



# Funkční vyšetření nemocného k plánovanému hrudnímu výkonu

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# Struktura

- Úvod
- Spirometrie
- DLCO, split function
- CPET
- Studie
- Strukturovaný guideline
- Závěr

# ÚVOD

- Rakovina plic je jednou z nejčastějších příčin úmrtí v západním světě.
- Plicní resekce zůstává v časných stadiích léčbou volby a často i jedinou kurabilní léčbou.
- Majorita pacientů podstupujících plicní výkony je starších, (ex)kuřáci, často s celou řadou komorbidit.
- Peri/pooperační průběh bývá zatížen celou řadou komplikací – kardiopulmonární - doba pobytu v nemocnici/JIP/ARO

# Úvod :

- celá řada testů k určení :
  1. schopnosti podstoupit daný výkon
  2. riziko komplikací mortalita/morbidity – peri/pooperačních
  3. úroveň monitorace pooperačně
  4. kvalita života poop. (dyspnoe, soběstačnost)
- guidelines - European Respiratory Society (ERS), British Thoracic Society (BTS), American College of Chest Physicians (ACCP)

# Plicní - spirometrie

- Základní hodnoty
- FVC – usilovná vitální kapacita  
FEV1- usilovně vydechnutý objem za 1sec  
poměr - FEV1/FVC
- FEV1 >2,0L nebo FEV1 >80%- pneumonektomie
- FEV1 >1,5L - lobektomie ,
- FEV1 >0,6L - klínovitá nebo segmentální resekce

# Plicní – difuzní kapacita

- DLCO- difuzní kapacita plic pro oxid uhelnatý – odráží integritu alveolární membrány a průtok plicním řečištěm
- DLCO je důležitý prediktor mortality a vzniku pooperačních komplikací(1)
- Pacienti s DLCO < 50%(2) 60%(3) by neměli podstoupit větší plicní resekci z důvodů vysokého rizika vzniku poop. komplikací

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# Plicní – difuzní kapacita, ABG

- ERS - DLCO by se mělo provádět u všech pacientů podstupujících plicní resekci , bez ohledu na spirometrii (včetně norm.nálezu)(4)
- DLCO > 80%predicted - schopen pneumonectomie, bez doplňujících vyšetření (za předpokladu, že FEV1 >80%
- paO2 – nižší než 50mmHg(5) nebo 60mmHg (6) je spojeno s vyššími poop. komplikacemi
- paCO2 – 45mmHg nepredikuje komplikace(6)

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# Split-function

- Dle ACCP a BTS mohou všichni pacienti s norm.plicními funkcemi podstoupit resekci do rozsahu pneumonektomie((7,8)
- Pacienti s FEV1 a DLCO pod 80% by měli podstoupit další vyšetření k predikci ppo (pooperative pulmonary function) (9)
- a) ventilačně perfuzní scan (inhalace Xe, Technecium iv)
- b) matematická formule – počet resekovaných segmentů

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8 Colice GL, Shafazand S, Griffin JP, Keenan R and Bolliger CT: American College of Chest Physicians. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines (2nd edition). *Chest* 132(3 Suppl): 161S-77S, 2007.

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# Split function

- matematický výpočet dokáže předpovědět ppo FEV1 se stejnou přesností jako ventilačně perfuzní scan(10-15)
- vyšší mortalita ve skupině ppo-FEV1 <40%(10)  
ppo-FEV1 <35%(11)

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# CPET

- cardiopulmonary exercise testing
- zatížení několika soustav (plíce, kardiovaskulární systém, svalově energetický systém) s následným nárůstem srdečního výdeje, ventilace, spotřebou kyslíku, výdejem CO<sub>2</sub> s nárůstající délkou a event. i intenzitou cvičení.
- preoperační CPET by mělo být použito jako prediktor pooperační morbidity a mortality(16)

# CPET

- Zátěž – narůstající vs trvalá,  
maximální vs submaximální
- $VO_2$  - spotřeba kyslíku (ml/kg/min, L/min, %)  
 $VCO_2$  – minutový výdej  $CO_2$   
 $VE$  - minutová ventilace
- TF, TK, ...
- celá řada studií se zaměřením na  $VO_2$

