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Predictors of Atelectasis After Pulmonary Lobectomy

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Abstract
Purpose. To define the incidence of and factors predisposing to postlobectomy atelectasis (PLA).
Methods. The subjects were 412 patients who underwent pulmonary lobectomy at our hospital between January 2004 and April 2007. This study was performed as a retrospective analysis of our prospective database. Postlobectomy atelectasis was defined as ipsilateral opacification of the involved lobe or segment with an ipsilateral shift of the mediastinum on chest radiograph, requiring bronchoscopy.
Results. Postlobectomy atelectasis developed in 27 patients (6.6%), accounting for 29% of all postoperative pulmonary complications. There were no significant differences between the PLA and no-PLA groups in age, sex, American Society of Anesthesiology performance status, cardiovascular comorbidity, or operation time. Chronic obstructive pulmonary disease (COPD) was the only preoperative variable predictive of PLA ($P < 0.05$). Right upper lobectomy (RUL), either alone or in combination with right middle lobectomy, was associated with a significantly higher incidence of PLA than any other type of resection ($P < 0.05$).
Conclusions. Postlobectomy atelectasis is an important postoperative complication. Patients with COPD and those undergoing RUL are at higher risk of this complication. Although often isolated, PLA is associated with longer hospital stay.

Key words Atelectasis · Bronchoscopy · Pulmonary lobectomy

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Introduction

Morbidity and mortality from major thoracic surgery continue to decline, as a direct result of improvements in preoperative selection, operative techniques and postoperative care.[1,2] The overall incidence of postoperative pulmonary complications after pulmonary resection is approximately 30%, but ranges from 7% to 49%.[3–6] The most common complications are prolonged air leak (1%–15%), bacterial pneumonia (4.8%–15%), acute respiratory failure (2.4%–10%), and postoperative atelectasis (1%–20%).[3,4,7–9] The wide variation in the incidence of postoperative atelectasis is attributed to the lack of consensus about a definition of clinical atelectasis. Many studies include patients with varying degrees of atelectasis; namely, lobar, segmental, and subsegmental. The aim of this study was to define the incidence of and factors predisposing to postlobectomy atelectasis (PLA).

Methods

Between January 2004 and April 2007, 412 consecutive patients underwent pulmonary lobectomy or bilobectomy in our institution. This retrospective study of our prospective database included only patients who underwent elective operations. Postlobectomy atelectasis was defined as ipsilateral opacification of the involved lobe or segment with an ipsilateral shift of the mediastinum on the chest radiograph, requiring bronchoscopy. We divided our patients into two groups: those with PLA (PLA group) and those without PLA (no-PLA group).

Preoperative variables included age, sex, body mass index (BMI), forced expiratory volume per second — percent predicted (FEV_1), forced vital capacity — percent predicted (FVC), FEV_1/FVC ratio, chronic obstructive pulmonary disease (COPD), smoking status, cardiovascular comorbidity (defined by a history of myocardial infarction, supraventricular arrhythmia, stroke, angina pectoris, hypertension), and American Society of Anesthesiology (ASA) performance status. Chronic obstructive pulmonary disease was defined as a $FEV_1 < 70\%$ of the predicted value and a FEV_1/FVC ratio of <70%. Information on smoking habits was obtained from a self-administered questionnaire on the health status of the patients at the time of admission. Current smokers were defined as those who had smoked within 1 month of surgery or who had not stopped smoking within 1 month of surgery ($n = 107$, 26%); past smokers were defined as those who had stopped smoking more than 1 month before surgery ($n = 226$, 55%); and never smokers were defined as those who had never smoked cigarettes ($n = 79$, 19%). We used the ASA status recorded in the anesthesiologists' preoperative notes once the validity was reassessed according to the medical records of each patient.

