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ORIGINAL ARTICLE

ONE-LUNG VENTILATION AND ITS ROLE IN POSTOPERATIVE PULMONARY MORBIDITY FOLLOWING LUNG SURGERY

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Abstract

Introduction: On one hand, one-lung ventilation is a method intended to improve surgical access while guaranteeing enough oxygenation and is often required for thoracic surgery. On the other hand, one-lung ventilation increases the risk of pulmonary complications both during and after surgery. Because they raise morbidity, lengthen hospital stays and may have negative consequences, these complications are clinically significant. Our evaluation's goal was to determine the frequency and predictors of these complications, which are crucial for enhancing patient care and maximizing surgical results.

Material and Methods:In this retrospective analysis, we assessed 80 elective patients who had one-lung ventilation and lung resection as a result of cancer. The anesthetic protocol for all patients followed a standardized approach, ensuring consistency in perioperative management. The defined inclusion and exclusion criteria were used to determine which patients were included in the study. We looked at pulmonary complications after surgery, such as respiratory insufficiency, pneumonia and atelectasis in the first week after surgery.

Results: The study included 80 patients, with a postoperative pulmonary complication rate of 30.0%. Atelectasis, pneumonia and respiratory failure were the most commonly observed complications, with pneumonia being the leading cause. Pulmonary complications were significantly more prevalent in patients undergoing lobectomy (79.2%) and in those over 60 years of age (75.0%). Male gender, higher BMI (>25), reduced FEV_1% (<70) and FVC (<70) significantly increased the risk of pulmonary complications. Although oxygen saturation (SpO_2%) dropped during one-lung ventilation, this was more pronounced on the right side, though without statistical significance.

Conclusion: It is very common for pulmonary complications to happen after thoracic surgery. This is mostly because of the physiological changes that happen in the operating room and the use of one-lung ventilation. These factors significantly impact respiratory mechanics and gas exchange, underscoring the need for vigilant perioperative monitoring and tailored management strategies to mitigate these complications.

Keywords: *atelectasis; one-lung ventilation; pneumonia; pulmonary complications; respiratory failure.*

Introduction

Anesthesia in thoracic surgery is inconceivable without the use of one-lung ventilation (OLV), which facilitates optimal surgical exposure. Typically achieved through the insertion of a double-lumen endotracheal tube or a bronchial blocker, OLV allows ventilation of a single lung while maintaining perfusion in both. But this method makes big changes to the lungs' physiology, like a ventilation/perfusion (V/Q) mismatch and intrapulmonary shunting, which can compromise oxygenation and raise the risk of pulmonary complications like atelectasis, pneumonia, and respiratory failure after surgery (1).

Multiple factors, including proper tube placement, the use of a bronchoscope, the patient's underlying respiratory status, body positioning during surgery, the type of surgical procedure, ventilator settings and the anesthesiologist's expertise in thoracic surgery, influence the risk of pulmonary complications during OLV (2,3). Hypoxemia, which is a drop in arterial oxygen saturation (SpO_2) below 90% as measured by pulse oximetry, may also happen during OLV, making patients even more likely to have pulmonary complications and bad outcomes after surgery (4).

Patients undergoing thoracic surgery often have pre-existing pulmonary and systemic comorbidities, such as chronic obstructive pulmonary disease (COPD), coronary artery disease, or anemia. These conditions, combined with the physiological challenges of OLV, can increase the likelihood of complications, including prolonged mechanical ventilation, pneumonia, atelectasis and acute respiratory distress syndrome (ARDS). Such complications can significantly compromise recovery and increase morbidity and mortality rates (5).

Preoperative risk assessment is crucial for identifying patients at high risk of developing postoperative pulmonary complications. Functional evaluations, including spirometry and arterial blood gas analysis, remain essential tools to assess pulmonary reserve and gas exchange capacity. Nonetheless, preoperative testing is a cornerstone of thoracic surgical planning to optimize patients’ outcomes (6-9). Our evaluation's goal was to determine the frequency and predictors of these pulmonary complications, which are crucial for enhancing patient care and maximizing surgical results.

Material and Methods

The Clinic for Thoracic and Vascular Surgery in Skopje conducted this retrospective/ prospective observational study over the course of a year (2022–2023). Eighty patients underwent standard lung resection procedures (segmentectomy, lobectomy, bilobectomy and pneumonectomy) to treat lung cancer. These procedures were done with a double-lumen endotracheal tube (DLT) and general anesthesia.