# CPET - VO2

- Pacienti s  $VO_2\text{max} > 15\text{ml/kg/min}$  měli dobrou prognosu navzdory  $FEV_1 < 40\%$ , ppo $FEV_1 < 33\%$  (17)
- $VO_2\text{max}$  – dobrý prediktor morbidity, mortality, možnosti rozsahu výkonu, komplikací
- pod  $10\text{ml/kg/min}$  – resekce nedoporučena,
- $10-15\text{ml/kg/min}$  - schopni resekce, vysoké riziko
- $15-20\text{ml/kg/min}$  - schopni resekce, norm. riziko
- nad  $20\text{ml/kg/min}$  – pneumonektomie

# CPET

- počet pater – 1 patro – mortalita 50%(18)  
2patra – mortalita 11%  
3patra – lobektomie  
5pater – pneumonectomie(19)  
4,6 pater odpovídá  $VO_2$  20ml/kg/min(20)
- shuttle test – méně než 25 obrátek je ekvivalentem  $VO_2$  10ml/kg/min (21)
- vzdálenost za 6,12 minut – 1000ft, desaturace

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# Causes of Breathing Inefficiency during Exercise in Heart Failure

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*J Card Fail.* 2010 October ; 16(10): 835–842. doi:10.1016/j.cardfail.2010.05.003.

**Background**—Patients with heart failure (HF) develop abnormal pulmonary gas exchange; specifically they have an abnormal ventilation relative to metabolic demand ( $V_E/V_{CO_2}$ , ventilatory efficiency) during exercise. The purpose of this investigation was to examine the factors that underlie the abnormal breathing efficiency in this population.

**Methods**—Fourteen controls and 33 moderate-severe HF patients, aged  $52 \pm 12$  and  $54 \pm 8$  years, respectively, performed submaximal exercise ( $\sim 65\%$  of maximum) on a cycle ergometer. Gas exchange and blood gas measurements were made at rest and during exercise. Submaximal exercise data were used to quantify the influence of hyperventilation ( $PaCO_2$ ) and dead space ventilation ( $V_D$ ) on  $V_E/V_{CO_2}$ .

**Results**—The  $V_E/V_{CO_2}$  relationship was lower in controls ( $30 \pm 4$ ) than HF ( $45 \pm 9$ ,  $p < 0.01$ ). This was the result of hyperventilation (lower  $PaCO_2$ ) and higher  $V_D/V_T$  that contributed 40% and 47%, respectively, to the increased  $V_E/V_{CO_2}$  ( $p < 0.01$ ). The elevated  $V_D/V_T$  in the HF patients was the result of a tachypneic breathing pattern (lower  $V_T$ ,  $1086 \pm 366$  vs  $2003 \pm 504$  ml,  $p < 0.01$ ) in the presence of a normal  $V_D$  ( $11.5 \pm 4.0$  vs  $11.9 \pm 5.7$  L/min,  $p = 0.095$ ).

**Conclusions**—The abnormal ventilation in relation to metabolic demand in HF patients during exercise was due primarily to alterations in breathing pattern (reduced  $V_T$ ) and excessive hyperventilation.

Numerous studies have shown  $V_E/V_{CO_2}$  slope or ratio to be a good predictor of survival that is, in fact, stronger than peak  $VO_2$ , the traditional measurement used to define HF class and prognosis.<sup>14</sup> The steepness of the slope or an increase in the ratio of  $V_E$  to  $V_{CO_2}$  also seems to reflect the severity of HF and may be a more beneficial diagnostic tool than those already used in clinical practice (i.e. LVEF or NYHA). The measurement and calculation of  $V_E/V_{CO_2}$  is simple, inexpensive, patient friendly and can be applied at low exercise intensities, hence it is a valuable tool that can be used to diagnose and track heart failure.