Operative variables included the type of lobectomy and the operating time. Pulmonary postoperative complications were defined as follows: pneumonia, indicated by a compatible chest radiograph, fever greater than 38°C, purulent sputum with Gram stain and culture confirming the presence of microorganisms; acute respiratory failure, indicated by postoperative ventilator dependence >24 h or a need for reintubation for controlled ventilation; prolonged air leak, indicated by an air leak requiring >7 days of postoperative chest tube drainage; pulmonary embolism, confirmed by pulmonary arteriogram or autopsy, or supported by a ventilation/perfusion radioisotope scan showing a "high probability" of pulmonary embolism; acute respiratory distress syndrome (ARDS), indicated by the acute onset of respiratory distress, with a PaO_2/fraction of inspired oxygen ≤200 mmHg and frontal chest radiograph findings of bilateral infiltrates with no clinical evidence of left atrial hypertension; and pneumothorax, confirmed by chest radiograph findings and requiring chest tube placement. Cardiovascular complications were defined as follows: symptomatic cardiac arrhythmia requiring treatment, acute myocardial infarction, and stroke.

Operability was based on existing guidelines for pneumonectomy and lobectomy.[10] All resections were performed with selective double lumen lung ventilation via a standard lateral thoracotomy approach. All bronchial stumps were closed with manual transverse suturing. We used interrupted 4-0 absorbable sutures (PDS II, Ethicon, Somerville, NJ, USA), mainly using the clamp with closed bronchus technique. Stumps were checked for air leakage with 30 cmH_2O sustained airway pressure. Negative margins were confirmed by frozen-section analysis. Pulmonary fissures were completed, when needed, using linear stapling machines. No sealant was used and we did not release the pulmonary ligament. We performed mediastinal lymph-node sampling, but prophylactic mini-tracheostomy was not done at the end of the operation.

Patients were given antibiotic prophylaxis, as cefazolinum 1 g at the induction of anesthesia followed by two additional doses postoperatively, unless there was a known or suspected allergy, or if a different type of prophylaxis was indicated, as for valve disease. All patients except one were extubated in the operating room at the completion of lobectomy and transferred to our postoperative thoracic ward. Postoperative pain was controlled by thoracic epidural analgesia, initiated during the operation. Patients received a bupivacaine and fentanyl infusion through a thoracic epidural catheter, and on-demand systemic opioid analgesia after the chest drain was removed. Chest tube management was standardized. Drains were removed when there was no sign of an air leak on coughing and less than 150 ml had been drained in the previous 24 h.

Physiotherapy was started the day before surgery and continued until discharge. Patients were instructed to cough effectively and to perform deep inspiratory maneuvers. Physiotherapy procedures included positioning, mobilization, manual hyperinflation, and breathing exercises. We gave mucolytic agents routinely, first parenterally and then orally when bowel function had recovered. Respiratory nebulizers were added to optimize the peripheral mobilization of secretions. Sputum samples were sent to our antibiotics center for investigation. Chest X-rays were taken immediately after the operation, on postoperative days (PODs) 1, 2, and 3, and before removal of the chest tubes. When PLA was evident, bronchoscopy was performed under local anesthesia with a flexible bronchoscope. Analysis of arterial blood gas was not done routinely during the postoperative period or during bronchoscopy.

A malignant neoplasm was diagnosed in 374 (91%) patients: as squamous cell carcinoma in 231 (56%), adenocarcinoma in 111 (27%), small cell carcinoma in 4 (1%), and other types of cancer in 20 (5%). Staging was as follows: stage I in 154 (42%), stage II in 88 (24%), stage IIIa in 81 (22%), stage IIIb in 32 (9%), and stage IV in 11 (3%). Eight (2%) patients had pulmonary metastases. Bronchiectasis was the most common benign lung disease, diagnosed in eight (2%) patients. Idiopathic pulmonary fibrosis (IPF) was diagnosed preoperatively in three patients and found incidentally after lobectomy in another three.

