Patient Presentation

- 50 yo male with **70 pack year** smoking history
- **Large R hilar lung mass** → biopsy proven **SCC** initially stage **IIIA**
- Whole body bone scan **negative**
Patient Presentation

• S/p neoadjuvant chemo radiation with carboplatin and Alimta (Pemetrexed), while on Alimta maintenance developed new local recurrence

• PET scan- new lung and adrenal lesions
  – Adrenal lesions biopsied: benign
### Preoperative PFTs

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Units</th>
<th>Pre Drug</th>
<th>Post Drug</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Actual</td>
<td>% Pred</td>
</tr>
<tr>
<td>FVC</td>
<td>L, btps</td>
<td>4.11</td>
<td>88</td>
</tr>
<tr>
<td>FEV.5</td>
<td>L, btps</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>FEV.5/FVC</td>
<td>%</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>FEV1</td>
<td>L, btps</td>
<td>2.17</td>
<td>59</td>
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<tr>
<td>FEV1/FVC</td>
<td>%</td>
<td>53</td>
<td>68</td>
</tr>
<tr>
<td>FEV3</td>
<td>L, btps</td>
<td>3.25</td>
<td></td>
</tr>
<tr>
<td>FEV3/FVC</td>
<td>%</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>FEF25-75%</td>
<td>L/s</td>
<td>0.88</td>
<td>27</td>
</tr>
<tr>
<td>MET</td>
<td>s</td>
<td>2.34</td>
<td></td>
</tr>
<tr>
<td>FEFmax</td>
<td>L/s</td>
<td>4.74</td>
<td>51</td>
</tr>
<tr>
<td>FEF25%</td>
<td>L/s</td>
<td>2.74</td>
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<tr>
<td>FEF50%</td>
<td>L/s</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>FEF75%</td>
<td>L/s</td>
<td>0.44</td>
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</tr>
<tr>
<td>TET</td>
<td>s</td>
<td>10.16</td>
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</tr>
<tr>
<td>MVV</td>
<td>L/min, btps</td>
<td>76.77</td>
<td>61</td>
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</table>
### Lung Volumes Plethysmography

<table>
<thead>
<tr>
<th>Units</th>
<th>Actual</th>
<th>% Pred</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC</td>
<td>6.66</td>
<td>98</td>
<td>6.81</td>
</tr>
<tr>
<td>FRC</td>
<td>3.87</td>
<td>114</td>
<td>3.39</td>
</tr>
<tr>
<td>RV</td>
<td>2.42</td>
<td>114</td>
<td>2.12</td>
</tr>
<tr>
<td>VC</td>
<td>4.25</td>
<td>91</td>
<td>4.69</td>
</tr>
<tr>
<td>IC</td>
<td>2.80</td>
<td>82</td>
<td>3.43</td>
</tr>
<tr>
<td>ERV</td>
<td>1.46</td>
<td>115</td>
<td>1.26</td>
</tr>
<tr>
<td>RV/TLC</td>
<td>36</td>
<td>116</td>
<td>31</td>
</tr>
<tr>
<td>RAW</td>
<td>cmH2O/Ls</td>
<td>313</td>
<td>1.34</td>
</tr>
<tr>
<td>VTG</td>
<td>4.14</td>
<td></td>
<td></td>
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<tr>
<td>SGaw</td>
<td>0.06</td>
<td>26</td>
<td>0.22</td>
</tr>
</tbody>
</table>

### Diffusion

<table>
<thead>
<tr>
<th>Units</th>
<th>Actual</th>
<th>% Pred</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dsb  ml/min/mmHg,stdp</td>
<td>20.10</td>
<td>63</td>
<td>31.82</td>
</tr>
<tr>
<td>DsbHb ml/min/mmHg,stdp</td>
<td>20.10</td>
<td>63</td>
<td>31.82</td>
</tr>
<tr>
<td>VAsb L,btps</td>
<td>5.42</td>
<td>81</td>
<td>6.66</td>
</tr>
<tr>
<td>D/VAsb ml/min/mmHg/L,stdp</td>
<td>3.71</td>
<td>78</td>
<td>4.78</td>
</tr>
<tr>
<td>D/VAsbHb ml/min/mmHg/L,stdp</td>
<td>3.71</td>
<td>78</td>
<td>4.78</td>
</tr>
<tr>
<td>Hgb g/dl</td>
<td>14.60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Operation

