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Research article

Preoperative risk factors for prolonged length of stay after bullectomy: A single-center retrospective study

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ABSTRACT

Objective: Prolonged length of stay (LOS) increases the economic burden on patients, therefore, optimizing LOS is a critical clinical challenge for physicians. This study aims to examine the correlation between the postoperative LOS and surgery-related adverse events after bullectomy. We defined prolonged postoperative LOS after bullectomy and analyzed the preoperative risk factors linked to prolonged LOS.

Methods: In this retrospective study, we analyzed patient data from thoracoscopic bullectomy performed at our hospital between January 2018 and December 2023. The receiver operating characteristic (ROC) curve was used to identify the optimal cut-off values defining prolonged LOS after bullectomy. It was then characterized as prolonged LOS. Patients were divided into prolonged and normal LOS groups based on their postoperative duration. Further, univariate and multivariate logistic regression analyses were performed to identify preoperative risk factors associated with prolonged postoperative LOS after bullectomy.

Results: Among the 152 patients analyzed, binary logistic regression revealed a significant effect of surgery-related adverse events after bullectomy on the LOS ($P < 0.001$). A postoperative LOS exceeding 3 days was considered prolonged. Among the 152 patients, 38.2 % (58/152) experienced a prolonged LOS out of which 20.4 % (31/152) developed surgery-related adverse events. Multivariate regression analysis revealed that preoperative risk factors associated with prolonged LOS included age ≥60 years (OR = 3.052, 95%CI 1.226–7.586, P = 0.016), current smoking status (OR = 2.754, 95%CI 1.482–6.346, P = 0.025), and ASA grade 3 (OR = 4.783, 95%CI 2.356–9.131, P = 0.003).

Conclusion: In summary, the postoperative length of stay beyond 3 days after bullectomy was considered prolonged. The preoperative risk factors associated with prolonged postoperative stays after bullectomy included age (over 60), current smoking, and grade 3 ASA. Therefore, quick identification and intervention in patients with these high-risk factors may promote rapid recovery.

1. Introduction

Spontaneous pneumothorax is categorized as either primary (occurring without underlying lung disease), or secondary (associated

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with underlying lung disease) [1]. Its treatment and management are crucial for reducing recurrence and improving prognosis. Surgical treatment is currently considered the most effective intervention for managing spontaneous pneumothorax [2–4]. Despite the widespread acceptance of surgical treatment, significant gaps and controversies still exist in the current literature [5]. Current research mainly focuses on surgical techniques and short-term outcomes, with relatively little attention to the relationship between prolonged postoperative length of stay (LOS) and surgery-related adverse events [6,7]. This lack of knowledge hinders our comprehensive understanding of surgical outcomes. Further research will help identify high-risk patients, optimize preoperative planning and postoperative management, and ultimately improve patient prognosis.

Enhanced Recovery After Surgery (ERAS), which improves the efficiency of medical resource utilization and substantially minimizes costs, is gaining increasing acceptance among healthcare professionals and patients [8,9]. Due to the ongoing strides in thoracoscopic techniques and increasing patient expectations for high-quality healthcare, thoracoscopic surgery has evolved as the preferred approach for bullectomy, aligning with ERAS principles [10,11]. However, healthcare providers face significant challenges in improving efficiency and reducing complications as well as costs due to surgery-related adverse events, such as postoperative persistent air leakage, resulting in prolonged LOS and high medical expenses [12]. The relationship between a prolonged postoperative LOS following bullectomy and surgery-related adverse events remains unclear. This study hypothesizes that: postoperative prolonged LOS is significantly associated with surgery-related adverse events, and preoperative high-risk factors can predict these adverse events. We retrospectively analyzed clinical data from bullectomy procedures to establish the relationship between postoperative LOS and surgery-related adverse events. Additionally, we investigate preoperative high-risk factors affecting prolonged LOS. This is geared towards improving postoperative management through early identification and intervention in high-risk patients, hence reducing complications and LOS.

