PREOPERATIVE PULMONARY ASSESSMENT FOR LUNG RESECTION SURGERY

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Introduction

- Lung Resection
- CA lung
  - One of the main indication
  - Prognosis of CA lung is poor without surgical resection
  - Only 15-25% found operable at the time of presentation in the western world
  - Only 6% found operable at the time presentation in South Africa*
- Other than CA lung
  - Bronchiectasis
    - Hemoptysis
    - Recurrent LRTI

*Nanguzgambo et al, J Thorac Oncol 2011;6(2):343-50

COMMON PROCEDURE

- Pneumonectomy
- Lobectomy
- Wedge Resection
- Segmentectomy

Post Resection : Physiological changes

- Impairment of Ventilatory responses to:
  - CO_2 at all level of work
  - Hypoxemia during heavy exercise
    - Due to V/Q heterogeneity
    - Diffusion limitation
- Reduce
  - Cardiac out put
  - VO_2
  - PaO_2

- Remaining lung
  - Increase Diffusion Capacity:
    - As removal of 42% lung(Left pneumonectomy) causes DLCO decrease by 30% only*
    - It is due to recruitment of new vessels by
      - PHT
      - Expansion of remaining lung

*Hisia et al, J Appl Physiol 1994;77:998-1005

- Changes in Lung Volume
  - Pneumonectomy:
    - FEV1 reduced by 34- 36%
    - FVC reduced by 36 - 40%
  - Lobectomy:
    - FEV1 reduced by 9 - 17%
    - FVC reduced by 7 - 11%

Mazzone PJ et al., Am J Med 2005; 118:578-58

Preoperative assessment to decide

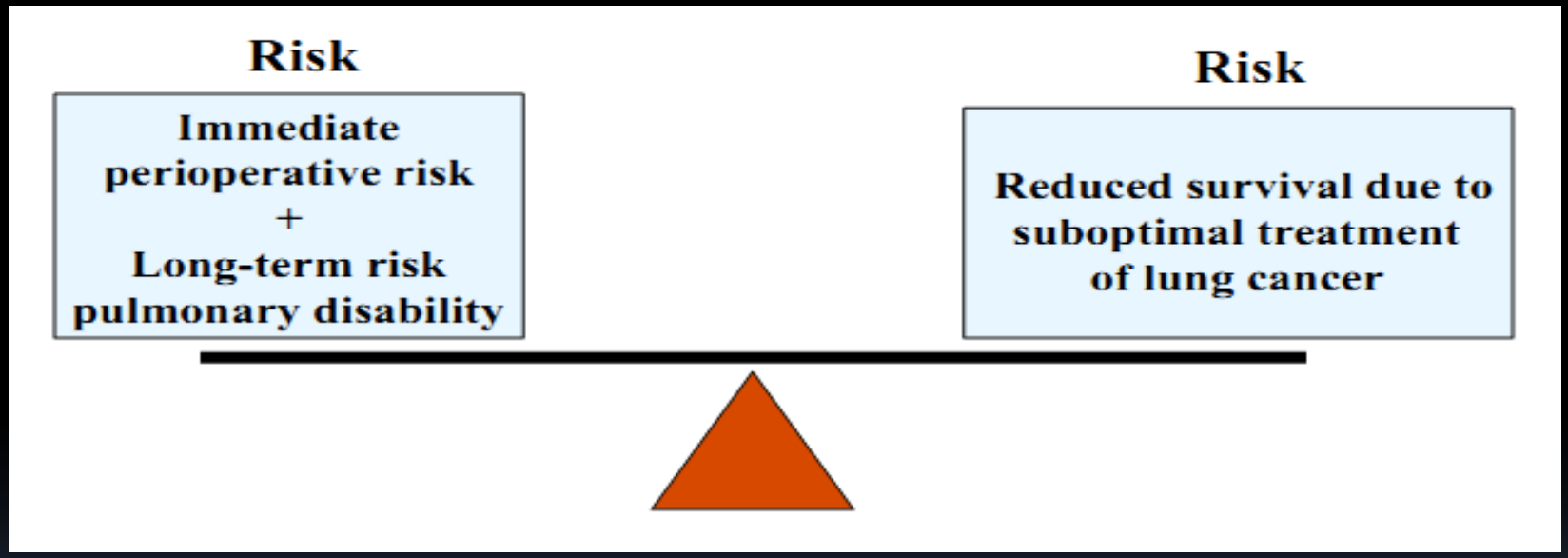
(A) Risk are so high that Sx should not be performed ?