- Bronchoscopy
- Mediastinoscopy
- Lymph node biopsy with frozen section
- R VATS
- Pneumolysis
- R posterolateral thoracotomcy
- R pneumonectomy
- Mediastinal lymphadenectomy
- Intercostal muscle flap
Postoperative Course

- Extubated in OR
- Weaned from Cardizem gtt
- Epidural for pain management
- D/ced home POD # 5
1. Level 7 lymph node
   - 1/1 lymph node negative for metastatic carcinoma
2. Right lung
   - Adenocarcinoma, poorly differentiated, 6.0 cm, with necrosis
     3/3 parabronchial lymph nodes negative for metastatic carcinoma (0/3)
3. Level 10 lymph node
   - 1/1 lymph node negative for metastatic carcinoma
4. Level R4 lymph node
   - 12/12 lymph nodes negative for metastatic carcinoma
Preoperative Evaluation for Pulmonary Resection
Bronchopulmonary Segments

- 18-19
- Anatomic - each supplied by specific tertiary bronchus
- Each contributes approximately 5% of pulmonary function
History

- Graham and Singer reported first successful pneumonectomy for carcinoma of lung in 1933
  - 48 yr old obstetrician, outlived Graham
Considerations

• Incidence of pulmonary complications directly related to proximity of procedure to diaphragm
  – Pulmonary, esophageal, other thoracic procedures high risk for pulmonary complications

• FRC declines:
  – by 35% after thoracotomy and lung resection
  – by 30% after upper abdominal surgery

• FRC approaches closing volumes → atelectasis
Considerations Prior to Resection

• For lung cancer, tumor must be non small cell
• Absence of significant mediastinal or distant spread
Suggested Tests

• History and physical
• Labs: CBC, BMP, LFTs, PT/PTT, T&C
• Imaging studies
• Blood gases
• Pulmonary function testing
• +/- Quantitative V/Q
• +/- Exercise test
• High risk patients ➔ Echo/cardiac eval
**Routine PFTS** → FEV1 > 60%, DLCO > 60%

FEV1 < 60%, DLCO < 60%

**Quantitative Lung Scan** → PPO-FEV1 > 40%
   → PPO-DLCO > 40%

PPO-FEV1 < 40% / PPO-DLCO < 40%

**EXERCISE TESTING** → VO2max > 15ml/kg/min

VO2max < 15ml/kg/min → Other Options prior to attempting Surgery

**FIGURE 1.** A schematic representation of a stepwise approach to preoperative evaluation prior to lung resection surgery.
Spirometry

- Volume of air inhaled and exhaled plotted against time during series of ventilator maneuvers
- Normal vs abnormal pattern of respiratory reserve
  - Obstructive vs restrictive disorders
- FEV$_1$ is the **primary spirometric value** for preop assessment
  - Correlates with degree of respiratory impairment in COPD, provides indirect measure of pulmonary reserve
Two have predictive value for postoperative complications:

- $\text{FEV}_1$
- DLCO
Volume (L)

Time (sec)

Forced expiratory volume in 1 second (FEV₁)

Inspiratory reserve volume (IRV)

Inspiratory capacity (IC)

Forced vital capacity (FVC)

Tidal volume (TV)

Expiratory reserve volume (RV)

Functional residual capacity (FRC)

Residual volume (RV)

Total lung capacity (TLC)
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Forced expiratory volume in 1 second; volume of air forcibly expired from a maximum inspiratory effort in the first second (L)</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC ratio</td>
<td>Ratio of FEV&lt;sub&gt;1&lt;/sub&gt; to FVC</td>
</tr>
<tr>
<td>FRC</td>
<td>Functional residual capacity; the volume of air in the lungs following a tidal volume exhalation = ERV + RV (L)</td>
</tr>
<tr>
<td>FVC</td>
<td>Forced vital capacity; the total volume that can be forcefully expired from a maximum inspiratory effort (L)</td>
</tr>
<tr>
<td>DLCO</td>
<td>Diffusing capacity of the lung; the capacity of the lungs to transfer carbon monoxide (mL/min/mm Hg)</td>
</tr>
<tr>
<td>RV</td>
<td>Residual volume; the volume of air that remains in the lungs after maximal exhalation (L)</td>
</tr>
<tr>
<td>TLC</td>
<td>Total lung capacity; the total volume of air in the lungs at full inhalation; the sum of all volume compartments (IC + FRC or IRV + VT + ERV + RV) (L)</td>
</tr>
<tr>
<td>TV or VT</td>
<td>Tidal volume; the volume of air that is inhaled or exhaled with each breath when a person is breathing at rest (L)</td>
</tr>
<tr>
<td>VC</td>
<td>Vital capacity; the maximum volume of air that can be exhaled starting from maximum inspiration, TLC (L) can be measured either as slow vital capacity (SVC) or forced vital capacity (FVC)</td>
</tr>
</tbody>
</table>
FEV1/FVC