# Exercise ventilatory inefficiency and mortality in patients with chronic obstructive pulmonary disease undergoing surgery for non-small-cell lung cancer

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## Abstract

**Objective:** Surgical resection is the treatment of choice to cure patients with non-small-cell lung cancer (NSCLC); nevertheless, the assessment of the lower limit of surgical tolerance remains difficult. Ventilatory inefficiency (measured as the ventilation to CO<sub>2</sub> production ratio ( $V'_E/V'_{CO_2}$  slope) is a survival predictor in pulmonary hypertension (PH) and chronic heart failure (CHF) and is considered a marker of PH in chronic obstructive pulmonary disease (COPD). The aim of this study was to investigate the role of  $V'_E/V'_{CO_2}$  slope as preoperative mortality and morbidity predictor in COPD patients submitted to lung resection for NSCLC and considered operable according to current standards. **Methods:** A retrospective analysis was performed in 145 consecutive COPD patients with lung cancer (128 males and 17 females), with a mean age of 64 years (range: 41–82 years) who were referred for preoperative evaluation. Because of bronchial obstruction or reduced pulmonary diffusion capacity for carbon monoxide ( $D_{L,CO}$ ), all these patients were considered operable only after a cardiopulmonary exercise test showed a preserved cardiopulmonary function. **Results:** A total of 98 lobectomies, eight bilobectomies and 39 pneumonectomies (13 left and 26 right) were performed. Twenty-one patients (14.5%) suffered severe cardio-respiratory complications; 15/106 patients (14.2%) after lobectomy/bilobectomy and 6/39 (15.4%) after pneumonectomy. Five patients (3.4%) died within 30 days after surgery (3/106 after lobectomy/bilobectomy (2.8%) and 2/39 after pneumonectomy (5.1%)). Considering all functional parameters before surgery and the postoperative predicted values, a logistic regression analysis individuated the  $V'_E/V'_{CO_2}$  slope as the only independent mortality predictor (odds ratio (OR): 1.24  $z = 2.77$ ;  $p < 0.007$ ). The  $V'_{O_2 \text{ peak}}$  was instead the best predictor for the occurrence of severe cardiopulmonary postoperative complications (OR: 0.05,  $z = -2.39$ ,  $p < 0.02$ ). **Conclusions:** In COPD patients, a high  $V'_E/V'_{CO_2}$  slope before lung resection is an independent mortality predictor even in the presence of an acceptable cardiopulmonary performance. COPD patients with high  $V'_E/V'_{CO_2}$  slope before surgery must be carefully screened to exclude pulmonary hypertension, especially before surgical procedures with large parenchymal exeresis.

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**Keywords:** Lung cancer; Postoperative complications; Cardiopulmonary exercise testing



# Minute Ventilation-to-Carbon Dioxide Output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) Slope Is the Strongest Predictor of Respiratory Complications and Death After Pulmonary Resection

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**Background.** This study assessed whether the minute ventilation-to-carbon dioxide output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) slope, a measure of ventilatory efficiency routinely measured during cardiopulmonary exercise testing (CPET), is an independent predictor of respiratory complications after major lung resections.

**Methods.** Prospective observational analysis was performed on 225 consecutive candidates after lobectomy (197 patients) or pneumonectomy (28 patients) from 2008 to 2010. Inoperability criteria were peak oxygen consumption ( $\dot{V}_{O_2}$ ) of less than 10 mL/kg/min in association with predicted postoperative forced expiratory volume in 1 second of less than 30% and diffusion capacity of the lung for carbon monoxide of less than 30%. All patients performed a symptom-limited CPET on cycle ergometer. Respiratory complications (30 days or in-hospital) were prospectively recorded: pneumonia, atelectasis requiring bronchoscopy, respiratory failure on mechanical ventilation exceeding 48 hours, adult respiratory distress syndrome, pulmonary edema, and pulmonary embolism. Univariable and multivariable regression analyses were used to identify independent predictors of respiratory complications.

**Results.** Cardiopulmonary morbidity and mortality rates were 23% (51 patients) and 2.2% (5 patients). The 25 patients with respiratory complications had a significantly higher  $\dot{V}_E/\dot{V}_{CO_2}$  slope than those without complications (34.8 vs 30.9,  $p = 0.001$ ). Peak  $\dot{V}_{O_2}$  was not associated with respiratory complications. Logistic regression and bootstrap analyses showed that, after adjusting for other baseline and perioperative variables, the strongest predictor of respiratory complications was  $\dot{V}_E/\dot{V}_{CO_2}$  slope (regression coefficient, 0.09; bootstrap frequency, 89%;  $p = 0.004$ ). Patients with a  $\dot{V}_E/\dot{V}_{CO_2}$  slope exceeding 35 had a higher incidence of respiratory complications (22% vs 7.6%,  $p = 0.004$ ) and mortality (7.2% vs 0.6%,  $p = 0.01$ ).

