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Lung surgery: identifying the subgroup at risk for sputum retention

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Abstract

Objectives: Sputum retention after lung surgery is a potentially lethal condition, which can progress to atelectasis, pneumonia and respiratory failure requiring ventilatory support. Previous studies have concentrated on the treatment of postoperative respiratory complications but few have studied the risk factors for sputum retention. This prospective study was designed to identify the risk factors which may lead to the development of sputum retention after lung surgery. Methods: Three hundred sixty-one patients underwent lung surgery between January 1997 and December 1999 in a specialist Thoracic Surgery Unit (pneumonectomy, lobectomy, wedge or segmental resection, bullectomy, etc). Preoperative and intraoperative data collected prospectively included potential risk factors: chronic obstructive airway disease (COAD), forced expiratory volume in 1 s (FEV1), 50%, current smokers, ischaemic heart disease (IHD), cerebrovascular disease (CVA), resection of phrenic or recurrent laryngeal nerve, or absence of regional analgesia. Univariate and multivariate analysis was performed. Results: Sputum related complications occurred in 108 patients (30%). There were 17 deaths of which nine were due to complications related to sputum retention. Univariate analysis confirmed current smokers (n = 128), COAD (n = 103), IHD (n = 41), prior history of CVA (n = 16), FEV1 < 50% (n = 48), and absence of regional anaesthesia as significant risk factors (P < 0.01). The multivariate analysis confirmed current smokers, IHD and absence of regional anaesthesia as risk factors. Conclusions: A subgroup of lung surgery patients at high risk for postoperative sputum retention can be predicted by the presence of one of the following criteria: current smokers, history of COAD, CVA, or IHD, and absence of regional analgesia. Prophylactic measures should be considered in this group to reduce the incidence of sputum retention. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Sputum retention; Postoperative pulmonary complications; Lung surgery

1. Introduction

Following lung surgery lung trauma and thoracotomy wound pain suppress coughing and interfere with the ability to clear secretions. Secretions produced in the lungs are transported to the upper trachea by the action of cilia but clearance from the trachea requires an effective cough or third party assistance. Retention of major airway secretions may lead to obstruction of broncho-pulmonary units and atelectasis. Pulmonary shunting, hypoxia and pneumonia may ensue with systemic sepsis. This sequence of events is more common in those with chronic lung disease and smokers who generally produce increased secretions in the immediate postoperative phase. Failure to control pain and intraoperative injury to either recurrent laryngeal or phrenic nerves also impairs coughing.

Sputum retention, by definition, exists whenever a patient is incapable of adequately clearing their own tracheobronchial secretions. Diagnosis of the condition is essentially clinical and is based on evidence of respiratory distress with rapid, shallow and bubbly respirations [1]. Matthews and colleagues further categorize sputum retention into compensated and decompensated phases. In the stage of decompensation the patient gets increasingly exhausted, with increasing hypoxia, hypercarbia and a resulting reduced level of consciousness. This can further result in a state of respiratory failure with attendant complications.

The preoperative prediction of postoperative pulmonary complications has been widely reported [2,3]. However, the precise role of sputum retention, which may be the precursor for the development of these complications, has not yet been directly addressed. In the present study we have tried to address the issue of risk factors for developing sputum retention and its relation to postoperative pulmonary complications.
2. Patients and methods

All patients admitted to the regional thoracic surgery unit for elective lung surgery from January 1997 to December 1999 were included in the present study (n = 361). Patients admitted for elective oesophageal surgery and thoracic trauma and patients undergoing non-pulmonary surgery were excluded from the present study. A further 107 patients who underwent lung surgery were omitted as they were enrolled in other clinical trials. All data concerning preoperative, intraoperative and postoperative course were collected prospectively.

2.1. Definitions

Sputum retention: inability to adequately clear the tracheobronchial secretions with standard respiratory physiotherapy. The diagnosis was essentially clinical, characterized by evidence of respiratory distress with rapid, shallow and bubbly respirations. The diagnosis was made by the physiotherapist and confirmed by the consultant in charge.

Current smoker: failure to cease tobacco smoking for 6 weeks prior to surgery.

Chronic obstructive airway disease (COAD): defined as a history of cough productive of sputum on most days for at least 3 months of the year for more than 1 year.

