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Factors Associated with Persistent Air Leaks after Video-Assisted Thoracoscopic Surgery for Lung Cancer and Advances in Nursing Care

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Abstract: *Surgery remains an effective treatment for non-small cell lung cancer. Video-assisted thoracoscopic surgery (VATS) has broadly replaced traditional thoracotomy due to its minimally invasive nature, quick recovery, simple operation, and clear field of view. However, complications such as pulmonary air leaks, insufficient tension, pleural effusion, and cardiac retention persist. Among these, persistent air leak (PAL) is a frequent complication, characterized by an abnormal pathway between a lung bulla and the pleural cavity, allowing air to enter the pleural space, leading to the formation of bullae or even pneumothoraces. The incidence of PAL varies between 8% and 26%. Although pneumothoraces can self-resolve, they require significant clinical attention as they can impact the patient's recovery process. This article aims to summarize the definition, risks, influencing factors, and nursing strategies for PAL, providing recommendations for the recovery of postoperative patients.*

Keywords: *Thoracoscopy; Lung Cancer Surgery; Persistent Air Leak; Nursing Practices*

1. Introduction

Video-Assisted Thoracoscopic Surgery (VATS) marks a significant advancement in thoracic surgery from the late 20th century, offering less trauma, minimal bleeding, reduced postoperative pain, fewer potential complications, and faster healing compared to traditional methods [1-2]. From a biomechanical perspective, the surgery might disrupt the stability of the chest profile, potentially leading to sternum fractures, thus imposing significant physical and psychological stress. VATS resolves these issues with notable advantages such as minimal invasiveness and rapid patient recovery. Typically involving no more than three small chest incisions, VATS is cosmetically appealing, allowing patients to get out of bed and potentially be discharged the day after surgery [3-4]. Over more than twenty years, VATS technology has matured and its application has broadened. Nevertheless, as evidence accumulates, the complexity of surgical interventions and the incidence of complications, including persistent air leaks, have also increased, with reported rates up to 6.7% [5-6]. According to Yishuai Li's analysis of 2100 cases of fiberoptic bronchoscopy, 66 patients experienced air leaks postoperatively, primarily older individuals or those suffering from severe diseases or common inflammatory conditions like COPD [7].

2. Meaning and Harm of PAL

2.1 Meaning

Currently, the definition of PAL is not clear; some scholars consider it as pulmonary air leaks lasting from 3 to 7 days, also referred to as PAL. Post-thoracoscopic surgery air leaks exceeding five days, and beyond seven days for open surgery, are considered PAL. However, many studies now define postoperative pulmonary air leaks extending beyond five days as PAL [8].

2.2 Harm

Patients with PAL experience extended hospital stays and increased medical costs. Studies indicate that PAL patients have hospital stays about three days longer than those without leaks, and their postoperative costs increase by approximately 35%. Reducing the incidence of PAL may shorten the patient's hospital and chest tube duration [9-10]. Research by Xiaowei Wang and others has shown that delayed discharge due to PAL extends the patient's hospital stay by an additional five days, potentially

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increasing hospital costs and the incidence of complications [11]. Yu J's study indicates that patients with PAL (>5 days) face significantly higher rates of cardiopulmonary complications compared to those without pneumothorax, including complications related to the chest, respiratory system, lungs, and red blood cell transfusions, with PAL patients undergoing VATS lobectomy more likely to suffer from cardiopulmonary complications [12].

3. Influencing Factors for PAL

3.1 Respiratory Capacity And Pulmonary History

Patients with a history of Chronic Obstructive Pulmonary Disease (COPD) often face unique challenges when undergoing lung surgery. Due to the nature of COPD, which involves prolonged airway limitation, these patients have alveoli (the tiny air sacs in the lungs) that remain inflated longer than normal. Over time, this can cause damage to the alveoli and reduce the elasticity of the lungs, which is crucial for the normal breathing process. Consequently, the healing process after lung resection surgeries—where part of the lung is surgically removed—can be slower, and sutures may not hold as well as expected. This slower recovery and weakened tissue integrity significantly increase the risk of postoperative complications like pulmonary embolism, a serious condition where one or more arteries in the lungs become blocked by a blood clot.

A retrospective analysis by Tong C of 207 patients who underwent lung resection highlighted the importance of measuring the first-second forced expiratory volume (FEV1%), a key indicator of respiratory function. The study found that lower FEV1% values were associated with a higher incidence of postoperative pulmonary embolism [13]. Further supporting this, Yang Shuo's research involving 359 patients who underwent thoracoscopic surgery (a minimally invasive form of lung surgery) also established a strong link between FEV1% and persistent air leaks (PAL). The findings suggested that an FEV1% below 80% indicates higher respiratory resistance and decreased pulmonary compliance. This reduced lung function not only makes postoperative pulmonary inflammation more likely but also impairs the lung's ability to close properly at the surgical site. As a result, conditions are ripe for the development of persistent air leaks, complicating recovery and potentially leading to longer hospital stays and increased healthcare costs [14].

By understanding these connections, medical professionals can better predict and manage risks associated with lung surgeries in patients with compromised pulmonary health, ensuring more tailored and effective postoperative care.

