Original Article

Impact of perioperative fluid overload on the occurrence of postoperative pulmonary complications following lobectomy

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Contributions: (I) Conception and design: H Liu, J Luo; (II) Administrative support: J Luo; (III) Provision of study materials or patients: H Liu, Y Shao; (IV) Collection and assembly of data: H Liu, Y Shao; (V) Data analysis and interpretation: H Liu, J Luo; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Background: The incidence of pulmonary complications following lobectomy remains substantial, with postoperative fluid volume playing a pivotal role. However, the optimal management of fluids after lobectomy remains uncertain. This study aimed to establish a benchmark for perioperative fluid overload in patients undergoing pulmonary surgery by comparing the incidence of pulmonary complications following standard surgical procedures among patients with varying fluid volumes.

Methods: A retrospective analysis was conducted on adult patients with non-small cell lung cancer (NSCLC) who underwent lobectomy between January 2018 and January 2019. The primary exposure variable was fluid overload within the initial 24-hour period. The observation outcomes were postoperative pulmonary complications, acute kidney injury (AKI), and postoperative length of stay. Univariate and multivariate analyses were performed.

Results: Among the 300 patients included in this study, the low-volume group exhibited a significantly shorter postoperative hospital stay compared to the high-volume group (P=0.02). Furthermore, the low-volume group demonstrated a significantly lower incidence of postoperative atelectasis (P=0.03) and pulmonary infection (P=0.02) compared to the high-volume group. Moreover, logistic regression analysis revealed that the high-volume group had higher odds ratios (ORs) for developing atelectasis [OR: 2.611, 95% confidence interval (CI): 1.050–6.496, P=0.04] and pulmonary infection (OR: 2.642, 95% CI: 1.053–6.630, P=0.04) following lobectomy when compared to the low-volume group.

Conclusions: In patients with NSCLC undergoing lobectomy, reducing intravenous infusion after surgery while maintaining hemodynamic stability can effectively shorten hospitalization duration and mitigate the risk of postoperative atelectasis and pulmonary infection.

Keywords: Fluid overload; lobectomy; pulmonary complications

Submitted Mar 22, 2024. Accepted for publication Jul 05, 2024. Published online Aug 16, 2024.
doi: 10.21037/jtd-24-478
View this article at: https://dx.doi.org/10.21037/jtd-24-478

Introduction

Background

Lung cancer is a prevalent malignancy worldwide, accounting for approximately 11.6% of all cancer diagnoses and contributing to 18.4% of overall cancer-related mortality in 2018 (1). Consequently, lung cancer stands as the foremost cause of both incidence and mortality among various cancers globally. The optimal surgical approach for early-stage non-small cell lung cancer (NSCLC) remains

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lobectomy accompanied by systematic mediastinal lymph node dissection (2).

The repertoire of minimally invasive lobectomy techniques, such as video-assisted thoracoscopic lobectomy and robot-assisted lobectomy, has expanded with the advancement of techniques and devices. Previous studies have demonstrated that minimally invasive lobectomy may offer a less invasive surgical approach compared to open thoracotomy, potentially resulting in fewer postoperative complications and lower in-hospital mortality rates (3-5). Nevertheless, the prevalence of postoperative complications remains substantial, ranging from 21.8% to 54.7% (6-8).

Rationale and knowledge gap

Although the etiology of complications is multifactorial, perioperative fluid administration is considered a pivotal factor in this cascade (9). Excessive perioperative fluid may precipitate respiratory complications, such as pulmonary edema, acute respiratory distress syndrome (ARDS), respiratory failure, and tissue edema (10). Conversely, restrictive fluid management raises concerns regarding coronary perfusion and renal function (11). Due to significant variations in perioperative intravenous fluid dosage among medical centers and the adoption of either restrictive or liberal infusion management strategies by doctors based on their individual practices, there is a need for more evidence-based medicine to guide clinical fluid management in patients undergoing pulmonary surgery.

