PCCP 17th MIDYEAR CONVENTION

State-of-the Art Pulmonology: Convergence of Practice

August 7, 2014

Preoperative Pulmonary Evaluation for Lung Resection

Outline of Discussion

- Objectives of preoperative pulmonary evaluation of patients for surgical resection
- Use of predicted postoperative pulmonary function parameters to identify patients at increased risk for complications after lung resection
- Prediction of postoperative pulmonary function by technique of simple calculation and use of lung perfusion scan
- Algorithm for preoperative evaluation of patients for lung resection

Reduction of Pulmonary Function after Resection

Across various studies, postoperative pulmonary function values were assessed at various time intervals after lobectomy or pneumonectomy:

- FEV1:
  84% - 91% of preoperative values for lobectomy,
  64% - 66% for pneumonectomy
- DLCO :
  89% - 96% of preoperative values after lobectomy
  72% - 80% after pneumonectomy.
- VO_2 max:
  87% - 100% of preoperative values after lobectomy
  71% - 89% after pneumonectomy.

P. Mazzone. Preoperative evaluation of the lung resection candidate. Cleveland Clinic Journal of Medicine May 2012; Vol 79, e-S17-22

Why do we do preoperative pulmonary evaluation?

- Physiologic changes in the respiratory system occur in all patients undergoing surgical/anesthetic procedures.

- These changes may lead to complications, mortality and/or morbidity.

Postoperative Complications
(Within 30 days of surgery)

- Acute CO_2 retention ($PaCO_2$ > 45 mm Hg)
- Prolonged mechanical ventilation (> 48 h)
- Infections (bronchitis & pneumonia)
- Atelectasis (necessitating bronchoscopy)
- Bronchospasm
- Exacerbation of the underlying chronic lung disease
- Pulmonary embolism
- Symptomatic cardiac arrhythmias
- Myocardial infarction
- Death

C. Wyser et al. Prospective Evaluation of an Algorithm for the Functional Assessment of Lung Resection Candidates. Am J Respir Crit Care Med 1999;159:1450–1456.

F. Grubisic-Cabo et al., Preoperative Pulmonary Evaluation for Pulmonary and Extrapulmonary Operations. Acta Clin Croat. Vol. 42 No. 3, 2003; 237-240

Preoperative Evaluation

The purpose of preoperative evaluation is not to "CLEAR" patients for elective operations but rather to EVALUATE and,* if necessary, *to IMPLEMENT measures to prepare high risk patients for the operation.

F. Grubisic-Cabo et al., Preoperative Pulmonary Evaluation for Pulmonary and Extrapulmonary Operations. Acta Clin Croat. Vol. 42 No. 3, 2003; 237-240

Objectives of Preoperative Pulmonary Evaluation

- RISK ASSESSMENT – ***to identify*** patients who are at increased risk of respiratory morbidity and mortality

- RISK REDUCTION – to institute corrective and preventive measures ***to minimize*** the risk of respiratory morbidity and mortality

Preoperative Evaluation for Lung Resection Surgery

Who should be evaluated?

The general answer….

All patients undergoing lung resection surgery, irrespective of age or extent of the lesion.

But unlike general surgery, preoperative evaluation of patients scheduled for lung resection, requires spirometry testing and, if necessary, cardiopulmonary exercise testing (CPET).

Current International Guidelines

American College of Chest Physicians (***ACCP***) - 3rd Edition, 2013

British Thoracic Society (***BTS***) / Society for Cardiothoracic Surgery in Great Britain and Ireland - 2010

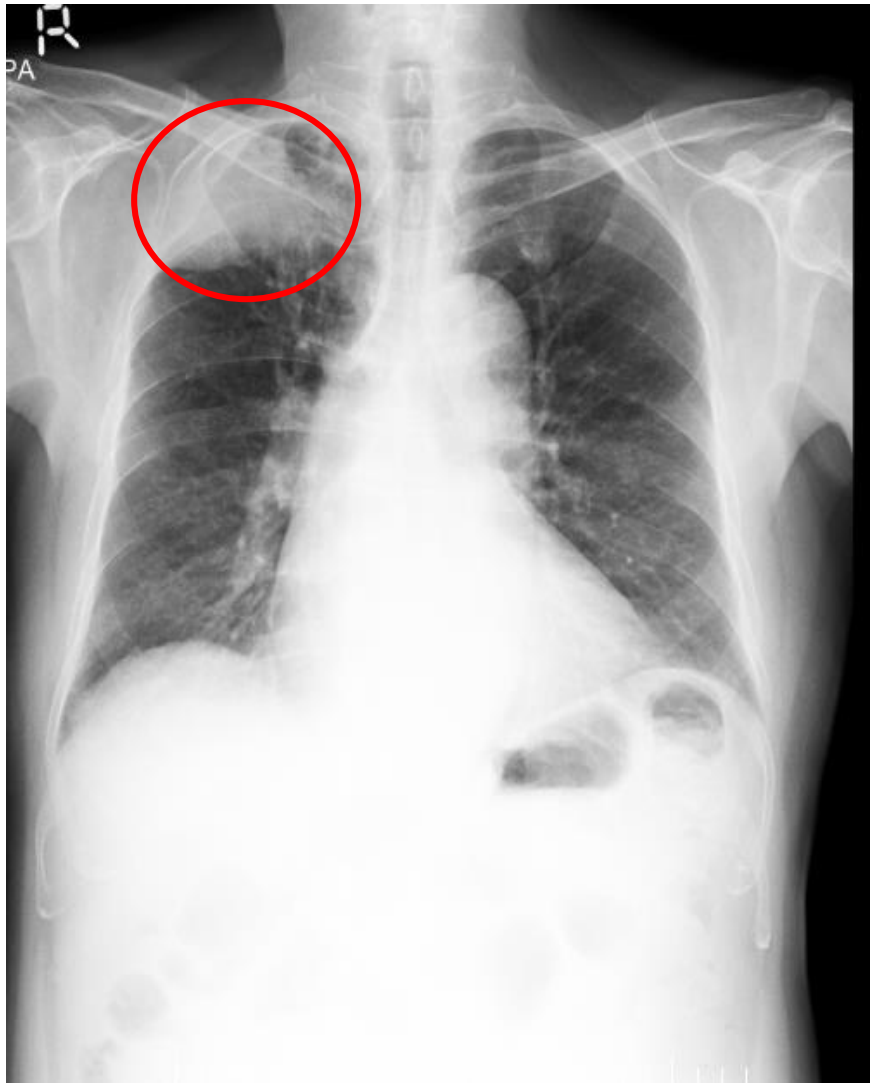
European Respiratory Society (***ERS***) / European Society of Thoracic Surgery (*ESTS*) - 2009

CASE

Z. B., 82-year-old male
former 40 pack years
smoker

CXR = RUL mass

FNAB = Squamous
cell carcinoma



Chest CT scan:

- 6.5 x 4.2 x 4.5 cm pleural based mass with punctate calcification & irregular, spiculated margins in the apical & posterior segments of RUL
- No enlarged lymph nodes seen.
- No pleural effusion seen.
- Liver and both adrenal glands appear normal.