Patients who met the ASA I–III classification, had an ejection fraction (EF) of at least 50%, hemoglobin levels of at least 90g/L, and had not been through any chemotherapy or radiation cycles before were eligible to take part. Patients with endocrinopathies, pathological arrhythmias, metastatic abnormalities in the contralateral lung, or significant pre-existing pulmonary impairment, such as a FEV_1 of less than 40% before surgery, were not eligible. The clinical ethics council granted ethical permission for the trial, and each participant gave their informed consent.

Every patient had the same anesthetic regimen. The thorough preoperative examinations included the patient's history, a clinical examination that focused on the respiratory and cardiovascular systems, a measurement of body weight and height, a measurement of non-invasive blood pressure (NIBP), and a computation of the optimal body mass index (BMI). A 12-lead electrocardiogram (ECG), preoperative echocardiogram, routine laboratory testing, imaging examinations such as chest computed tomography (CT), and a baseline pulmonary function assessment were among the other assessments. We performed standard preoperative procedures, including premedication with 5mg diazepam tablets and fasting.

We monitored all patients intraoperatively with standard parameters such as an arterial line, NIBP, pulse oximetry and ECG. We used an epidural catheter to provide postoperative analgesia. We used a consistent protocol to induce general anesthesia, administering 2mg midazolam, 3g/kg fentanyl, and 1-2mg/kg propofol. We then administered rocuronium bromide (0.6mg/kg) to relax the muscles and facilitate the placement of the DLT. We used auscultation and bronchoscopy to verify the correct positioning of the DLT.

We used a continuous infusion of propofol (6–7mg/kg/h), intermittent fentanyl (2g/kg), and rocuronium (0.3mg/kg/h) to maintain anesthesia during the procedure. Tidal volumes of 7ml/kg of ideal body weight during two-lung ventilation (TLV) were lowered to 5ml/kg during one-lung ventilation (OLV), with PEEP set to 5cmH2O and a FiO_2 of 0.5. We modified these ventilation parameters based on the stage of operation. We adjusted other ventilatory parameters, such as respiratory rates and inspiratory-to-expiratory ratios, as needed to maximize oxygenation.

Within the first 7 days postoperatively, we focused particularly on evaluating, tracking and recording postoperative pulmonary complications, such as respiratory failure requiring intubation and mechanical ventilation, pneumonia as defined by the European Perioperative Clinical Outcome (EPCO) criteria, and atelectasis. A decrease in peripheral oxygen saturation (SpO_2) to less than 90%, as determined by pulse oximetry with a FiO_2 of 0.5, was referred to as hypoxemia. We assessed pulmonary problems using clinical and radiological results.

In order to reduce the risk of unfavorable outcomes, this study sought to improve the preoperative and perioperative care of patients undergoing thoracic surgery by identifying characteristics linked to a higher incidence of complications.

Results

The study included 80 patients. The characteristics of the cohort are presented in Table 1. The percentage difference between genders was statistically significant and a significant association was observed between gender and lung malignancy at $p<0.05$. Male gender increased the likelihood of developing lung malignancy by four times (OR=4.333, 95% CI [2.12577–8.8337]). The average age of all participants was 62.9±8.2 years, ranging from 41 to 80 years. A total of 64.0% of participants were older than 64 years. The average age among male participants was 63.1±8.1 years, while the average age among female participants was slightly lower at 61.7±9.0 years.
The difference in mean values between genders was not statistically significant ($p>0.05$). The percentage difference between the two BMI groups was not statistically significant as well ($p>0.05$).

Table 1. Characteristics of the cohort.

Value	Age		Gender		BMI	
	≤ 60 years	≥ 60 years	Male	Female	≥25	≤25
%	37.5	62.5	81	19	56.25	43.75

We also analyzed the distribution of patients according to the ASA classification and comorbidities presented in Figure 1 and 2.