3.2 Nutritional Factors

Patients with a low body mass index (BMI), slender physique, and insufficient muscle levels are at increased risk of potential lung leaks after lung resection surgery, even though the disease might be fully resolved but some lung tissue remains, increasing the risk of pulmonary leakage. However, current literature has not established a unified standard for BMI. Studies suggest that a BMI under 18.5 kg/m² might increase the risk of potential pulmonary leaks, and this finding is supported by the literature. Surgical patients with a BMI under 24 kg/m² are considered at risk for postoperative pulmonary complications. Zhengwei Chen mentioned that patients with a BMI less than 25 kg/m², less than 25.5 kg/m², and less than 23 kg/m² have similar nutritional requirements [15]. Postoperative serum protein levels are more sensitive to BMI and other blood nutrient indicators, helping predict PAL in lung cancer patients. Despite this, PAL is still considered an independent risk factor post-surgery, and postoperative hypoglycemia is also regarded as another independent risk factor for PAL. Sedighim S's research pointed out that among patients diagnosed with non-small cell lung cancer after surgery, those in the high nutritional score group had lower levels of PAL compared to those in the low nutritional score group. Postoperative malnutrition is associated with a higher incidence of PAL, and improving patients' nutritional status plays a crucial role in shortening the duration of postoperative PAL [16].

3.3 Surgical Factors

Many studies have investigated what might cause persistent air leaks (PAL) after lung surgery, but the answers are still not completely clear. During operations where parts of the lung are removed, known as lung resection surgeries, patients often develop PAL. This complication is believed to be linked to the natural adhesions that form in the lungs and chest cavity. These adhesions make the surgery more difficult

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because the lung tissue sticks to the surrounding areas. Furthermore, the specific length and positioning of the endotracheal tube used during surgery are also crucial factors that may influence the risk of PAL. The presence of chest adhesions has been identified as a significant risk factor, as these can prevent the lung from sealing properly after surgery, leading to air leaks. This is particularly true following the resection of the upper lobe of the lung, where an apical residual cavity may remain open and not heal immediately, thereby increasing the likelihood of PAL. Guangwen Xu's research supports this, emphasizing that intraoperative adhesions are a key element linked to the occurrence of PAL after lung surgery [17].

3.4 Smoking History and Gender

The influence of smoking history and gender on the risk of developing PAL after lung cancer surgery is substantial and well-documented. Smoking, known for its detrimental effects on pulmonary health, contributes to both obstructive and restrictive lung diseases. These conditions can induce bronchospasms and exacerbate respiratory insufficiency, factors that heighten the vulnerability to PAL. It has been established that individuals with a smoking history exceeding 20 pack-years exhibit a significantly elevated risk of PAL. This correlation underscores the impact of long-term smoking on lung integrity and its direct implications for surgical outcomes in lung cancer patients [3]. Gender differences also play a critical role in the incidence and prognosis of postoperative outcomes. According to Yuqiu Lin's research, there is a marked discrepancy in the rates of postoperative complications between genders, with males exhibiting an 11% and females a 39% higher incidence of lung cancer post-surgery, respectively [3]. These findings suggest that male patients may have a predisposition to worse outcomes, possibly linked to differences in smoking patterns and physiological responses to surgical interventions.

4. Nursing Strategies

4.1 Optimization of Rehabilitation Programs

Respiratory muscle strength and endurance training are vital. Adjusting breathing rhythms reduces oxygen consumption and enhances respiratory efficiency, promoting respiratory system recovery and improving patient activity levels and quality of life. Reducing oral breathing duration, increasing respiratory sac pressure, and preventing early airway closure are beneficial for sac release and pulmonary function improvement. Techniques include sitting upright, stretching the upper body, pulling shoulders together, and relaxing muscles. Breathing should be slow through the nose while maintaining quiet. Pinching the lips and blowing out as if extinguishing a candle from approximately 15-20 cm away, without holding breath or inhaling excessively, can be practiced with a 2:1 or 3:1 breathing ratio.

Alternating breathing training can enhance physical strength and relieve respiratory muscle burden, partially improving lung function. Methods include sitting comfortably or in a semi-seated position, lying down or standing, and placing hands on the abdomen. Deep breaths through the nose should be coordinated with abdominal lifting, moving hands from bottom to top, holding for 1-2 seconds to allow full chest expansion. Slow exhalation involves gently pressing the abdomen and massaging below the ribs to stimulate muscle movement and promote gas expulsion from the lungs.

Deep, slow breathing exercises aim to strengthen muscle contraction and enhance lung function. Steps include adopting a comfortable posture such as standing, semi-recumbent, or sitting, placing hands on the abdomen and chest, relaxing the body, inhaling slowly through the nose to expand the abdomen while keeping the chest still, then exhaling slowly while contracting the abdomen. Perform 7-8 breaths per minute, 10-20 minutes per session, twice daily.

Pursed-lip breathing technique aims to improve gas diffusion and ventilation function, alleviating respiratory distress and observing potential interactions. The method involves closing the lips during inhalation for several seconds of nasal breathing, then exhaling through the mouth in a manner resembling blowing out fireworks or a whistle, lasting 4-6 seconds.

