Changes in pulmonary function test and cardio-pulmonary exercise capacity in COPD patients after lobar pulmonary resection

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Abstract

Objective: Pulmonary Function Tests (PFT) and Cardio-Pulmonary Exercise Testing (C-PET) are useful to evaluate operability in functionally compromised patients. Although modifications of PFT and C-PET after lung surgery have been widely explored, little information exists as to modifications of exercise capacity in COPD patients undergoing lung resection. We prospectively analyzed the changes in PFT and C-PET in patients with COPD after a pulmonary lobar resection. Methods: From January 2003 to March 2004 all patients scheduled for lung resection were considered for participation in the study protocol. Those patients with a preoperative diagnosis of COPD on PFT were explored through a C-PET. Only patients who had undergone a lobar pulmonary resection were subsequently considered; these patients had a new complete cardio-respiratory evaluation 3 months after surgery. The pre- and postoperative values compared were those of FEV1, TLC, DLCO, VO2max, and VE/VCO2. Data are expressed as mean ± standard deviation (SD). Statistic evaluation was made using the Wilcoxon test. Results: During this period 11 patients completed the study protocol. Ten patients underwent surgery for NSCLC and one for a pulmonary aspergilloma. Nine lobectomies and two bilobectomies were performed. In the study population, the preoperative mean value of FEV1 resulted as being 53% (SD ± 20) of the predicted mean value, that of TLC 120% (SD ± 35) and that of DLCO 65% (SD ± 27). The preoperative mean value of VO2max resulted as being 17.8 ml/Kg/min (SD ± 3.25) and mean VE/VCO2 resulted as being 35.7 (SD ± 4). Three months after surgery the measured mean value of FEV1 was 53% (SD ± 18), that of TLC was 99% (SD ± 24) and that of DLCO 52% (SD ± 18). The mean value of VO2max resulted as being 14.1 ml/Kg/min (SD ± 3.04) and that of VE/VCO2 was 42.5 (SD ± 12.8). Statistical analysis of PFT values showed that FEV1 and DLCO were not significantly modified (P > 0.05); in contrast, TLC had significantly decreased (P = 0.008). VO2max had significantly decreased (P = 0.004) and VE/VCO2 had significantly increased (P = 0.018). Conclusions: Three months after a lobar pulmonary resection, patients with COPD were found to have a significant decrease in exercise tolerance. PFT alone can underestimate the postoperative loss of exercise capacity through exercise.

Keywords: Exercise capacity; Pulmonary function; Lobectomy; COPD

1. Introduction

Patients scheduled for lung resection often present with chronic cardio-pulmonary disease. In such cases, a careful preoperative evaluation is mandatory, both to establish the ability of the patient to survive the physical stress of surgery and to assess the predicted residual pulmonary function after surgical removal of lung parenchyma.

For this purpose, the preoperative measurement of exercise capacity (EC), defined as maximal oxygen uptake at peak of exercise (VO2max), has been reported as being a better predictor of postoperative complication and mortality than resting pulmonary and cardiac function testing [1–3]. With the aim of evaluating the residual EC after pulmonary resection, several authors have studied the modifications of VO2max after lung surgery, and have attempted to correlate the amount of lung tissue loss with the postoperative modifications of EC [4–9]. However, scant information exists as to the modification of EC in patients with COPD undergoing lung resection, and since even a mild form of COPD can be responsible for exercise intolerance with symptom limitation [10–12], it seems crucial to understand the changes in cardio-pulmonary function in COPD patients undergoing lung surgery.
The primary objective of the study was to quantify EC loss after a lobar pulmonary resection in patients with a preoperative diagnosis of COPD. For this purpose, the preoperative data of resting Pulmonary Function Test (PFT) and cycle-ergometric Cardio-Pulmonary Exercise Test (C-PET) were collected and compared to those measured 3 months after a lobar pulmonary resection. Duration of hospital stay and outcome of surgery including complications and mortality were also documented.