Institutional review board approval was not sought because all patients received standard of treatment and care. Informed consent for us to enter data in the database for clinical and investigational purposes was obtained from all patients. Data were computerized and analyzed using SPSS version 10.0 statistical packages.

Table 1. Characteristics of the patients who underwent pulmonary lobectomy

	No PLA	PLA	*P*-value
Age, years	59 ± 12	61 ± 9	NS
Male, %	72	77	NS
COPD, *n* (%)	66 (17%)	14 (51%)	<0.05
Smoking status (C/P/N), %	26/50/24	30/59/11	NS
Malignancy, %	91%	88%	NS
Cardiac comorbidity, *n* (%)	138 (36%)	11 (43%)	NS
ASA	2.2 ± 0.4	2.5 ± 0.5	NS
BMI	24.9 ± 8	25.9 ± 2	NS

PLA, postlobectomy atelectasis; COPD, chronic obstructive pulmonary disease; C, current smokers; P, past smokers; N, never smokers; BMI, body mass index; ASA, American Society of Anesthesiology score; NS, not significant

Categorical variables were compared using the χ^2 test or Fisher's Exact test. Student's *t*-test was used to compare continuous variables between the groups. Unless otherwise stated, results are expressed as mean ± SD for continuous variables and as percentages for categorical variables. We defined $P < 0.05$ as significant, $P < 0.01$ as highly significant, and $P > 0.05$ as not significant (NS). The risk factors predictive of PLA at univariate analysis were entered into a multivariate regression analysis, to identify independent variables.

Results

A collective total of 90 postoperative pulmonary complications developed in 80 (19.5%) of the 412 patients who underwent pulmonary lobectomy. A persistent air leak was the most common complication, found in 36 (8.7%) patients, followed by atelectasis in 27 (6.6%). Postlobectomy atelectasis was never bilateral, but two patients suffered atelectasis of the contralateral lung. Postlobectomy atelectasis accounted for 29% of all the postoperative pulmonary complications. There were no significant differences between the PLA and no-PLA groups in age, BMI, sex, or ASA performance status. Current smokers were at higher risk of PLA, but the incidence did not reach significance (Table 1). COPD remained the only preoperative variable predicted of PLA ($P < 0.05$). Patients who underwent right upper lobectomy, either alone or in combination with right middle lobectomy, had a significantly higher incidence of PLA than those who underwent left upper lobectomy or any other type of resection ($P < 0.05$). Table 2 shows the incidence of PLA in relation to the lobe resected. The operation time was not significantly longer in the PLA group than in the no-PLA group, at 126 ± 27 min vs 117 ± 35 min, respectively. Postlobectomy atelectasis occurred most frequently on PODs 2 or 3 (58%), whereas contralateral atelectasis occurred in the immediate postoperative period on POD0. Most (60%) patients underwent one bronchoscopy, although 20% of patients with PLA underwent two bronchoscopies. The bronchoscopic findings were consistent with mucus plugging of the affected lobe or segment. Following RUL, mucus plugging developed in the middle lobe or its segments in 65% of the patients. Another common bronchoscopy finding after RUL was slight kinking of long bronchus intermedius. Tracheostomy was done for two patients with severe sputum retention and PLA, who required repeated bronchoscopies. Pneumonia developed in 12 (2.9%) patients, two of whom had suffered PLA (Table 3). Ten patients had concomitant prolonged air leak and PLA. All patients with pro-

Table 2. Types of resection and incidence of PLA

	n	PLA	Incidence, %
Total	412		
RUL	126	15	12
RML	18	0	0
RUL, RML	12	1	8
RLL, RML	27	1	3
RLL	55	2	3
LUL	121	7	6
LLL	53	1	2

RUL, right upper lobectomy; RLL, right lower lobectomy; RML, right middle lobectomy; LUL, left upper lobectomy; LLL, left lower lobectomy; PLA, postlobectomy atelectasis