Forced expiratory volume in 1 s (FEV1): preoperative FEV1 ≤ 50% of the predicted value for height, weight and age (≤70% for pneumonectomy).

Ischaemic heart disease (IHD): history of IHD (presence of current angina pectoris or a history of myocardial infarction).

Cerebrovascular disease (CVA): history of CVA, transient ischaemic attack or complete stroke prior to surgery.

Absence of regional analgesia: absence or failure of regional analgesia (thoracic epidural or extra pleural intercostal nerve infusional block).

Standard postoperative treatment: regional pain relief consisted of either a thoracic epidural (Fentanyl and bupivacaine 5 mg/h) or a continuous unilateral infusion of bupivacaine (0.25% at 5 ml/h) to the intercostal nerves 2–10. The latter was delivered via a cannula sited after extra pleural dissection and was accompanied by patient controlled narcotic analgesia (PCA). Patients who received PCA morphine were administered metoclopramide 10 mg IV/IM every 8 h or cyclizine 50 mg IV/IM to counter nausea and reduced gastrointestinal motility. In addition patients who had a history of gastro-oesophageal reflux or acid peptic disease received proton pump inhibitors throughout the perioperative period. Where not contraindicated, and in the presence of adequate urine output, non-steroidal analgesic drugs were administered. Oxygen was administered by facemask. CPAP was available by mask when required. Nebulized bronchodilators (Salbutamol 2.5 mg and Budesonide 500 mcg bd) were commenced preoperatively and continued postoperatively (Ipratropium bromide 500 mcg qid was added if required). A trained respiratory physiotherapist routinely visited the patient twice a day with extra visits as required. Nasotracheal suction was used if tolerated by the patient. More frequent physiotherapy was administered if required. If sputum retention was diagnosed, a therapeutic minitracheostomy was performed. Alternatively a flexible bronchoscopy was performed. Rigid bronchoscopy was employed if the above interventions failed to clear the bronchial tree.

Atelectasis: radiological evidence of plate atelectasis, lobar collapse or total lung collapse.

Pneumonia: clinical and radiological evidence of lobar or bronchopneumonia. It was diagnosed if there was a pyrexia >38.5 °C, infective infiltrates or consolidation on chest radiograph, and WBC > 11 × 10⁹/l, or if there was purulent sputum with positive sputum cultures.

Positive sputum culture: positive identification of organisms on gram stain and growth in culture media obtained by serial sputum sample collections.

Prophylactic antibiotics: cefuroxime 1.5 g, every 8 h for a total of three doses, with the first dose beginning at the initiation of anaesthesia.

Therapeutic antibiotics: administration of an antibiotic other than the perioperative prophylaxis (three doses only) for a suspected or diagnosed respiratory infection or as guided by positive sputum cultures. A number of pneumonectomy patients who did not fulfil all the above criteria for chest infection were treated with antibiotics at the consultant’s discretion.

Respiratory failure: respiratory failure was defined as the presence of significant hypoxia and/or hypercarbia leading to exhaustion or cardiac dysfunction requiring assisted ventilation.

Mortality: wherever possible the cause of death was confirmed by post-mortem examination. In cases in which the post-mortem examination was not possible due to relatives’ wishes, the cause of death was determined by the clinical evaluation of a senior member of the medical team.

2.2. Statistical analysis

Sputum retention was considered as an endpoint as defined above. Statistical analysis using Fisher’s exact test and the Mann–Whitney U-test was performed with respect to risk and endpoint variables as appropriate.

Odds ratios for sputum retention and their 95% confidence intervals were calculated using binary logistic regression in both non-variable and multivariable analyses. The variables considered were current smoking, low FEV1, age, sex, history of IHD, COAD, previous cerebrovascular accident, absence of regional analgesia, resection of phrenic and recurrent laryngeal nerve, and sleeve resection. In the multivariable analyses a final model was obtained using a backward stepwise likelihood ratio method and confirmed by a forward stepwise procedure. Data were analyzed using SPSS 9.0™ statistical software.
3. Results

3.1. Risk factor analysis

Sputum related complications occurred in 108 of the 361 patients (30%). Sputum retention was statistically significantly \( (P < 0.01) \) associated with patients who developed postoperative pulmonary complications (Table 1). On univariate analysis patients smoking within 6 weeks of surgery or with a history of COAD, low FEV1, IHD, CVA or absence of regional analgesia were more likely to develop sputum retention (Table 2). The multivariate analysis (Table 3) showed that current smoking, a history of IHD and absence of adequate regional pain control remained significant predictors of sputum retention. One of these risk factors was present in all cases of sputum retention.

