ORIGINAL ARTICLE

Prolonged air leak after pulmonary resections

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ABSTRACT

Background. The aim of our study was to determine risk factors for prolonged air leak after pulmonary resections.
Methods and Results. Two hundred and five patients underwent operations in our department between January 2003 and March 2004. Prolonged air leak (PAL) was defined as an air leak persisting for 7 days or more of post-operative chest tube drainage. PAL occurred in 17 (8.3%) patients and it lasted 10.1±3.5 days. Chronic obstruction pulmonary disease (COPD) remained the only predictive variable for PAL ($p<0.05$). This complication significantly prolongs the length of hospitalization ($p<0.01$).
Conclusions. COPD patients have a significantly higher risk of PAL following pulmonary resection. Intraoperative prevention of air leaks requires meticulous surgical technique, stapler use and application of pericardial bovine strips.
Key words: pulmonary resection, prolonged air leak, chronic obstructive pulmonary disease.

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INTRODUCTION

Prolonged air leak following pulmonary resections is a factor preventing early release of patients from surgical clinics. At a time of improved quality of medical care, modern anesthesiology, advanced quality of surgical instruments and equipment, staplers and suturing material, thoracic surgeons are challenged to do everything possible to prevent post-operative complications related to the operation technique. Increased incidence of post-operative complications not only affects mortality but also represents an economic burden on thoracic surgery centers.

Prolonged air leak can be considered a relatively frequent post-operative complication that is potentially avoidable. We define prolonged air leak as an air leak persisting for at least 7 days after pulmonary surgery. The incidence of this complication worldwide is between 3 and 25 per cent in a heterogeneous group of patients with benign and malignant tumors who underwent pulmonary surgery (1-5).

The aim of this work was to find the incidence of PAL at our clinic and also to identify pre- and post-operative risk factors that affect and lead to this incidence.

PATIENTS AND METHODS

Altogether 205 elective pulmonary resections due to benign and malignant tumors were performed in the period between January 2003 and March 2004. The resections comprised 134 lobectomies, 15 bilobectomies, 45 non-anatomical resections and 11 enucleactions. Pneumonectomies, acute pulmonary resections and explorative thoracotomies were excluded from the study. Prolonged air leak was defined as chest-tube drainage due to persistent air leak lasting 7 days or longer. Drainage performed because of persistent exudates without air leak was excluded. The patients were divided into two groups according to the presence or absence of this complication. The PAL group included patients with this complication, the nonPAL group patients without this complication.

The monitored pre-operative factors were age, sex, body mass index (BMI), FEV1 (forced expiratory volume per second, percent of predicted), FVC (forced vital capacity, percent of predicted), FEV1/FVC. Chronic obstruction pulmonary disease (COPD) was defined as FEV1<70% of predicted and FEV1/FVC ratio of < 70% (5).

Monitored peri- and post-operative parameters included type of pulmonary surgery, condition of pulmonary fissures, duration of chest-tube drainage, pulmonary complications (pneumonia, atelectasis with bronchofibroscopic aspiration, prolonged air leak), cardiac complications (arrhythmia treated with medication, ECG and enzymes confirmed acute myocardial infarction) and wound complications, length of hospitalization.

The patients were indicated for pulmonary surgery according to existing guidelines for the scope of pulmonary resections determined on the basis of pre-operative investigations (6). All pulmonary resections were performed with selective lung ventilation by a standard anterolateral thoracotomy. The stump of the bronchus after the lobectomy was closed by two layers of interrupted sutures (PDS II 4/0, Ethicon); the pulmonary veins were ligated (Silon EP 3, Chirmax) and sutured using continuous vascular sutures (Prolen 4/0, Ethicon). The branches of the pulmonary artery were centrally double ligated (Silon EP 2, Chirmax). Incomplete pulmonary fissures were divided using a linear stapler (TCT 75, Ethicon) without reinforcement of the stapler line with pericardial bovine strips. A single chest-tube drain was used for thoracic drainage. Post-operative analgesia was controlled by means of epidural analgesia. Care for the chest-tube drain was standard. After the operation, the chest-tube drain was switched to active suction. If there was no air-leak into the drain, the drain was switched to no-suction. The drain was removed after clinical control of uncollapsed lungs and lung x-ray. In case of air leak, aggravation of signs of pneumothorax on the x-ray of the lungs, the drain was once again switched to active suction.