Other Metastatic Work-ups: Negative

Clinical Stage: T2bN0M0 (Stage IIA)

Cardiac Evaluation: Low risk

Management Plan: Lung resective surgery

Case : Pulmonary Function Tests

Spirometry	Ref	Pre Meas	Pre % Ref	Post Meas	Post % Ref	% Chg
FEV1/FVC	68	58		55		
FEV1 (L)	1.88	1.26	67	1.27	68	0
FVC (L)	2.97	2.18	73	2.30	77	6

Diffusion	Ref	Pre Meas	Pre % Ref
DLCO	4.1	3.0	72
DL/VA		1.16	
VA Liters		2.56	

Role of Pulmonary Function Testing

- Aim: To determine the risk for respiratory complications and mortality based on the patient's preoperative lung function and estimated section lung function.
- FEV_1 : predictive of postoperative complications, including death
- DLCO : predictive of postoperative complications, including death, length of hospital stay and hospital costs

Question 1

What will be your next step in the preoperative assessment?

A. Clear patient for RU lobectomy

✓ B. Calculate for the percent predicted FEV_1 and DLCO

C. Order a lung perfusion scan

D. Order CPET

Abbreviations

PPO FEV_1%	percent predicted postoperative FEV_1
PPO DLCO%	percent predicted postoperative diffusing capacity for carbon monoxide
PPO VO_2 max%	percent predicted postoperative maximal or peak oxygen consumption

The PPO designation is added to indicate that the estimated parameter refers to the late postoperative period (3-6 months after the surgical procedure).

Degani-Costa, et al. Rev Bras Anestesiol. 2014

FEV_1 and PPO FEV_1

- FEV_1 and PPO FEV_1 associated with increased respiratory morbidity & mortality rates

- FEV_1 an independent predictor of respiratory morbidity (OR, 1.1 for every 10% decrease in FEV_1)
  FEV_1 < 30% → 43% morbidity rate
  FEV_1 > 60% → 12 % morbidity rate

- Licker et al. (*Ann Thorac Surg* . 2006) confirmed that the best cutoff value of FEV_1 for predicting respiratory complications was 60%.

ACCP Evidence-Based CPG (3rd Edition) 2013

Preoperative FEV_1

- Data from > 2,000 patients in 3 large series in the 1970s :

  Mortality rate of < 5% if –

  - Preoperative FEV_1 > 2 L for a pneumonectomy
  - Preoperative FEV_1 > 1.5 L for a lobectomy

- FEV1 > 80% predicted accepted indicates that the patient should be considered suitable to undergo pneumonectomy without further evaluation.

ACCP CPG (2nd Edition) 2007
BTS CPG 2001

Preoperative FEV_1

- If there is no evidence of either undue dyspnea on exertion or interstitial lung disease and:

  FEV_1 > 80% predicted or > 2 L → suitable for resection including pneumonectomy without further physiologic evaluation.

  FEV1 is > 1.5 L → suitable for a lobectomy without further physiologic evaluation.

ACCP CPG (2nd Edition) 2007

Absolute Values vs Percent Predicted

- Absolute values (preoperative FEV_1 and PPO FEV_1) did not predict surgical outcome defined by 30-day mortality and post-operative respiratory failure
- In contrast, all values (preoperative FEV_1 and DLCO, PPO FEV_1 and PPO DLCO) expressed as a percentage of the normal predicted value) correlated significantly with both complicated post-operative course and poor surgical outcome.
- Recommendation: Percentage predicted rather than absolute lung function values be used in assessing patients for lung cancer surgery → future guidelines should adopt percentage predicted rather than absolute values.

T. Win et al. Relationship between pulmonary function and lung cancer surgical outcome. Eur Respir J 2005; 25: 594–599

DLCO and PPO DLCO

- Reduced PPO DLCO strongly associated with the risk of post-resection pulmonary complications & mortality

- % PPO DLCO → higher correlation with postoperative deaths than the % PPO FEV_1

- % PPO DLCO < 60% was associated with a 25% mortality & 40% pulmonary morbidity (Ferguson et al) – confirmed by other authors

ACCP Evidence-Based CPG (3rd Edition) 2013

Correlation between FEV_1 and DLCO

- Correlation between FEV_1 and DLCO is consistently poor
- Reduced PPO DLCO is a predictor of cardiopulmonary complications and mortality even in patients with an otherwise normal FEV_1
- More than 40% of patients with an FEV_1 > 80% may have a DLCO < 80% ; 7% of them may have a PPO DLCO < 40%

