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ORIGINAL ARTICLE

Oncology

A Predictive Model for 90-Day Mortality After Lobectomy in Patients with Non-Small Cell Lung Cancer: A Multicenter Retrospective Study

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Abstract

Background: Over the past decade, multiple prognostic models have been developed to estimate short-term (including in-hospital) mortality following lobectomy. However, 90-day postoperative mortality is not as widely used as a standard measure for evaluating outcomes after lobectomy. The objective of this study was to evaluate 90-day mortality following lobectomy with mediastinal lymphadenectomy for non-small cell lung cancer (NSCLC), and to identify factors independently associated with this outcome.
Methods and Results: This retrospective multicenter study included data from 700 patients who underwent anatomical lobectomy with systematic mediastinal lymphadenectomy for histologically confirmed NSCLC. A clinically homogeneous cohort was formed to validate the assessment of intra- and postoperative risk factors associated with 90-day mortality.
Among 700 patients included in the study, the 90-day postoperative mortality rate was 3.7%. Multivariate logistic regression identified the following independent predictors of 90-day mortality: prolonged air leak (AOR=2.505; 95% CI: 1.115–5.629, P=0.026), intraoperative blood loss (AOR=1.003; 95% CI: 1.001–1.005, P=0.004), and forced expiratory volume in one second (AOR=0.965; 95% CI: 0.945–0.985, P=0.001). To assess the relationship between the probability of 90-day postoperative mortality and the value of the logistic function P, a ROC analysis was performed. The area under the ROC curve (AUC) was 0.719 (95% CI: 0.606–0.832; P<0.001). The sensitivity and specificity of the resulting predictive model were 65.4% and 77.1%, respectively.
Conclusion: The proposed model incorporating three key clinical variables may serve as a practical tool for postoperative risk stratification and guiding follow-up strategies in patients undergoing lobectomy for NSCLC.(**International Journal of Biomedicine. 2025;15(3):505-510.**)

Keywords: lung cancer • lobectomy • 90-day mortality • predictive model • nomogram

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Abbreviations

FEV1, forced expiratory volume in one second; **IOBL**, intraoperative blood loss; **NSCLC**, non-small cell lung cancer; **PAL**, prolonged air leak; **TMM**, thoracic morbidity and mortality

Introduction

Lung cancer remains one of the leading causes of cancer-related mortality worldwide. Anatomical pulmonary resection remains the standard of care for patients with early-stage lung malignancies.[1] Despite significant advancements in thoracic surgical techniques and perioperative management, along with the growing adoption of minimally invasive approaches, postoperative mortality remains a substantial clinical concern.

Traditionally, surgical outcomes have been assessed using 30-day mortality rates. Over the past decade, multiple prognostic models have been developed to estimate short-term (including in-hospital) mortality following lobectomy. However, 90-day postoperative mortality is not as widely used as a standard measure for evaluating outcomes after lobectomy, despite increasing evidence suggesting its clinical relevance.[2-4]

The objective of this study was to evaluate 90-day mortality following lobectomy with mediastinal lymphadenectomy for non-small cell lung cancer (NSCLC), and to identify factors independently associated with this outcome.

Materials and Methods

This retrospective multicenter study included data from 700 patients who underwent anatomical lobectomy with systematic mediastinal lymphadenectomy for histologically confirmed NSCLC from January 1, 2021 to December 31, 2024. The study was conducted across three thoracic oncology centers in Russia:

- •Ulyanovsk Regional Oncology Dispensary
- •Sverdlovsk Regional Oncology Center (Yekaterinburg)
- •Tolyatti City Clinical Hospital No. 5

Inclusion criteria

- •Patients aged ≥18 years
- •Underwent curative (R0) anatomical lobectomy
- •Histologically verified NSCLC
- •Pathological stage I–IIIB based on the 8th edition of the TNM classification[5]

Exclusion criteria

- •Incomplete clinical data
- •Non-lobectomy resections
- •Palliative surgery or R1/R2 resections

A clinically homogeneous cohort was formed to validate the assessment of intra- and postoperative risk factors associated with 90-day mortality.