- Perioperative mortality
- Post operative complication

(B) What will be post operative quality of life ?

- Will post operative PFT sufficient to allow reasonable quality of life

Balancing risk by preoperative assessment



Poor lung function alone rule out Sx in > 37% pt who presented with anatomically resectable disease.

Baser et al, Clin Lung Cancer 2006; 7: 344-49

- MORTALITY RATES
  - Pneumonectomy : 6.8%
  - Bi-lobectomy : 4.4 %
  - Lobectomy : 3.9 %
  - Lesser Resection : 1.4 %

Damhuis et al, Eur Respir J 1996 ; 9:7-10

Post-lobectomy complications

	All patients	Length of stay <14 days	Length of stay >14 days	Significant for LOS *p* value
n	4,979	4,628 (93%)	351 (7%)	
Pneumonia	4%	3%	28%	<0.0001
Atelectasis	4%	2%	21%	<0.0001
ARDS	1%	0.5%	11%	<0.0001
Myocardial infarction	0.4%	0.2%	3%	<0.0001
Ileus	1%	0.6%	18%	<0.0001
Renal failure	1.4%	0.9%	9%	<0.0001
Pulmonary embolus	0.3	0.3%	2%	0.02
Atrial arrhythmias	12%	11%	27%	0.07
Air leak >5 days	10%	8%	36%	<0.0001

Wright et al, Ann Thorac Surg 2008;85:1857–65

Functional Operability

- Age
- General health
- Performance status
- Smoking
- Cardiac Function
- Respiratory assessment (the "three-legged stool")
  1. Lung mechanical function
     - FEV1
  2. Lung parenchymal function
     - DLCO
     - ABG
  3. Cardiopulmonary reserve
     - CPET
     - Low cost alternatives
- Regional lung function

Age

- Advancing age - increase risk
  - <70 yrs of age 4-7% mortality
  - >70 yrs of age 14% mortality
- The comorbidities associated with advanced age responsible for this*
- Lung cancer pt should not denied lung resection on the ground of age alone.^
- When pneumonectomy is planned age should be consider#

*Smetana et al, N Engl J Med 1999;340(12):937-44

^Gene et al, CHEST 2007;132:161S-177S (ACCP Guideline)

BTS, Thorex 2001;56:89-108

General health

- Malnutrition (Alb <3 mg%)
  - Reduce ventilatory derive to hypoxia & hypercapnia
  - Respiratory Ms dysfunction
  - Alters lung elasticity
  - Impair immunity
- Renal impairment(Blood urea >30 mg%)
  - Odd ratio of 2.3 for postoperative complication

Performance status

- American Society of Anesthesiologist Classification (I to V)
  - ASA III or Higher have 2.6 time post op complication than ASA I or II
- Karnofsky Index (100 to 0)
- ECOG-WHO Scale (0 to 4)
  - Pt who are dependent, not candidate for Sx

Smoking

- Smoking increase the risk for post operative pulmonary complication.
- Carboxy Hb concentrations decrease if smoking is stopped >12 h†
- Significant risk reduction seen after >8 wks cessation.^
- Quit smoking before Sx lower the risk of complication.
- The longer the period of cessation, the greater the risk-reduction*
- All smoker should be encouraged to quit smoking with appropriate treatment

† Akrawi et al, J Cardiothorac Vasc Anesth. 1997;11:629–40

^ Conti et al, Minerva Chir 2002;57(3):317-21

* Mills et al, Am J Med 2011;124(2):144-54

- Surgical Patients who Quit Smoking for
  - > 2 days
    - Decrease intra op ST changes
  - >4wk
    - Decrease post op wound complications
    - Decrease resp. complications of thoracic Sx
  - >8 wk
    - Decrease resp. complications of cardiac Sx

Warner DO, Anesth Analg 2005; 101: 481-7

Cardiac Function :
Revised Goldman Cardiac Risk Index

1. High-risk type of surgery
2. History of ischemic heart disease
   a. History of myocardial infarction (within 6 months)
   b. Positive exercise test
   c. Current complaint of ischemic chest pain
   d. Use of nitrate therapy
   e. Pathologic Q waves on ECG

(Not included: prior coronary revascularization procedure unless one of the other criteria for IHD is present)

3. History of cardiac failure
4. History of cerebrovascular disease
5. DM requiring treatment with insulin
6. Preoperative serum creatinine >2.0 mg/dL