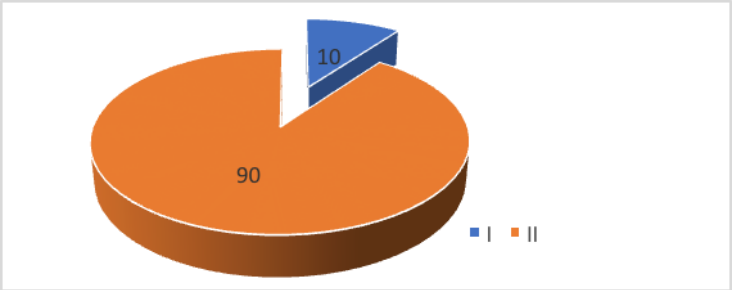

Figure 1. Graphical representation of the percentage distribution of ASA classifications.

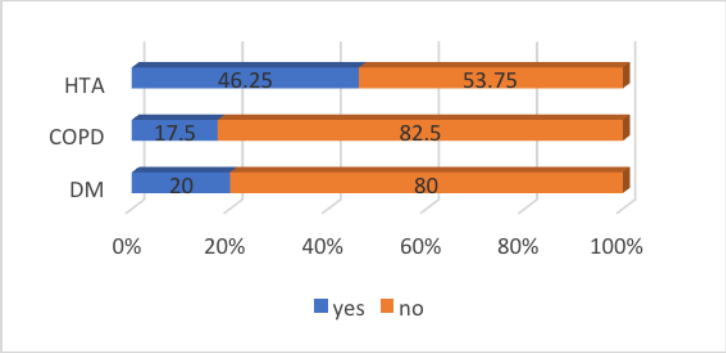

Figure 2. Graphical representation of the percentage distribution of diabetes mellitus (DM), hypertension (HTN) and chronic obstructive pulmonary disease (COPD).

Table 2 presents the characteristics of both the type of surgery and the surgical side. The percentage difference between lobectomy and other types of surgery is significant at $p<0.05$. The right side was affected in significantly higher percentage, with a significant difference at $p<0.05$. The average duration of single-lung collapse during surgery was 125.9±54.7 minutes, ranging from 20 to 285 minutes. In 50% of the patients, the duration of single-lung collapse during surgery exceeded 120 minutes, with a median of 120 minutes and an interquartile range (IQR) of 100–150 minutes.

Table 2. Characteristics of the surgery.

Surgery	***No***	***%***	***No***	***%***
Lobectomy	38	67.8	19	79.2
Pneumonectomy	11	19.6	0	0
Bilobectomy	4	7.1	3	12.5
Segmentectomy	3	5.4	2	8.3
Side of surgery				
Right	32	57.2	15	62.5
Left	24	42.8	9	37.5

The incidence of postoperative pulmonary complications in thoracic interventions with OLV in this study was 30.0%. The occurrence of complications, including atelectasis, pneumonia and postoperative respiratory insufficiency requiring mechanical ventilation, was observed in 30.0% of the patients, while 70.0% of the patients showed no complications. The percentage difference between patients with and without complications is significant at $p<0.05$ (Figure 3.).

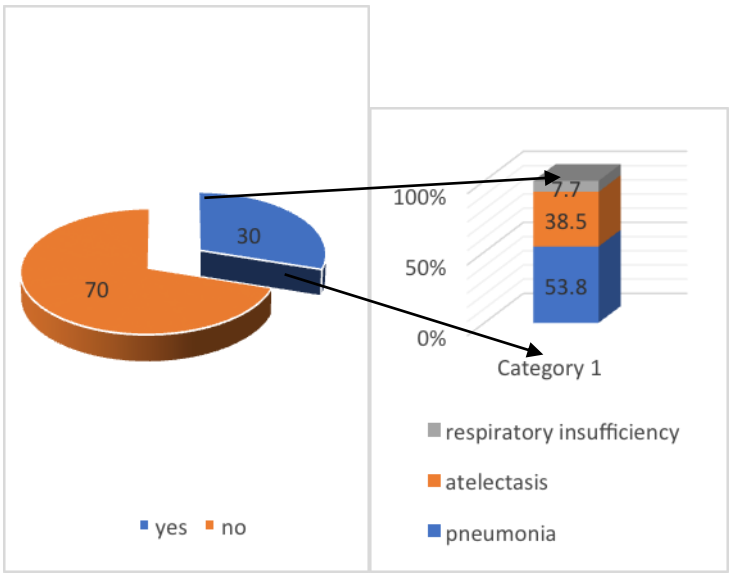

Figure 3. A graphical representation of the occurrence of complications and their types.