The traditional risk factors for sputum retention, injury to phrenic nerve (33.7%), resection of recurrent laryngeal nerve (44.4%) and sleeve resection (16.7%), though not reaching statistical significance, did have a high incidence of sputum retention and must still be regarded as risk factors.

3.2. Treatment of established sputum retention

One hundred and ninety-six patients needed only the routine two visits per day by the physiotherapists, 118 patients needed more than two but less than four visits per day, 35 patients needed more than four but less than six visits per day and 12 patients needed six or more visits per day. Minitracheostomy was the primary treatment for sputum retention in 100 patients and flexible bronchoscopy primarily in eight patients, all of whom subsequently had a minitracheostomy inserted. Rigid bronchoscopy was carried out in three patients after either minitracheostomy insertion or flexible bronchoscopy for further bronchial toilet. Seven patients who needed to be ventilated had further flexible bronchoscopies carried out for bronchial toilet; two of these patients had minitracheostomy, flexible bronchoscopy and rigid bronchoscopy carried out prior to intubation (Fig. 1). The median duration of minitracheostomy insertion was 3 days (range 2–7 days).

3.3. Mortality

All in-hospital deaths (12 patients) underwent post-mortem examination. Nine patients died of pneumonia. In each case pneumonia was preceded by postoperative sputum retention. Another patient developed pulmonary oedema due to massive myocardial infarction probably induced by the hypoxia, which followed his documented sputum retention. Two patients died of pulmonary embolism unrelated to sputum retention.

4. Discussion

There is paucity of medical literature on sputum retention. Although the condition is recognized, it is usually regarded as unimportant and one is given the impression that it is easy to treat. Diagnosis of the condition is essen-

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### Table 1

Univariable analysis of postoperative pulmonary complication with respect to sputum retention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sputum retention ((n = 108)) (%)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atelectasis</td>
<td>60/85 (70.58)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>22/31 (70.96)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Positive sputum culture</td>
<td>33/54 (61.11)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Therapeutic antibiotics</td>
<td>48/75 (64)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>20/25 (80)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

