Pulmonary Function Testing

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June 17, 2020

Boston PF Support Group

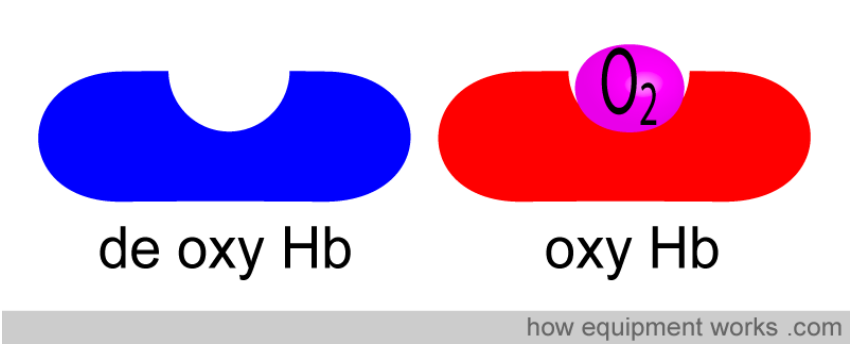
Why we breathe

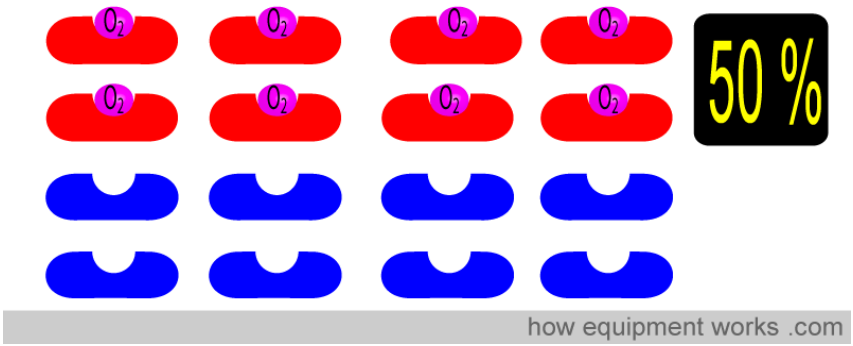
- Inhaling brings air – (21% oxygen) through airways into to the air sacs (“alveoli”)
- Oxygen crosses from alevoli to attach to “hemoglobin” in the blood
- Carbon dioxide floats off hemoglobin into the alveoli and out the airways
- Heart can then pump blood with oxygenated hemoglobin to vital organs

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: <u>oxygenated hemoglobin</u>
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

ON THE

CAPACITY OF THE LUNGS,

AND ON THE

RESPIRATORY FUNCTIONS,

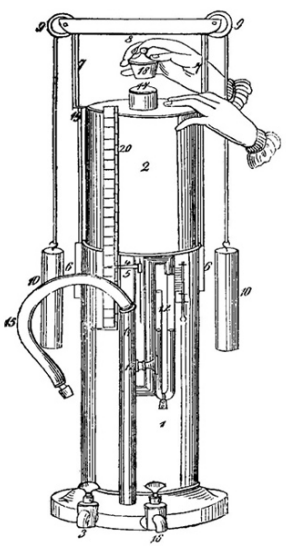
WITH A VIEW OF ESTABLISHING A PRECISE AND EASY METHOD OF DETECTING DISEASE BY THE SPIROMETER.

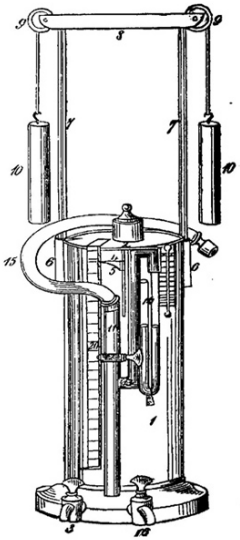
By JOHN HUTCHINSON, Surgeon.