The percentage difference observed between pneumonia and atelectasis versus respiratory insufficiency is significant for $p<0.05$. The profile of patients experiencing postoperative complications during thoracic interventions with one-lung ventilation is significantly skewed towards males (87.5%) compared to females (12.5%), with a statistically significant difference of $p<0.05$. Postoperative pulmonary complications during thoracic interventions with OLV are observed in 75.0% of the patients aged over 60 years. The percentage difference compared to patients under 60 years old is statistically significant for $p<0.05$. Patients with complications have a mean age of 65.7±8.1 years. Complications are significantly more common in 79.2% of the patients who underwent lobectomy compared to other types of surgery. Among patients with complications, 65.4% had FEV_1% and FVC% values greater than or equal to 70. SpO_2 % values were below 90 in 32.3% of the patients with complications, and 91.1% were smokers. An association was observed between the occurrence of complications and BMI (normal vs. overweight) for $p<0.05$. A higher BMI above 25 (overweight) increases the likelihood of complications during thoracic interventions with one-lung ventilation by three times (OR=3.0, 95% CI [1.1138–9.0804]). For the other variables - gender, age, type of surgery, side, ASA classification, SpO_2%, smoking, diabetes mellitus, COPD, hypertension and duration of lung collapse, no significant associations with the occurrence of complications were observed for $p>0.05$ in this group of patients.

Figure 4 presents the results we obtained for the oxygen saturation in our cohort of patients. A nonsignificant greater drop in oxygen saturation was observed during right-sided operations compared to left-sided ones. The values of oxygen saturation (SpO_2%) were lower on the right sided surgeries ($P<0.05$).

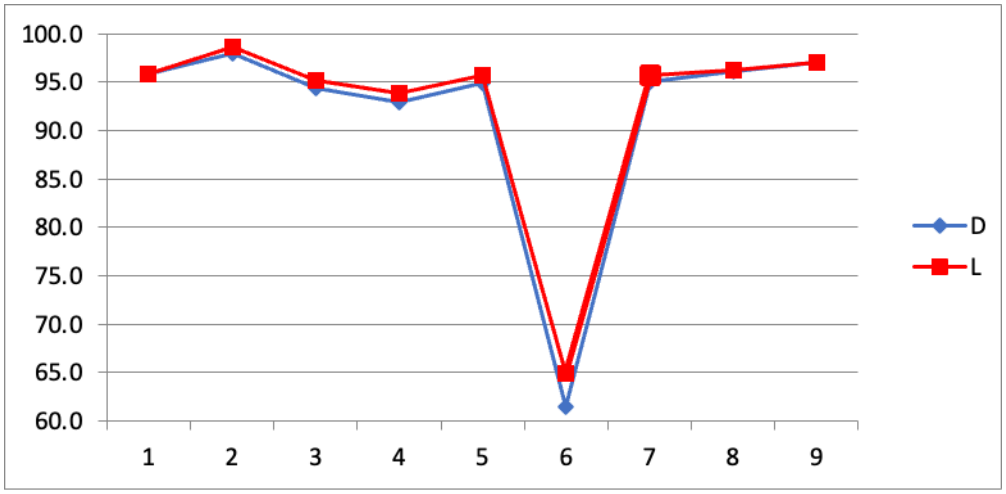

Figure 4. Line diagram of average SpO_2% values by side of the surgery.
*D - right, L – left.

Discussion

In our study, we observed a postoperative pulmonary complication (PPC) rate of 30.0%, aligning closely with findings reported in previous literature. The most common complications in our cohort were pneumonia (17.5%) and atelectasis (12.5%), with respiratory failure, necessitating mechanical ventilation, occurring in 2.5% of the patients. These findings emphasize the critical nature of PPC as significant contributors to postoperative morbidity. In one of the largest multicenter randomized clinical trials, 1,170 patients scheduled for lung resection were included, focusing, among other things, on postoperative complications depending on the type of ventilation (10,11). Pulmonary complications were reported in 40.5% to 42.8% of the patients, depending on the ventilation parameters. This is a higher incidence than observed in our study; however, Park et al. also considered hypoxemia (SpO_2 <90%) and empyema as postoperative complications, which were not included in our study (12). The higher reported incidence may also be attributed to differences in patients' demographics, surgical techniques, or intraoperative ventilation strategies employed across the two studies.
In the study by Fernandez et al., which analyzed 189 patients after lung resection (13), the incidence of PPC was reported at 34.3%, with pneumonia being the dominant complication, affecting 29.7% of the patients. This aligns with findings that pneumonia often represents the leading cause of morbidity following thoracic surgeries due to altered lung mechanics, immunosuppression and impaired mucociliary clearance in the postoperative period. François and colleagues, in a study involving 266 patients, reported a slightly lower incidence of postoperative pulmonary complications, documented at 25% (14). This variation in incidence highlights the importance of standardized definitions and methodologies when assessing postoperative outcomes in thoracic surgery.
In our study, the incidence of postoperative pulmonary complications was 30.0%, aligning with previous studies. The postoperative complications analyzed in our study included atelectasis,