ACCP CPG (3rd Edition) 2013

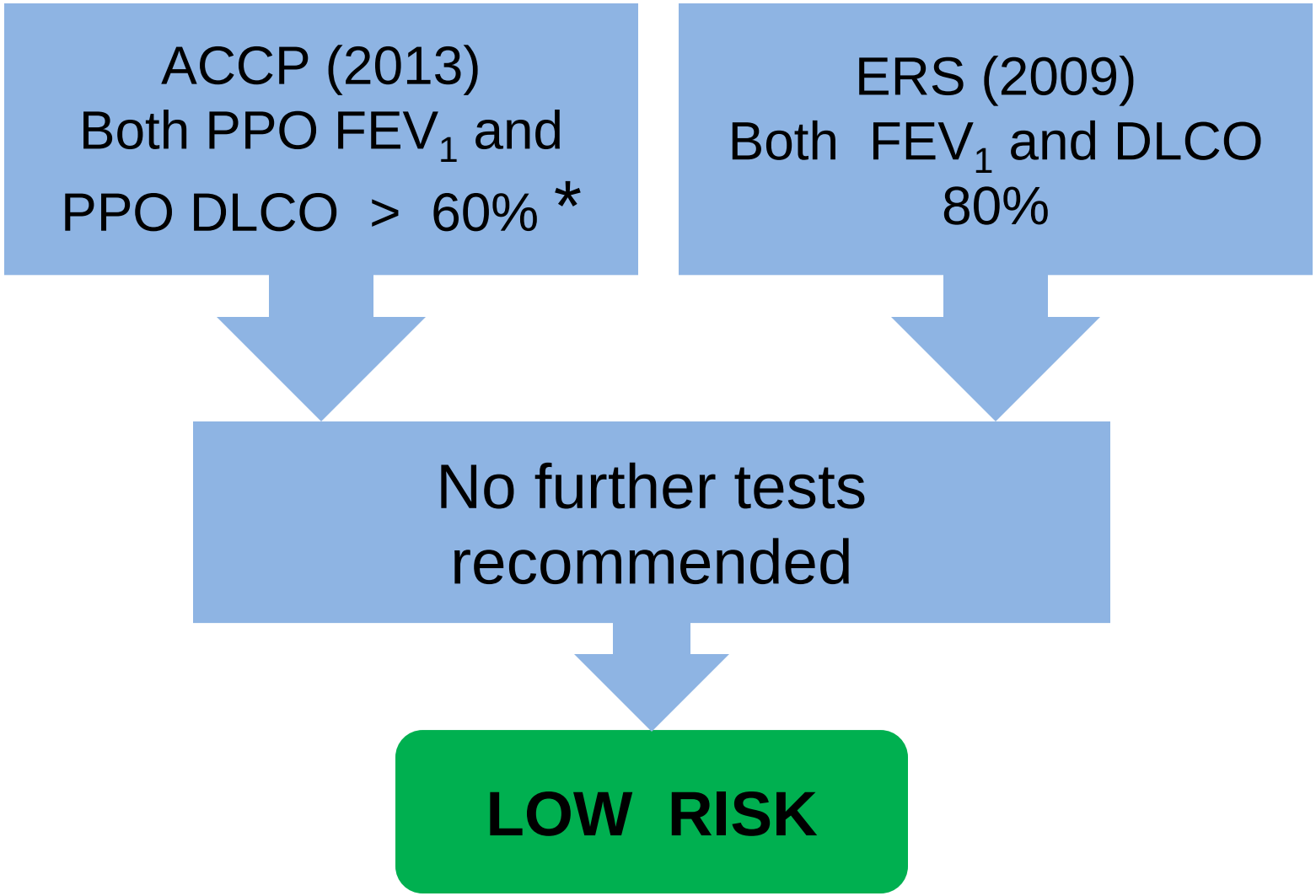
Recommendation: Lung Function

ALL patients for lung resection

Measure both FEV_1 and DLCO
and
Calculate both PPO FEV_1 and PPO DLCO

ACCP CPG (3rd Edition) 2013

Recommendation: FEV_1 and DLCO



* PPO FEV_1 or PPO DLCO cut off values of 60% predicted values has been chosen based on indirect evidences and expert consensus opinion.

Estimation of PPO FEV_1 and PPO DLCO

Anatomic Method (Segment Counting): only for lobectomy

PPO FEV_1 = preoperative FEV_1* x (1 – y/z)

* *the best measured postbronchodilator value*

PPO DLCO = preoperative DLCO x (1 – y/z)

y = the number of functional or unobstructed lung segments to be removed

z = the total number of functional segments

ACCP CPG (3rd Edition) 2013

PPO FEV_1 = preop FEV_1 x (1 – number of functional or unobstructed lung segments to be resected / total number of functional segments)

PPO DLCO = preop DLCO x (1 – number of functional or unobstructed lung lung segments to be resected / total number of functional segments)

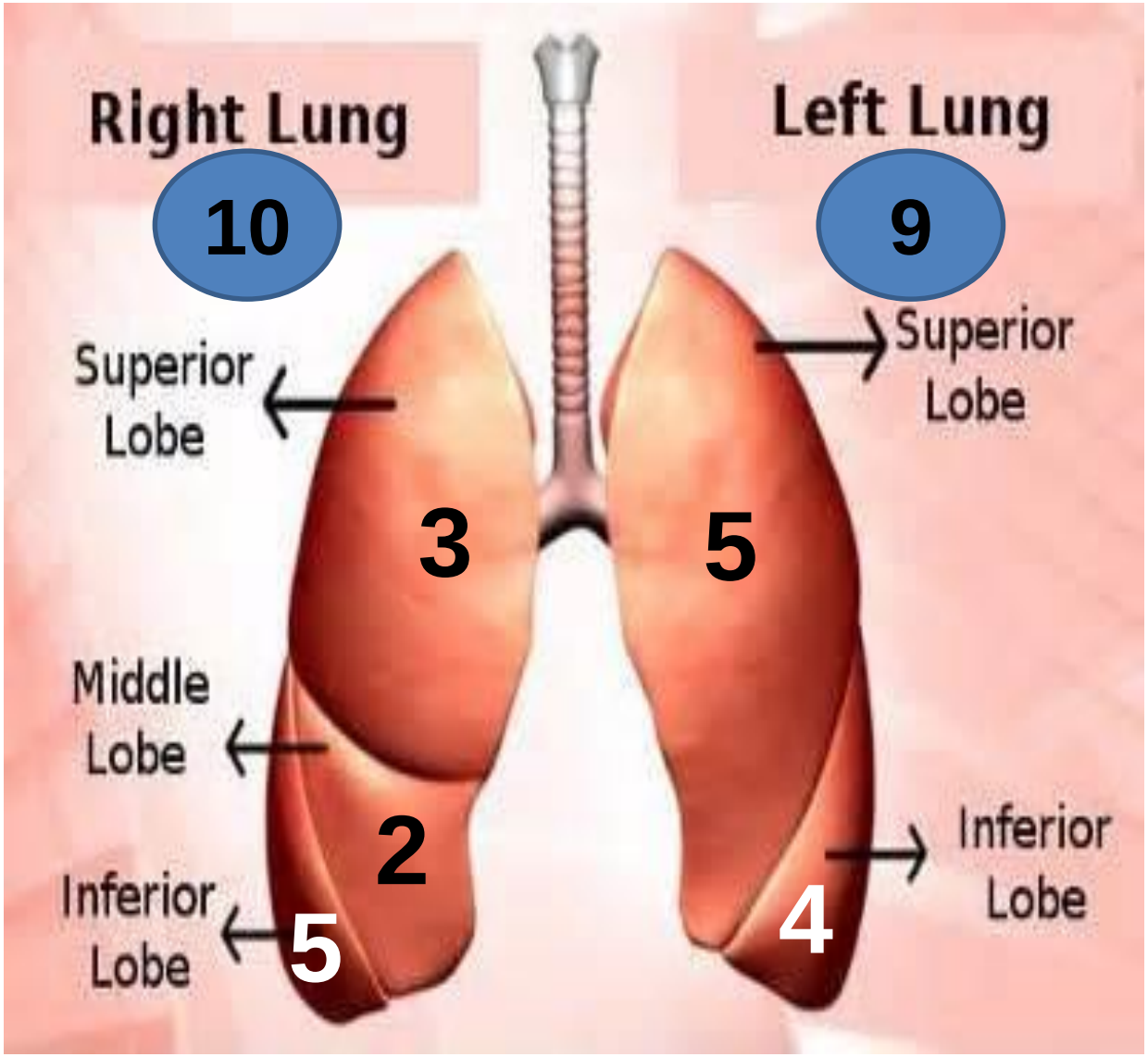
* Only segments not totally obstructed should be taken into account: evaluated by image techniques and/or bronchoscopy