Statistical data were processed with the help of SPSS 10.0. Categorical variables were compared using the χ^2 test. A student's *t*-test was used in the analysis of continuing variables. A statistically significant factor was defined as $p<0.05$ and highly significant factor as $p<0.01$.

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RESULTS

Altogether 63 women and 142 men, average age 59 years (range from 21 to 80 years), were included in our study. One hundred and forty five patients were without post-operative complications. There were 72 post-operative complications in our group. One patient died of multiple organ failure on the 27th day after a left upper lobectomy. PAL occurred in 17 (8.3%) patients. PAL was identified as the only complication in 13 patients. Four patients had chest-tube drainage for longer than 14 days. All patients were treated conservatively without reoperation.

The results of the statistical analysis of the monitored groups of patients are summarized in Table 1. The comparison of differences in age, sex, non-adjuvant therapy, BMI did not show significant difference. The only significant risk factor identified in the onset of PAL was COPD ($p<0.05$). The average length of hospital stay of patients with PAL was 13.3 days (range 9 to 23 days). This period of hospitalization was significantly longer than in the case of patients without this complication (13.3 vs. 7.9 days, $p<0.01$).

We performed an analysis of patients after pulmonary lobectomy (Tab. 2) to find the incidence of prolonged air leak. During the given period, we performed 134 lobectomies. We operated on 39 women and 95 men, average age 59 years. One hundred and seven lobectomies were performed because of non-small cell lung cancer. Six lobectomies were performed for pulmonary metastases. In 91 patients the post-operative course was uneventful. There were 53 complications and one patient died. Thirteen patients (9.7%) had a PAL complication. This complication was the only complication in 11 patients. Two patients (15%) had a heart complication besides PAL. The incidence of this complication was similar to that in the group without PAL (19%). The average duration of chest-tube drainage was 10.4 days, range 7 to 17 days. All patients were treated conservatively. No significant difference depending on age, sex and BMI was observed between the monitored groups. No significant difference depending on the type of lobectomy was observed. The only risk factor associated with PAL was observed in the group of patients with COPD ($p=0.047$).

Prolonged air leak after pulmonary resection leads to a significant lengthening of the patients' stay in the ICU and of post-operative hospitalization. We acquired data from the health insurance (HI) companies accounts of 10 randomly chosen patients from each group to find out the cost of a lobectomy without PAL and lobectomy with PAL. The aim was to identify the amount paid by health insurance companies to the individual clinics treating patients after pulmonary lobectomies. The total patient account comprised the individual bills for performed interventions: surgery and post-operative care, anesthesia, histology, x-ray, physiotherapy, microbiology, laboratory (Tab.3).

In the case of patients with PAL, the HI cost of a performed lobectomy was 19,220 CZK (Czech Crowns) higher, i. e. +26%. The cost of anesthesia was also higher, by 25%; the histology cost was the same. The number of x-ray investigations was higher and physiotherapy, too, was more intensive. This was reflected in the higher cost of these items. It is interesting to study the ratios of the individual items. Health insurance companies evaluated a performed lobectomy with 5,748 points. At a price of 0.89 CZK per

Tab. 1. Comparison of patients without prolonged air leak (nonPAL) and with complication (PAL)

	nonPAL	PAL	*p* value
Patients	188	17	
Sex M/F	127/61	15/2	NS
Age	58.3±11.04	63.3±11.3	NS
BMI	25.9±3.77	26.1±3.77	NS
Non-adjuvant chemotherapy	11	1	NS
Lobectomy	121	13	NS
Bilobectomy	12	3	
Non-anatomic resection	55	1	
COPD/ non-COPD	32/156	7/10	<0.05
Chest tube drain	3.8±0.9	10.1±3.5	<0.01
IUC care	4.6±1.9	7.1±3.3	<0.01
Length of hospital stay	7.9±1.4	13.3±3.7	<0.01

