Why we breathe

• Inhaling brings air – (21% oxygen) through airways into to the air sacs ("alveoli")
• Oxygen crosses from alveoli to attach to "hemoglobin" in the blood
• Carbon dioxide floats off hemoglobin into the alveoli and out the airways
• Heart can then pump blood with oxygenated hemoglobin to vital organs
Measuring breath

• Lung function tests
  – Oxygenation – how much oxygen is in blood
  – Air movement – “PFTs”
  – Exercise capacity

• Use of lung function tests
  – Diagnosis
  – Prognosis
Measuring oxygenation:
Pulse oximetry:

% saturation: oxygenated hemoglobin
  oxygenated + deoxygenated hemoglobin

Invasive alternative: Arterial blood gas
drawing blood to measure actual concentration of dissolved
  oxygen and carbon dioxide in the blood

http://www.howequipmentworks.com/pulse_oximeter/
Measuring Air Movement:
Pulmonary Function Tests: “PFTs”

• Spirometry
• Lung volumes
  – Plethysmography or helium dilution
• Diffusion capacity
Considerations for PFTs

• Values compared to people with no lung disease
• Based on age and height
• Use arm span if height is unreliable
• Normal values less useful at height extremes
Spirometry: measuring breath

• Take a deep breath in and blow out! (keep going keep going....)
• Measures how air **moves** in and out of lungs
• Equipment fairly available so most commonly done PFT

By Joe Mabel, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=7274654
ON THE
CAPACITY OF THE LUNGS,
AND ON THE
RESPIRATORY FUNCTIONS,
WITH A VIEW OF ESTABLISHING A PRECISE AND EASY METHOD
OF DETECTING DISEASE BY THE SPIROMETER.

BY JOHN HUTCHINSON, Surgeon.

Communicated by George Cursham, M.D.,
One of the Secretaries of the Society.

Received January 22nd—Read April 28th, 1846.

- John Hutchinson measured "exhaled vital capacity" in 2,130 individuals
- Correlated the vital capacity to age and height

PMCID: PMC2116876 http://pulse.embs.org/january-2014/spirometry-a-historical-gallery/
Richard Johnston and Max Valentinuzzi | December 6, 2013
Spirometry key numbers

- FVC: forced vital capacity
- FEV1: Forced expiratory volume in 1 second
- FEV1/FVC: ratio of exhaled air in first second to total exhaled air
- Slow exhalation = low FEV1/FVC
- Suggests “obstruction”

Spirometry images

Flow-volume loops

Volume-time curve

Total volume of air

Exhale

Inhale

https://www.spirometry.guru/spirometry.html
Spirometry example: fibrosis

Severe RESTRICTION: total volume is low, exhalation is fast. FEV1/FVC is HIGH

Exhalation complete in 3 seconds
Spirometry example: COPD

Severe OBSTRUCTION: total volume is normal or high.
Exhalation is slow
PFTs: Measuring lung volume

• Two methods:
  – Plethysmograph “body box”: change in pressure in a closed system allows calculation of change in volume
  – Helium dilution: dilutes known volume of helium, into the air in lungs
  – If air can’t get out of lungs, helium and body box will give different values

• Key values:
  – TLC: total lung capacity: All the air in lungs
  – VC: vital capacity: All air breathed out
  – RV: residual volume: All air in lungs after exhale
Lung volumes: diagram

Diffusing capacity: measuring oxygen intake

Measures absorption of carbon monoxide to estimate oxygen absorption

Breathe in gas mix: 21.0% O2, 0.3 % CO, 10.0% helium – to measure volume, rest N2

Calculates CO absorbed (by hemoglobin) in lung in a single breath

Results are very variable test to test and lab to lab
Diffusing capacity values

**DLCO** - total CO absorbed

**DLCO Hgb** - corrected for hemoglobin
- less hemoglobin, less CO absorbed

**V_A**: alveolar volume (measured using the helium)

**DL/ V_A** Absorption per liter lung volume
- smaller breath, less CO absorbed

Other lung function tests

• 6 minute walk test
  – Careful measurement of distance walked in 6 minutes
  – Functional outcome
  – Used for pulmonary hypertension evaluations

• CPET
  – measures exercise capacity very precisely
  – distinguished heart problems from lungs
  – Useful for general shortness of breath
  – very invasive
Use of PFTs: diagnosis

• American Thoracic Society and European Respiratory Society officially define disease
• “Obstructive” lung disease: low FEV1/FVC
• “Restrictive” lung disease: low TLC
• Often used to determine disability benefits
Disability parking placard requirements

• “Restricted by lung disease to such a degree that your forced (respiratory) expiratory volume (FEV) in one second, when measured by spirometry, is less than one (1) liter.”

  or

• Use portable oxygen.