2. Materials and methods

We retrospectively analyzed data from patients who underwent thoracoscopic bullectomy in our thoracic surgery department between January 2018 and December 2023. The study strictly adhered to the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Wenzhou Central Hospital (L2024-04-028). All participants provided written and verbal informed consent.

Inclusion Criteria: Patients diagnosed with spontaneous pneumothorax, preoperative chest CT confirming the presence of a pulmonary bulla; patients aged between 18 and 80 years; those undergoing thoracoscopic bullectomy; patients with ASA classification <4; patients who provided signed informed consent.

Exclusion Criteria: Patients with a history of same-side lung surgery; simultaneous bilateral bullectomy; conversion to open thoracotomy; incomplete recording of case data.

2.1. Define surgery-related adverse events

Surgery-related adverse events included conversion to open thoracotomy, operative time $\geq$3 h, transfusion events, chest tube drainage duration $\geq$48 h [13], unplanned reoperation, antibiotic use $\geq$48 h, lung infection, lung atelectasis, and lung air leakage. Lung air leakage was specifically defined as persistent leakage spanning $\geq$48 h [14].

2.2. Define prolonged LOS after bullectomy

Patients were categorized into prolonged and normal groups based on postoperative LOS after bullectomy. The incidence rate of adverse surgical events was calculated for each group. The relationship between surgical adverse events after bullectomy and LOS was investigated using receiver operating characteristic (ROC) curve analysis. The AUC was calculated to measure the overall performance of the LOS threshold in predicting adverse surgical events. The AUC value ranged from 0.5 to 1, with higher values indicating better discrimination capacity. The Youden Index (J = Sensitivity + Specificity - 1) was used to establish the optimal cut-off value. The threshold corresponding to the maximum Youden Index was selected as the critical value for prolonged LOS. The chosen cut-off value was validated by comparing the incidence rates of adverse surgical events in patients with prolonged and normal LOS. Logistic regression analysis was performed to validate the relationship between the identified threshold and the risk of prolonged LOS.

2.3. Statistical analysis

Statistical data were analyzed using SPSS (version 22.0 SPSS Inc., IL, USA). Continuous data were presented as the mean $\pm$ standard deviation, and independent sample t-tests were used for between-group comparisons. Categorical variables were expressed as percentages and assessed using the Chi-square test or Fisher's exact test. Univariate factors were identified using Fisher's exact test or Chi-square test. Categorical variables with a significance level of $P < 0.1$ in univariate analysis were incorporated into multivariate regression analysis. The results were reported as odds ratios (OR) with 95 % confidence intervals (95 % CI). $P < 0.05$ was considered statistically significant.

3. Results

A total of 152 patients met the inclusion criteria. Among them, 94 patients had a normal LOS, and 58 patients had a prolonged LOS

(Fig. 1). Table 1 shows the overall clinical characteristics of the two groups. Surgery-related adverse events significantly influenced the postoperative LOS ($p < 0.001$), and the occurrence of surgery-related adverse events had a significant diagnostic value for postoperative LOS after bullectomy (AUC = 0.818, $p < 0.001$) (Fig. 2). A postoperative LOS of 3 days after bullectomy was identified using a maximum Youden Index of 0.602; durations exceeding this threshold were considered prolonged. The incidence of prolonged LOS after bullectomy was 38.2 % (58/152), and 20.4 % (31/152) of the patients who experienced surgery-related adverse outcomes. This indicates a significant relationship between the incidence of adverse events and the prolongation of LOS. This suggests that adverse events are associated with, and may promote prolonged LOS.

In this patient cohort, the rates of specific adverse events were as follows: conversion to open thoracotomy (2.0 %, 3/152), operative time ≥3 h (3.3 %, 5/152), transfusion events (3.3 %, 5/152), chest tube drainage duration ≥48 h (11.8 %, 18/152), unplanned reoperation (0.7 %, 1/152), lung infection (5.3 %, 8/152), lung atelectasis (14.5 %, 22/152), lung air leakage (9.2 %, 14/152), and antibiotic usage ≥48 h (11.2 %, 17/152; Table 2).