Tab. 2. Comparison of patients with PAL and without this complication (nonPAL) in lung lobectomies

	nonPAL	PAL	*p* value
Lobectomy	121	13	
Sex M/F	84/37	11/2	NS
Age, years (average±SD)	58.6±10.7	64.7±11.6	NS
BMI (average±SD)	25.6±3.6	25.9±4.2	NS
Upper/middle/lower lobectomy	69/6/46	7/1/5	NS
COPD/nonCOPD	26/95	5/8	<0.05
Chest tube drain. days (aver.±SD)	4.0±0.8	10.4±3.2	<0.01
Length of hospital stay, days (aver.±SD)	7.9±1.4	13.7±3.9	<0.01

Tab. 3. Total cost to HI (CZK) of lobectomy without complications and with PAL

	nonPAL	PAL	Δ	%
Total costs±SD	73 974±12 816	93 194±18 573	19 220	+ 26 %
Surgery	58 146	72 808	14 662	+ 25 %
Anesthesia	10 463	12 564	2 101	+ 20 %
Histology	2 642	2 650	8	+ 0 %
X-ray	472	902	430	+ 90 %
Physiotherapy	737	1 626	889	+120 %
Microbiology	458	1 235	777	+169 %
Other	1 043	1 490	447	+ 42 %

Other: biochemical and hematological investigation, Δ: difference PAL - nonPAL

point, the total price is 5,117 CZK. For a performed lobectomy, the surgical team thus gets twice as much as histology and half the amount that goes to the anesthesiologists.

DISCUSSION

Our work was concerned with one of the potential and rather frequent complications of pulmonary surgery. The question is how to define this complication and how to determine its time limit. Most of the works discussing this complication during the last ten years define prolonged air leak as a leak of air into the chest-tube drain persisting for 7 or more days. This is a limit set for the purpose of comparing individual centers. This is the limit we, too, have chosen for evaluating our group of patients.

In literature, the incidence of this complication is given as 1% to 15% patients after pulmonary resection. Rice and Kirby published an incidence of prolonged air leak in 30 (15.2%) patients from a group of 197 (7). Venuta et al. reported the incidence of this complication in 4% patients after pulmonary lobectomy (8). Keagy et al. published 4.3% incidence of air leak in 369 lobectomies (9).

One of the identified predictors of PAL was upper lobectomy (4). It is assumed that this is caused by the large residual space after the lobectomy and the inadequate apposition of the visceral and parietal pleura. This could be a predisposition to prolonged air leak. Some authors recommend the creation of a pleural tent in the upper part of the hemithorax. They consider this a safe technique to reduce the length of hospital stay and decrease costs (8). This is not a commonly applied technique at our clinic.

Cerfolio, in a prospective trial, applied 1,200 ml of air after bilobectomy through a small trans-diaphragmatic orifice into the peritoneal cavity. According to his results, pneumoperitoneum after bilobectomy reduces the incidence of air leak and shortens hospital stay without increasing patient morbidity (10).

During prolonged air leak and the necessity of draining the hemithorax it is possible to replace filtering flasks with Heimlich's valve. This allows better rehabilitation of the patient as well as the possibility of releasing the patient into home care and outpatient follow up.

According to the Brunelli trial, the age of the patient was not identified as a significant predictor of PAL after pulmonary surgery (2). Nor did earlier studies performed at the 3rd Department of Surgery identify age as a risk factor in the incidence of PAL during the comparison of two age groups after pulmonary surgery (11).

Another risk factor is the presence of pleural adhesions. This was the only common PAL predictor in upper and lower lobectomy in the work of Brunelli et al. (2). During the mobilization of the lung the latter can be impaired, especially if loosened bluntly and without visual control. That is why very meticulous preparation, endeavor to prevent damage to the pulmonary parenchyma and preferably extra pleural dissection are recommended in such cases.

PAL is also considered a predictor of the development of other, especially pulmonary, complications. Brunelli gives an increased incidence of post-operative morbidity (empyema), fever or pneumonia. This association may be explained by the presence of these complications caused by the residual pleural space, chest-tube drains and continuous air leak from the pulmonary parenchyma into the pleural cavity together with the unfavorable condition of the parenchyma (2). In our study we did not observe an increased incidence of other pulmonary or cardiac complications compared with the group without PAL.