- Forced expiratory volume in 1 second (airflow) – 4.0 L
- Forced vital capacity (lung volume) – 5.0 L
- FEV1/FVC = 80%
Forced Expiratory Flow 25-75% 
(FEF$_{25-75}$)

- Mean forced expiratory flow during middle half of FVC
- "Midexpiratory phase"
- Measure in L/sec
- Variable
Diffusing Capacity of the Lungs for CO (DLCO)

• Definition: Ability of the lungs to transfer gas from inhaled air in the alveoli to RBCs in pulmonary capillaries
  – Reflects alveolar membrane integrity and pulmonary capillary blood flow
  – Decreases in emphysema, increases in asthma

• Most important predictor of mortality and postop complications
DLCO

- Normal range: 75-80%
- According to AMA, DLCO <45% predicted implies severe respiratory impairment
Blood Gases

• CO2 retention due to obstructive defect (PCO2 > 45mm Hg) - relative contraindication to resection

• Hypoxemia not a consideration
Prediction of Postoperative Lung Function (PPO)

• Ppo lung function an important predictor of operative risk

• Two approaches:
  
  – **Simple calculation** (for lobectomies)
    • Ppo-FEV1=FEV1[1-(# segments resected x 0.0526)]

  – **Regional assessment of lung function** (for pneumonectomies)
    • Qualitative V/Q scan is current standard
    • Reported as a % function contributed by 6 regions
    • Ppo value=baseline value x (100 - % ventilation or perfusion in the region of planned resection/100)
Ventilation-Perfusion Scans

- Demonstrates contribution of lobes/segments to ventilation and perfusion
- Allows calculation of functional remaining parenchyma/predicted post-resection FEV1 value
Traditionally, a ppo-FEV1 or DLCO of <40% categorized as high risk.

But lung volume reduction and MIS techniques have reduced the lower ppo limit to 30% in select cases.
Current Guidelines

• British Thoracic Society (BTS) :
  – **FEV₁ > 2L** (or >80% predicted) tolerate pneumonectomy
  – **FEV₁ > 1.5L** tolerate lobectomy
  – **FEV₁ = 0.6L** tolerate wedge/segment resection
Split Lung Function Testing

- Need to perform if \textbf{FEV1} < 2L
- Lung with tumor burden may not contribute significantly to total FEV1 volume \textbf{or} it may be the better lung
- Quantitative \textbf{V/Q scan} performed
Split Lung Function Testing

• For example: FEV1= 1.5L R lung perfusion 30%, L lung 70%
  – Tumor in right lung
  – Following R pneumonectomy, 1.5 x 0.7= 1.05L
  – Minimal accepted ppo FEV1 = 800mL
Cardiopulmonary Exercise Testing

• Stresses the entire cardio-pulmonary and O2 delivery system

• Maximal oxygen uptake
  – >20mL/kg/min
    • No increased risk for complications or death
  – <15mL/kg/min
    • Increased risk
  – <10mL/kg/min (35% predicted)
    • Very high risk
Exercise Tolerance

- Historically, patients considered suitable for
  - lobectomy if able to climb three flights of stairs
  - pneumonectomy if able to climb five flights
<table>
<thead>
<tr>
<th>Higher Risk</th>
<th>Lower Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt;70</td>
<td>FEV₁ &gt;2 L for pneumonectomy; &gt;1 L for lobectomy; &gt;0.6 L for segmentectomy</td>
</tr>
<tr>
<td>Higher extent of resection</td>
<td>Predicted postoperative FEV₁ &gt;30–40% of predicted (pneumonectomy &gt; lobectomy &gt; wedge resection)</td>
</tr>
<tr>
<td>Poor exercise performance</td>
<td>Stair climbing &gt;5 flights for pneumonectomy; 3 flights for lobectomy</td>
</tr>
<tr>
<td>Low predicted postoperative FEV₁</td>
<td>Cycle ergometry &gt;83 W</td>
</tr>
<tr>
<td>Low predicted postoperative DLCO</td>
<td>Predicted postoperative DLCO &gt;40% of predicted</td>
</tr>
<tr>
<td>High PCO₂ (controversial)</td>
<td>Maximal oxygen uptake &gt;15–20 mL/kg/min</td>
</tr>
</tbody>
</table>
**Figure 1.** A schematic representation of a stepwise approach to preoperative evaluation prior to lung resection surgery.
Postoperative Complications