Table 3. Complications after pulmonary lobectomy

Complication	*n*	%
Postlobectomy atelectasis	27	6.6
Prolonged air leak	36	8.7
Pneumonia	12	2.9
Pleural effusion (requiring chest tube drainage)	10	2.5
Postoperative mechanical ventilation	6	1.4
Pneumothorax (requiring chest tube drainage)	5	1.2
Reoperations	5	1.2
Peptic ulcer bleeding	1	0.2
Mortality	3	0.7

Table 4. Clinical characteristics of the two groups of patients who underwent lobectomy

	No PLA	PLA	*P*-value
Operation time, min	117 ± 35	126 ± 27	NS
Postoperative mechanical ventilation, *n*	4	2	NS
Mortality, *n*	2	1	NS
Hospitalization (days)	7.5 ± 2.2	11.3 ± 3.1	<0.05

PLA, postlobectomy atelectasis

longed air leak were treated conservatively. Two patients with IPF suffered a persistent air leak, and there was no mortality in this group. Postoperatively, none of the patients suffered acute exacerbation of their IPF.

Ninety-eight (23%) patients suffered cardiovascular complications, among which atrial fibrillation was the most common, seen in 82 (20%) patients. Although atrial fibrillation was solitary in 56 (68%) patients, 26 patients suffered other postoperative complications. Atrial fibrillation was followed by PLA in two patients and preceded by PLA in two patients.

There were three deaths; caused by pneumonia leading to ARDS in two patients and by bronchopleural fistula (BPF) with empyema in one patient. The mean hospital stay was significantly longer in the PLA group than in the no-PLA group, at 11.3 days vs 7.5 days, respectively (Table 4).

Discussion

Atelectasis following pulmonary resection has been described as a common postoperative complication with a wide range in incidence of 1%–20%; probably because "clinically significant atelectasis" has not been clearly defined. To our knowledge, this is the first study that deals with one type of pulmonary resection in a prospective database.

The incidence of lobar and segmental atelectasis after pulmonary lobectomy in this series was 6.6%, which is similar to the 7.8% reported by Korst et al. and the 5% reported by Uzieblo et al.[7,8] The first signs of PLA are dyspnea or tachypnea, reduced breath sounds on the ipsilateral side, and dullness with percussion of the affected lobe. Classic roentgenogram findings include opacification of the remaining lung parenchyma. The general signs of atelectasis relate to volume loss as displacement of the interlobar fissure, an increased hemidiaphragm, and mediastinal shift. There is compensatory over-inflation of the remaining aerated segments in the affected lobe and the collapsed part of the lung has increased opacity and often appears triangular. The "silhouette" sign allows identification of the lobe or segment of the lung that is affected.

The cause of PLA is multifactorial. Several factors are involved in the pathogenesis of atelectasis after pulmonary resection; namely, abnormal ciliary transport of mucus, preoperative smoking history, COPD, age, and operating time.[3,8,11] A high performance ASA status is the most common risk factor for postoperative complications, regardless of the circumstances.[3,12] Interestingly, although a high ASA status has been associated with postoperative pneumonia and prolonged postoperative intubation,[12] in our study ASA performance status did not seem to be a powerful univariate predictor of PLA.

As reported by Korst et al. and Uzieblo et al., patients undergoing RUL resection are predisposed to PLA.[7,8] The reason for this predisposition is unclear, but it may relate to an anatomic factor. After RUL, the lower lobe expands to fill the right hemithorax, which may result in an anatomic rearrangement of bronchi after expansion of the remaining lobe. These anatomic changes may include some degree of kinking or shifting of the major bronchi when the remaining lobes expand to fill the chest. Right upper lobectomy leaves two lobes distal to a long bronchus intermedius, which may account for the higher risk of PLA after RUL than after LUL. It could also result in the pooling of secretions and blood in the proximal airways. Mucus plugging, with consequent lung atelectasis, may be a result of this anatomic rearrangement combined with impaired ciliary transport, which is very common in past or current smokers.