Reduced pulmonary function is associated with the increased incidence of PAL. This is probably due to the increased resistance in the airways and pathological changes of the pulmonary parenchyma. Brunelli identified FEV1 as a predictor of PAL after upper lobectomy (2). In patients with pulmonary carcinoma, ppoFEV1 (predicted post-operative FEV1) can be a much more reliable indicator of pre-existing lung damage, since it is less affected by the size of the tumor, the associated atelectasis and concomitant misbalance of ventilation and perfusion in comparison with the preoperative parameters (12). Patients with reduced ppoFEV1 should therefore undergo perfect preoperative bronchodilation and proper physiotherapeutic rehabilitation. In our study, COPD was identified as the only predictor of PAL.

PAL is a complication that leads to a significant lengthening of hospitalization, and it is the duty of every thoracic surgeon to reduce the risk of PAL. Prevention requires precise technique, observation of pneumostatic principles and keeping damage to the remaining parenchyma to the minimum. Electrocoagulation is applied during the dissection of the pulmonary parenchyma and the linear stapler is used to complete incomplete pulmonary fissures. It is also possible to use pericardial bovine strips to prevent damage to the tissue during resection (13). Cooper was the first to publish the application of pericardial strips to reduce air leak (14). Miller et al. published a prospective randomized trial of the use of pericardial strips in anatomic and segmental resections (15). He documented a decrease in PAL incidence and shortening of hospital stay when these strips were used in patients with a risk of PAL. The work also discusses the economic aspects of reducing the incidence of PAL. The cost of a performed pulmonary resection was $ 23,910±9,943 in the group with pericardial strips and $ 28,678±5,355 in the control group. The price of one pericardial strip is $ 135. On average, 3 pericardial strips are used in one operation. This means an expense of $ 400 to prevent PAL in risk patients. The application of pericardial strips shortened hospitalization by one day. The saving, after calculating all the costs, starting with medical devices, pharmaceuticals, medical staff and deducting 1.4 days of hospital stay, is $ 4,000. The higher costs incurred by the control group were due to 1) longer operating time, 2) longer hospital stay of non strip patients, 3) longer time of chest-tube drainage and of air leak in this group. The cost of pericardial strips was 1.6% of the total costs of patient care. An increase of material costs by 1.6% brings a saving in total cost of medical care of 16%. The use of pericardial strips is economical for American surgeons. In 1997, Wright et al. published a work on the economical options in thoracic surgery, leading especially to the shortening of hospitalization (16). The average price of hospitalization of a patient with pulmonary lobectomy at the Harvard Medical School in 1995 was $ 16,063 for an average hospital stay of 7 days. In 1997, a 6-day stay in hospital cost $ 14,792. The shortening of hospitalization and reduction of the cost of pulmonary lobectomy was ascribed to the following factors: 1) admission on the day of the operation, 2) removal of the epidural catheter one day before the removal of the chest-tube drain, 3) checking morning x-rays during the morning report to be able to select the proper type of management of the chest-tube drain on the same day.

The total cost to HI of pulmonary lobectomies was, according to our study, $ 2,960±513 in the case of patients without the complication of PAL, and $ 3,727±743 in patients with the complication of PAL. This is 26% more. The price of a lobectomy in the Czech Republic is only 12% of the price quoted by Miller in the U.S. The analysis of the total cost and also the comparison of evaluation of individual interventions according to the tariff rates of interventions show a great disproportion between the individual interventions. Consensus will have to be sought during the draft of new tariffs. That is not going to be easy.

CONCLUSION

It should be the aim of every surgeon to prevent such damage to the pulmonary parenchyma that would lead to prolonged air leak.