Based on the univariate analysis, age, smoking status, ASA classification, and history of chronic lung disease were the significantly correlated factors linked to prolonged LOS after bullectomy. In addition, age ≥60 years ($p = 0.003$), current smoking status ($p < 0.001$), ASA classification 3 ($p = 0.012$), and history of chronic lung disease ($p = 0.021$) were significantly different among the two groups. The other preoperative indicators showed no significant differences (Table 1). Factors with $P < 0.1$ in univariate analysis were included in multivariate regression analysis to identify independent preoperative risk factors for prolonged LOS after bullectomy. The significant factors included age ≥60 years (OR = 3.052, 95 % CI 1.226–7.586, P = 0.016), current smoking status (OR = 2.754, 95 % CI 1.482–6.346, P = 0.025), and ASA classification of 3 (OR = 4.783, 95 % CI 2.356–9.131, P = 0.003; Table 3).

4. Discussion

Thoracoscopic bullectomy is an extensively applied surgical intervention for treating spontaneous pneumothorax. Nonetheless, the resulting prolonged LOS increases medical expenses and reduces patient satisfaction [15]. As such, it is important to understand the preoperative risk factors that influence a prolonged LOS for preventing and effectively managing this concern. Herein, we observed a significant effect of postoperative complications on LOS, corroborating the findings from previous research [16].

Primary preoperative risk factors included baseline health of the patient, disease severity, and surgical complexity. Patient age, smoking history, and comorbidities are potential factors that can influence the speed and efficacy of postoperative recovery. Several studies have proposed that elderly patients may be prone to extended LOS after bullectomy [17]. In the present study, we identified patient age >60 years as an independent risk factor influencing prolonged LOS in both univariate and multivariate analyses. This observation may be linked to decreased physiological reserves, increased comorbidities, and slower recovery rates among elderly patients [18]. We identified current smoking status as an independent risk factor for prolonged LOS. Researchers have speculated that smoking may increase respiratory secretions, presenting challenges to expectoration. In non-emergency situations, patients are advised to quit smoking for at least two weeks according to the recommendations by Kwak et al. [19] These findings underscore the significance of preoperative assessment and risk stratification among patients undergoing thoracoscopic bullectomy. Early identification of high-risk patients enables targeted interventions, such as optimizing perioperative care, managing underlying conditions, promoting smoking cessation before surgery, and refining surgical plans. These measures can minimize postoperative complications, reduce hospital stays, and expedite patient recovery.

Lin et al. postulated that patient comorbidities, including emphysema, pulmonary fibrosis, and intraoperative pleural adhesions, could affect postoperative LOS [20]. In this investigation, patients with a history of lung diseases had a significantly higher occurrence

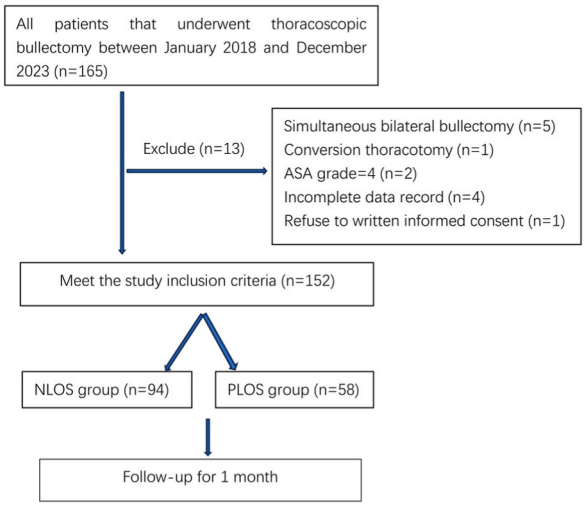

Fig. 1. Details of the study enrollment. ASA = American Society of Anesthesiology; NLOS = normal length of stay; PLOS = prolonged length of stay.

Table 1
Clinical characteristics and univariate analysis of PLOS with patients.