Highlight box

Key findings

- The duration of hospitalization can be effectively reduced and the risk of postoperative atelectasis and pulmonary infection can be mitigated in patients with non-small cell lung cancer (NSCLC) undergoing lobectomy by optimizing intravenous infusion.

What is known and what is new?

- The optimal surgical approach for early-stage NSCLC remains lobectomy accompanied by systematic mediastinal lymph node dissection; however, the prevalence of postoperative pulmonary complications remains substantial.
- The present study aimed to investigate the impact of perioperative fluid overload on the occurrence of postoperative pulmonary complications.

What is the implication, and what should change now?

- In clinical practice, reducing intravenous infusion post-lobectomy while ensuring hemodynamic stability can lower the risk of postoperative atelectasis and pulmonary infection.

Objective

The objective of the present study was to conduct a retrospective audit on fluid overload within the initial 24-hour period, encompassing both intraoperative and postoperative phases. Our objective is to establish a benchmark for perioperative fluid overload in patients undergoing pulmonary surgery by comparing the incidence of pulmonary complications following standard surgical procedures among patients with varying fluid volumes. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-478/rc).

Methods

Patients

In this observational retrospective cohort study, a total of 351 patients with NSCLC who underwent lobectomy at The First Affiliated Hospital of Chongqing Medical University between January 2018 and January 2019 were included. Among these patients, 9 had received preoperative chemotherapy, 26 underwent multiple lobectomies, 13 underwent palliative excision, and the data of 3 patients were lost and therefore excluded from the analysis. Hence, a final sample size of 300 patients was considered for further analysis. Clinicopathological classification was performed based on the Union for International Cancer Control tumor/node/metastasis (TNM) classification (8th edition) (12). All patients received first- or second-generation prophylactic cephalosporins until postoperative inflammatory markers were normal. In case postoperative pulmonary infection was diagnosed, third-generation cephalosporins were administered. Recovery from anesthesia was followed by oral intake initiation in all patients, unless they were identified as being at risk for aspiration, after a 4-hour timeframe. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional review board of The First Affiliated Hospital of Chongqing Medical University (No. 2022-K572) and individual consent for this retrospective analysis was waived.

Fluid balance

The fluid balance was defined as the cumulative sum of

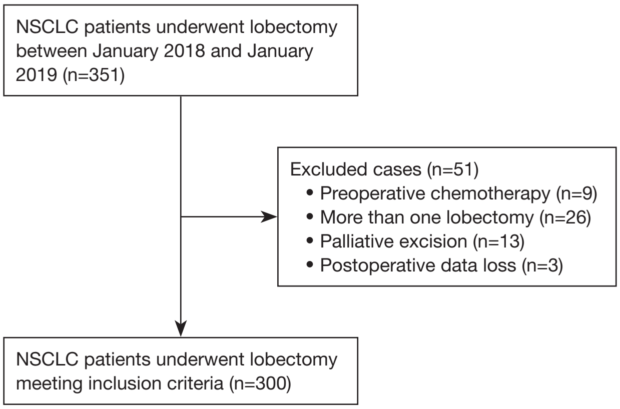

Figure 1 Flowchart of data selection. NSCLC, non-small cell lung cancer.

administered fluids, drainage losses, intraoperative blood loss, and diuresis, excluding fluid losses from insensible perspiration and evaporation at the surgical site.

The calculation of fluid balance encompassed both intraoperative and postoperative fluid volumes over a 24-hour period, standardized by patient body surface area. High fluid overload was defined as a positive exceeding 79.65 mL/m^2/h within the first 24 hours based on the median calculations. Patients were categorized into high or low-volume groups according to their calculated positive fluid balances. Incidence of pulmonary complications during hospitalization was prospectively recorded.