2. Materials and methods

This was a prospective study concerning all patients scheduled for major lung resection attending the Thoracic Unit of the Department of Surgical Science at the University of Parma between January 2003 and March 2004. Functional evaluation of all patients enrolled in the study was done at the Respiratory Disease Division of the Department of Clinical Science at the University of Parma. During the study period, all patients with a diagnosis of COPD on preoperative PFT and an indication for a major pulmonary resection were also functionally explored through a C-PET. A preoperative rehabilitation program (daily appointment, 5 days a week, for 3 weeks) was always administered. The diagnosis of COPD was retained on behalf of the GOLD Scientific committee [13]. Indication for surgery was maintained in the presence of a preoperative VO2max value higher than 10 ml/Kg/min on C-PET. This study is an analysis and presentation of the data of patients submitted to a lobar pulmonary resection. Patients were excluded who had undergone less than a lobar pulmonary resection, a lobar resection extending to surrounding structures (i.e. bronchial tree, parietal wall, mediastinum or diaphragm), or pneumonectomy. The preoperative evaluation included a detailed medical history and complete physical examination, chest roentgenogram, fiber-optic bronchoscopy and thorax computed tomography scan. The cardio-pulmonary assessment also included routine blood test, arterial blood gases, electrocardiography and echocardiography. Patients with a proved NSCLC underwent preoperative clinical and pathological staging to rule out a mediastinal lymphatic or systemic metastatic disease. All patients had surgery through a posterolateral muscular sparing thoracotomy, and, in the case of NSCLC diagnosis, pulmonary resection was associated with a mediastinal lymph node dissection. During the first 3 postoperative days, postoperative analgesia was delivered by a respiratory therapist daily for 2 weeks after surgery. Three months after surgical intervention, a new cardio-pulmonary functional evaluation including PFT and C-PET was scheduled.

2.1. Spirometry and C-PET measurement

All lung function parameters were measured at the Division of Respiratory Diseases of the Department of Clinical Sciences at the University of Parma. PFTs were done with a flow-sensing spirometer and a body plethysmograph connected to a computer for data analysis (Vmax 22 and 6200, Sensor Medics, Yorba Linda, US); Forced Expiratory Ventilation in 1 second (FEV1), Total Lung Capacity (TLC) and Carbon Monoxide Transfer Capacity (DLCO) as absolute value and as percentage of predicted value were noted.

The C-PET evaluation consisted of exercise capacity assessment by an incremental exercise test using an electronically braked cycle ergometer (Corival PB, Lode BV, Groningen, The Netherlands). After a 3-min period of rest and a 3-min period of unloaded pedaling, patients cycled at 60 rpm with an incremental load of 5—15/W up to exhaustion (i.e. inability to maintain a constant speed of at least of 50 rpm and/or intolerable dyspnea). Oxygen uptake (VO2, ml/min), CO2 production (VCO2, ml/min) and minute ventilation (VE, L/min) were computed according to breath-by-breath analysis; data were displayed using an on-line computer (Vmax 229, Sensor Medics, Yorba Linda, US). If detectable, the Ventilatory Anaerobic Threshold (AT) was determined, according to the V-slope method and/or ventilatory equivalent method. The heart rate was monitored continuously by electrocardiography (Corina, GE Medical Systems IT inc., Milwaukee, USA) and oxygen saturation (SpO2, %) by pulse oxymetry (Nonin, Medical Inc, MPLS, MN, US). When patients had completed the exercise capacity test, they were asked to record on a visual analogue scale (0—100 mm) the reason for stopping, both as leg discomfort (VAS leg) and as dyspnea (VAS dys).

2.2. Statistical analysis

Computations were performed using the SPSS for Windows statistical software package (SPSS Inc., version 12.0, Chicago, IL). Data are expressed as mean ± standard deviation (SD) with range in brackets. Comparison of mean values was done with the Wilcoxon range test for non-parametric variance analysis.

3. Results

During the 14 months of the study period the data of 11 patients were collected. There were nine males and two females, with a mean age of 65 years (SD ± 8) and a mean body mass index of 27 (SD ± 5).