**Conclusions.**  $\dot{V}_E/\dot{V}_{CO_2}$  slope is a better predictor of respiratory complications than peak  $\dot{V}_{O_2}$ . This inexpensive and operator-independent variable should be considered in the clinical practice to refine operability selection criteria.

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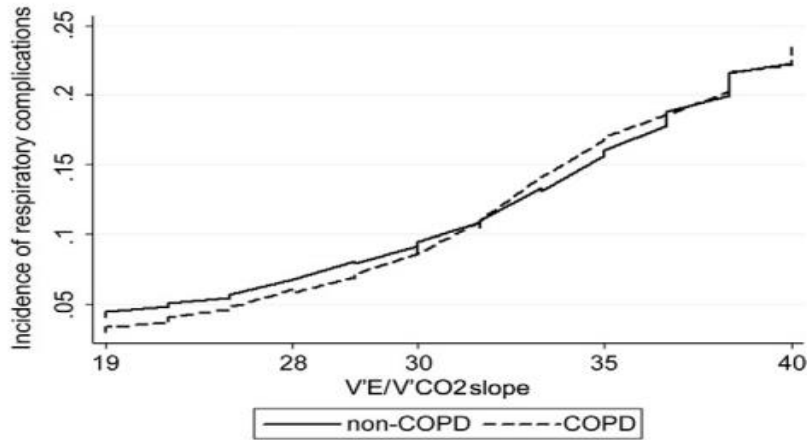


Fig 2. Relationship between the level of the minute ventilation-to-carbon dioxide output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) slope and the incidence of respiratory complications in patients with (dotted line) and without (solid line) chronic obstructive pulmonary disease (COPD).

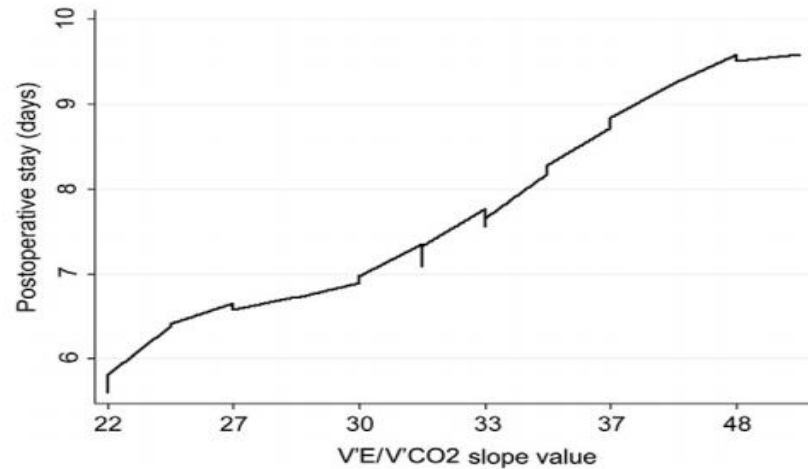


Fig 4. Relationship between the level of the minute ventilation-to-carbon dioxide output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) slope and postoperative length of stay.