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

Med Chir Trans. 1846; 29: 137–252.
PMCID: PMC2116876 http://pulse.embs.org/january-2014/spirometry-a-historical-gallery/
Richard Johnston and Max Valentinuzzi | December 6, 2013

Spirometry key numbers

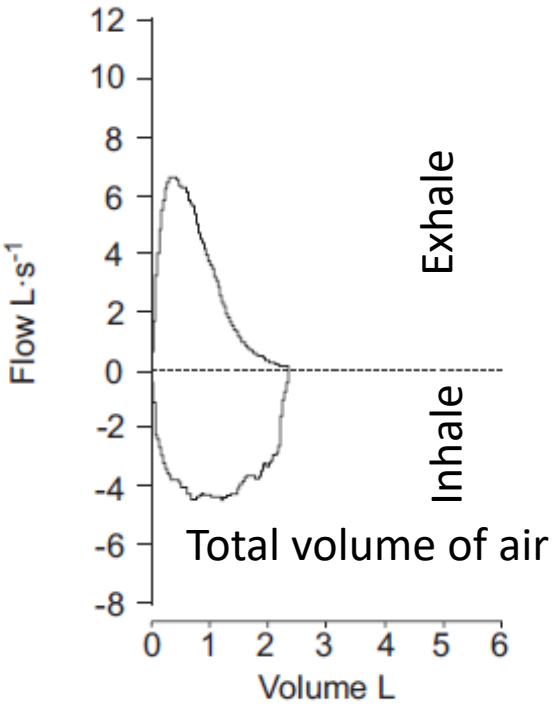
- FVC: forced vital capacity
- FEV1: Forced expiratory volume in 1 second

- FEV1/FVC: ratio of exhaled air in first second to total exhaled air
- Slow exhalation = low FEV1/FVC
- Suggests “obstruction”

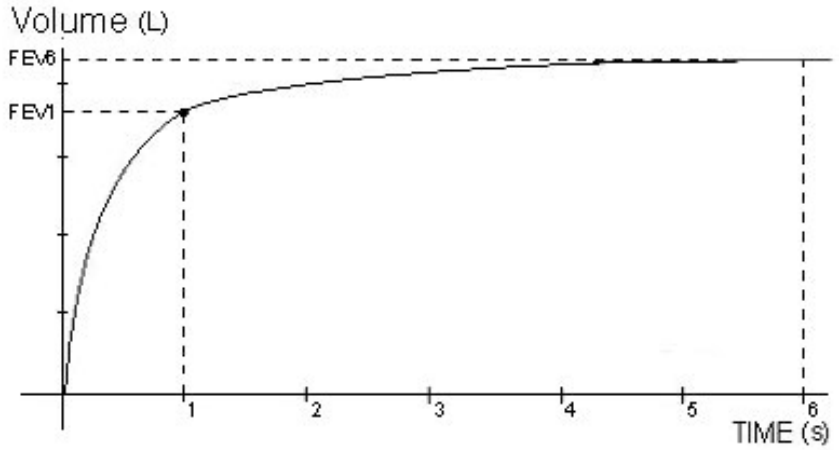
*Developed in part in attempt to follow coal miners for the development of occupational lung disease – pushed by NIOSH to produce standards.
http://news.thoracic.org/john-l-hankinson-lynchpin-of-spirometry-standardization-and-reference-values/