The following variables were extracted from medical records and surgical reports:

- •Demographic and clinical characteristics: age, sex, smoking history, chronic obstructive pulmonary disease (COPD), coronary artery disease (CAD), previous myocardial infarction
- •Intraoperative variables: surgical approach (thoracotomy vs. video-assisted thoracoscopic surgery; conversions classified as thoracotomy), duration of surgery, intraoperative blood loss (IOBL) in mL, need for blood transfusion, presence of pleural adhesions
- •Postoperative outcomes: length of drainage, length of stay, postoperative complications, need for reintervention

Special attention was paid to prolonged air leak (PAL), defined as persistent air leakage beyond 5 days postoperatively, in accordance with the European Society of Thoracic Surgeons guidelines.[6] Postoperative complications were graded using the modified thoracic morbidity and mortality (TMM) classification system.[7]

Statistical analysis

All statistical analyses were performed using StatTech v.4.8.3 (Stattech LLC, Russia). The distribution of continuous variables was assessed using the Shapiro–Wilk test (n < 50) or the Kolmogorov–Smirnov test (n ≥ 50). Quantitative variables were presented as median (Me) and interquartile ranges (IQR [Q1;Q3]). Categorical variables were described using absolute numbers and percentage. A non-parametric Mann-Whitney U test was used to compare the differences between the two independent groups. The frequencies of categorical variables were compared using chi-square test or Fisher's exact test (2-tail), when appropriate. A multiple logistic regression analysis was conducted to calculate the unadjusted and adjusted odds ratios (UOR and AOR) with 95% confidence intervals (95%CI). A nomogram was constructed using R statistical software (version 4.4.2), and internal validation was performed via 1,000 bootstrap resamples. Model performance was evaluated using the area under the ROC curve (AUC), calibration plots, and Brier score. A *P*-value of less than 0.05 was considered statistically significant.

Results

Among 700 patients included in the study, the 90-day postoperative mortality rate was 3.7%. The baseline demographic and clinical characteristics of patients who survived and those who died within 90 days after surgery are summarized in Table 1. Analysis of clinical and anamnestic parameters revealed that forced expiratory volume in one second (FEV_1) had a statistically significant impact (*P*=0.006) on 90-day postoperative mortality.

Table 1.

Clinical and anamnestic characteristics of the study patients.

Variable	Category	90-day postoperative mortality		*P*-value
		Survived (n=674)	Died (n=26)	
Sex	Male	411 (61.0%)	20 (76.9%)	0,149
	Female	263 (39.0%)	6 (23.1%)	
Age, years (Me, [IQR])		66 (60–71)	69.5 [62.25;73.5]	0.118
COPD	Yes	98 (14.5%)	5 (19.2%)	0,569
	No	576 (85.5%)	21 (80.8%)	
Diabetes mellitus	Yes	50 (7.4%)	3 (11.5%)	0,438
	No	624 (92.6%)	23 (88.5%)	
Smoking history	Yes	332 (49.3%)	14 (53.8%)	0,646
	No	342 (50.7%)	12 (46.2%)	
CAD	Yes	150 (22.3%)	7 (26.9%)	0,619
	Prior myocardial infarction	12 (1.8%)	1 (3.8%)	
	No	511 (75.9%)	18 (69.2%)	
LVEF (%), Me [IQR]		62 [58; 66]	61.5 [58.25; 66]	0.924
FEV_1 (%), Me [IQR]		87 [75; 99]	72.5 [54.5; 94.75]	0.006

COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; LVEF, left ventricular ejection fraction.

Analysis of the morphological characteristics of the studied patients revealed that none of the evaluated parameters had a statistically significant impact on 90-day mortality (Table 2). The need for blood transfusion in the postoperative period had a significant impact on 90-day mortality. The presence of complications, prolonged air leak, extended chest drainage duration, prolonged hospital stay, and higher TMM complication grades were all statistically significant predictors of 90-day mortality following lobectomy (Tables 3 and 4).

Table 2.