Outcome measures

The primary outcomes assessed were postoperative pulmonary complications and acute kidney injury (AKI). Postoperative pulmonary complications encompassed ARDS, pulmonary embolism, prolonged air leak (>7 days), atelectasis, and pneumonia occurring during the postoperative hospitalization period (13). Prolonged air leak was defined as a persistent leakage lasting more than 7 days. Postoperative pneumonia was diagnosed when a new pulmonary infiltrate, accompanied by leukocytosis and fever (axillary temperature >38.0 ℃), was observed on chest X-ray (14). AKI was defined as an increase in serum creatinine level of at least 0.3 mg/dL or 50% compared to the preoperative level within 48 hours after surgery (15). Other secondary outcomes included intraoperative bleeding, duration of the operation, surgical options, NSCLC staging, postoperative pathology, and acute physiology and chronic health evaluation (APACHE) II scoring and postoperative length of stay.

Statistical analysis

Summary statistics were presented as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. These variables were compared between groups with unpaired *t*-tests, Fisher exact tests or analysis of variance (ANOVA) where appropriate. The hazard ratios (HRs) and 95% confidence intervals (95% CIs) were calculated using univariate and multivariate binary logistic regression analyses. P values smaller than 0.05 were considered significant. All analyses were performed using IBM SPSS Statistics 21 software.

Results

A total of 300 patients were enrolled in the study after applying the inclusion and exclusion criteria (*Figure 1*). The preoperative clinical characteristics of 300 patients with NSCLC are summarized in *Table 1*. There were no statistically significant differences observed in age (P=0.23), sex (P=0.82), body mass index (P=0.26), American Society of Anesthesiology status (P=0.58), tobacco use (P=0.40), presence of diabetes (P=0.86), coronary disease history (P=0.16), forced vital capacity levels (P=0.76) and forced expiratory volume in the first second (FEV1) values (P=0.61) between the high fluid overload group and the low fluid overload group.

The intraoperative and postoperative data of the patient are presented in *Table 2*. In comparison, the postoperative hospital stay (P=0.02) and postoperative pulmonary complications (P<0.001) were significant increased in the high-volume group. The intraoperative bleeding (P=0.20), duration of the operation (P=0.22), surgical options (P=0.31), NSCLC staging (P=0.89), postoperative pathology (P=0.35), and APACHE II scoring (P=0.08) exhibited no significant differences between the high-volume group and the low-volume group.

The prevalence of various pulmonary complications outcome parameters was compared between two groups, and these findings are illustrated in *Figure 2*. *Figure 2A,2B* shows that the incidence of pulmonary infection (P=0.02) and postoperative atelectasis (P=0.03) exhibited statistical significance between the two groups. However, *Figure 2C,2D* shows that no statistically significant differences were observed in terms of prolonged air leak (P=0.09) and pulmonary embolism (P=0.32).

Table 1 The preoperative clinical characteristics

Characteristics	Low-volume group	High-volume group	P value
Age (years)	59.8±10.5	58.4±9.9	0.23
Sex (male/female)	75/75	77/73	0.82
BMI (kg/m^2)	23.2±2.8	23.6±3.2	0.26
ASA			0.58
I	0	0	
II	85	83	
III	64	67	
IV	1	0	
Tobacco use			0.40
Nonsmoker	91	92	
Stop <1 year	11	17	
Active	48	41	
Diabetes	19	18	0.86
Coronary disease history	6	11	0.16
FVC (L)	3.25±0.78	3.22±0.76	0.76
FEV1 (L)	2.38±0.69	2.34±0.69	0.61

Data are presented as mean ± standard deviation or number. BMI, body mass index; ASA, American Society of Anesthesiology; FVC, forced vital capacity; FEV1, forced expiratory volume in the first second.

Table 2 The intraoperative and postoperative data

Variables	Low-volume group	High-volume group	P value
Intraoperative bleeding (mL)	169.7±122.4	209.5±358.2	0.20
Length of operation (min)	182.3±61.8	191.2±62.7	0.22
Surgical options			0.31
Videoscope	139	134	
Open	11	16	
NSCLC staging			0.89
IA	81	83	
IB	28	30	
IIA	9	6	
IIB	15	12	
IIIA	17	19	
Postoperative pathology			0.35
Adenocarcinoma	122	121	
Squamous cell carcinoma	24	28	
Other	4	1	
APACHE II	10.4±3.2	9.8±2.7	0.08
Postoperative length of stay (days)	6.3±3.9	7.8±5.9	0.02
Pulmonary complications	24	53	<0.001

Data are presented as mean ± standard deviation or number. NSCLC, non-small cell lung cancer; APACHE, acute physiology and chronic health evaluation.

