Predictors of exercise oxygen desaturation following major lung resection

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Abstract

Objective: To identify predictors of postoperative exercise oxygen desaturation (EOD) in patients submitted to lobectomy or pneumonectomy for lung carcinoma. Patients and methods: A consecutive series of 227 patients with non-small cell lung cancer submitted to lobectomy or pneumonectomy from January 2000 through October 2002 were prospectively analyzed. Maximal stair-climbing tests were performed preoperatively (the day before the operation) and postoperatively (on average, 9.2 days after operation) in room air for all patients. A fall in oxygen saturation during the exercise below 90% was termed ‘desaturation’. Univariate and multivariate analyses were performed to identify predictors of postoperative EOD. Results: Thirty-five patients (15.4%) developed postoperative EOD. After multivariate analysis, the only independent predictor of postoperative EOD resulted a reduction in oxygen saturation during the preoperative exercise ($P = 0.0004$). Conclusions: Patients with a reduction in oxygen saturation during the preoperative exercise test are at increased risk to develop a postoperative EOD below 90%. A postoperative exercise test should be performed in all these patients. Should EOD be confirmed, an intermittent home oxygen therapy is recommended in order to facilitate recovery from operation and improve the quality of life.

Keywords: Exercise test; Stair-climbing test; Oxygen desaturation; Lung resection; Lung cancer

1. Introduction

After pulmonary resection the patients slowly regain, more or less completely, their lost function by progressively resuming their daily activities or, more ideally, by participating in a rehabilitation program. However, following surgery, some patients experience arterial hypoxemia on effort, which limits their physical activity, hindering the postoperative recovery and worsening their quality of life.

The objective of this study was to identify the predictors of postoperative exercise oxygen desaturation (EOD) following lobectomy or pneumonectomy for lung cancer, in order to select those patients to be submitted to postoperative maximal exercise test for assessment of their oxygen saturation status.

2. Patients and methods

Two hundred and twenty-seven patients with non-small cell lung cancer who underwent pulmonary lobectomy (189 patients) or pneumonectomy (38 patients) at our institution from January 2000 through October 2002 were prospectively enrolled in the study after giving informed consent. All the patients performed a preoperative (the day before the operation) and a postoperative (on average, 9.2 days after the operation) symptom-limited stair-climbing test. Our hospital has 16 flights of stairs, each flight having 11 steps. Each step is 0.155 m in height. The patients were asked to climb at a pace of their own choice the maximum number of steps and to stop only for exhaustion, limiting dyspnea, leg fatigue, or chest pain. A physician accompanied all patients during their exercise, and used a continuous verbal interaction with them for encouragement and assessment of the dyspnea and the occurrence of other symptoms. All tests were performed in room air. During the exercise, the pulse rate and capillary oxygen saturation were monitored by means of a portable pulse oximeter, and the same device was used for all patients. For the purpose of this study, a...
fall in oxygen saturation during exercise below 90% was termed ‘desaturation’. For each patient, the number of steps climbed and the time taken to complete the test were recorded in order to calculate the following ergometric variables: work (height of step (m) × steps per minute × body weight (kg) × 0.1635) [1]; maximum oxygen consumption (VO₂max) in ml per min (5.8 × weight (kg) + 151 + 10.1 × work) [1].

The following spirometric variables were considered for the present study: forced expiratory volume in 1 s (FEV1); forced vital capacity (FVC); carbon monoxide lung diffusion (DLCO); FEV1/FVC ratio; predicted postoperative FEV1 (ppoFEV1) calculated by the formula (preoperative FEV1/number of preoperative functioning segments) × number of postoperative functioning segments; predicted postoperative DLCO (ppoDLCO) calculated by the formula (preoperative DLCO/number of preoperative functioning segments) × number of postoperative functioning segments. All the spirometric data, with the exception of FEV1/FVC ratio, were expressed as percentage of predicted value for age, sex, and height. Pulmonary function tests were performed according to the American Thoracic Society criteria. DLCO was measured using the single-breath method.

The estimate of the number of functioning segments was made by using computed tomographic (CT) scan and bronchoscopy findings. In patients with a calculated ppoFEV1 less than 50% of predicted and in all pneumonectomy candidates, a quantitative perfusion lung scan was performed [2]. The simple calculation of ppoFEV1 was shown to be as reliable as lung perfusion scan [2]. The percentage of functional lung tissue removed during operation (Func loss%) was calculated by means of CT scan, bronchoscopy, and when performed, quantitative lung perfusion scan [3]. The following conditions were indicative of a concomitant cardiac disease: previous cardiac surgery, previous myocardial infarction, history of coronary artery disease, current treatment for arrhythmia, cardiac failure, or hypertension.

All the patients with a concomitant cardiac disease underwent an extensive cardiac evaluation before the exercise test and they were allowed to perform stair climbing only when deemed in a hemodynamically stable state.