Pathomorphological characteristics of the study patients

Variable	Category	90-day postoperative mortality		*P*-value
		Survived (n=674)	Died (n=26)	
Pathological stage, n (%)	IA1	97 (14.4%)	6 (23.1%)	0.191
	IA2	89 (13.2%)	4 (15.4%)	
	IA3	38 (5.6%)	1 (3.8%)	
	IB	179 (26.6%)	9 (34.6%)	
	IIA	69 (10.2%)	2 (7.7%)	
	IIB	94 (13.9%)	1 (3.8%)	
	IIIA	95 (14.1%)	1 (3.8%)	
	IIIB	13 (1.9%)	2 (7.7%)	
Tumor size (mm), Me [IQR]		26 [19; 40]	24.5 [17.5; 31.5]	0.516

Table 3.

Surgical parameters of the study patients.

Variable	Category	90-day postoperative mortality		*P*-value
		Survived (n=674)	Died (n=26)	
Surgical approach	Thoracotomy	556 (82.5%)	24 (92.3%)	0.288
	VATS	118 (17.5%)	2 (7.7%)	
Lobe resected	Upper	378 (56.1%)	20 (76.9%)	0.081
	Middle	45 (6.7%)	0 (0.0%)	
	Lower	251 (37.2%)	6 (23.1%)	
Side of resection	Right	414 (61.4%)	16 (61.5%)	0.991
	Left	260 (38.6%)	10 (38.5%)	
Operative time (min), Me [IQR]		145 [120;180]	162.5 [121.25;180]	0.178
Blood loss (mL), Me [IQR]		100 [62.5;200]	150 [62.5;200]	0.231
Blood transfusion	Yes	8 (1.2%)	2 (7.7%)	0.050
	No	666 (98.8%)	24 (92.3%)	
Pleural adhesions	Yes	70 (10.4%)	4 (15.4%)	0.343
	No	604 (89.6%)	22 (84.6%)	

Table 4.

Postoperative parameters of the study patients.

Variable	Category	90-day postoperative mortality		*P*-value
		Survived (n=674)	Died (n=26)	
Prolonged air leak (PAL)	Yes	172 (25.5%)	13 (50.0%)	0.011
	No	502 (74.5%)	13 (50.0%)	
Time to drain removal (days), Me [IQR]		7 [5; 11]	10.5 [8; 22.5]	< 0.001
Length of stay (days), Me [IQR]		12 [9; 17]	17.5 [14; 27]	< 0.001
Postoperative complications	Yes	86 (12.8%)	11 (42.3%)	< 0.001
	No	588 (87.2%)	15 (57.7%)	
TMM grade	Grade 0-I	465 (69%)	13 (50%)	< 0.001
	Grade II	134 (19.9%)	4 (15.4%)	
	Grade IIIA	68 (10.1%)	2 (7.7%)	
	Grade IIIB	1 (0.1%)	2 (7.7%)	
	Grade IVA	5 (0.7%)	3 (11.5%)	
	Grade IVB	1 (0.1%)	0 (0.0%)	
	Grade V	0 (0.0%)	2 (7.7%)	

Multivariate logistic regression identified the following independent predictors of 90-day mortality: PAL (AOR= 2.505; 95% CI: 1.115–5.629), IOBL (AOR=1.003; 95% CI: 1.001–1.005) and forced expiratory volume in one second FEV_1 (AOR=0.965; 95% CI: 0.945–0.985) (Table 5).

Table 5.

The predictor model for the probability of 90-day mortality.

Predictor	Unadjusted		Adjusted	
	UOR (95% CI)	P-value	AOR (95% CI)	*P*-value
PAL: Present	2.913 (1.324-6.404)	0.008	2.505 (1.115-5.629)	0.026
Blood loss (mL)	1.003 (1.001-1.005)	0.006	1.003 (1.001-1.005)	0.004
FEV_1 (%)	0.964 (0.945-0.983)	< 0.001	0.965 (0.945-0.985)	0.001

PAL – prolonged air leak; FEV_1 – forced expiratory volume in one second

To assess the relationship between the probability of 90-day postoperative mortality and the value of the logistic function *P*, a ROC analysis was performed. The area under the ROC curve (AUC) was 0.719 (95% CI: 0.606–0.832; *P*<0.001) (Figure 1) The sensitivity and specificity of the resulting predictive model were 65.4% and 77.1%, respectively.