Full-body breathing exercises aim to enhance physical strength and optimize lung function, incorporating abdominal breathing, chest expansion, and body tilting. Techniques include maintaining steady breathing, exhaling while leaning forward, exhaling with one hand, and inhaling with both hands. Deep breaths involve lifting the arms, then exhaling downwards; deep breathing with raising both hands, then exhaling; and deep breathing with turning the head followed by exhalation.

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4.2 Care of Chest Drains

Postoperatively, single or double chest drains are routinely installed to ensure unobstructed drainage. It's important to monitor the oscillation of the water column in the drainage tube, avoiding pressure, bending, blockage, or displacement, and regularly pressing to prevent blockage. When adjusting positions, care must be taken to avoid stretching and moving the drainage tube. Close monitoring of urine output and recording of drainage are necessary. If urine output decreases, plasma lightens, no bubbles overflow, and chest X-rays show no fluid accumulation, the chest drain can be removed. After three days post-surgery, if the patient coughs up bubbles, and right chest X-rays show pulmonary function defects and negative pressure, interventions like erythromycin, high-glucose, and partial whey have been used to promote chest adhesion. The balloon humidification method has improved bubble tension, enhanced lung function, stimulated lung expansion, and accelerated the expulsion of chest residues. Four times daily, family members are assisted in comprehensively clearing internal and external disturbances. Listening to bilateral lung sounds and checking for lung swelling are important. After 28 days of coughing without bubble leakage, chest X-ray showing healthy lung tissue and no gas accumulation allows for the removal of the chest drain.

4.3 Enhancing Nutrition

Patients with lung diseases often struggle with nutritional deficiencies, which can complicate their recovery after surgery. It's important to spot these deficiencies early and start nutritional support before the surgery. By boosting nutritional reserves before the operation, we can lower the chances of complications like persistent air leaks (PAL) after surgery. Pan H's research has shown that good nutritional care after surgery, which might include special drinks or pills to boost nutrition, can significantly improve a patient's nutrition before they even go into surgery. This better nutritional status provides enough energy for the body to heal after the operation, helps speed up recovery, and reduces the risk of nutrition-related complications that could lead to PAL.

The European Society for Clinical Nutrition and Metabolism emphasizes the importance of addressing any nutritional shortages before surgery. If a patient isn't eating enough, it's crucial to start them on nutritional supplements right away. In hospitals and clinics, it's very important to have clear rules to figure out who isn't getting enough nutrition and who might be at risk of malnutrition. Once these patients are identified, healthcare providers should quickly start a diet plan that is rich in protein. This kind of diet can significantly improve the nutritional status of patients after surgery, making their recovery smoother and helping prevent serious complications like postoperative pulmonary leaks. [18,19].

4.4 Smoking Cessation

It is vital for patients who smoke to quit before undergoing lung surgery to minimize postoperative risks such as persistent air leaks (PAL). Healthcare professionals are encouraged to play an active role in this by strongly recommending smoking cessation and supporting patients through this process. The benefits of stopping smoking include reduced risk of pulmonary complications and better overall lung function post-surgery. Li Bo's innovative medical cooperation monitoring platform provides a unique support system. Through this platform, patients can regularly update their smoking cessation efforts, share their successes, and discuss the hurdles they face, which fosters a supportive community environment. This transparency allows family members to be more involved and supportive, contributing positively to the patient's cessation journey. Nurses are instrumental in this process, providing daily motivation and tracking progress, thereby ensuring continuous engagement and high-quality support. This concerted effort greatly improves the chances of successful smoking cessation, which is crucial for enhancing lung recovery after surgery and reducing the potential for additional lung damage[20].

5. Conclusion

Persistent air leak (PAL) is a significant concern for the prognosis of patients undergoing lung surgery. Thoracic surgeries, which often include extensive dissection and the removal of lymph nodes, are procedures that can lead to potential lung damage and PAL. This makes it critical to have thorough preoperative and postoperative care strategies in place. Monitoring the closed chest drainage systems diligently is key to ensuring that any air leaks are detected early and managed promptly, which is crucial for the recovery of lung function.

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Enhancing nutritional support is another vital aspect of care. Proper nutrition helps the body heal faster and more effectively, supporting the recovery of lung tissue damaged during surgery. Treating underlying conditions such as diabetes, heart disease, or chronic respiratory issues is also essential, as these conditions can complicate the recovery process if not managed well.

Implementing psychological interventions plays a crucial role in patient recovery as well. Surgery can be a significant source of stress for patients, and effective psychological support can help reduce anxiety and improve overall treatment outcomes. Personalized care tailored to meet the individual needs of patients is essential. This approach includes understanding each patient's specific health background, their fears and expectations, and adapting the care plan to suit these needs.

For nursing staff, a deep understanding of what PAL entails, the risks associated with it, and its implications for patient care is vital. Nurses must be equipped to provide tailored care and prevention strategies, aiming to reduce postoperative complications and enhance surgical outcomes. By reducing the time catheters are in place, for example, nurses can help decrease the risk of infection and other complications, thus facilitating quicker patient recovery and better overall surgical results.

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