Variables	PLOS group (n = 58)	NLOS group (n = 94)	P value
Age (years), n (%)			
≤40	27 (46.6)	30 (31.9)	0.07
40-60	15 (25.9)	15 (16.0)	0.136
≥60	16 (27.6)	49 (46.8)	0.003
Weight (kg), mean (SD)	59 (9.5)	63 (7.8)	0.152
Height (cm), mean (SD)	166 (11.7)	163 (14.2)	0.347
Sex, n (%)			0.557
Male	33 (56.9)	58 (61.7)	
Female	25 (43.1)	36 (38.3)	
Smoking status, n (%)			
Never	24 (41.4)	26 (27.7)	0.08
Former	28 (48.3)	33 (35.1)	0.281
Current	6 (10.3)	35 (37.2)	<0.001
ASA, n (%)			
1	36 (62.1)	52 (55.3)	0.413
2	21 (36.2)	29 (30.9)	0.495
3	1 (1.7)	13 (13.8)	0.012
Pleural adhesion, n (%)			0.851
Yes	8 (13.8)	14 (14.9)	
No	50 (86.2))	80 (85.1)	
Chronic lung disease, n (%)			0.021
Yes	5 (8.6)	22 (23.4)	
No	53 (91.4)	72 (76.6)	
Hypertension or diabetes			0.731
Yes	11 (19.0)	20 (21.2)	
No	47 (81.0)	74 (78.8)	

SD = standard deviation; ASA = American Society of Anesthesiology; NLOS = normal length of stay; PLOS = prolonged length of stay.

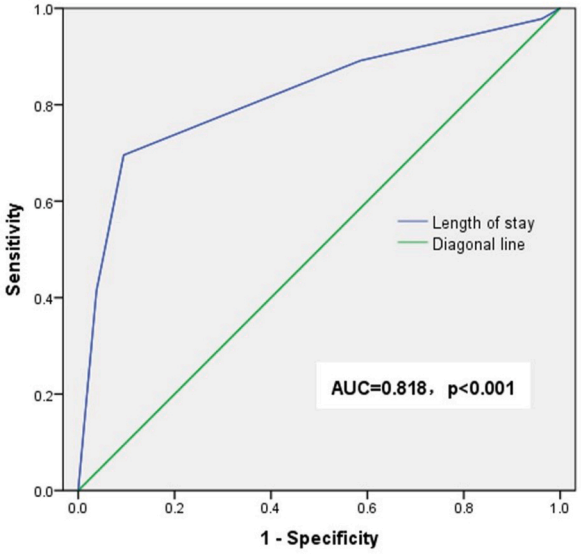

Fig. 2. ROC curve showed the predictability of length of stay after bullectomy based on operation-related adverse outcomes. ROC = Receiver Operating Characteristic Curve.

of postoperative complications and an extended LOS than those without such a history. In a multifactorial retrospective analysis however, a history of lung diseases was not an independent risk factor, in line with the clinical research findings of Wakefield et al. [21]. Furthermore, pleural adhesions are not regarded independent risk factor promoting an extended LOS.

The ASA classification is a significant risk factor for extended LOS. In this study, patients categorized as ASA Class 3 had a substantially prolonged LOS, according to the results reported by Choy et al. [22] This is because patients with severe underlying diseases are more susceptible to postoperative complications, such as pneumothorax, pneumonia, and respiratory failure, hence causing extended LOS.

This study has limitations. First, the small sample size and its nature as a single-center retrospective study may introduce an inherent selection bias, making it difficult to control all potential confounding factors. As a consequence, the findings may not be

Table 2
Operation related adverse outcomes and LOS after bullectomy.

Operation related adverse outcomes, n (%)	LOS after bullectomy (days)				
	1 (n = 55)	2 (n = 39)	3 (n = 28)	4 (n = 17)	≥5 (n = 13)
Conversion to open	0	0	0	1	2
Operative time ≥3 h	0	0	3	1	1
Transfusion event	0	1	2	1	1
Drainage time ≥48 h	0	0	3	10	5
Unplanned reoperation	0	0	0	0	1
Lung infection	0	0	0	2	6
Atelectasis	0	5	3	9	5
Air leakage	0	0	0	8	6
Using antibiotic time ≥48 h	0	0	6	7	4

LOS = length of stay

Table 3
Risk factors of PLOS by multivariate analysis.