Multicollinearity analysis confirmed that the predictors included in the model were independent of each other. To validate the nomogram (Figure 2), a bootstrap method with 1,000 resamples was applied to improve the accuracy of the estimates. A calibration curve was constructed to assess the agreement between predicted probabilities and actual outcomes (Figure 3). The dashed diagonal line represents perfect agreement between predicted and observed probabilities. The solid line reflects the actual calibration of the model based on LOESS smoothing, while the dotted bands indicate the 95% confidence interval. Vertical tick marks along the axis denote the distribution of predicted probabilities across the sample. Internal validation yielded a mean absolute error of 0.008, indicating acceptable performance of the developed predictive model.

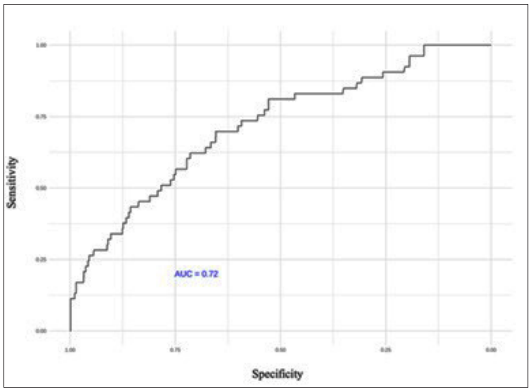

Figure 1. *ROC curve representing the relationship between the predicted probability of 90-day postoperative mortality and the actual outcomes.*

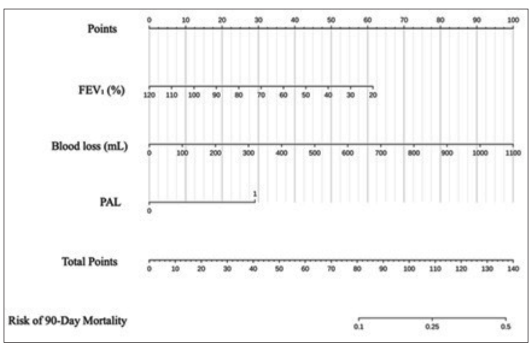

Figure 2. *Nomogram for predicting 90-day mortality in patients after lobectomy.*

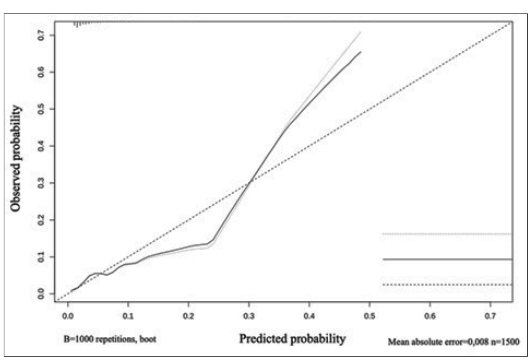

Figure 3. *Calibration curve plot for internal validation of the 90-day mortality prediction model.*

Discussion

Pezzi et al.[8] demonstrated that 90-day mortality following lung cancer resection nearly doubles that of the 30-day metric (5.4% vs. 2.8%), being influenced by a variety of factors, including age, surgical type, and comorbidities. In this multicenter retrospective study, we investigated predictors of 90-day mortality in patients undergoing lobectomy for NSCLC. Despite advances in surgical techniques and perioperative care, early postoperative mortality beyond the conventional 30-day window remains a relevant clinical concern.

Among the key variables associated with 90-day mortality, a reduced FEV_1 demonstrated a statistically significant impact (P=0.006). In our cohort, patients who died within 90 days had notably lower median FEV_1 values than survivors. Similar findings were reported by Soldath et al.,[9] where impaired FEV_1 was linked to decreased long-term survival and a higher risk of postoperative complications.

PAL was also a significant predictor, occurring in 50% of deceased patients compared to 25.5% among survivors (P=0.011). This finding aligns with results from Gooseman et al.,[10] who identified PAL as one of the most common and clinically relevant complications following anatomical lung resections, with a strong influence on length of stay and risk of mortality.