PPO FEV_1 and PPO DLCO expressed as a percentage of predicted to calculate % PPO FEV_1 and DLCO:

$$\%\ \text{PPO FEV}_1 = \frac{\text{computed PPO FEV}_1}{\text{predicted normal FEV}_1} \times 100$$

$$\%\ \text{PPO DLCO} = \frac{\text{computed PPO DLCO}}{\text{predicted normal DLCO}} \times 100$$

Number of Lung Segments



Case : FEV_1 and DLCO

	Ref	Pre Meas	Pre % Ref	Post Meas	Post % Ref	% Chg
FEV_1 (L)	1.88	1.26	67	1.27	68	0
DLCO	4.1	3.0	72			

Case : Calculation of PPO FEV_1 %

Anatomic Method (for RU lobectomy):

$PPO\ FEV_1 = \text{preoperative } FEV_1 \times (1 - y/z)$

$= 1.27 \times (1 - 3/19)$

$= 1.27 \times (1 - 0.158)$

$= 1.27 \times 0.842$

$= 1.069 \simeq \mathbf{1.07\ L}$

$PPO\ FEV_1\ \% = [PPO\ FEV_1 / \text{pred } FEV_1] \times 100$

$= [\ 1.07 / 1.88\ ] \times 100$

$= 0.569 \times 100 = 56.9\% \simeq \mathbf{57\%}$

Case : Calculation of PPO DLCO %

Anatomic Method (for RU lobectomy):

PPO DLCO = preoperative DLCO x (1 - y/z)

= 3.0 x (1 – 3/19)

= 3.0 x (1 – 0.158)

= 3.0 x 0.842

= 2.526 ≃ **2.53**

PPO DLCO % = [PPO DLCO / predicted DLCO] x 100

= [2.53 / 4.1] x 100

= 0.617 x 100 = 61.7 % ≃ **62%**

Case : PPO FEV_1 % and PPO DLCO%

Anatomic Method (for RU Lobectomy)

PPO FEV_1 % = **57 %**

PPO DLCO % = **62 %**

Question 2

Based on calculated PPO FEV_1 % and PPO DLCO% by anatomic method, what is your assessment ?

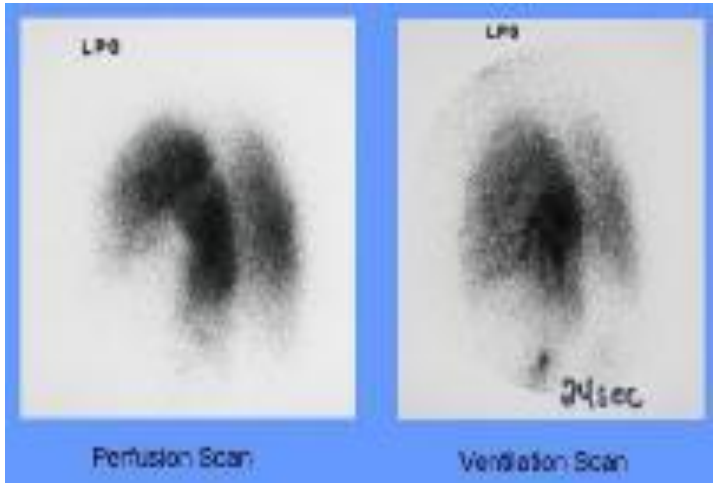
A. Assess as low risk for RU lobectomy
B. Assess as moderate risk for RU lobectomy
C. Assess as high risk for RU lobectomy
✓ D. Needs further assessment; Order a perfusion scan

Quantitative Radionuclide Scanning

- Anatomic (segment counting) method: recommended only to estimate lung function after a lobectomy

- To estimate the PPO FEV_1 and DLCO after pneumonectomy → A quantitative radionuclide perfusion scan is performed to measure the fraction of total perfusion for the resected lung.

- Either ventilation or perfusion scan can be used to predict PPO lung function. Perfusion scan more commonly used. No additional benefit in performing both.



Beckles et al, physiologic evaluation of patients with lung cancer being considered for resectional sugery. Chest 2003
Guidelines on the radical management of patients with lung cancer. British Thoracic Society and the Society for Cardiothoracic Surgery in Great Britain and Ireland. Thorax 2010;65

Estimation of PPO FEV_1 and PPO DLCO

Perfusion Method: to calculate predicted postoperative values of FEV_1 or DLCO for pneumonectomy

- PPO FEV_1 = preoperative FEV_1 * x (1 – fraction of total perfusion for the resected lung)

  ** the best measured postbronchodilator values*

- PPO DLCO = preoperative DLCO x (1 – fraction of total perfusion for the resected lung)

PPO FEV_1 and PPO DLCO → expressed as a percentage of predicted to calculate % PPO FEV_1 and DLCO

Case: Lung Perfusion Scan

	Right Lung	Left Lung
Upper Zone	9.1 %	13.5 %
Middle Zone	25.3 %	29.2 %
Lower Zone	12.6 %	10.3 %
Total :	47 %	53 %

Case : Calculation of PPO FEV_1

Perfusion Method (for RU lobectomy):

PPO FEV_1 = preoperative FEV_1 x (1 - fraction of total perfusion for the resected lung)

= 1.27 x (1 – 9.1 %)

= 1.27 x (1 – 0.091)

= 1.27 x (0.909)

= 1.15443 $\simeq$ **1.15 L**

PPO FEV_1 % = [PPO FEV_1 / pred FEV_1] x 100

= [1.15 / 1.88] x 100

= 0.612 x 100 = **61.2 %**

Case : Calculation of PPO DLCO

Perfusion Method (for RU lobectomy):

PPO DLCO = preoperative DLCO x (1 - fraction of total perfusion for the resected lung)

= 3.0 x (1 – 9.1 %)

= 3.0 x (1 – 0.091)

= 3.0 x 0.909

= 2.727 ≃ **2.73**

PPO DLCO % = [PPO DLCO / pred DLCO] x 100

= [2.73/ 4.1] x 100

= 0.666 x 100 = **66.6 %**

Case : Calculation of PPO FEV_1

Perfusion Method (for Right Pneumonectomy):

$PPO\ FEV_1$ = preoperative FEV_1 x (1 - fraction of total perfusion for the resected lung)

= 1.27 x (1 – 47 %)

= 1.27 x (1 – 0.47)

= 1.27 x (0.53)

= **0.67**

$PPO\ FEV_1\ \%$ = [$PPO\ FEV_1$ / pred FEV_1] x 100

= [0.67 / 1.88] x 100

= 0.356 x 100 = **35.6 %**

Case : Calculation of PPO DLCO

Perfusion Method (for Right Pneumonectomy):

PPO DLCO = preoperative DLCO x (1 - fraction of total perfusion for the resected lung)

= 3.0 x (1 – 47 %)

= 3.0 x (1 – 0.47)

= 3.0 x 0.53

= **1.59**

PPO DLCO % = [PPO DLCO / pred DLCO] x 100

= [1.59 / 4.1] x 100

= 0.388 x 100 = **38.8 %**

Case : Summary of PPO FEV_1% and PPO DLCO%

Anatomic Method : RU Lobectomy

PPO FEV_1 % = **57 %**

PPO DLCO % = **62 %**

Perfusion Method : RU Lobectomy

PPO FEV_1 % = **61.2 %**

PPO DLCO % = **66.6 %**

Perfusion Method : R Pneumonectomy

PPO FEV_1 % = **35.6 %**

PPO DLCO % = **38.8 %**

Question 3

At this point, what is your risk assessment of this patient?