Postlobectomy atelectasis occurs most frequently on PODs 2 and 3.[8] Conversely, contralateral PLA occurs much sooner than its ipsilateral counterpart, suggesting different mechanisms. In contralateral PLA, the pooling of mucus and blood in the dependent lung during surgery is a provocative factor. Jaworski et al. concluded that the intraoperative buildup of secretions was not the major cause of PLA, based on the finding that immediate postoperative bronchoscopy performed prophylactically did not prevent its occurrence because the critical point of bloody mucus buildup is usually 2–3 days after lobectomy.[13]

The use of bronchoscopy to clear retained secretions has become a standard procedure for patients with atelectasis, with success rates ranging from 70% to 89%.[11,14]

Patients with lobar atelectasis respond better than those with retained secretions or subsegmental atelectasis, probably because they have large central plugs, which can be removed by bronchoscopy.[14] On the other hand, bronchoscopy is not without risk. Matot et al. reported that 17% of patients >50 years of age had ST segment changes consistent with ischemia during the procedure, although all were asymptomatic.[15] The possible risks of bronchoscopy include exacerbated hypoxemia, hypercapnia, and elevated end-inspiratory pressure.[14]

Physiotherapy is a crucial part of the postoperative management of patients undergoing lobectomy, considering the prevalence of postoperative pulmonary problems and previous comorbidities.[8,16,17] The most common techniques practiced by physiotherapists include positioning, mobilization, manual hyperinflation, and breathing exercises.[16,17] Varela et al. reported that prophylactic respiratory physiotherapy decreases the rate of postoperative atelectasis following pulmonary lobectomy significantly, with considerable monetary savings.[17] Although Gosselink et al., found that adding incentive spirometry to physiotherapy did not reduce pulmonary complications or hospital stay after thoracic surgery,[18] others found it to be as beneficial as physiotherapy.[19] Respiratory physio- and motion-therapy offers continuous support to critically ill and intubated patients, and is as effective as adjuvant or complementary treatment to standard therapy.[20]

Adequate pain control is an important factor in postoperative management. Insufficient pain control may result in decreased cough effort, which may play a role in PLA. The epidural route seems the best for delivering opioids to prevent postoperative pulmonary complications.[21,22] Thoracic epidural analgesia may result in earlier recovery of respiratory function after thoracotomy.

Sputum retention is associated with postoperative pulmonary complications, including atelectasis. This occurs when a patient is incapable of adequately clearing their own tracheobronchial secretions. Its diagnosis is essentially clinical and based on evidence of respiratory distress with rapid, shallow, and bubbly respirations. Patients with COPD, smokers, and those with inadequate regional analgesia are at risk of sputum retention. Bonde et al. reported that prophylactic minitracheostomy reduced the incidence of sputum retention from 29% to 2% in series of patients at risk of respiratory complications after lung surgery.[23]

The relative risk of complications after surgery for smokers versus nonsmokers has been reported to increase from 1.4-fold to 4.3-fold.[24–26] Smoking causes the small airways in the lung to narrow, making them prone to collapse with increased susceptibility to infection and other postoperative pulmonary complications. Vaporciyan et al. identified smoking within 1 month as a significant predictor of pneumonia and other major pulmonary events after pneumonectomy.[25] A prospective study by Barrera et al. found no paradoxical increase in pulmonary complications associated with stopping smoking within 8 weeks prior to thoracic surgery in comparison with those who continued to smoke up until the time of surgery.[26]

In conclusion, patients with COPD and those who undergo RUL are at risk of PLA. After identifying patients at risk of PLA, the next step is to eliminate or reduce the risks: this may include preoperative risk-reduction strategies such as trying to convince the patient to stop smoking, treating airflow obstruction in patients with COPD, and teaching the patient lung-expansion maneuvers. Intraoperative considerations such as the operative time and postoperative measures such as intensive physiotherapy and effective postoperative pain control also decrease the risk of PLA.

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