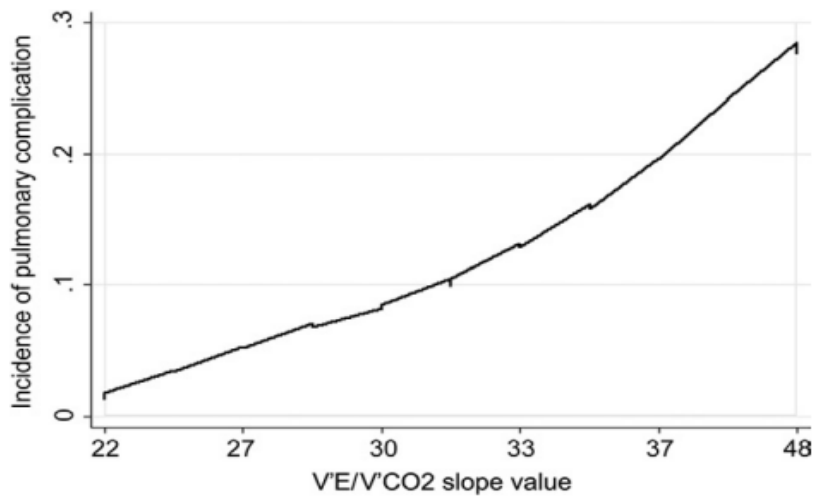


Fig 1. Relationship between the level of the minute ventilation-to-carbon dioxide output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) slope and the incidence of respiratory complications.

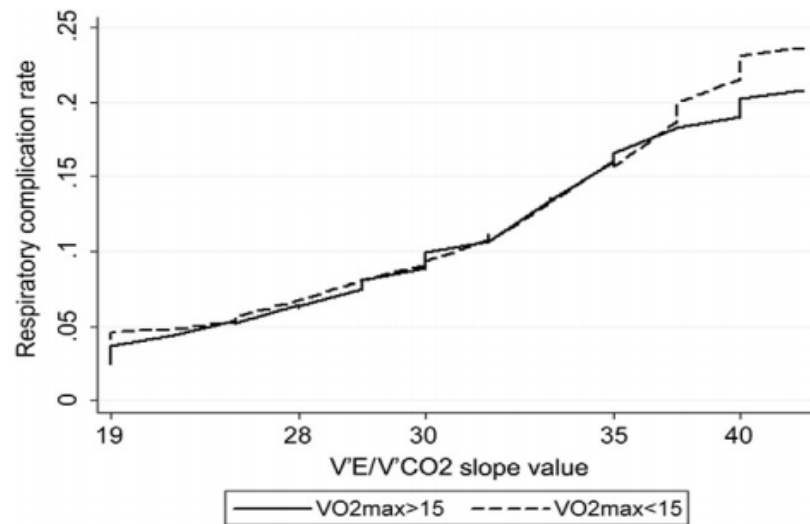
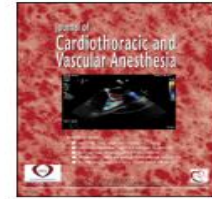


Fig 3. Relationship between the level of the minute ventilation-to-carbon dioxide output ( $\dot{V}_E/\dot{V}_{CO_2}$ ) slope and the incidence of respiratory complications in patients with peak oxygen consumption ( $\dot{V}O_2$ ) greater (solid line) or lower (dashed line) than 15 mL/kg/min.



Original Article

## Ventilatory Efficiency Identifies Patients Prone to Hypoxemia During One-Lung Ventilation

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**Objectives:** One-lung ventilation (OLV) may be complicated by hypoxemia. Ventilatory efficiency, defined as the ratio of minute ventilation to carbon dioxide output ( $V_E/VCO_2$ ), is increased with ventilation/perfusion mismatch and pulmonary artery hypertension, both of which may be associated with hypoxemia. Hence, the authors hypothesized increased  $V_E/VCO_2$  will predict hypoxemia during OLV.

**Design:** Prospective observational study.

**Setting:** Single-center, university, tertiary care hospital.

**Participants:** The study comprised 50 consecutive lung resection candidates.

**Interventions:** All patients underwent cardiopulmonary exercise testing before surgery. Patients who required inspired oxygen fraction ( $F_iO_2$ )  $\geq 0.7$  to maintain arterial oxygen ( $O_2$ ) saturation  $> 90\%$  after 30 minutes of OLV were considered to be hypoxemic. The Student *t* or Mann-Whitney *U* test were used for comparison of patients who became hypoxemic and those who did not. Multiple regression analysis adjusted for age, sex, and body mass index was used to evaluate which parameters were associated with the  $V_E/VCO_2$  slope. Data are summarized as mean  $\pm$  standard deviation.