A. Low risk for both RU lobectomy and R pneumonectomy
B. Moderate risk for both RU lobectomy and R pneumonectomy
C. High risk for both RU lobectomy and R pneumonectomy
✓ D. Low risk for RU lobectomy, but needs further test for possible R pneumonectomy

Lung Cancer Surgery

- The objective is to ascertain that after surgical resection of the lung , there will be sufficient pulmonary reserve to keep the patient comfortable and will not become a respiratory cripple.
- One should always evaluate the patient to determine whether he could withstand a pneumonectomy , even if it is believed preoperatively that all that is needed is a lobectomy or a wedge resection.
- If during the exploratory thoracotomy the tumor crosses the major fissure or extends to the hilum and a pneumonectomy is needed, the opportunity for an extensive physiologic evaluation is generally too late.

F. Grubisic-Cabo et al., Preoperative Pulmonary Evaluation for Pulmonary and Extrapulmonary Operations. Acta Clin Croat. Vol. 42 No. 3, 2003; 237-240

Olsen GN. Pulmonary Physiologic Assessment of Operative Risk. General Thoracic Surgery by Shields, TW. 5th ed. 2000; Chapter 19 : 297-304.

Question 4

What additional test will you order to further assess risk for pneumonectomy?

A. 6 minute walk test
✓ B. Stair climb
✓ C. Shuttle walk test
✓ D. CPET
E. Any of the above

Exercise Tests

- Aim of exercise testing: to stress the whole cardio-pulmonary / systemic oxygen delivery systems and estimate the physiological reserve that may be available after surgery.
- Meta-analysis by Benzo et al. (*Respir Med 2007*) :
  - has shown that exercise capacity, expressed as VO_2 peak is lower in patients that develop post-operative cardiorespiratory complications after lung resection.
- Besides early postoperative outcome, performance on exercise tests is also a better predictor of long-term exercise capacity than conventional pre-operative PFTs. (*Bolliger et al. Eur Respir J 1996*)
- Nevertheless, exercise tests are usually recommended only in selected cases (unfit or reduced FEV1 and/or DL,CO)

ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo- radiotherapy). Eur Respir J 2009; 34: 17–41

Cardiopulmonary Exercise testing (CPET)

- CPET: a sophisticated physiologic testing technique that provides an objective evaluation of functional capacity of both the lungs & heart and is known as a safe test procedure
- Inability to perform a preoperative exercise test → indication of limited aerobic capacity
- Recommended by previous & current guidelines as the next step in the preoperative risk-assessment process in those patients with compromised pulmonary function.

ACCP Evidence-Based CPG 2013
Tilburg et al. Eur Respir J 2009; 33

Cardiopulmonary Exercise Testing

- Standardized CPET using VO_2 max has been shown to predict postoperative complications, including perioperative and long-term morbidity and mortality
- ACCP: CPET indicated
  - positive high-risk cardiac evaluation
  - either FEV_1 or DLCO < 30% or
  - SCT < 22 m or SWT < 400 m
- ERS: CPET recommended when FEV_1 or DLCO < 80%

Cardiopulmonary Exercise Testing

The risk for perioperative complications has been reported to be higher with lower measured VO_2max :

- VO_2 max > 20 ml/kg/min or > 75% predicted::
  - can safely safely undergo the planned resection (up to pneumonectomy)
- VO_2 max between 10-15 ml/kg/min or between 35%- 75% predicted:
  - indicates an increased risk of perioperative death compared with higher values of VO_2 max.
- VO_2 max of <10 ml/kg/min or < 35% predicted:
  - very high risk for postoperative death
  - generally regarded as a contraindication to major anatomic resections

ACCP Evidence-Based CPG (3rd Edition) 2013

Low Technology Exercise Tests

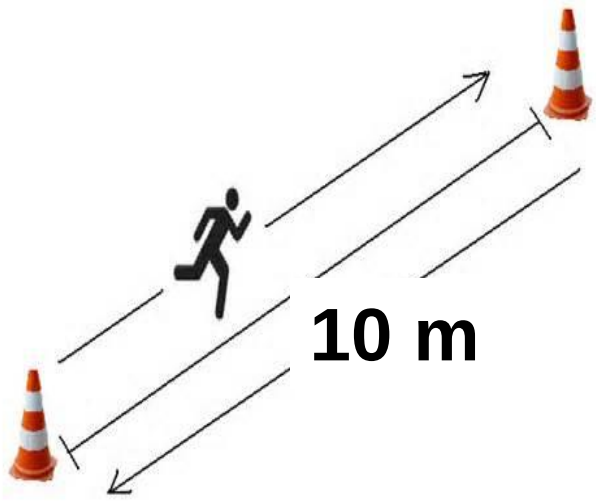
STAIR CLIMBING TEST (SCT)

- Can used be as a first-line functional screening test to select those patients that can undergo safely to operation (height of ascent > 22 m)
- Limitation of test : lack of standardization - the duration of stair climbing, the speed of ascent, the number of steps per flight, the height of each step, and the criteria for stopping the test have varied from study to study.