- Two or more variables : indicate a high risk and are associated with a postoperative cardiac complication rate of >10%.
- These pts needs evaluation and potential intervention by a cardiologist

Lee et al, Circulation 1999;100(10):1043–9

Respiratory assessment

1. Lung Mechanical Function

- Spirometry
  - FEV1 absolute value*
    - > 0.6 L low risk for segmentectomy
    - > 1.5 L low risk for a lobectomy
    - > 2.0 L low risk for a pneumonectomy
  - But absolute value does not consider patient related variables (age, sex, height)
  - FEV1 >80% or > 2L and without e/o SOB/ILD can be considered for pneumonectomy without further testing.^

*Boushy et al,Chest 1971;59:383-91
Wernly et al, J Thorac Cardiovasc Surg 1980;80:535-43
^Colice et al (ACCP),Chest 2007;132(S3):161-177

2. Lung Parenchymal function

- DLCO
  - Reflects alveolar capillary membrane integrity and blood flow in the patient's lungs
  - ACCP- If e/o SOB or ILD even FEV1 >80% or >2L.
  - ERS/ESTS/BTS- DLCO in all pts regardless of FEV1
  - If either of FEV1 or DLCO are<80%, peak VO2 assessed by CPET.
  - DLCO *
    - < 80% pred associated with ↑ po complications,
    - < 60% pred associated with ↑ mortality

* Ferguson et al, Ann Thorac Surg 2008; 85(4):1158-64

- ABG
  - SaO_2 < 90% increase risk of perioperative complications*
  - Historically $PaCO_2$ >45mmHg was considered exclusion criteria for lung resection as it was associated with poor ventilatory function^
  - $PaCO_2$ >45 mmHg is not an independent risk for perioperative complications*

^BTS, Thorex 2001;56:89-108

^ Celli et al, Med Clin North Am 1993; 77:309-25

^ Zibark et al, Ann Intern Med 1990; 112:763-71

* Colice et al (ACCP),Chest 2007;132(S3):161-177

3. Cardiopulmonary reserve
   - CPET
   - Low cost alternatives
     - Stair Climbing
     - Shuttle walk
     - 6 MWT

CPET

- Exercise = Work performed by Sk Ms
- Amount of O_2 consumed = amount of work done

  (Body has limited capacity to store O_2)

  $VO_2 = (VI \times FiO_2) - (VE \times FeO_2)$

  $VO_2 = C.O. \times (a\text{-}v)\ O_2$ content

  $VCO_2 = VE \times FeCO_2$
- Resting VO_2 = 3.5 ml/min/kg = One Metabolic equivalent (MET)

Energy consumption in various activities

Activity	METS
Sitting quietly	1
Walking 1 block	2
Playing the accordion	2
Climbing 1 flight stairs	4
Sexual intercourse [a]	6
Bowling [a]	8
Ice Hockey	8
Running 6 mph	10
Cross country ski racing	14

1 MET = basal oxygen consumption = 3.5 mL/kg/min

Hlatky et al, Am J Cardiol. 1989;15:651–4;
Fleisher et al, J Am Coll Cardiol 2007;50:1707–32;
Ainsworth et al, Med Sci Sports Exerc. 1993;25:71–80.

- VO_2 max
  - VO_2 that remains invariant despite increment in workload after AT VO_2.
    - (< 1ml/min/kg difference for > 30 seconds)
- AT VO_2 (Anaerobic Threshold)
  - Critical level of work at which lactic acidosis develop
  - VCO_2 and VO_2 cross over take place due to

    (1) a disproportionate rise in VCO_2, VE, or R relative to VO_2

    (2) a disproportionate rise in end-tidal O_2 relative to end-tidal CO_2

- Moderate Exercise
  - Exercise below AT VO_2
  - Can be continued for prolong period without discomfort or fatigue
- Heavy Exercise
  - Exercise above AT VO_2
  - Can not be sustained for prolong period

- CPET
  - Safe but not without risk
  - Serious complication during test 1-5/10000*
  - Absolute C/I to max exercise
    - Acute infectious illness
    - Instability of cardiac rhythm or hemodynamics
    - Temporal proximity to acute MI
    - Decompensated state of chronic diseases

*Arena et al, Circulation 2007;116:329-43

- If FEV1 or DLCO < 80% predicted – Peak VO2 is recommended
- Peak VO2 Normal value*
  - Male = Ht in cm – Age in yr x 21
  - Female = Ht in cm – Age in yr x 14
- LLN = 83% of predicted