Patients with and without postoperative EOD were compared by means of the Student’s t test (for the numerical variables) and the Chi-square test (for the categorical variables). Significant variables at univariate analysis were then used as predictors in a stepwise logistic regression analysis (dependent variable: presence of postoperative EOD).

All tests were two-tailed, with a significance level of 0.05. Statistical analysis was performed by using the statistical software Statview 5.0 (SAS Inc., Cary, NC, USA).

3. Results

Thirty-five patients (15.4%) developed postoperative EOD. Six of these patients experienced a preoperative EOD as well. Other six patients had a preoperative EOD but did not develop a postoperative EOD. None of the 12 patients with preoperative EOD had postoperative cardiopulmonary complications. The occurrence of postoperative EOD did not differ between complicated (seven of 33 patients) and non-complicated (28 of 194 patients) patients (P = 0.3). Of the 35 patients with postoperative EOD, three had a desaturation of 3% (i.e. from 90 to 87%), eight had a desaturation between 4 and 6%, 13 had a desaturation between 7 and 9%, and 11 had a desaturation greater than 9%. All these patients stopped their postoperative maximal stair-climbing test for limiting dyspnea.

In those patients who did not have postoperative EOD, 124 of 192 (64.6%) stopped their postoperative exercise test for limiting dyspnea, 30 for leg pain, 29 for exhaustion, and 9 for other reasons. The rate of dyspnea as a limiting symptom was significantly higher in patients with postoperative EOD compared with those without it (Chi-square test = 17.7; P < 0.0001). The results of the comparison between patients with and without postoperative EOD are shown in Table 1. In particular, compared with the patients without postoperative EOD, the patients with postoperative EOD had a lower FEV1 (P = 0.001), FVC (P = 0.009), FEV1/FVC ratio (P = 0.04), ppoFEV1 (P = 0.0007), and ppoDLCO (P = 0.04). They also showed a greater reduction in oxygen saturation during preoperative exercise (P < 0.0001). Moreover, patients who were submitted to pneumonectomy desaturated more frequently than those submitted to lobectomy (P = 0.04).

As shown in Table 1, preoperative values of PaO₂ and PaCO₂ did not differ between the two groups of patients. However, compared with the patients without postoperative EOD, those with postoperative EOD had a lower level of preoperative pH at rest (7.39 versus 7.41, respectively; P = 0.02). Moreover, the levels of lactates immediately after the preoperative and postoperative efforts trended toward higher values in the patients with postoperative EOD (preoperative levels (mg/dl): 42.5 versus 39.5, P = 0.2; postoperative levels (mg/dl): 31.7 versus 28.9, P = 0.2).

The logistic regression analysis showed that a reduction in oxygen saturation during the preoperative exercise was the only significant predictor of postoperative EOD (regression coefficient: 0.22; P = 0.0004).

Among the patients who experienced a preoperative reduction in oxygen saturation, the ratio of postoperative/preoperative percent reduction in oxygen saturation between rest and peak exercise (delta satO₂ ratio) was calculated. Three groups were derived: group A, patients with a delta satO₂ ratio ≤ 1; group B, patients with a delta satO₂ ratio greater than 1 but lower than 3; group C, patients with a delta satO₂ ratio ≥ 3. The three groups were compared in terms of reduction of total steps climbed...
between preoperative and postoperative stair-climbing test, by means of the analysis of variance (ANOVA) test. Groups A, B, and C showed a progressively greater reduction in steps climbed between preoperative and postoperative exercise test (32.9, 47.6 and 50.4, for group A, B and C, respectively). The difference between groups A and B \( (P = 0.009) \), and that between groups A and C \( (P = 0.01) \) was statistically significant.

### 4. Discussion

EOD has been studied, with contrasting results, as a possible predictor of postoperative morbidity \([4–6]\). However, we regard the occurrence of postoperative oxygen desaturation during exercise as a complication in itself. After discharge from the hospital, the patients with EOD are limited not only in participating in rehabilitation programs, but, sometimes, even in returning to their usual daily activities, because of their reduced exercise tolerance and exertional dyspnea.

Supplemental oxygen in patients with lung disease and exercise hypoxemia has been shown to improve exercise tolerance and breathlessness \([7–13]\), and the American Thoracic Society has endorsed its use in these patients. Even though no similar data are available in the literature concerning patients submitted to lung resection for lung cancer, it is reasonable assuming that, also in these patients, the correction of hypoxemia during exercise might lead to a more effective rehabilitation by permitting a greater degree of training than would otherwise be possible \([14]\). Moreover, oxygen dependence is perceived by patients as one of the most feared outcome after lung resection \([15]\). Hence, predicting such complication may also be useful for counseling surgical candidates.