**Measurements and Main Results:** Twenty-four patients (48%) developed hypoxemia. There was no significant difference in age, sex, and body mass index between hypoxemic and nonhypoxemic patients. However, patients with hypoxemia had a significantly higher  $V_E/VCO_2$  slope ( $30 \pm 5$  v  $27 \pm 4$ ;  $p = 0.04$ ) with exercise and lower partial pressure of oxygen/ $F_iO_2$  ( $129 \pm 92$  v  $168 \pm 88$ ;  $p = 0.01$ ), higher mean positive end-expiratory pressure ( $6.6 \pm 1.5$  v  $5.6 \pm 0.9$  cmH<sub>2</sub>O;  $p = 0.02$ ), and lower mean pulse oximetry  $O_2$  saturation/ $F_iO_2$  index ( $127 \pm 20$  v  $174 \pm 17$ ;  $p < 0.01$ ) during OLV. Multiple regression showed  $V_E/VCO_2$  to be independently associated with the mean pulse oximetry  $O_2$  saturation/ $F_iO_2$  index ( $b = -0.28$ ;  $F = 3.1$ ;  $p = 0.05$ ).

**Conclusions:** An increased  $V_E/VCO_2$  slope may predict hypoxemia development in patients who undergo OLV.

# Resting End-Tidal Carbon Dioxide Predicts Respiratory Complications in Patients Undergoing Thoracic Surgical Procedures



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**Background.** Ventilatory efficiency ( $\dot{V}_E/\dot{V}_{CO_2}$  slope [minute ventilation to carbon dioxide output slope]) has been shown to predict morbidity and mortality in lung resection candidates. Patients with increased  $\dot{V}_E/\dot{V}_{CO_2}$  during exercise also exhibit an increased  $\dot{V}_E/\dot{V}_{CO_2}$  ratio and a decreased end-tidal  $CO_2$  at rest. This study hypothesized that ventilatory values at rest predict respiratory complications and death in patients undergoing thoracic surgical procedures.

**Methods.** Inclusion criteria for this retrospective, multicenter study were thoracotomy and cardiopulmonary exercise testing as part of routine preoperative assessment. Respiratory complications were assessed from the medical records (from the hospital stay or from the first 30 postoperative days). For comparisons, Student's *t* test or the Mann-Whitney *U* test was used. Logistic regression and receiver operating characteristic analyses were performed for evaluation of measurements associated with respiratory complications. Data are summarized as mean  $\pm$  SD; *p* <0.05 is considered significant.

**Results.** Seventy-six subjects were studied. Postoperatively, respiratory complications developed in 56 (74%) patients. Patients with postoperative respiratory complications had significantly lower resting tidal volume ( $0.8 \pm 0.3$  vs  $0.9 \pm 0.3$ L; *p* = 0.03), lower rest end-tidal  $CO_2$  ( $28.1 \pm 4.3$  vs  $31.5 \pm 4.2$  mm Hg; *p* < 0.01), higher resting  $\dot{V}_E/\dot{V}_{CO_2}$  ratio ( $45.1 \pm 7.1$  vs  $41.0 \pm 6.4$ ; *p* = 0.02), and higher  $\dot{V}_E/\dot{V}_{CO_2}$  slope ( $34.9 \pm 6.4$  vs  $31.2 \pm 4.3$ ; *p* = 0.01). Logistic regression (age and sex adjusted) showed resting end-tidal  $CO_2$  to be the best predictor of respiratory complications (odds ratio: 1.21; 95% confidence interval: 1.06 to 1.39; area under the curve: 0.77; *p* = 0.01).

**Conclusions.** Resting end-tidal  $CO_2$  may identify patients at increased risk for postoperative respiratory complications of thoracic surgical procedures.