Spirometry images

Flow-volume loops

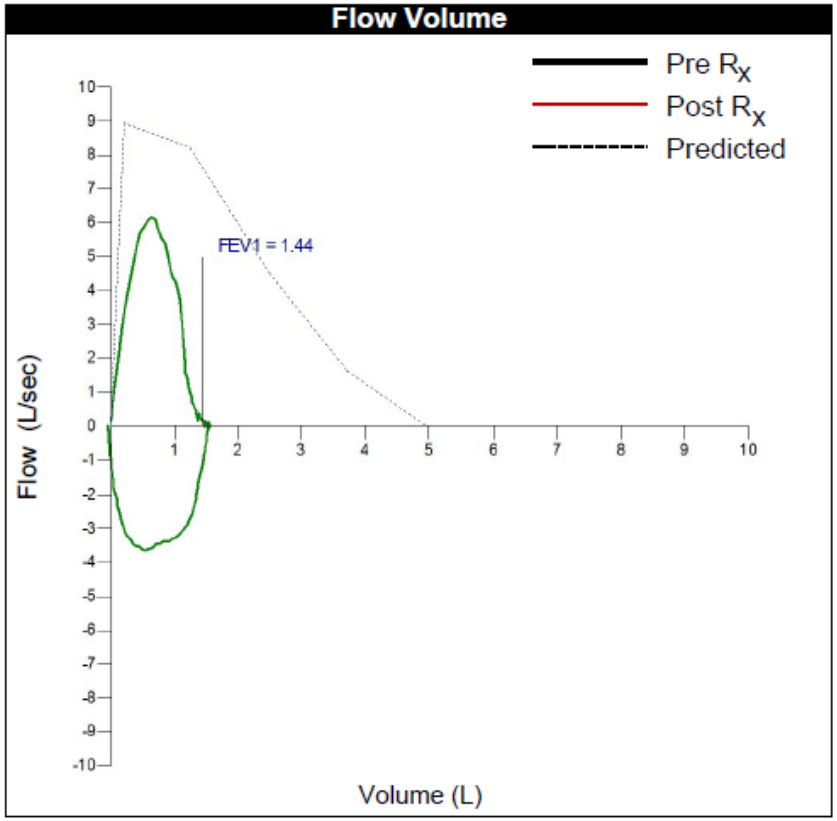


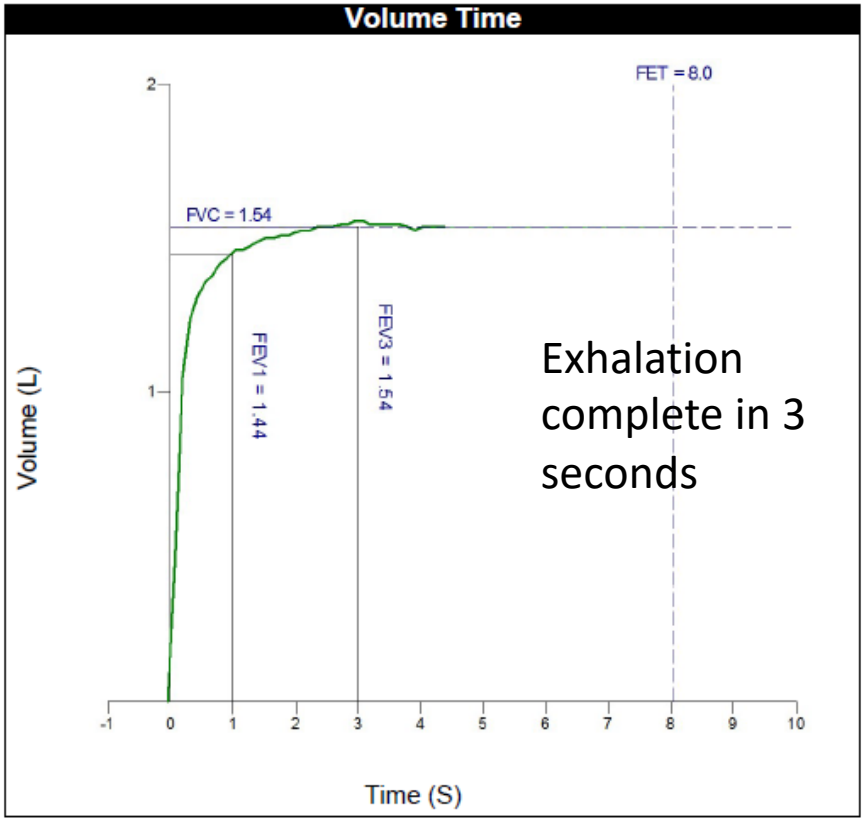
Volume-time curve



https://www.spirometry.guru/spirometry.html