Variable	OR	95 % CI	P-value
Age (Years)			
≤40 (Ref)			
40-60	1.648	0.829–22.036	0.34
≥60	3.052	1.226–7.586	0.016
Smoking status			
Never (Ref)			
Former	1.212	0.324–1.895	0.358
Current	2.754	1.482–6.346	0.025
ASA			
1 (Ref)			
2	1.845	0.960–3.211	0.13
3	4.783	2.356–9.131	0.003

CI = confidence interval; OR = Odds Ratio; ASA = American Society of Anesthesiology; Ref = Reference; PLOS = prolonged length of stay.

generalizable to all medical centers. Nevertheless, we used ROC curve analysis to determine a precise cut-off value for defining prolonged LOS after bullectomy. Previous studies have shown inconsistent definitions of prolonged LOS, causing variability in clinical practice and patient management. By defining prolonged LOS as more than 3 days, this study provides a clear, evidence-based threshold applicable to future clinical protocols and research. This is specifically important for guiding the optimization of medical resource allocation.

Therefore, early identification of high-risk factors in patients and using targeted interventions, among them optimizing perioperative care, addressing underlying conditions, promoting preoperative smoking cessation, and refining surgical plans, can reduce postoperative complications, resulting in reduced hospital stays and swift patient recovery.

Ethical approval and consent to participate

This study complied with the Declaration of Helsinki and was approved by the Ethics Committee of the Wenzhou Central Hospital (L2024-04-028).

Data availability statement

Research data will be provided by the corresponding author upon a reasonable request.

Conflict of interest disclosures

The authors declare no conflicts of interest.

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CRediT authorship contribution statement

Wei-Hong Huang: Writing – original draft, Funding acquisition, Formal analysis, Data curation. **Yuan-liang Zheng:** Writing – review & editing, Writing – original draft, Validation, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37947.