This applies especially to COPD patients, who have a higher risk of PAL. Prevention requires meticulous technique, the use of staplers to loosen intralobar crevices. This is where the issue of pericardial strips should be considered. We do not use them at our clinic. Another important decision is when to perform the suture of the injured pulmonary parenchyma after lobectomy, when during control air leak from the pulmonary parenchyma is under the water. Too many sutures may aggravate the situation rather than help, and in the end everything will depend on the experience of the surgeon and his judgment. It is sometimes better to do little than too much. Another option is using a Tachocomb for the pulmonary tissue or a piece of intercostal muscle on the injured pulmonary parenchyma.

In spite of best efforts, air leaks after pulmonary resections do appear. This is when the surgeon has to take many factors into account. They include patience, consideration of suction or no-suction, need of additional drains, and application of Heimlich's valve or necessity of reoperating the patient. This is where the inestimable experience of the thoracic surgeon comes in.

This work was presented at the international surgical symposium "58th Kostlivý Day" in Bratislava on December 3, 2004.

Abbreviations

BMI	- body mass index
COPD	- chronic obstruction pulmonary disease
FEV1	- forced expiratory volume per second
FVC	- forced vital capacity
HI	- health insurance company
IUC	- intensive care unit
nonPAL	- group of patients without prolonged air leak
PAL	- prolonged air leak
ppoFEV1	- predicted post-operative FEV1
SD	- standard deviation

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COMMENTARY

Commentary on the paper by Stolz et al. ”Prolonged air leak after pulmonary resections”

It is the common aim of the pneumologist and thoracic surgeon to treat lung disease quickly, effectively and without complications. We try to advance closer to this ideal situation, but due to a large number of variables, we shall probably never achieve surgery without complications.

Prolonged air leak (PAL) is a frequent complication of lung surgery that increases morbidity, prolongs hospital stay and increases the cost of medical care (1, 2). PAL is most commonly defined as an air leak from a pulmonary suture persisting for more than 7 days (1, 3, 4-6). In some publications, PAL is defined as an air leak persisting for more than 48 hours (2). The frequency of PAL depends on the type of intervention. It is most frequent in lung volume reduction surgery (LVRS) for heterogeneous emphysema, where it occurs in almost half (43%) of the operated patients; in pneumonectomy this complication does not occur at all (5). Airtight suture of the lung during thoracotomies used to be achieved by two rows of sutures, first continuous suture and, in the next layer, individual sutures. During video-assisted thoracic operations staplers are used to suture pulmonary tissue; they speed up the intervention, but it is not always possible to close the pulmonary tissue so as to be airtight. In lobectomies PAL persisting for more than 7 days occurs in 10% to 15.6% of the operated patients. According to published data, its frequency depends on FEV1 and on the presence of pleural adhesions (1, 4). If PAL is defined as an air leak persisting for 48 hours or more, this complication occurs in 35% of operated patients (2). In the study of Stolz et al., PAL persisting for 7 days or more occurred in 8.3% of the cohort (134 lobectomies, 15 bilobectomies, 45 non-anatomical resections and 11 enucleations) and concomitant chronic obstructive pulmonary disease (COPD) was found to be a significant risk factor. The work does not, however, present the values of ventilatory parameters like FEV1. In the case of lobectomies, PAL occurred in 9.7% of the group, which is similar to international data. This complication leads to a 26% increase in the financial cost of a lobectomy in the Czech Republic.

What kind of measures could help limit the incidence of PAL? Published studies describe the reduction of the incidence of this complication by the application of fibrin glues, pericardial bovine stripes, shrinkage of pulmonary tissue by laser and other procedures. The effect of these complimentary procedures is not very convincing (5). A study was published last year involving 12 patients (3x large bulla, 4x pulmonary cyst, 5x pulmonary metastases), in whom a new system was applied: joining the impaired pulmonary tissue without sutures and staplers with a special electrocauter (LigaSure Vessel Sealing System - LVSS). With this method, PAL was observed only in one operated patient, which is still about 10% (bearing in mind the possible error due to the small size of the group) (6).

In spite of testing and using new methods in thoracic surgery, PAL will continue to occur. During the management of PAL, the surgeon must consider a whole number of possible procedures, like the indication of active suction, gravity drainage, the use of additional chest-tube drains, the application of Heimlich’s valve or the necessity of reoperating on the patient.

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