score.

Figure 4

The correlation of risk level with the range of risk score.

Supplementary Files

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