References

[1] M. Gottlieb, B. Long, Managing spontaneous pneumothorax, Ann. Emerg. Med. 81 (5) (2023 May) 568–576.
[2] K. Shaikhrezai, A.I. Thompson, C. Parkin, et al., Video-assisted thoracoscopic surgery management of spontaneous pneumothorax–long-term results, Eur. J. Cardio. Thorac. Surg. 40 (1) (2011 Jul) 120–123.
[3] S. Fung, M. Kivilis, A. Krieg, A. Schauer, A. Rehders, L. Dizdar, W.T. Knoefel, Video-Assisted thoracoscopic surgery with bullectomy and partial pleurectomy versus chest tube drainage for treatment of secondary spontaneous pneumothorax-A retrospective single-center analysis, Medicina (Kaunas) 58 (3) (2022 Feb 27) 354.
[4] J. Nakajima, Surgery for secondary spontaneous pneumothorax, Curr. Opin. Pulm. Med. 16 (4) (2010 Jul) 376–380.
[5] J. Zhou, N. Chen, Y. Hai, M. Lyu, Z. Wang, Y. Gao, L. Pang, H. Liao, L. Liu, External suction versus simple water-seal on chest drainage following pulmonary surgery: an updated meta-analysis, Interact. Cardiovasc. Thorac. Surg. 28 (1) (2019 Jan 1) 29–36.
[6] Y.L. Zheng, R.S. Huang, Sub-axillary cosmetic incision versus single-incision thoracoscopic surgery for primary spontaneous pneumothorax, J. Cardiothorac. Surg. 18 (1) (2023 Jul 12) 228.
[7] S. Yeo, J. Chen, L. Leow, H. Luo, J.K. Chung Tam, Efficacy of mesh coverage in surgical bullectomy for primary spontaneous pneumothorax: a systematic review and meta-analysis, Surgeon 21 (6) (2023 Dec) e378–e406.
[8] M. Darras, C. Schneider, S. Marguerite, W. Oulehri, O. Collange, P.M. Mertes, J.P. Mazzucotelli, M. Kindo, Early chest tube removal on the 1st postoperative day protocol of an enhanced recovery after cardiac surgery programme is safe, Eur. J. Cardio. Thorac. Surg. 65 (3) (2024 Mar 1) ezae092.
[9] A.B. Stone, M.C. Grant, C.L. Wu, E.C. Wick, Enhanced recovery after surgery for colorectal surgery: a review of the economic implications, Clin. Colon Rectal Surg. 32 (2) (2019 Mar) 129–133.
[10] L. Zheng, X. Zhang, Q. Ma, et al., Application of multimodal analgesia combined with opioid-free anesthetics in a non-intubated video-assisted thoracoscopic surgery bullectomy: a case report, Front Surg 10 (2023 Feb 13) 1116523.
[11] Z. Guo, S. Li, W. Yin, J. He, Implementation of a novel enhanced recovery after surgery program in thoracoscopic bilateral bullectomy, J. Thorac. Cardiovasc. Surg. 153 (5) (2017 May) e115–e118.
[12] G.M. Marta, F. Facciolo, L. Ladegaard, H. Dienemann, A. Csekeo, F. Rea, S. Dango, L. Spaggiari, V. Tetens, W. Klepetko, Efficacy and safety of TachoSil® versus standard treatment of air leakage after pulmonary lobectomy, Eur. J. Cardio. Thorac. Surg. 38 (6) (2010 Dec) 683–689.
[13] R.J. Mehran, L.W. Martin, C.M. Baker, G.E. Mena, D.C. Rice, Pain management in an enhanced recovery pathway after thoracic surgical procedures, Ann. Thorac. Surg. 102 (6) (2016 Dec) e595–e596.
[14] I. Firlinger, E. Stubenberger, M.R. Müller, O.C. Burghuber, A. Valipour, Endoscopic one-way valve implantation in patients with prolonged air leak and the use of digital air leak monitoring, Ann. Thorac. Surg. 95 (4) (2013 Apr) 1243–1249.
[15] A. Ahmad Khan, M. Zahid, M. Ahmad Alhiyari, et al., Demographics, clinical characteristics, and recurrence rate of patients with primary spontaneous pneumothorax at a tertiary care center in Qatar, Qatar Med. J. 2022 (4) (2022 Nov 16) 56.
[16] D. Kim, B. Jung, B.H. Jang, et al., Epidemiology and medical service use for spontaneous pneumothorax: a 12-year study using nationwide cohort data in Korea, BMJ Open 9 (10) (2019 Oct 28) e028624.
[17] S. Nagata, M. Omasa, K. Tokushige, T. Nakanishi, H. Motoyama, Efficacy and safety of surgery for spontaneous pneumothorax in elderly patients, Interact. Cardiovasc. Thorac. Surg. 30 (2) (2020 Feb 1) 263–268.
[18] F. Takahashi, T. Takihara, N. Nakamura, Y. Horio, K. Enokida, N. Hayama, T. Oguma, T. Aoki, I. Masayuki, K. Asano, Etiology and prognosis of spontaneous pneumothorax in the elderly, Geriatr. Gerontol. Int. 20 (10) (2020 Oct) 878–884.
[19] H.V. Kwak, K.C. Banks, Y.Y. Hung, et al., Utilization and outcomes of observation for spontaneous pneumothorax at an integrated health system, J. Surg. Res. 288 (2023 Aug) 28–37.
[20] C.K. Lin, K.I. Leong, C.H. How, et al., Drainless thoracoscopic surgery should be avoided in primary spontaneous pneumothorax with pleural adhesion, Interact. Cardiovasc. Thorac. Surg. 35 (4) (2022 Sep 9) ivac237.
[21] C.J. Wakefield, C.W. Seder, A.T. Arndt, et al., Cannabis use is associated with recurrence after primary spontaneous pneumothorax, Front Surg 8 (2021 May 25) 668588.
[22] M.C. Choy, D. Pescod, Pneumothorax in association with spontaneous ventilation general anesthesia–an unusual cause of hypoxemia, Anaesth. Intensive Care 35 (2) (2007 Apr) 270–273.