Prediction of morbidity after lung resection with risk factors using treadmill exercise test

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Abstract

Objective: To predict accurate morbidity after lung resection using treadmill exercise test. Methods: A total of 130 patients (108 men and 22 women, with mean age 67.1 ± 11.4 years (range, 34–78 years)) of 1129 patients underwent standard lobectomy were performed both treadmill exercise test and spirometry preoperatively. We measured maximum oxygen uptake/body weight (VO\textsubscript{2max}/BW) and change in arterial blood oxygen pressure from rest to symptom-limited maximum loading (delta aPaO\textsubscript{2}) and calculated exercise-induced hypoxemia (delta PaO\textsubscript{2}/delta VO\textsubscript{2}/BW), and retrospectively compared these parameters for patients with and without complications. Results: There were five patients with severe postoperative complications, including three requiring use of a respirator, two with home oxygen therapy. %Vital capacity, VC (%, 80.2 ± 13.2 vs. 92.5 ± 20.9, \(P = 0.026\)), delta PaO\textsubscript{2} (Torr, −29.3 ± 4.3 vs. −13.2 ± 10.8, \(P = 0.0004\)), VO\textsubscript{2max}/BW (ml/min/kg, 16.5 ± 2.9 vs. 20.6 ± 5.1, \(P = 0.018\)) and delta PaO\textsubscript{2}/delta VO\textsubscript{2}/BW (Torr/ml/min/kg, −1.98 ± 0.26 vs. −0.57 ± 0.47) were significantly associated with worse outcome. All the five patients with complications had delta PaO\textsubscript{2}/delta VO\textsubscript{2}/BW < −1.7. Conclusions: Treadmill exercise testing is a good method for assessment of cardiopulmonary reserve. Limited resection must be performed if delta PaO\textsubscript{2}/delta VO\textsubscript{2}/BW is under −1.7.

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1. Introduction

Spirometry has been used widely for preoperative prediction of complications in patients undergoing lung resection [1–3]. But clinically in most cases, lethal complications occur as a result not only due to decline of ventilatory function independently but also of complex cardiopulmonary damage. It is thus very so important to assess individual exercise capacity to obtain an overall estimate of cardiopulmonary function; exercise testing is quite very useful for this purpose. Maximum oxygen uptake (VO\textsubscript{2max}) has been reported as an indicator of exercise capacity [4–6].

To more accurately predict the postoperative risks, we investigated individual exercise-induced hypoxemia (EIH) using treadmill exercise testing and compared various parameters for patients with and without complications.

2. Methods

2.1. Eligibility

From Jan 1992 to Dec 1999, 130 patients (108 men and 22 women, with mean age 67.1 ± 11.4 years (range, 34–78 years)) undergoing standard lobectomy at Hyogo Medical Center for Adults performed both a treadmill exercise test and spirometry in preoperative evaluation. During the same period, a total of 1129 patients underwent lung resection in our institute.

Indications for exercise testing were (1) elderly status above 70 years, (2) poor spirometry results (%VC < 70 and/or forced expiratory volume in 1 s (FEV1.0) % < 60), (3) previous performance of lung resection, or (4) planned pneumonectomy.

The patients who had acute myocardial infarction within 6 months, heart failure or heavy atrial fibrillation were excluded.
2.2. Treadmill exercise test

In the treadmill exercise test, performed with the MAT-6000C (Fukuda, Osaka, Japan) using the Bruce method [7] (Table 1), radial arterial blood gases were measured at rest and at 3 min intervals during exercise. A catheter was placed in the radial artery for repeated collection of arterial blood sample.

We calculated change in arterial oxygen pressure from rest to symptom-limited maximum loading (delta PaO_2, Torr). The maximum oxygen uptake/body weight (VO_2-max/BW, ml/min/kg) was measured using the RM-300 respirometer (Minato, Osaka, Japan).

We retrospectively compared these parameters for patients with and without complications along with VC, VC%, FEV1.0, FEV1.0% measured by spirometer (Minato, Osaka, Japan).

Cardiopulmonary complications were defined as follows: (1) wearing respirator more than 24 h after operations or difficulty in weaning because of hypoventilation or hypoxemia, (2) requirement of home oxygen therapy (HOT).

2.3. Statistics

All values are presented as mean ± SD, and were analyzed by unpaired t-test using the Stat View program (SAS Institute, Heidelberg, Germany). One-sided P values < 0.05 were considered significant.