Next, we performed a logistic regression analysis for the postoperative atelectasis and pulmonary infection and results are illustrated in *Tables 3,4*. Intraoperative heavy bleeding constituted an independent risk factor for the occurrence of postoperative pulmonary infection. The incidence of atelectasis (P=0.04) and pulmonary infection (P=0.04) following lobectomy was 2.6 times higher in the high-volume group compared to the low-volume group.

Discussion

The pathophysiology of pulmonary complications following lobectomy appears to be multifactorial, involving fluid overload and pain resulting from surgical trauma, as well as potential adverse effects associated with one-lung ventilation (16,17). In this study, we conducted an analysis on perioperative fluid overload and respiratory outcomes following lobectomy. Among 300 patients with NSCLC who underwent lobectomy, we observed a significant correlation between the volume of intravenous fluids administered within the initial 24-hour period and the incidence of postoperative pulmonary complications. The primary finding of this study demonstrates that extensive administration of intravenous fluids within the initial 24-hour period exacerbates the prevalence of postoperative pulmonary complications in patients with NSCLC undergoing lobectomy. Furthermore, excessive administration of intravenous fluids can lead to prolonged postoperative hospitalization.

Perioperative intravenous fluid therapy is employed to restore and maintain water, electrolyte balance, and organ perfusion in order to achieve physiological homeostasis (18). Messina *et al.* assessed the importance of perioperative fluid administration in noncardiac surgery, but did not extend their assessment to lung resections (9). Previous studies