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# INTERACTIVE CARDIOVASCULAR AND THORACIC SURGERY

## Increased ventilatory drive during exercise may predict prolonged air leak after pulmonary lobectomy

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**Abstract** : Increased ventilatory drive defined as minute ventilation to carbon dioxide production during exercise ( $V_E/V_{CO_2}$  slope) may be associated with dynamic hyperinflation and thereby promote development of prolonged air leak (PAL) after lung resection. Consecutive lung lobectomy candidates (n=96) were recruited for this prospective two-center study. All subjects underwent pulmonary function tests and cardiopulmonary exercise testing prior to surgery. PAL was defined as presence of air leak from the chest tube on the 5<sup>th</sup> postoperative day and developed in 28 (29%) subjects. Subjects with PAL were not different in age, sex, ASA class, type of surgery (thoracotomy/video-assisted thoracoscopic surgery) and site of surgery (right/left lung; upper/lower lobes). Subjects with PAL had more frequent pleural adhesions (50% vs. 21%; p=0.006) and higher  $V_E/V_{CO_2}$  slope (3577 vs. 3075; p=0.001). Stepwise logistic regression showed only the presence of pleural adhesions (OR=3.9; 95% CI 1.4-10.9; p=0.008) and  $V_E/V_{CO_2}$  slope (OR 1.1; 95% CI 1.0-1.2; p=0.003) were independently associated with PAL (AUC=0.74; 95% CI 0.62-0.86). We conclude that increased  $V_E/V_{CO_2}$  slope during exercise may identify patients at greater risk for development of PAL after lung lobectomy.

**Conclusion** : Markers of increased ventilatory drive (increased  $V_E/V_{CO_2}$ ) during exercise may identify patients at greater risk for development of PAL after lung lobectomy.

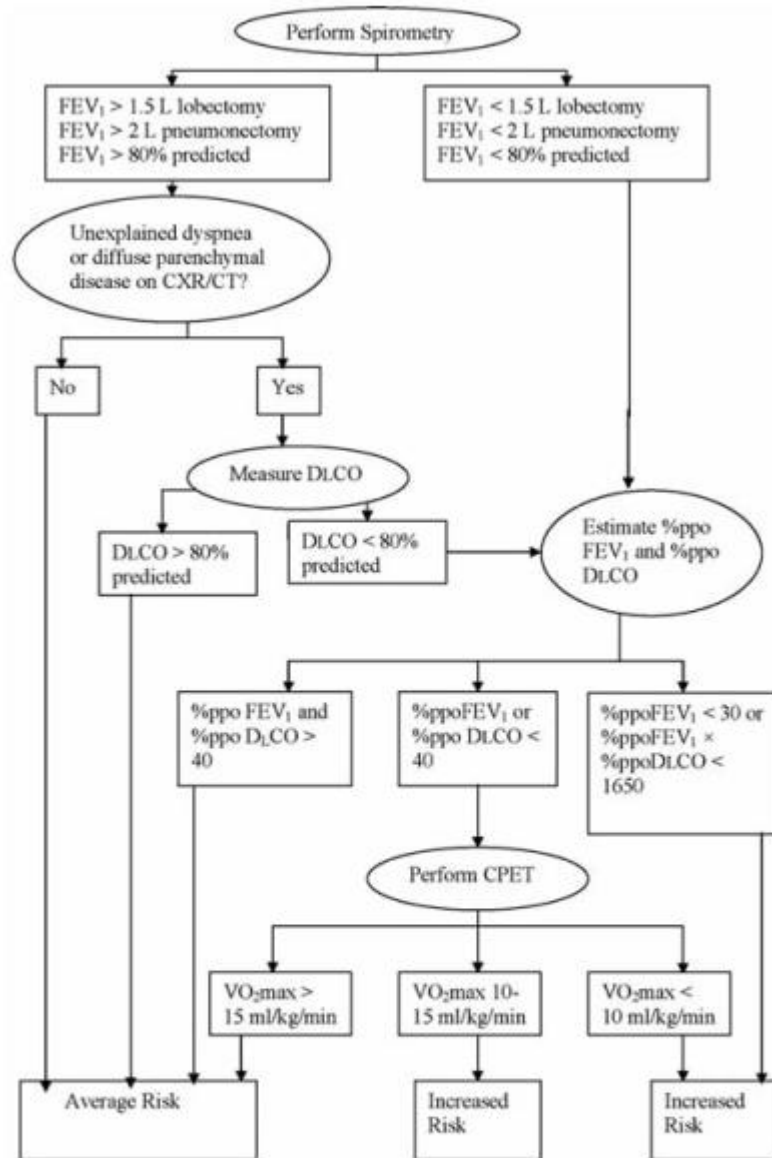


Figure 1. Guidelines of ERS for the preoperative evaluation of lung cancer patients. FEV1, forced expiratory volume in 1 second; CXR, chest X-ray; CT, computerized tomography; DLCO, diffusing capacity of the lung for carbon monoxide; ppoFEV1, predicted postoperative forced volume in 1 second; ppoDLCO, predicted postoperative diffusing capacity of the lung for carbon monoxide; CPET, cardiopulmonary exercise testing;  $VO_{2max}$ , maximum oxygen uptake (9).