3. Results

There were five patients with complications in the postoperative course (3.8% of patients who performed treadmill exercise tests), three requiring a respirator and two with HOT. According to univariate analysis, %VC (%: 80.2 ± 13.2 vs. 92.6 ± 20.9, P = 0.026), delta PaO_2 (Torr, −29.3 ± 4.3 vs. −13.2 ± 10.8, P = 0.0004) and VO_2-max/BW (ml/min/kg, 17.1 ± 3.8 vs. 20.5 ± 5.2, P = 0.021) were significantly associated with worse outcome. Furthermore, delta PaO_2/delta VO_2/BW (Torr/ml/min/kg, −1.98 ± 0.26 vs. −0.57 ± 0.47, P < 0.0001) was more significantly different than delta PaO_2 or VO_2-max/BW between two groups (Table 2).

All the five patients with complications had delta PaO_2/VO_2/BW less than −1.7 (Fig. 1).

In the period of this study, there were three operative deaths (within 1 month postoperatively) unrelated to cardiopulmonary complications (one acute mesenteric artery thrombosis, two intrathoracic bleeding). These three patients did not perform the exercise test.

4. Discussion

Many attempts have been made to predict postthoracotomy morbidities. Spirometry is the most common modality for which results are correlated closely with frequency of pulmonary complications, and is widely used. When pneumonectomy was more common and had higher mortality than at present, temporary unilateral occlusion of the pulmonary artery was performed frequently as an accurate method for prediction of high risk, although this method is difficult to perform and invasive [8,9].

![Fig. 1. Distribution of the results of treadmill exercise test.](https://academic.oup.com/wjcts/article-abstract/26/3/480/354220)
Furthermore, in addition to pulmonary scintigraphy, measurement of remaining lung volume using determination of number of segments is easy and useful, and has correspondingly come into wide use. Morbidity and quality of life after lung resection have been improving with combined use of these modalities to determine indications for surgery and development of postoperative care management.

However, pulmonary function tests such as spirometry are static methods of assessment performed only in resting condition. It is difficult to assess postoperative pulmonary function with this test alone. There are cases in which lethal complications occur related to cardiopulmonary condition after lung resection when elevation of intracapillary pressure, pulmonary hypertension and right heart load develop following decrease of lung volume and the increase of pulmonary capillary pressure. Thus, without the dynamic assessment, it is impossible to decrease postoperative mortality. Treadmill exercise testing is suitable for comprehensive cardiopulmonary assessment, and especially the dynamic estimation.

Maximum oxygen uptake has been used widely for the cardiopulmonary assessment with treadmill exercise testing [4–6]. In our study, this parameter differed significantly between patients with and without complications. However, in our study, for many patients lobectomy was possible despite low VO_{2max}. It is difficult to determine candidates for limited surgery based only on VO_{2max}.

Deterioration of ventilation–perfusion inequality in lung during exercise results in EIH [10]. Wasserman and colleagues reported that normal humans exhibit almost no EIH [11]. Minh and colleagues reported that EIH was frequently observed in chronic obstructive pulmonary disease patients even in the presence of normal PaO_2 at rest. They concluded that EIH was an essential limiting factor for exercise in patients with chronic obstructive pulmonary disease [12]. The degree of hypoxemia, delta PaO_2/delta VO_2/BW correlated closely with survival of such patients [13].

We hypothesized that patient with marked EIH would feature high morbidity if undergoing lobectomy. Therefore, in this study, we examined not only VO_{2max} but also arterial blood oxygen pressure at 3 min intervals. As a result, preoperative EIH was found to be a valuable risk factor for morbidity following lung resection. Even more commonly, patients with delta PaO_2/delta VO_2/BW <−1.7, if they underwent lobectomy, had severe cardiopulmonary complications such as difficult respirator weaning or HOT.

Some authors reported that diffusing capacity for carbon monoxide (DLco%) predicted the likelihood of pulmonary complication after lung resection [14–16]. In Wang and associates’ review [14], receiver operator analysis showed that the curve of DLco% was sifted up and to the left, compared with the same maximum oxygen consumption (VO_{2max}), indicating that DLco% was superior to VO_{2max} in the prediction of pulmonary complications. It is unknown whether EIH is more closely correlated with pulmonary complication than DLco% or not, because we did not measure DLco in this series. Assessment by DLco% has been confined to pulmonary complication, such as postoperative ventilation support, reintubation for pulmonary failure or pneumonia. We think that it serves different purpose to EIH assessing cardiopulmonary function by the gross.

As this review is lacking in statistical power because of small number of the complicated patients, we concluded that treadmill exercise testing can predict morbidity after lung resection widely and preoperative EIH was found to be a valuable risk factor.

References