3.1. Surgical results

Ten patients underwent surgery for NSCLC and one for pulmonary aspergilloma. Nine patients underwent a lobectomy: three upper right, 5 upper left and 1 right inferior. Two had an inferior right bilobectomy. All patients were admitted postoperatively to the intensive care unit (IUC) and discharged after 24 h. No readmission to the IUC was noted. No postoperative deaths occurred, and mean recovery time was 12 days (range 8—14 days). Postoperative complications were noted in 6 patients (55%). In 4 patients, a diagnosis of clinical sputum retention necessitating a suction fiber-optic bronchoscopy was made; because of persistent sputum retention 24-h after bronchoscopy, three of these patients...
underwent a 4 mm diameter percutaneous cricothyroid mini-
tracheostomy (Mini-Trach II, Portex®). All patients recovered.
There were two cases of postoperative prolonged pulmonary
air leak. These patients were both discharged from hospital
with the pleural drain connected to a Heimlich valve. The
air leak was removed with no late complications at outpatient
visit. Two patients had a postoperative supraventricular
arrhythmia, successfully treated during the recovery period
with amiodarone.

3.2. Data of preoperative and postoperative functional
evaluation
Preoperative PFT and C-PET data are shown in Tables 1
and 2, respectively. Postoperative PFT data are shown in
Table 3 and postoperative C-PET data in Table 4. The
postoperative C-PET was done after a mean interval of 109
days (±19 days). Changes between pre- and postoperative
mean values of PFT are shown in Fig. 1. No significant
changes resulted in FEV1 (P = 0.999) and DLCO values
(P = 0.139); in contrast, TLC significantly decreased from a
mean of 120% to a mean of 99% of the predicted value.
Preoperative C-PET evaluation revealed a mean VO2max at
1.326 Lt./min (17.8 ml/Kg/min referenced to body weight
in kilograms), which decreased to a mean value of
1.048 Lt./min (14.1 ml/Kg/min) on postoperative evalua-
tion (P = 0.003), corresponding to a postoperative loss
of 21% in VO2max. Preoperatively mean value of VO2max
measured at the anaerobic threshold (VO2max at AT) resulted
as being 1.010 Lt./min, which represented 60% of
the VO2max peak. Postoperatively only 6 patients reached
the anaerobic threshold during exercise, and among these
patients the mean value of VO2max at AT resulted as being
0.932 Lt./min, which represented 50% of the VO2 max
peak. The slope between minute ventilation and CO2
production (VE/VO2), corresponding to the liters of air
needed to eliminate one liter of CO2 and which normally
ranges between 25 and 30, [14] was found, preoperatively,
to have increased to a mean value of 35 (SD ± 4).
Postoperatively the relationship increased significantly,
to a mean value of 42 (SD ± 12) (P = 0.018). The mean
preoperative peak heart rate was 141/bpm, which
decreased postoperatively to 123/bpm. The ratio
of VO2max to heart rate, conventionally termed Oxygen
Pulse (O2 pulse), slightly decreased from a mean pre-
operative value of 8.8 ml/bpm (SD ± 1.2) to a post-
operative mean value of 8.6 ml/bpm (SD ± 1.2). The
mean workload decreased from a preoperative mean value
of 89 W (SD ± 36) to a postoperative mean value of 66 W
(SD ± 26). Evaluation of limiting factor to exercise by VAS
found a stable predominant sensation of dyspnea versus leg
fatigue.

4. Discussion
In the study population, a lobar pulmonary resection led, 3
months after surgery, to a significant 21% loss in VO2max.
Postoperative deconditioning was characterized by a
decreased peak of workload during exercise and by an early
onset of metabolic acidosis, with 5 patients not able to reach
the anaerobic threshold. The EC loss was characterized by a
pattern of excessive ventilation for the metabolic require-
ment with a postoperative significantly increased relationship between minute ventilation and CO\(_2\) production. Limitation to exercise, evaluated by a visual analogue score, resulted as being more related to dyspnea than to leg fatigue.