Postoperative complications, including infectious, thromboembolic, and cardiovascular events, showed a clear association with 90-day mortality (P<0.001). Patients who died experienced TMM grade III–V complications more often, reflecting a more severe postoperative course. These findings are consistent with results from Ma et al.,[11] who demonstrated that TMM grade is an independent risk factor for early mortality and can be incorporated into preoperative risk stratification models.

Additional predictors included the need for blood transfusion, prolonged chest drainage, and increased hospital stay. Blood transfusions may reflect both IOBL and severe postoperative complications. Similar associations were described by Yao and Wang,[12] where transfusions were linked to higher rates of respiratory complications and delayed recovery. Prolonged drainage and extended hospitalization may also result from PAL-related complications.

Interestingly, traditional baseline factors such as age, sex, COPD, CAD, smoking status, and surgical approach were not significantly associated with 90-day mortality in our dataset. This may be attributed to the clinical homogeneity of the cohort and effective preoperative risk selection, which could have mitigated the impact of individual baseline variables. However, in more heterogeneous populations, these parameters may remain relevant, as demonstrated by Halldorsson et al.[13] in elderly cancer patients. A recent systematic review identified 22 models designed to predict short-term mortality after thoracic surgery, of which only two focused on 90-day outcomes.[14-16] The most recent model was developed in the UK population, highlighting the need for locally validated tools tailored to specific patient cohorts.[17] In addition to univariate analysis, we constructed a multivariable logistic regression model incorporating variables that had statistically significant associations with 90-day mortality. Prolonged air leak, IOBL, and FEV_1 emerged as independent predictors of postoperative death. Of particular interest is the finding that blood loss remained significant in the multivariable model (OR=1.003; 95% CI: 1.001–1.005; *P*=0.004), underscoring the clinical importance of even moderate increases in intraoperative bleeding. Yao and Wang[12] reached similar conclusions, demonstrating that IOBL correlates with respiratory complications and adverse outcomes. Based on this model, we developed a nomogram to facilitate individualized, 90-day mortality risk prediction. This graphical tool allows clinicians to integrate multiple factors and estimate a patient's postoperative risk in a simple, interpretable format. Such tools are particularly valuable in multidisciplinary cancer centers and can aid in shared decision-making and tailored perioperative strategies.

However, this study has several limitations. First, the retrospective design inherently introduces limitations in data completeness and accuracy. Second, although the multicenter nature and sample size are strengths, the cohort consisted exclusively of patients undergoing lobectomy, limiting generalizability. Third, while the nomogram showed good calibration and internal performance, it requires external validation in independent populations. Previous studies have shown that even well-calibrated models may vary in predictive accuracy across institutions and regions.[18-20] Despite these limitations, our findings highlight the importance of a multifactorial approach in assessing postoperative risk. The proposed model and nomogram provide clinicians with a practical tool for predicting 90-day mortality and optimizing postoperative care.

Although PAL did not show a significant association with 30-day mortality, it emerged as an independent predictor in our 90-day mortality model (AOR=2.505; *P*=0.026). Shen et al.[21] reported similar associations between PAL and increased risk of reintervention, pulmonary infections, and delayed recovery. The adverse effects of PAL may be mediated by several mechanisms. Persistent air leak can prolong the inflammatory response and promote pleural space colonization, increasing the risk of nosocomial pneumonia and empyema.[22] Moreover, PAL is often observed in patients with emphysema and impaired lung function, limiting physiological reserves and hampering recovery. Finally, prolonged postoperative courses due to PAL may delay or preclude adjuvant therapy, particularly in stage II disease, where timely systemic treatment is critical.[23]

The proposed model incorporating three key clinical variables may serve as a practical tool for postoperative risk stratification and guiding follow-up strategies in patients undergoing lobectomy for NSCLC.

Ethical Considerations

The study protocol was approved by the local ethics committees of all participating institutions. All data were anonymized in compliance with data protection and confidentiality standards.

Competing Interests

The authors declare that they have no competing interests.

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