pneumonia and respiratory failure (i.e., the need for mechanical ventilation), defined according to EPCO criteria (15). Consistent with the study by Fernandez et al., our findings show that pneumonia is the most common complication following lung surgery. In our cohort, pneumonia occurred in 17.5% of the patients, which aligns with data from the literature (16-18). This finding underscores the critical need for early recognition and management of pneumonia to improve postoperative outcomes, especially in high-risk patient groups.

Atelectasis was observed in 12.5% of patients in our study. This complication, although common, is often transient and resolves with appropriate postoperative care, including physiotherapy and respiratory support. However, persistent atelectasis can significantly impact postoperative recovery, particularly in patients with pre-existing pulmonary conditions or obesity (19). Development of atelectasis has been reported as one of the most frequent respiratory complications during the perioperative period, affecting nearly 90% of the patients (20,21). The persistence of atelectasis beyond the immediate postoperative phase may exacerbate local inflammation, impair gas exchange, and predispose patients to secondary infections, including pneumonia (22). Preventive strategies, such as the use of recruitment maneuvers, optimal intraoperative ventilation and early postoperative mobilization, remain crucial in minimizing the incidence and severity of atelectasis.

Respiratory failure, defined as the need for mechanical ventilation postoperatively, was noted in 2.5% of our patients. While less common than other complications, respiratory failure is associated with significant morbidity and prolonged hospitalization. Factors contributing to respiratory failure include inadequate pulmonary reserve, prolonged surgical duration, and intraoperative events such as hypoxia or hemodynamic instability. Identifying at-risk patients preoperatively and optimizing their condition can play a pivotal role in reducing this complication.

In literature, the incidence of PPC after lung resection varies widely across studies. Differences in patients' selection, comorbidities, surgical techniques and perioperative management likely contribute to this variability. For instance, studies utilizing advanced surgical techniques such as video-assisted thoracoscopic surgery (VATS) often report lower complication rates compared to traditional open thoracotomy approaches (23-27). Similarly, enhanced recovery protocols, including early ambulation and improved pain management, have been shown to mitigate the risk of PPC. Nonetheless, there is consensus that these complications are common.

Most of the studies agree that patients undergoing lung surgery often are presented with high burden of comorbidities during preoperative preparation, contributing to the elevated risk of postoperative pulmonary complications (24,28,29). Common comorbidities such as chronic obstructive pulmonary disease (COPD), diabetes mellitus and cardiovascular disease are known to increase susceptibility to PPC by reducing baseline pulmonary reserve and compromising immune function. Addressing these comorbidities through multidisciplinary preoperative assessment and tailored perioperative care is essential to improve surgical outcomes.

Finally, while variations in reported incidence rates exist, these studies underscore the importance of a comprehensive approach to the prevention, early detection and management of

PPC in thoracic surgery. Future research should aim to harmonize definitions and methodologies to enable meaningful comparisons and develop evidence-based guidelines to optimize patient care.

Conclusion

Pulmonary complications are highly prevalent after thoracic surgery, primarily due to the physiological challenges introduced during the procedure and the use of one-lung ventilation. These challenges include significant alterations in respiratory mechanics, reduced lung compliance and ventilation-perfusion mismatch, all of which contribute to impaired gas exchange. The combination of surgical stress, anesthesia and mechanical ventilation further exacerbates the risk of complications. Effective perioperative strategies are essential to minimize these risks. Tailoring these interventions to the individual patient's risk profile can significantly enhance outcomes and reduce morbidity associated with thoracic surgery. By implementing a comprehensive and multidisciplinary approach to patient management, healthcare teams can mitigate the incidence and severity of pulmonary complications, thereby improving recovery and reducing hospital stay duration.

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