Various authors have studied the changes in EC after pulmonary resection. Pelletier et al. [4] found, 3 months after surgery, a loss of 20% in EC after lobectomy and of 28% after pneumonectomy. Larsen et al. [5] reported, 6 months after surgery, a non-significant loss of 12.9% after lobectomy and a significant loss of 16% after pneumonectomy; at the same point in time of postoperative functional evaluation, Bollinger et al. [6] reported no residual functional loss after lobectomy and a permanent loss of 20% after pneumonectomy. The latter author, evaluating separately the subgroup of patients with an impaired preoperative pulmonary function, reported that the EC modifications were similar to those of the whole group [10]. Our results in terms of EC loss evaluated 3 months after surgery are similar to those reported by all these authors [4–6]; however, the subjective limitation to exercise of our study population, resulted as being limited more because of respiratory symptoms than because of muscular leg fatigue.

Regarding PFT modification after lung resection, FEV\(_1\) resulted as being unchanged and a significant decrease in TLC was noted. Such findings, also reported by other authors [5,6,15,16], confirm the low value of FEV\(_1\) to predict postoperative EC and show a tendency of FEV\(_1\) to overestimate EC loss after lung resection. Furthermore, such PFT modifications could be interpreted as an improvement on bronchial airway obstruction related to relief of pulmonary hyperinflation and to a better respiratory muscle activity of the diaphragm secondary to lung resection [17]. However, since no preoperative nuclear medicine ventilation/perfusion scans were done, and no data on lung emphysema distribution at preoperative CT scan were collected, there is a lack of proof to support such a hypothesis.

Although various authors [18,19] recommend the use of the percentage of the predicted value of VO\(_2\)max per kilogram of body weight in the evaluation of operative risk in functionally compromised patients, in the face of the low rate of postoperative complications encountered in the study we found that the use of a cutoff value of VO\(_2\)max at more than 10 ml/Kg/min at peak of exercise can be considered an equally safe and appropriate method of selecting patients suitable for lobe resection [20].

### Table 3

<table>
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<tr>
<th></th>
<th>TLC (Liters)</th>
<th>FEV(_1) (Liters)</th>
<th>FEV(_1)/FVC (ml/min)</th>
<th>DLCO (ml/min %)</th>
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TLC, total lung capacity; FEV\(_1\), forced expiratory ventilation in 1 s; DLCO, carbon monoxide transfer capacity; FVC, forced ventilatory capacity; SD, standard deviation.

### Table 4

<table>
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<tr>
<th></th>
<th>VO(_2)max (L/min)</th>
<th>VO(_2)max (ml/kg/min)</th>
<th>VO(_2) at AT (L/min)</th>
<th>VO(_2) at AT (% max)</th>
<th>VEVO2</th>
<th>HR max (bpm)</th>
<th>O(_2) pulse (ml/bbp)</th>
<th>Workload (W)</th>
<th>VAS dys (mm)</th>
<th>VAS leg (mm)</th>
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VO\(_2\)max, maximal oxygen uptake at peak of exercise; VO\(_2\) at AT, maximal oxygen uptake at anaerobic threshold; VEVO2, ventilatory equivalent for CO\(_2\); HR max, maximal heart rate; O\(_2\) pulse, ratio of VO\(_2\)max to heart rate; VAS dys and VAS leg, visual analogue scale for dyspnea and leg fatigue. n.a., not assessed.
In conclusion, the present study shows that COPD patients undergoing lobectomy may be found, 3 months after surgery, to have a persistent, significant EC loss in the absence of modifications of FEV1. Because of the small number of patients enrolled in the study and because of the wide range of COPD severity of the patients enrolled, no definitive conclusion can be drawn as to EC changes in COPD patients after lobectomy. Indeed, a much longer follow-up could better clarify the adjustment of cardio-pulmonary function in COPD patients after lung resection surgery.

References