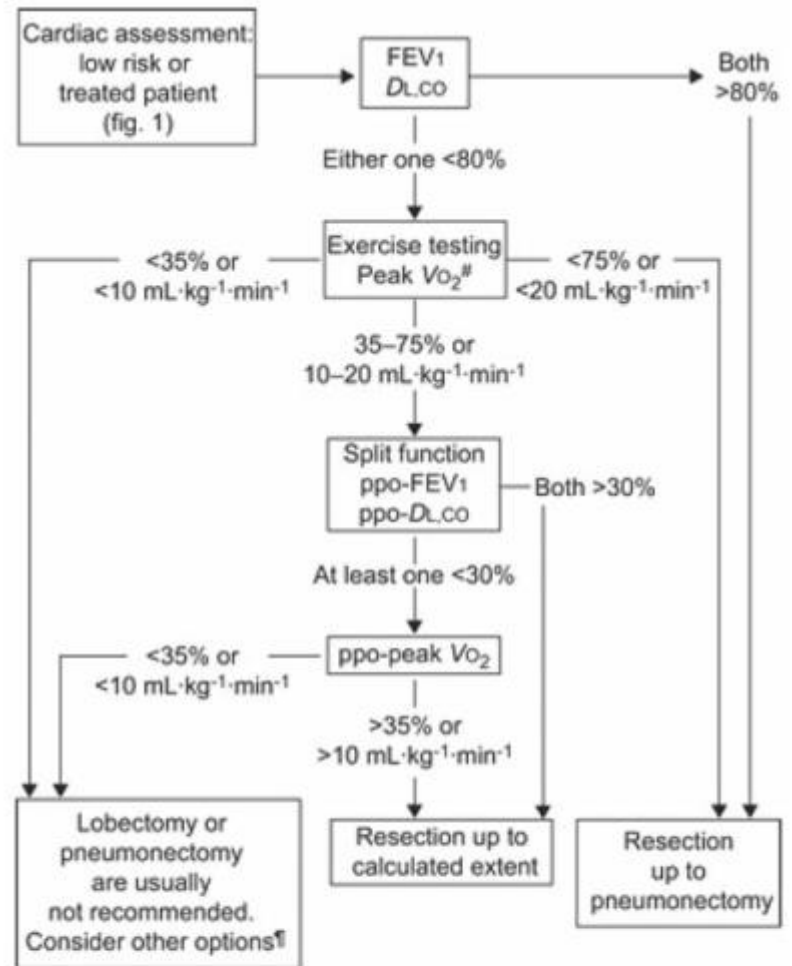


Figure 2. Guidelines of ACCP for the preoperative evaluation of lung cancer patients. FEV1, forced expiratory volume in 1 second; DL, CO, diffusing capacity of the lung for carbon monoxide; peak  $VO_2$ , peak oxygen uptake (alternative for  $VO_{2max}$ ); ppo-FEV1, predictive postoperative forced expiratory volume in 1 second; ppo-DLCO, predicted postoperative diffusing capacity of the lung for carbon monoxide; ppo-peak  $VO_2$ , predicted postoperative peak oxygen uptake (alternative for ppo- $VO_{2max}$ ) (8).

# Závěr

- Existuje celá řada doporučení stran postupu léčby, stratifikace rizika, předoperační přípravy, úrovně léčby, pooperačního průběhu a mnoha dalších faktorů.
- Spirometrie zůstává základním vyšetřením.
- Dalšími vyšetřeními jsou DLCO, split function, CPET.

# Závěr II:

- CPET bývá často neprovedeno – finančně/technické důvody či odmítání pacientem.
- Snahou do budoucna je identifikace parametrů, které představují minimální zátěž pro pacienty a systém.
- Jedním z těchto faktorů by mohlo být i  $VE/VCO_2$  a klidové  $etCO_2$ .



**Děkuji za pozornost**