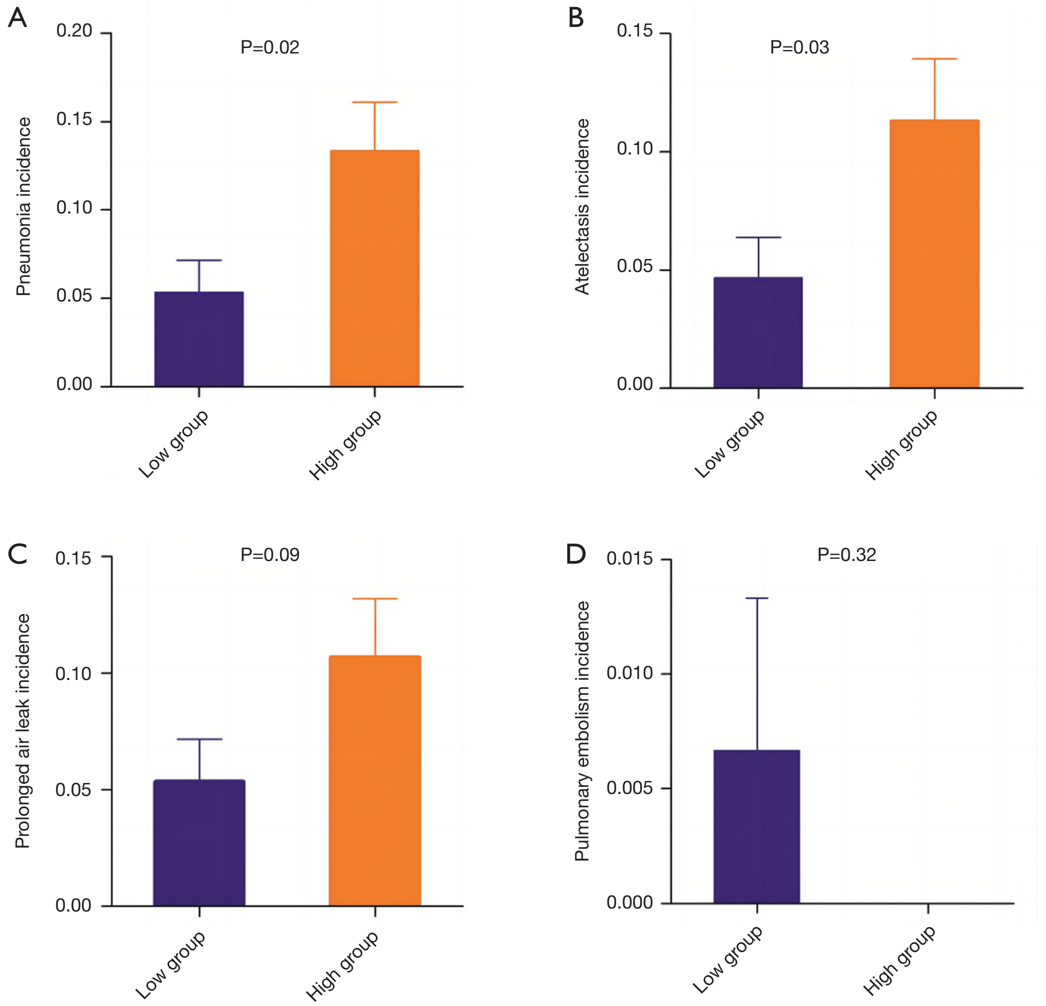

Figure 2 Pulmonary complication outcome. (A) Pneumonia. (B) Postoperative atelectasis. (C) Prolonged air leak. (D) Pulmonary embolism.

solely assessed the intravenous fluid volume 24 hours post-lobectomy, disregarding the potential augmentation of intraoperative intravenous fluid volume due to emergent circumstances like intraoperative massive hemorrhage or hypotension, thus failing to accurately reflect the extent of intravenous fluid infusion (15,17). Arslantas *et al.* solely investigated intraoperative fluid administration's impact on postoperative pulmonary complications following anatomic lung resections, ignoring the volume of intravenous fluids within the initial 24 hours after surgery (8).

Some studies have suggested potential harm associated with excessive perioperative fluid restriction, including the risk of low blood volume and postoperative organ dysfunction (19,20). However, our study did not observe any instances of low blood volume or postoperative organ dysfunction, which may be attributed to our emphasis on early postoperative eating.

In clinical practice, the volume of postoperative fluids varies significantly among surgical patients due to variations in clinician practices and the occurrence of emergent situations necessitating increased fluid infusion (e.g., postoperative hemorrhage and hypotension). Given the absence of a standardized clinical protocol for perioperative 24-hour fluid infusion in lobectomy, clinicians currently employ arbitrary volumes. Therefore, it is imperative to develop institution-specific strategies for postoperative fluid management. This study serves as a valuable reference for optimizing perioperative 24-hour fluid management in clinical settings.

Our findings demonstrated a significantly higher incidence of pulmonary complications in the high-volume group compared to the low-volume group. Furthermore,

Table 3 Factors associated with atelectasis by univariate

Variables	Univariate analysis		
	OR	95% CI	P
Age (years)	0.993	0.954–1.035	0.75
Sex	1.400	0.601–3.260	0.44
BMI (kg/m^2)	0.968	0.841–1.114	0.65
ASA	1.582	0.685–3.657	0.28
Tobacco use	1.071	0.453–2.535	0.88
Diabetes	1.473	0.474–4.575	0.50
Coronary disease history	2.663	0.709–10.008	0.15
FVC (L)	0.972	0.562–1.681	0.92
FEV1 (L)	0.883	0.478–1.632	0.69
Intraoperative bleeding (mL)	1.000	0.999–1.001	0.34
Length of operation (min)	0.999	0.992–1.006	0.78
Surgical options	2.392	0.310–18.441	0.40
NSCLC staging	0.747	0.231–2.418	0.63
Postoperative pathology	0.882	0.315–2.472	0.81
APACHE II	1.026	0.896–1.175	0.77
Fluid overload	2.611	1.050–6.496	0.04

BMI, body mass index; ASA, American Society of Anesthesiology; FVC, forced vital capacity; FEV1, forced expiratory volume in the first second; NSCLC, non-small cell lung cancer; APACHE, acute physiology and chronic health evaluation; OR, odds ratio; CI, confidence interval.