ERS/ESTS CPG 2009
ACCP Evidence-Based CPG (2rd Edition) 2007

Low Technology Exercise Tests

SHUTTLE WALK TEST (SWT)



- Procedure :
  - Requires the patient to walk back and forth between 2 markers set 10 m apart
  - Walking speed is increased each minute in a graded fashion and paced by an audio signal
  - End of test : when patient is too breathless to maintain speed
- Inability to complete 25 shuttles (250 m) on 2 occasions suggests a VO_2 max of < 10 ml/kg/min

M. Beckles et al. CHEST 2003;123
ACCP CPG (2nd Edition) 2007

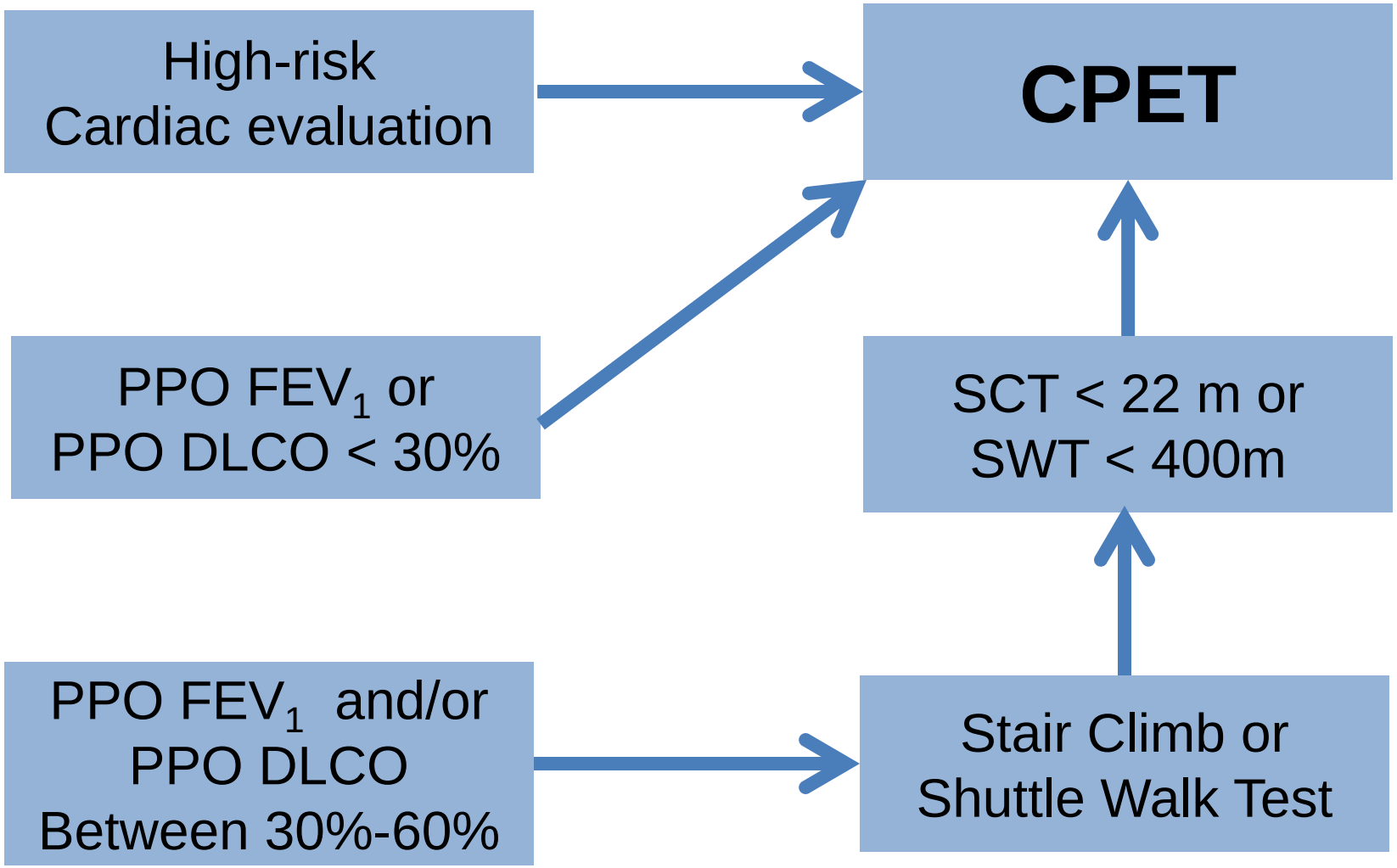
Low Technology Exercise Tests

SIX MINUTE WALK TEST (SMWT)

- Procedure measures the distance that the patient can quickly walk on a flat, hard surface in a period of 6 minutes.
- Patients instructed to walk as far as possible in a period of 6 minutes. Rest during the test is permissible.
- Interpretation of the distance walked in 6 min currently not well standardized.
- Current guidelines: The 6-min walk test should not be used to select patients for operation.

ERS/ESTS CPG 2009

Recommendation: Exercise Tests



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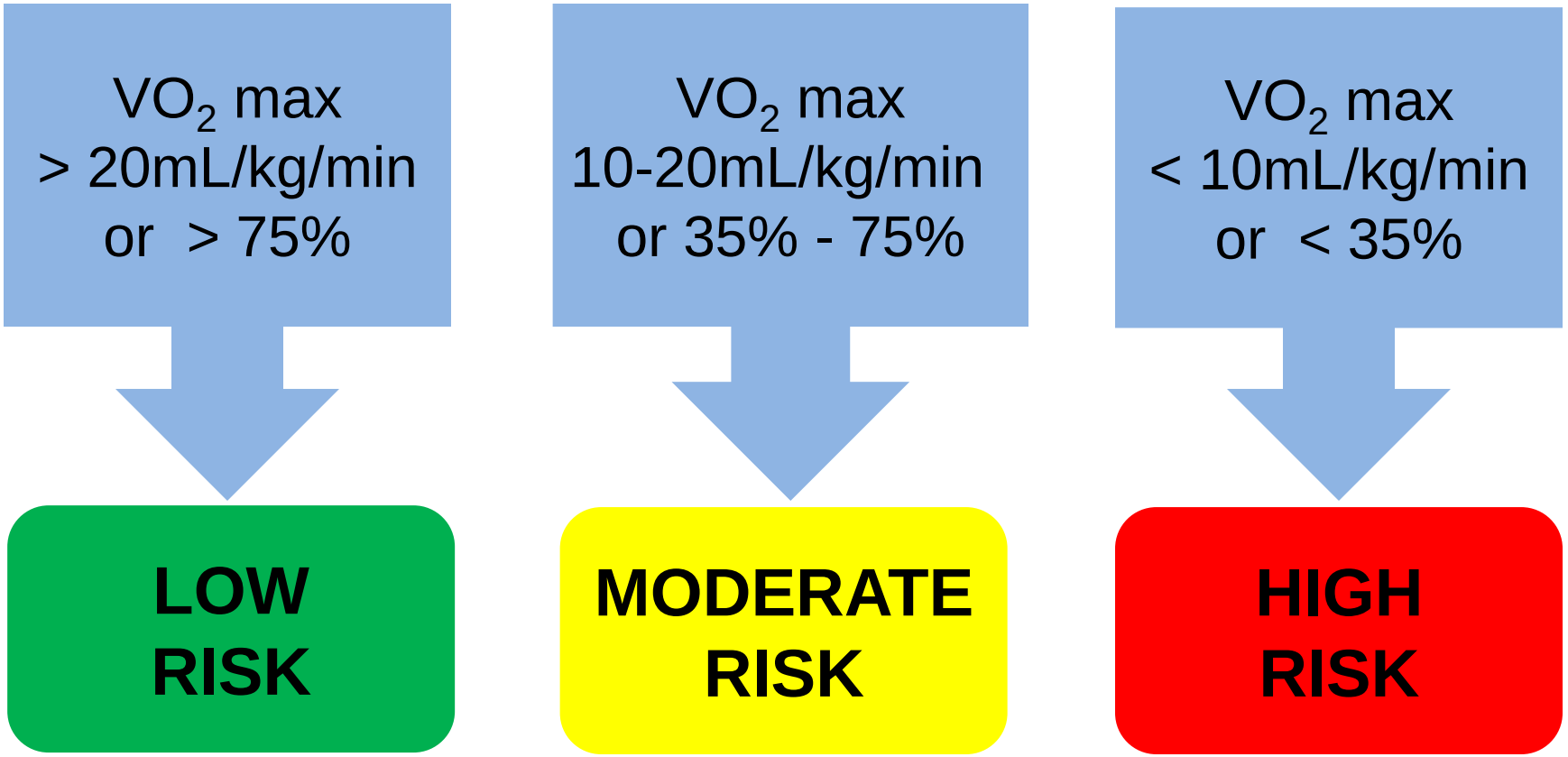
Recommendation: CPET