• Arterial oxygen tension is less than 60 mm/hg on room air at rest. (uses an arterial blood gas value)
PFTs for prognosis

- Change in FVC currently used as outcome measurement in IPF trials
  - Easy to do
  - Reproducible
  - Has clinical significance
- 10% change currently seen as significant
- Best predictor we have for disease progression
- Hotly debated
PFTs in ILD: Prognosis

• FVC and DLCO assess severity of disease
• “GAP” score
• https://www.acponline.org/journals/annals/extras/gap/
• Gender, Age, Physiology (PFT)
  – uses % predicted FVC and DLCO
• Calculates stage and predicted mortality

GAP risk assessment for IPF

Stage I
- Female
- Age <60
- FVC >75%
- DLCO >55%

- GAP index: 0 (1 if male)
- One year mortality: 5.6

Stage III
- Male
- Age >65
- FVC <55%
- Unable to perform DLCO

- GAP index 8 (7 if DLCO<35%)
- One year mortality: 39.2

Typical FVC falls 150-200 mL/year in IPF.

Fall in FVC over time in placebo arm of drug trials.

- Pirfenidone $^1 = -0.13$
- Imatinib $^2 = -0.15$
- IFN $^3 = -0.16$
- Pirfenidone $^4 = -0.16$
- Etanercept $^5 = -0.2$
- Bosentan $^6 = -0.21$
- NAC $^7 = -0.19$

Brett Ley; Harold R. Collard; Talmadge E. King Jr.; Am J Respir Crit Care Med 2011, 183, 431-440
Stable FVC suggests better survival

Recent changes in PFTs may be more significant than specific values

Brett Ley; Harold R. Collard; Talmadge E. King Jr.; Am J Respir Crit Care Med 2011, 183, 431-440
# Following PFTs: an example

<table>
<thead>
<tr>
<th>Date</th>
<th>DLCO/2</th>
<th>TLC</th>
<th>FVC</th>
<th>FEV1</th>
<th>DLCOunc</th>
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<td>12.55</td>
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<td>2.04</td>
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<tr>
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<td>2.00</td>
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<td>3.32</td>
<td>2.07</td>
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<td>8.79</td>
</tr>
<tr>
<td>11/12/14</td>
<td>4.20</td>
<td>3.08</td>
<td>1.82</td>
<td>1.58</td>
<td>8.40</td>
</tr>
<tr>
<td>3/5/15</td>
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<td>2.96</td>
<td>1.81</td>
<td>1.60</td>
<td>7.80</td>
</tr>
<tr>
<td>6/17/15</td>
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<td>2.72</td>
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<td>1.54</td>
<td>1.44</td>
<td>4.15</td>
</tr>
</tbody>
</table>
Ventilatory Capacities in Liters

PFT results

- DLCO/2
- TLC
- FVC
- FEV1
Summary points

• PFTs are used to diagnose lung
  – Low TLC defines restrictive disease
  – Low FEV1/FVC defines obstructive disease
• Changes in FVC and DLCO relevant to ILD
• Fall in FVC and DLCO suggest worsening disease
• Stabilizing FVC used to show drug efficacy
Online resources

https://www.ildcollaborative.org/resources/pulmonary-function-testing

https://www.pulmonaryfibrosis.org/life-with-pf/pff-educational-resources/webinars/understanding-pulmonary-function-tests

https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/pulmonary-function-tests
Pulse oximeter: measures absorption of light by hemoglobin

More hemoglobin, more absorption

Wider blood vessel, more absorption
Light sources for red and infrared distinguish oxygenated and deoxygenated hemoglobin

Deoxygenated hemoglobin absorbs red light
Oxygenated hemoglobin absorbs infrared light
Pulsatile flow allows calculation of light absorption by artery only.

Amount of blood varies over time in artery.

Oximeter subtracts out the stable absorption. Reports only pulsatile absorption!