### Table 2

Univariable analysis of risk factors for sputum retention

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Sputum retention (%)</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) &gt;70</td>
<td>4/28 (14.3)</td>
<td>NS</td>
</tr>
<tr>
<td>Age (years) &lt;70</td>
<td>104/333 (31.2)</td>
<td></td>
</tr>
<tr>
<td>Gender Male</td>
<td>36/220 (25.9)</td>
<td>NS</td>
</tr>
<tr>
<td>Gender Female</td>
<td>41/141 (29.1)</td>
<td></td>
</tr>
<tr>
<td>Operation Pneumonectomy</td>
<td>7/56 (12.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Operation Lobectomy/ bilobectomy</td>
<td>70/179 (39.1)</td>
<td></td>
</tr>
<tr>
<td>Operation Segmentectomy/wedge</td>
<td>15/57 (26.3)</td>
<td></td>
</tr>
<tr>
<td>Operation Chest wall resection</td>
<td>3/20 (15.0)</td>
<td></td>
</tr>
<tr>
<td>Operation Sleeve resection</td>
<td>1/6 (16.7)</td>
<td></td>
</tr>
<tr>
<td>Operation Exploratory/emphysema</td>
<td>12/43 (27.9)</td>
<td></td>
</tr>
<tr>
<td>Operation time (min) ≥120</td>
<td>69/240 (28.75)</td>
<td>NS</td>
</tr>
<tr>
<td>Operation time (min) &lt;120</td>
<td>39/121 (32.23)</td>
<td></td>
</tr>
<tr>
<td>Smoking ≥6 weeks prior</td>
<td>52/128 (40.6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Smoking &gt;6 weeks</td>
<td>56/233 (24.03)</td>
<td></td>
</tr>
<tr>
<td>COAD Present</td>
<td>46/103 (44.7)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>COAD Not present</td>
<td>62/258 (24.0)</td>
<td></td>
</tr>
<tr>
<td>FEV1 &lt;50% (&lt;70% pneumo)</td>
<td>30/48 (62.5)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>FEV1 ≥50%</td>
<td>78/313 (24.92)</td>
<td></td>
</tr>
<tr>
<td>IHD Present</td>
<td>41/95 (43.2)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>IHD Not present</td>
<td>67/266 (25.2)</td>
<td></td>
</tr>
<tr>
<td>CVA Past history</td>
<td>10/16 (62.5)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CVA No history</td>
<td>98/345 (28.4)</td>
<td></td>
</tr>
<tr>
<td>Regional analgesia</td>
<td>81/242 (33.5)</td>
<td>0.038</td>
</tr>
<tr>
<td>Regional analgesia</td>
<td>27/119 (22.7)</td>
<td></td>
</tr>
<tr>
<td>Bronchoplasty Sleeve resection</td>
<td>1/6 (16.7)</td>
<td>0.673</td>
</tr>
<tr>
<td>Bronchoplasty No bronchoplasty</td>
<td>107/355 (30.1)</td>
<td></td>
</tr>
<tr>
<td>Phrenic nerve</td>
<td>1/3 (33.3)</td>
<td>1.0</td>
</tr>
<tr>
<td>Phrenic nerve</td>
<td>107/358 (29.9)</td>
<td></td>
</tr>
<tr>
<td>Laryngeal nerve</td>
<td>4/9 (44.4)</td>
<td>0.46</td>
</tr>
<tr>
<td>Laryngeal nerve</td>
<td>104/352 (29.5)</td>
<td></td>
</tr>
</tbody>
</table>
tially clinical. As the radiological changes are usually delayed by several hours or even days the progression to pneumonia is well under way by the time they are evident. It is important therefore to recognize this clinical entity on examination findings. This study emphasizes the importance of this condition and identifies risk factors, which may assist in determining which patients may benefit from the prophylactic measures.

In the early phase of sputum retention, patients compensate for the loss of respiratory units due to secretions by increasing the respiratory rate. Though they are short of breath, tachypneic and restless, their colour and arterial blood gases, buoyed by supplemental oxygen therapy, may belie their underlying evolving condition. The untreated patient becomes exhausted, hypoxic and hypercarbic, ultimately leading to an altered level of consciousness. As the cough reflex is suppressed and the retained secretion load increases the patient spirals into the decompenated phase characterized by increasing drowsiness, cyanosis, tachycardia, sweating, and audible, bubbly respiration. Urgent interventions are needed either in the form of bronchoscopy or endotracheal intubation and ventilation to avert respiratory arrest.

In this study the occurrence of sputum retention was independent of patient demographics and the extent of the lung resection. The multivariable analysis identified current smoking, a prior history of IHD and inadequate regional analgesia as significant risk factors for developing sputum retention with trends also for prior history of COAD and CVA. Both COAD and smoking are known to produce excess pulmonary secretions and smoking tends to paralyze the cilia responsible for secretion transport. In the postoperative period the patients are usually prevented from smoking and the secretion production increases even further increasing the prospect of sputum retention. While we used a cut off period of 6 weeks for this study, the period of increased secretion after smoking cessation lasts significantly longer and sputum prophylaxis should probably be considered for those still smoking within 6 months of major lung surgery. IHD itself may not contribute to sputum retention but shares the common smoking aetiology. We postulate that the reason it remains significant on multivariate analysis is that patients with IHD do not tolerate the hypoxia associated with sputum retention and are at risk for major cardiovascular complications. The incidence of sputum retention following phrenic nerve resection, recurrent laryngeal nerve resection and sleeve resection was high but due to small numbers did not reach significance. They remain risk factors and these patients should also be considered for sputum retention prophylaxis.

The diagnosis of postoperative chest infection is not straightforward and the distinction between prophylaxis and treatment can, at times, be blurred. More patients received therapeutic antibiotics than had positive sputum cultures, particularly following pneumonectomy. Despite not fulfilling all the above criteria for chest infection treatment was commenced at the consultant’s discretion. Postoperative pulmonary atelectasis, pneumonia, and respiratory failure were significantly more common in those patients who developed sputum retention and the total postoperative pulmonary complications were comparable to previously published reports [3–5].