• Cardiopulmonary
  – Hypercapnia
  – Prolonged mechanical ventilation (>48 hrs)
  – Arrhythmias (atrial fibrillation)
  – Pneumonia
  – Pulmonary emboli
  – Myocardial infarction
  – Atelectasis requiring bronchoscopy
Principles of Postoperative Care

• Early extubation!! Early mobility!!
• Restrict fluid administration
  – Improve pulmonary compliance and overall lung function
• Pain control- epidural catheter
  – Stay away from narcotics
• Chest tube to minimum suction
• Reverse Trendelenburg to reduce risk of aspiration
• Perioperative beta blockers to reduce risk of atrial fibrillation
• DVT/PE prophylaxis
Summary

- 2 tests with the best predictive value for postoperative morbidity/mortality
  - **FEV1** and **DLCO**

- **FEV1 >2L**: proceed with pneumonectomy
- **FEV1 >1L**: proceed with lobectomy
- Need **ppo-FEV1 >0.8** (40% predicted)
- Need **ppo-DLCO >11-12 mL/min/mmHgCO** (40% predicted)
Summary

• If borderline values → V/Q scan, recalculate
• If still unsure, exercise testing
  – Need ppo-VO2Max > 10 ml/kg/min
• Need ppo-FVC > 1.5L
• No resection if pCO2 > 45 or pO2 < 50
References

Pulmonary function testing (cont.)

- Spirometry
  - performed when the patient is clinically stable and receiving maximal bronchodilator therapy
  - Risky for Pneumonectomy
    - FEV1 < 60% of the predicted value or < 2 liters
    - DLCO < 60% of the predicted value
    - MVV < 50% of the predicted value
  - Safe lower limit for Pneumonectomy
    - FEV1 > 80% of the predicted value or > 2 liters
  - Safe lower limit for Lobectomy
    - FEV1 > 1.5 litres or > 60% of the predicted value
### Pulmonary function testing (cont.)

Table 2. Criteria for estimating the post-operative risk in lung resective surgery

<table>
<thead>
<tr>
<th>Lung Function Test</th>
<th>Parameters</th>
<th>Increased Risk</th>
<th>High risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spirometry</td>
<td>FEV₁</td>
<td>&lt; 50% of the predicted value or &lt; 2 Litres</td>
<td>&lt; 1 Litre</td>
</tr>
<tr>
<td></td>
<td>MVV</td>
<td></td>
<td>&lt; 50% of the predicted value</td>
</tr>
<tr>
<td>Diffusion Capacity</td>
<td>DL₅₀</td>
<td>&lt; 60% of the predicted value</td>
<td></td>
</tr>
<tr>
<td>Blood Gas Analysis</td>
<td>SaO₂</td>
<td>&lt; 90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PaCO₂</td>
<td>&gt; 45 mm Hg</td>
<td></td>
</tr>
</tbody>
</table>

At-risk pt require a closer diagnostic examination to estimate the likely post-resection pulmonary reserve.
Split lung function studies (cont.)

- **FEV1ppo > 40%, DLco ppo > 40%**
  - Widely accepted as a predictor of average risk for complications
- **FEV1ppo < 40%, DLco ppo < 40%**
  - High risk of perioperative complications including death
  - FEV1ppo <1L → sputum retention
  - FEV1ppo <0.8L → preclude resection, dependent on a ventilator
- **Post-operative lung function shows borderline values** → Cardiopulmonary exercise test
Assessment of p’t candidate for lung resection

Pulmonary Function Testing

FEV₁ < 2 L or < 60% of predicted
DLCO < 60% of predicted

Split Lung Function Studies

FEV₁ ppo < 40%
DLCO ppo < 40%

Cardiopulmonary Exercise Test

V’O₂max < 15 ml/Kg/min < 50-60% of predicted

Other Procedures

FEV₁ > 2 L or > 60% of predicted
DLCO > 60% of predicted

FEV₁ ppo > 40%
DLCO ppo > 40%

V’O₂max > 15 ml/Kg/min > 50-60% of predicted

Surgical Procedures
• Fitness for surgery based on:
  – Age
  – Cardiovascular fitness
  – Nutrition
  – Performance status
  – Respiratory function