* Hansen et al, Am Rew Respir Dis 1984;129(S):S 49-55

- Peak VO_2
  - >20 ml/kg/min or > 75%
    - Allow resection up to pneumonectomy
  - <10 ml/kg/min or < 35%
    - Usually not recommended any resection
  - 10-20 ml/kg/min or 35-75%
    - Subjected to Regional lung function (ppo)

Brunelli et al, Eur Respir J 2009;34(1):22

Low Cost Alternatives of CPET

- Stair Climbing
  - Widely used and validated as a surrogate of CPET.
    - 3 flights of stairs (12 meters Ht)
      - FEV1 > 1.7 L
      - Suitable for lobectomy
    - 5 flights of stairs (20 meters Ht)
      - FEV1 > 2 L
      - VO_2 max >20 ml/kg/min
      - Suitable for pneumonectomy

Bolton et al, Chest 1987;92:783-87

Brunelli et al, Chest 2002;121:1106-10

- Speed of ascent also showed linear correlation with VO2 max*
  - Ascent @ 15 m/min = VO2 max 20ml/kg/min
  - Ascent @ 12 m/min = VO2 max 15ml/kg/min
- Limitations
  - Not a standardized
  - Duration, speed of ascent, steps per flight, height of each step very

*Koegelenberg et al,Respiration 2008;75(4):374-9

- Shuttle walk
  - Patient walk back and forth b/w two markers set 10 m apart.
  - Walking speed increase with each min
  - End of Test: When pt is too breathless to maintain required speed

- < 25 shuttles = Peak VO2 <10 ml/kg/min*
- But prospective studies failed to validate this test^

*Singh et al, Thorex 1992;47:1019-24

^Win et al, Eur J Cardiothorac Surg 2004;26(6):1216-19

^Win et al, Thorex 2006;61(1):57-60

- 6MWT
  - Rest for 10 min
  - Record baseline SOB on Borg Scale (1 -10)
  - Walk at comfortable pace to complete 60 m lap
  - Post walk Borg Scale
  - Record total distance walked over 6 min
  - Interpretation is not standardized*

*ATS, Am J Respir Crit Care Med 2002;166:111-17

Regional lung function

- Bronchospirometry
- Pulmonary Hemodynamics
- Qualitative CT (Segment Method)
- Perfusion SPECT
- Quantitative CT
- Dynamic Perfusion MRI
- Vibratory Response Imaging (VRI)

Bronchospirometry

- Double lumen catheter is passed in the trachea under fluoroscopy
- One lumen open in LMB other in Trachea for RMB.
- R & L Lung isolated and Spirometry of both lung recorded separately.
- Invasive test no longer performed as better non invasive test are available.

Donald ,Postgraduate Medical journal, March 1952:171-78

Pulmonary Hemodynamics

- Temporary occlusion of pul artery at rest & exercise
- It simulate "Physiological Pneumonectomy"
  - Growth in pressure – ↑ post OP risk & complications*
  - Pul artery pressure >35mmHg
  - PaO_2 < 45 mmHg

  } Pt is inoperable^
- Currently this is rarely used
  - Invasive
  - Complex
  - Noninvasive test have equal or superior efficacy

*Gass et al, Chest Jan 1986;89(1):127-35

^Olsen et al, Am Rev Respir Dis April 1975;111(4):379-87

Qualitative CT

- Anatomic Calculation
  - Old, tested and simple
  - Reliable predictor of ppo lung function*
  - But can overestimate the extent of functional loss
    - Collapsed, destroyed or emphysematous lung resected with little functional loss.
- 19 lung segment method
- 42 lung sub segment method

*Koegelenberg et al, Thorac Surg Clin 2008;18(1)19-29

19 lung segment method

ppo lung function

= Pre OP Lung function x 19-A/19

Or

= Pre OP Lung function x (19-B)-A/19-B

A= No. of seg to be resected

B= No. of nonfunctional seg

42 lung sub segment method

ppo lung function

= Pre OP Lung function x 42-A/42

A= no. of sub segments to be resected

Perfusion SPECT

- Used to be gold standard in assessing regional lung function
- Using iv technetium-99 micro aggregated albumin
- Isotope taken up by lung
- Images obtained by gamma camera

  (SPECT-single photon emission computed tomography)

- % of radioactivity correlated with lung function
- Perfusion scan offer a good prediction of ppo lung function
- No additional benefit of doing ventilation scan*

