Usefulness of conventional pleural drainage systems to predict the occurrence of prolonged air leak after anatomical pulmonary resection

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Abstract

OBJECTIVES: One of the reported advantages of digital pleural drainage system is the possibility of predicting the occurrence of prolonged air leak (PAL) based on the recorded pleural pressures and/or air flow through chest tubes. Nevertheless, this fact has never been well supported. The objective of this investigation is to evaluate if the occurrence of PAL can accurately be predicted using clinical data and air leak measurements 24 h after lung resection on conventional pleural drainage system (CPDS).

METHODS: Prospective observational study on 100 consecutive non-complicated patients undergoing anatomical lung resection (segmentectomy, lobectomy or bilobectomy). Prior to the operation, the risk of PAL was evaluated according to the score previously published. Twenty-four hours after surgery, two independent observers measured the air flow at forced deep expiration on a CPDS with graduated analagical leak monitor. The agreement between both observers was determined and in case of discrepancy, the mean of both observations was calculated. After discharge, the occurrence of PAL (defined as persistent air leak 5 or more days after the operation) was recorded. A logistic regression model was constructed including two independent categorical variables (PAL score and air flow) and the performance of the model was assessed by non-parametric receiver operating characteristic curves.

RESULTS: The series includes 81 lobectomies, 8 bilobectomies and 11 anatomical segmentectomies. Median preoperative PAL score was 1 (range 0–3.5). Any postoperative air flow was observed in 30 cases with a median value of 0 (0–3.5). The prevalence of PAL in the series was 10% (10 of 100 cases). Both independent variables entered in the multivariate model (PAL score \( P = 0.050 \), air flow: \( P = 0.016 \)) and C-index was 0.83.

CONCLUSION: The performance of this simple predictive model, without any electronic recording, warrants a larger multi-institutional study to validate its usefulness in clinical decision-making regarding the management of patients with air leak after lung resection.

Keywords: Pulmonary resection • Prolonged air leak • Pleural drainage systems

INTRODUCTION

Although there is not a standard definition of prolonged air leak (PAL) in the literature, in concordance with the median hospital stay in our series, we have defined it as a persistent air leak of 5 or more days through the chest tube [1]. Nowadays, PAL is the most prevalent complication after anatomical pulmonary resection [2] and its occurrence has been associated, by different authors, with increased median hospital stay and postoperative cost [1], as well as with a higher risk of pleural infections [1, 3, 4].

To date, different studies have tried to correlate air leak and pleural pressures observed in the first 24 h with the incidence of PAL [5, 6]. All of these studies are based on the measures obtained with DPDS, not available in every hospital and with higher costs than conventional drainage systems. With this rationale, this study aims to: (i) correlate clinical variables and the air flow measured in the first 24 h in a CPDS with the incidence of PAL. (ii) Analyse interobserver variability when measuring air flow in the first 24 h on a CPDS. (iii) Create a multivariate model based on clinical data and air flow at 24 h to predict PAL after anatomical lung resection.

MATERIALS AND METHODS

We have designed a prospective observational study of 100 consecutive patients treated with anatomical lung resection in our...
Thoracic Surgery Department between January and December 2013. The study was approved by the institutional ethics committee and a special consent form was designed for it. All the data were recorded in a prospective computerized database with double quality control. There were no missing values.

**Studied population**

All patients treated with anatomical lung resection (segmentectomy, lobectomy or bilobectomy) were included in the study after they signed an informed consent form. The indication of the resection and the final pathological diagnosis were not taken into account for the study purposes. The exclusion criteria were as follows: (i) the presence of strong diffuse adherences, as we considered that the complete detachment of the lung could favour the incidence of PAL by itself, (ii) haemothorax as a postoperative complication, (iii) prolonged mechanical ventilation required after surgery, (iv) reintervention in the first 5 postoperative days, (v) inability of the patient to perform deep forced expirations for 1 min when measuring air flow and (vi) postoperative pneumonia or atelectasis.