ACCP CPG (3rd Edition) 2013
ERS/ESTS CPG 2009

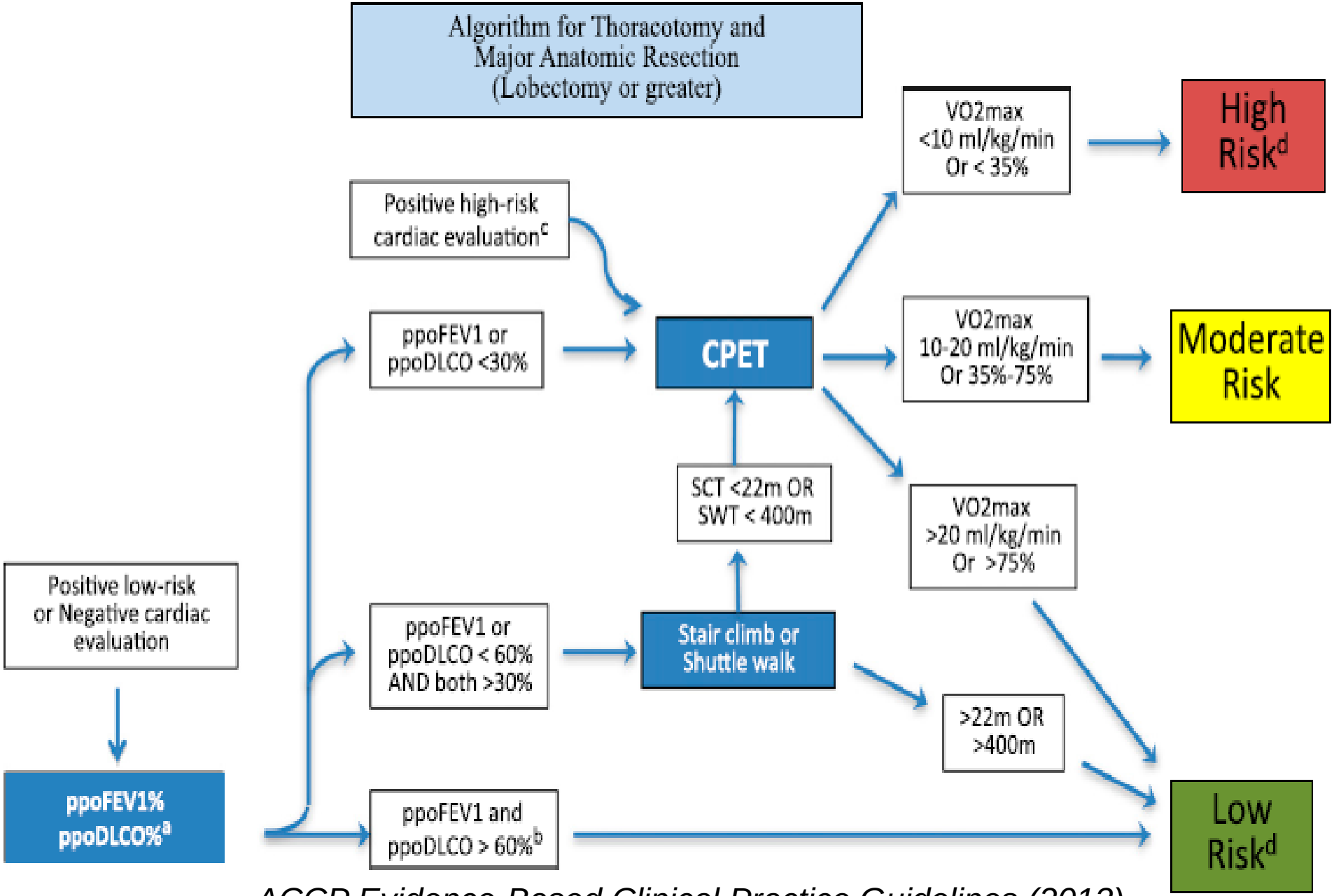
Estimation of PPO VO_2 max

For Pneumonectomy:

PPO VO_2 max = preoperative VO_2 max x
(1 – fraction of total perfusion for the lung to be resected)