*Zeiher et al,Chest July 1995;108(1): 68-72

ppo FEV1 =

Pre OP FEV1 x Total lung vol radioactivity - radioactivity in ROI to be resected/ Total lung vol radioactivity

Anterior

Posterior

Quantitative CT

- After empirical scan delay of 20 s b/w contrast & scan
- CECT Chest during breath hold in full inspiration
- 5 mm slice reconstructed
- Dual thresholds of -500 and -910 H applied
- Quantitative assessment done with the help of software (Pulmo, Siemens)

- Areas excluded from functional lung volume
  - Emphysema (<-910 H)
  - Air space loss(>-500 H)
    - Tumor related
      - Tumor it self
      - Post obstructive atelectasis
    - Tumor not related (eg.TB sequelae)
      - Fibrosis
      - Atelectasis
- FLV (between -500 & -910 H)

Quantitative CT scan

Functional lung :

b/w -500 & -910 H (red),

Emphysema :

< -910H(black)

Air space loss :

> -500 H(white)

ppo FEV1= pre op FEV1 x TFLV-RFLV/TFLV

TFLV = Total functional lung volume

RFLV = regional functional lung volume (Area to be resected)

Dynamic Perfusion MRI

- CEMRI calculate regional pulmonary blood volume
  - Patients receive 3–5 ml of gadopentetate dimeglumine @ 3- 5 ml/s f/b 20 ml NS at same rate.
  - 25 images taken during 25 s breath hold in each acquisition.

- ROI delineated with the help of software in each slice of lung field. (RU,RM,RL,LU,LM,LL)
- Each patient 60 ROI
- Large vessels were excluded from ROI
  - ppo FEV1 = FEV1 x qMRI all lung field - qMRI ROI/qMRI all lung field

VRI: Vibration Response Imaging

- Developed in 2001 by Dr. Igal Kushnir (Israeli Pediatrician)
- It use basic principle of stethoscope and amplifies into an objective and quantitative digital imaging of regional lung function
- It use the natural vibration energy generated by the body.

Air flow in bronchial tree

Turbulent vibration

Vibration altered by structural/functional changes of lung

Picked up by VRI at various location over the thoracic cage

- Comce et al done study on 25 pts in Turkey
- They compared VRI v/s Quantitative perfusion scintigraphy
- Strong correlation of VRI with Q scan for
  - ppo FEV1% (r=0.87, p<0.001)
  - ppo FEV1 (r=0.90, pp<0.001)
  - ppo DLCO% (r=0.90, p<0.001)
- Correlation b/w VRI ppo FEV1 and Actual po FEV1
  - FEV1% (r=0.52, p=0.044)
  - FEV1 (r=0.79, p<0.001)

Respir Care 2011 Dec;56(12):1936-41

- VRI
  - Simple
  - Rapid
  - Cost effective
  - Noninvasive
  - Radiation free
  - Real time imaging
- But require validation in larger studies

- Ohno et al prospectively compare the utility of different modalities to assess ppo FEV1
- They compared ppo FEV1 with actul po FEV1 in 150 pts (87m & 63f) obtained by
  - Dynamic perfusion MRI
  - Quantitative CT
  - Qualitative CT (Seg Method)
  - Perfusion SPECT

AJR 2007;189:400-408

- Correlation of actual with predicted FEV1
  - Perfusion MRI (r=0.87, p<0.001)
  - Quantitative CT (r=0.88, p<0.001)
  - Qualitative CT (r=0.83, p<0.001)
  - Perfusion SPECT (r=0.83, p<0.001)
- Mean of difference and limits of agreement between actual and predicted FEV1 (mean ± 2SD)
  - Perfusion MRI (5.3% ± 11.8%)
  - Quantitative CT (5.0% ± 11.6%)
  - Qualitative CT (6.8% ± 14.4%)
  - Perfusion SPECT (5.1% ± 14.0%)

- All four version of ppo FEV1 correlate well with actual po FEV1.
- Quantitative CT and perfusion MRI had better correlation than qualitative CT and perfusion SPECT
- Low risk surgical candidates
  - Go for
    - qualitative CT (Seg Method)
- High risk surgical candidate
  - Go for
    - quantitative CT/perfusion MRI/ perfusion SPECT