Table 4 Factors associated with pneumonia occurring during the postoperative hospitalization period by univariate and multivariate analyses

Variables	Univariate analysis			Multivariate analysis		
	OR	95% CI	P	OR	95% CI	P
Age (years)	1.046	1.003–1.091	0.04	1.030	0.974–1.088	0.30
Sex	2.652	1.129–6.227	0.03	3.772	0.863–16.495	0.08
BMI (kg/m^2)	1.051	0.925–1.195	0.44	–	–	–
ASA	2.533	1.127–5.692	0.02	1.934	0.706–5.297	0.20
Tobacco use	0.443	0.201–0.974	0.04	2.419	0.619–9.452	0.20
Diabetes	1.630	0.579–4.590	0.36	–	–	–
Coronary disease history	1.313	0.284–6.060	0.73	–	–	–
FVC (L)	0.820	0.488–1.380	0.46	–	–	–
FEV1 (L)	0.534	0.291–0.981	0.04	0.733	0.331–1.625	0.44
Intraoperative bleeding	1.004	1.002–1.006	0.001	1.004	1.002–1.007	0.001
Length of operation	1.005	0.999–1.010	0.12	–	–	–
Surgical options	0.806	0.227–2.868	0.74	–	–	–
NSCLC staging	2.760	1.249–6.101	0.01	1.895	0.766–4.686	0.17
Postoperative pathology	0.315	0.138–0.716	0.006	0.437	0.156–1.220	0.11
APACHE II	1.030	0.908–1.169	0.65	–	–	–
Fluid overload	2.731	1.163–6.413	0.02	2.642	1.053–6.630	0.04

BMI, body mass index; ASA, American Society of Anesthesiology; FVC, forced vital capacity; FEV1, forced expiratory volume in the first second; NSCLC, non-small cell lung cancer; APACHE, acute physiology and chronic health evaluation; OR, odds ratio; CI, confidence interval.

the low-volume group exhibited a significantly lower incidence of postoperative atelectasis and pulmonary infection compared to the high-volume group. Excessive administration of fluids may lead to the accumulation of extravascular fluid in lung tissue, resulting in pulmonary edema (21). Refraining from excessive fluid administration has been widely advocated and integrated into enhanced recovery after surgery protocols, constituting a pivotal component of these programs (22). Therefore, shortening intravenous infusion post-lobectomy while ensuring hemodynamic stability can effectively decrease hospitalization duration and lower the risk of postoperative atelectasis and pulmonary infection.

There are several limitations to our study, which investigated the associations between perioperative fluid balance and postoperative complications. For instance, this retrospective study was conducted in a single institution and our subsequent study will select patients with segmental resection. To validate these findings, it is imperative to conduct large-scale prospective studies at multiple centers. Additionally, the participation of anesthesiologists and intensive care unit (ICU) doctors in this study was random rather than consistent, leading to variations in indications for fluid management or blood products.

Conclusions

The present study demonstrated that in patients with NSCLC undergoing lobectomy, a reduction in post-lobectomy intravenous infusion while ensuring hemodynamic stability can effectively shorten hospitalization duration and mitigate the risk of postoperative atelectasis and pulmonary infection.

Acknowledgments

Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-478/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-478/dss

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-478/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-478/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional review board of The First Affiliated Hospital of Chongqing Medical University (No. 2022-K572) and individual consent for this retrospective analysis was waived.

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Cite this article as: Liu H, Shao Y, Luo J. Impact of perioperative fluid overload on the occurrence of postoperative pulmonary complications following lobectomy. J Thorac Dis 2024;16(8):5201-5208. doi: 10.21037/jtd-24-478