**Perioperative management**

Before surgery, all the patients were studied through an extensive work-up, which included physical examination, haematological and biochemical tests, electrocardiogram, chest X-rays, computed tomography scan of the chest as well as abdomen and bronchoscopy. Further image investigations were performed only if clinical findings or abnormal laboratory results suggested their indication. Pulmonary function tests were indicated in all patients. For this study, we have reviewed only forced expiratory volume in 1 s (FEV1) in percent values according to age, gender and height of the patient and diffusing capacity of the lung for carbon monoxide (DLCO).

PAL risk [7] was assessed in every patient preoperatively and prevention measures were planned in advance when needed. All the patients with a previous history of cardiovascular disease or any suspicious changes in the electrocardiogram were referred for assessment by a cardiologist. Perioperative management was uniform for all cases during the study period. All cases were operated on by the same team of senior thoracic surgeons, either through video assisted thoracic surgery, anterolateral or muscle-sparing posterolateral approach. In all patients, a 28F chest tube was left in apical position and connected to an Atrium® Ocean® Water Seal Chest Drain device. This device has a scale in the water seal, graded from 0 to 3, that allows air flow quantification.

Anaesthesia procedures were indicated and performed or supervised by a senior cardiothoracic anaesthetist. Preoperative antibiotic regimen consisted of a unique dose of Cefuroxime 1500 mg that was repeated 6 h later if surgery continued. Extubation was performed in the operating theatre and, after a few hours in the recovery room, patients were transferred to the cardiothoracic ward. For postoperative analgesia, an epidural catheter was inserted and bupivacaine and fentanyl were infused through it during the first 2 or 3 days. Afterwards, it was followed by oral paracetamol and non-steroid anti-inflammatory drugs. Nursing care was also homogeneous in all cases and included incentive spirometry. All the patients were included in our specific pre- and postoperative chest physiotherapy programme [8].

**Air flow measurement**

Air flow was measured on the first postoperative day by two independent observers, both of them from our Thoracic Surgery team. All the measures were recorded on an ad hoc data recording sheet, where the clinical variables related to the risk of postoperative PAL were also included.

To control air leak in the operative field, a graded scale ranging from 0 to 3 was used [9]. To summarize, 0 was the absence of air leak before closing, 1 was the presence of isolated and small air bubbles, 2 was the presence of continued and well-located air bubbles and 3 was the presence of continuous and diffuse air bubbles. When value 2 or 3 was observed before closing the chest wall, additional measures to control air leak were applied, consisting in the reinforcement of the mechanical parenchymal sutures manually or with pulmonary sealants (Coseal®) or the reparation of any parenchymal tears.

Twenty-four hours after the surgery, with the patient in the cardiothoracic ward and once he had performed chest physiotherapy, air flow through the chest tube was assessed by the two observers. The patient performed deep forced expirations along 1 min. In every expiration, the air flow observed in the graded water seal of the CPDS was recorded by each observer and the record was blinded to the other.

Afterwards, the maximum values of air flow from both observers were compared and the mean was calculated in case of discrepancies.

**Variables in the study**

The outcome studied was PAL (defined as the presence of air flow through the chest tube 5 or more days after surgery). The independent recorded variables were PAL risk score [7] (including age, FEV1%, DLCO, body mass index and the presence of pleural adherences) and the maximum average air flow was observed at 24 h.

**Data analysis**

The inter-rater agreement between both observers was analysed with the Kappa index. Both independent variables, PAL score and average air flow at 24 h, entered the multivariate logistic regression model, whose performance was assessed with non-parametric receiver operating characteristic (ROC) curves and its 95% confidence intervals (CI). All the data analysis was performed with Stata/IC 13 (StataCorp, TX, USA).