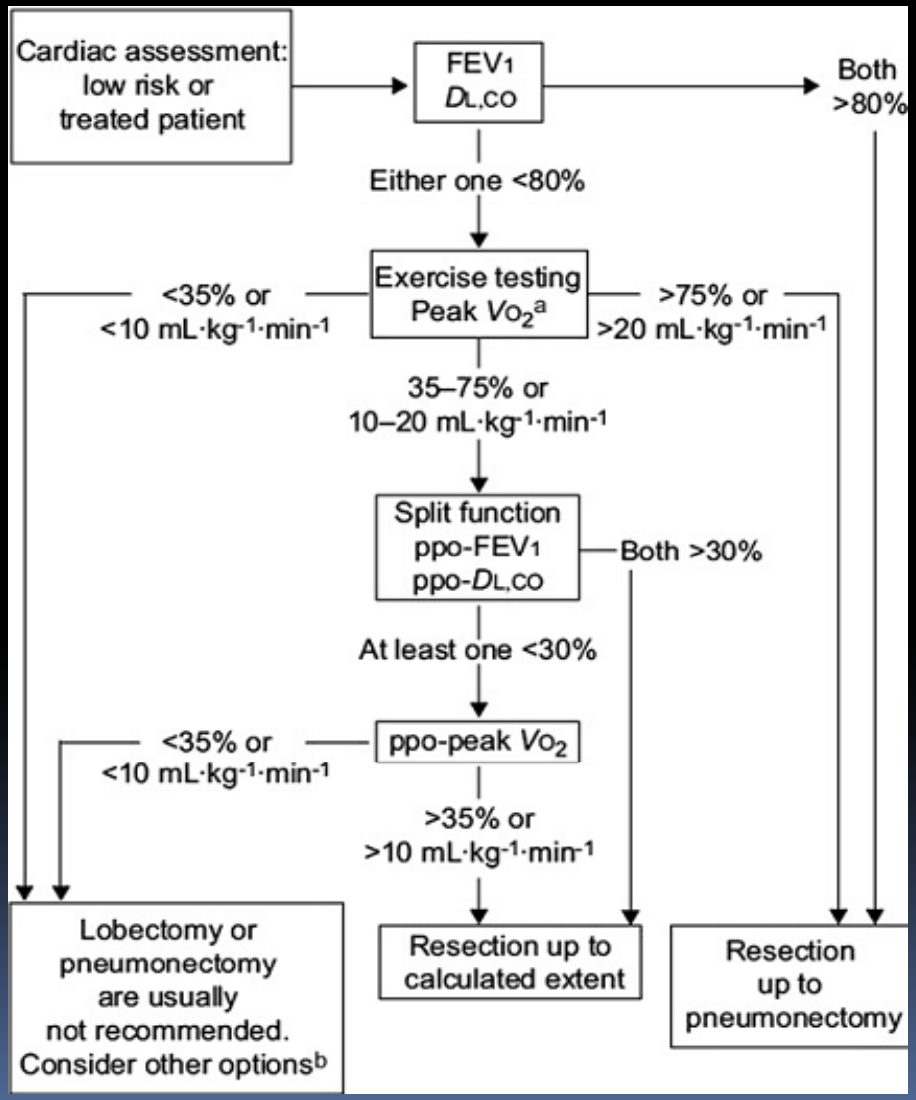
Conclusions

- Pt should not denied lung resection on the ground of age alone.
- Pt who are dependent, not candidate for Sx
- All smoker should be encouraged to quit smoking with appropriate treatment
- Patients with FEV1and DLCO >80% with no e/o SOB/ILD ⟶ Sx up to pneumonectomy without undergoing other tests
- FEV1 or DLCO <80% ⟶ CPET or Stair climbing

- Peak VO2 >20ml/kg/min or >75% → Sx up to pneumonectomy
- Peak VO2 <10ml/kg/min or < 35% → Sx not recommended
- Peak VO2 10-20ml/kg/min or 35-75% → ppo FEV1 & ppo DLCO by Regional lung function
- Regional lung function
  - Low Sx risk → qualitative CT (Seg Method)
  - High Sx risk → quantitative CT/perfusion MRI/ perfusion SPECT

- ppo FEV1 & ppo DLCO >30% → Sx up to calculated extend
- ppo FEV1 or ppo DLCO <30% → ppo peak VO_2 by Regional lung function
- ppo VO_2 >10ml/kg/min or >35% → Sx up calculated extend
- ppo VO_2 <10ml/kg/min or <35% → Sx not recommended

Algorithm: The Assessment of Pulmonary Resection



DLCO
ACCP- Pts having e/o DOE or ILD
ERS/ESTS- all pts

[a] If peak VO2 is not available, CPET can be replaced by stair climbing

Brunelli et al. ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients.
Eur Respir J 2009;34(1):22