ERS/ESTS CPG 2009

Physiologic Evaluation Resection Algorithm

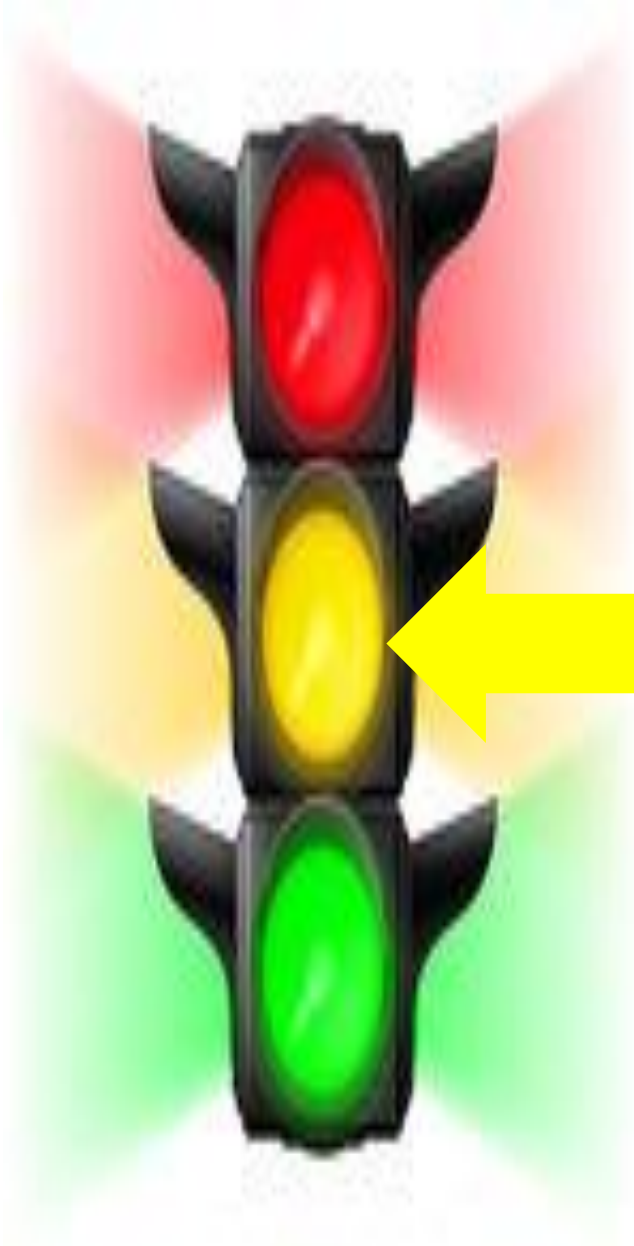


ACCP Evidence-Based Clinical Practice Guidelines (2013)

Definition of Low Risk

- Indicates that the patient's functional reserve is sufficient to withstand the stress of surgery and perform daily activities in the late postoperative period
- The expected risk of mortality is below 1%.
- Major anatomic resections can be safely performed in this group.

ACCP CPG (3rd Edition) 2013
Degani-Costa, et al.
Rev Bras Anestesiol. 2014



Definition of Moderate Risk

- Morbidity and mortality rates may vary according to the values of split lung functions, exercise tolerance and extent of resection.
- The benefit of surgery is considered to outweigh the risks.
- Risks and benefits of the operation should be thoroughly discussed with the patient.

ACCP CPG (3rd Edition) 2013
Degani-Costa, et al.
Rev Bras Anestesiol. 2014

Definition of High Risk

- Generally considered a contraindication to surgery due to the high mortality rate (>10%) after standard major anatomic resections
- Considerable risk of severe cardiopulmonary morbidity and residual functional loss is expected.
- Patients should be counseled about alternative surgical (minor resections or minimally invasive surgery) or nonsurgical options.

ACCP CPG (3rd Edition) 2013
Degani-Costa, et al.
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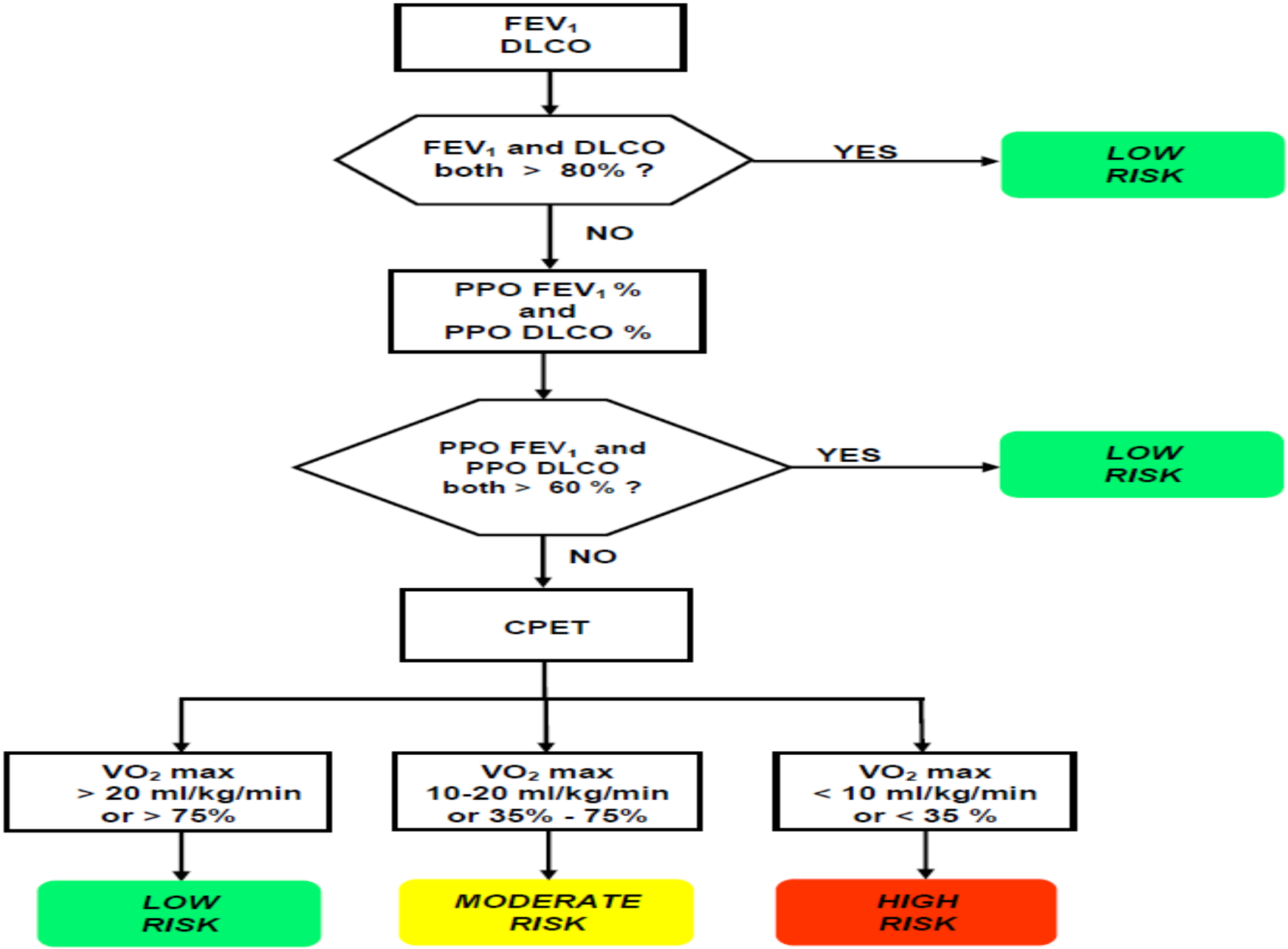
Proposed Algorithm for Preoperative Risk Assessment for Lung Resection



SUMMARY

- ✓ All patients being considered for lung resection should undergo preoperative physiologic evaluation.
- ✓ Pulmonary function testing using spirometry (FEV_1), DLCO and VO_2 max help predict the risk of post-operative complications and mortality.
- ✓ Predicting postoperative lung function using the proportion of lung segments to be resected, perfusion scanning, or other methods is important for assessing surgical risk.
- ✓ Current international guidelines provide algorithms for preoperative risk assessment.