**RESULTS**

Between January and December 2013, 108 patients who underwent anatomical lung resection for any indication in our Department and met the inclusion criteria were studied. From them, 8 patients were excluded: 3 due to the presence of strong diffuse adherences, other 3 because of their incapacity to perform deep forced expirations for 1 min, 1 because he required prolonged postoperative ventilation and another patient because he needed reintervention in the first 5 postoperative days. In total, 100 patients formed the final series (11 segmentectomies, 81 lobectomies and 8 bilobectomies). Lung resection was indicated for non-small-cell lung cancer (95 cases) or pulmonary metastases
Table 1: Distribution of the variables related to PAL risk

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1%</td>
<td>88.6 (17.8)</td>
</tr>
<tr>
<td>DLCO</td>
<td>80.6 (20.9)</td>
</tr>
<tr>
<td>BMI</td>
<td>26.9 (4.3)</td>
</tr>
<tr>
<td>Age</td>
<td>66 (10.75)</td>
</tr>
</tbody>
</table>

FEV1: forced expiratory volume in 1 s; DLCO: diffusing capacity of the lung for carbon monoxide; BMI: body mass index.

Table 2: Inter-rater agreement

<table>
<thead>
<tr>
<th>Agreement</th>
<th>Expected agreement</th>
<th>Kappa index</th>
<th>95% CI of Kappa</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.91%</td>
<td>53.37%</td>
<td>0.81</td>
<td>0.75–0.85</td>
<td>0.07</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 3: Multivariate logistic regression model

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAL score</td>
<td>2.18</td>
<td>0.99–4.78</td>
<td>0.87</td>
<td>0.050</td>
</tr>
<tr>
<td>Air flow</td>
<td>2.31</td>
<td>1.16–4.59</td>
<td>0.80</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Figure 1: Non-parametric ROC for the logistic regression model. ROC: receiver operating characteristic.

Variability in clinical practice regarding the removal of chest tubes, and consequently, patient discharge has been evidenced in the literature, with different recommendations depending on the authors [4, 13, 14]. In a study previously published by our group [15], we showed that CPDSs were related to a great interobserver variability when indicating the removal of chest tubes, even with previously established criteria. This variability was considerably diminished when using DPDS (Kappa index went from 0.37 with conventional systems to 0.88 with digital ones). Nevertheless, in the present study, when we assessed the interobserver variability when measuring air flow, the Kappa index was 0.81, rendering the measures reliable and reproducible [16]. This finding could be explained mainly by three facts: (i) team training on air flow measurement manoeuvres, previously established; (ii) air flow was the only variable quantified, without taking into account other issues influencing the removal of the chest tube, such as for example, drainage debit; (iii) before measuring air flow, it was routinely verified that the patient had already performed chest physiotherapy, thus minimizing the presence of microatelectasis that could interfere with the air flow measurement.

It has already been reported that the risk of PAL is measurable [7] considering only clinical variables, but there are different studies, one from Brunelli et al. [5] and other from Jimenez et al. [6], demonstrating that measuring air flow and intrapleural pressures in the first 24 postoperative hours with DPDS, could also predict PAL. In Brunelli et al.’s study [5], the prediction model was based on the differential expiratory-inspiratory intrapleural pressures measured in the first 6 postoperative hours. However, Jimenez et al.’s study reported a direct correlation between the maximum expiratory pressure after the first 12 postoperative hours and the incidence of PAL. Indeed, they observed a relationship between the intensity of air leak after the first 12 postoperative hours and the presence of PAL. As we have used only CPDS in our study, we were not able to measure intrapleural pressures; just an analogue measure of air flow in the graded water seal, which was eventually directly related to the incidence of PAL in our series.

Although this model, based on clinical data and air flow measured at 24 h, performs reasonably well, as indicated by the non-parametric ROC curve, we have not validated the model on a different population. Indeed, as the prevalence of PAL in our series is 10%, the predictive values of the model obtained could be affected.

We are aware of other limitations of this study, including the small number of patients and the absence of control group with electronic devices. Furthermore, a selection bias could have occurred, taking into account that patients with strong diffuse pleural adherences, who may be more predisposed to PAL, were excluded from the study to minimize the variability. The exclusion
of intraoperative variables, such as fissureless technique and specific circumstances of air leak measurements, could be also considered a limitation of the study.

In conclusion, in our series, this simple model based on clinical variables and visual scoring of pleural air leak has a reasonably good performance, minimizing the lack of electronic pleural systems in clinical practice.

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Conflict of interest: Gonzalo Varela is an advisor for Atrium Medical.

REFERENCES