A number of methods are used to treat sputum retention. Naso-tracheal suction can be used to pass the vocal cords and remove secretions from the trachea but it requires the

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### Table 3
Multivariate analysis of risk factors for sputum retention

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Sputum retention (%)</th>
<th>Multivariate $P$ value</th>
<th>Odds ratio</th>
<th>95% CI (lower)</th>
<th>95% CI (upper)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current smoker</td>
<td>52/128 (40.6)</td>
<td>$&lt;0.01$</td>
<td>2.81</td>
<td>0.30</td>
<td>1.03</td>
</tr>
<tr>
<td>COAD</td>
<td>46/103 (44.7)</td>
<td>0.08</td>
<td>1.65</td>
<td>0.28</td>
<td>0.50</td>
</tr>
<tr>
<td>IHD</td>
<td>41/95 (43.2)</td>
<td>$&lt;0.01$</td>
<td>3.14</td>
<td>0.31</td>
<td>1.14</td>
</tr>
<tr>
<td>CVA</td>
<td>10/16 (62.5)</td>
<td>0.096</td>
<td>3.67</td>
<td>0.78</td>
<td>1.30</td>
</tr>
<tr>
<td>No regional analgesia</td>
<td>81/242 (33.5)</td>
<td>$&lt;0.01$</td>
<td>4.2</td>
<td>0.33</td>
<td>1.45</td>
</tr>
</tbody>
</table>

---

Fig. 1. Postoperative management. MT, minitracheostomy; FB, flexible bronchoscopy; RB, rigid bronchoscopy; NT, nasotracheal suction.
skills of an experienced respiratory therapist and is poorly tolerated by many patients. Flexible bronchoscopy requires trained bronchoscopists and is uncomfortable for patients. There is often a significant delay from diagnosis to bronchoscopy and it frequently requires repetition. Cricothyroidotomy, and the minitracheostomy device in particular, have been used extensively to treat sputum retention. These techniques are most effective when used before lung obstruction has occurred. The advantages of minitracheostomy are that it is a ward procedure, performed under local anaesthetic, requires minimal skill and requires minimal attention. Nursing, medical or physiotherapy staff can perform sputum aspiration via the cannula without specialist training. It is relatively well tolerated by patients. Following the identification of the above risk factors our centre now uses the minitracheostomy device for prophylaxis as well as a therapeutic option for development of sputum retention [1,6,7].

5. Conclusions

A subgroup of lung surgery patients at high risk of developing sputum retention can be predicted. The high-risk group includes current smokers with prior history of IHD and with inadequate control of regional analgesia. There is also a trend towards increased sputum retention in patients with a history of COAD and preoperative CVA and, though not significant in this series, a high incidence of sputum retention in patients with phrenic nerve, recurrent laryngeal nerve and sleeve resection. For this high-risk group prophylactic measures should be considered.

Acknowledgements

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References


Appendix A. Conference discussion

Dr H. Wertzel (Lostau, Germany): If patients are still heavy smokers before operation, you don’t operate on them or do you operate on them also if they had smoked in the last week 30 cigarettes?

Mr Bonde: Presently we will tell the patient to cease smoking before we operate on them, but during the period this study was considered we did not plan any intervention in these patients and it was an observational prospective study. But presently we do tell our respiratory therapist actually when the first diagnosis is made to convince the patient to stop smoking because that will have subsequently an effect on the postoperative outcome.

Dr Wertzel: And if he doesn’t stop smoking?

Mr Bonde: We would go ahead and do the operation because there is no way in that group of patients you can convince them to stop smoking.

Mr D. Ngaage (Leeds, UK): Did these patients have pre and post operative physiotherapy? We know that this actually helps in sputum expulsion in these patients. Did you include this in your study to see whether it could affect or influence the rate of sputum retention in your patients?

Mr Bonde: Most of these patients did not go in a program of respiratory physiotherapy before going for their operation, and this study concluded in December of 1999. Since then, these high risk patients that we identified, we are trying to put them through a routine five days preoperatively of putting them on bronchodilators, giving them physiotherapy before we do the surgery, but during this trial all these patients did not have any preoperative physiotherapy.
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