The need of oxygen supplementation may go undetected without an exercise test, which will disclose the oxygen desaturation and the exertional dyspnea.

Thus, the objective of this study was to identify preoperatively the predictors of postoperative EOD below 90%. Patients at increased risk should all be submitted to a postoperative exercise test before discharge from the hospital to confirm or rule out EOD. We chose the stair-climbing test as a form of maximal exercise test, inasmuch as it is safe, economical, and widely applicable. Since stair climbing is a more stressful exercise than cycle or treadmill \([16–18]\), it is a valid tool for detecting abnormalities in the oxygen transport system.

Oxygen saturation during the test was monitored by means of a portable pulse oximeter. This technique has been shown to accurately estimate changes in arterial saturation between rest and peak preoperative exercise test; Func. loss %: percentage of functional lung tissue removed during operation; cardiac disease: presence of concomitant cardiac disease.

### Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Without EOD</th>
<th>With EOD</th>
<th>( t ) value</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>66.4 (9.1)</td>
<td>66.8 (8.1)</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>PaO2</td>
<td>81.0 (11.4)</td>
<td>79.1 (9.8)</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>PaCO2</td>
<td>37.4 (3.7)</td>
<td>37.4 (4.5)</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>FEV1%</td>
<td>87.5 (18.0)</td>
<td>76.4 (19.2)</td>
<td>3.3</td>
<td>0.001</td>
</tr>
<tr>
<td>FVC%</td>
<td>95.6 (16.2)</td>
<td>87.3 (21.5)</td>
<td>2.6</td>
<td>0.009</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>0.71 (0.10)</td>
<td>0.67 (0.11)</td>
<td>2.0</td>
<td>0.04</td>
</tr>
<tr>
<td>DLCO%</td>
<td>78.6 (19.1)</td>
<td>72.2 (19.0)</td>
<td>1.7</td>
<td>0.08</td>
</tr>
<tr>
<td>ppoFEV1%</td>
<td>69.2 (16.5)</td>
<td>58.7 (16.6)</td>
<td>3.4</td>
<td>0.0007</td>
</tr>
<tr>
<td>ppoDLCO%</td>
<td>62.3 (18.1)</td>
<td>55.3 (18.2)</td>
<td>2.0</td>
<td>0.04</td>
</tr>
<tr>
<td>Altitude preop. (m)</td>
<td>20.01 (4.7)</td>
<td>20.51 (4.5)</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>V̇O₂max (ml/kg/min)</td>
<td>26.0 (4.5)</td>
<td>26.8 (4.7)</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Delta satO₂</td>
<td>0.7 (2.3)</td>
<td>2.7 (4.2)</td>
<td>4.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Func. loss%</td>
<td>21.0 (8.9)</td>
<td>22.8 (10.7)</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Pneumonectomies (%)</td>
<td>28 (14.6%)</td>
<td>10 (28.6%)</td>
<td>4.2*</td>
<td>0.04</td>
</tr>
<tr>
<td>Cardiac disease (%)</td>
<td>85 (44.3%)</td>
<td>14 (40%)</td>
<td>0.2*</td>
<td>0.6</td>
</tr>
</tbody>
</table>

\( \ast \) Results are expressed as means ± standard deviations unless otherwise specified; \*Chi-square test. Delta satO₂: difference in oxygen saturation between rest and peak preoperative exercise test; Func. loss %: percentage of functional lung tissue removed during operation; cardiac disease: presence of concomitant cardiac disease.
of perfused lung tissue removed during operation did not differ between those who had postoperative EOD and those who did not (29.3 versus 28.5%, respectively; $P = 0.8$).

Some spirometric parameters (FEV1, FVC, FEV1/FVC ratio, ppoFEV1, and ppoDLCO) and the type of operation performed (pneumonectomy) resulted significantly associated with postoperative EOD at univariate analysis, showing that the ventilatory impairment due to obstructive lung disease, the diffusion limitation and the extent of the resection may all increase the risk to develop this complication. However, a fall in oxygen saturation during the preoperative exercise remained the only independent significant predictor of postoperative EOD below 90% after the effect of the other variables was controlled in a logistic regression analysis. The reduction of oxygen saturation during the preoperative stair-climbing test should be interpreted as a marker of some deficit in the oxygen transport system (mainly for ventilatory and cardiovascular reasons) that will be further exacerbated by the surgical stress.

In conclusion, we think that all the patients who showed a reduction in oxygen saturation during the preoperative exercise test should also perform a postoperative exercise test before discharge. Should EOD be confirmed, intermittent home oxygen therapy during physical rehabilitation and strenuous daily activities should be prescribed in order to improve the quality of life and facilitate recovery. These patients need to be frequently re-evaluated in order to verify improvements in their oxygen saturation status and for possible oxygen therapy discontinuation.

References