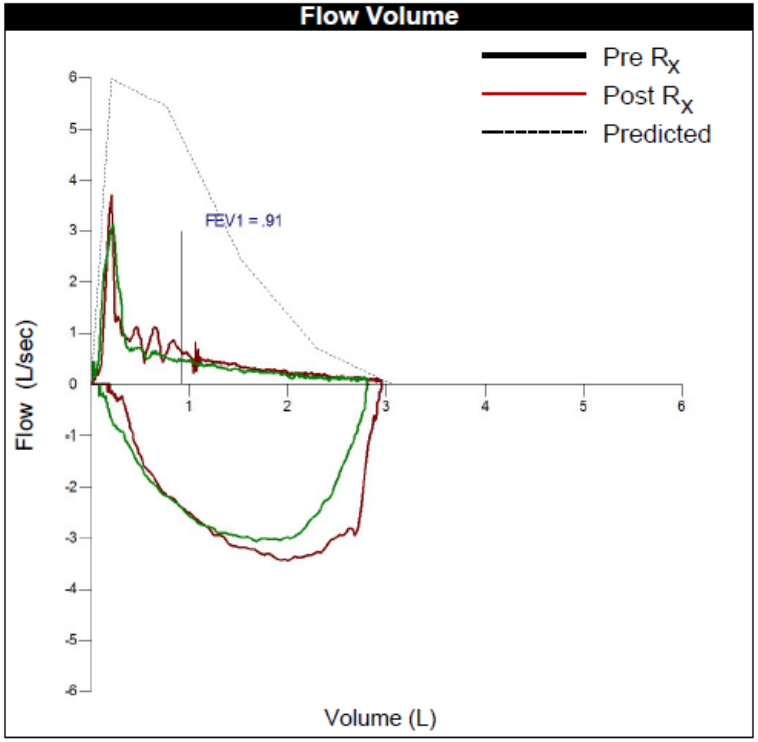
Spirometry example: fibrosis

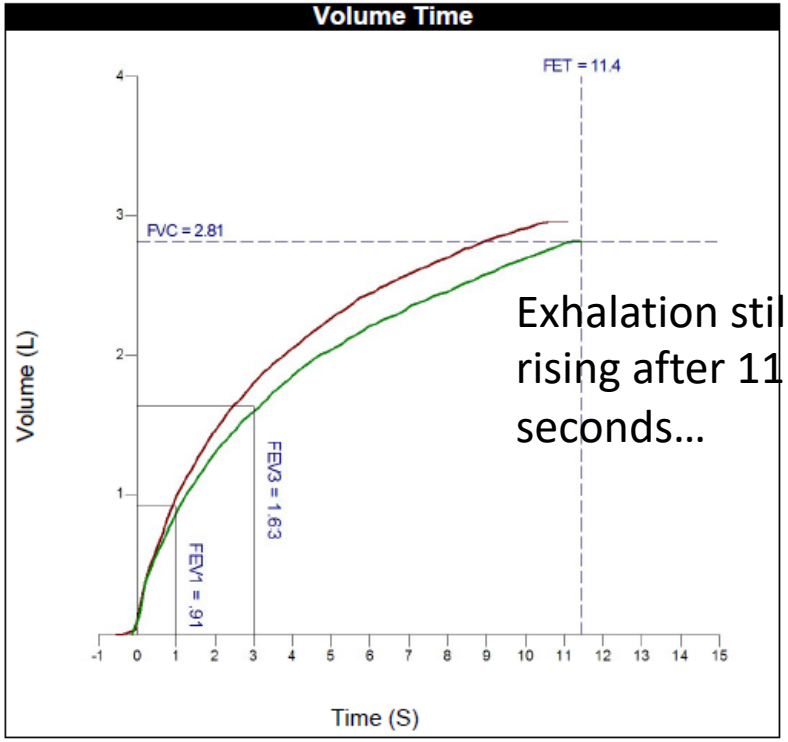




Severe RESTRICTION: total volume is low, exhalation is fast. FEV1/FVC is HIGH

Spirometry example: COPD





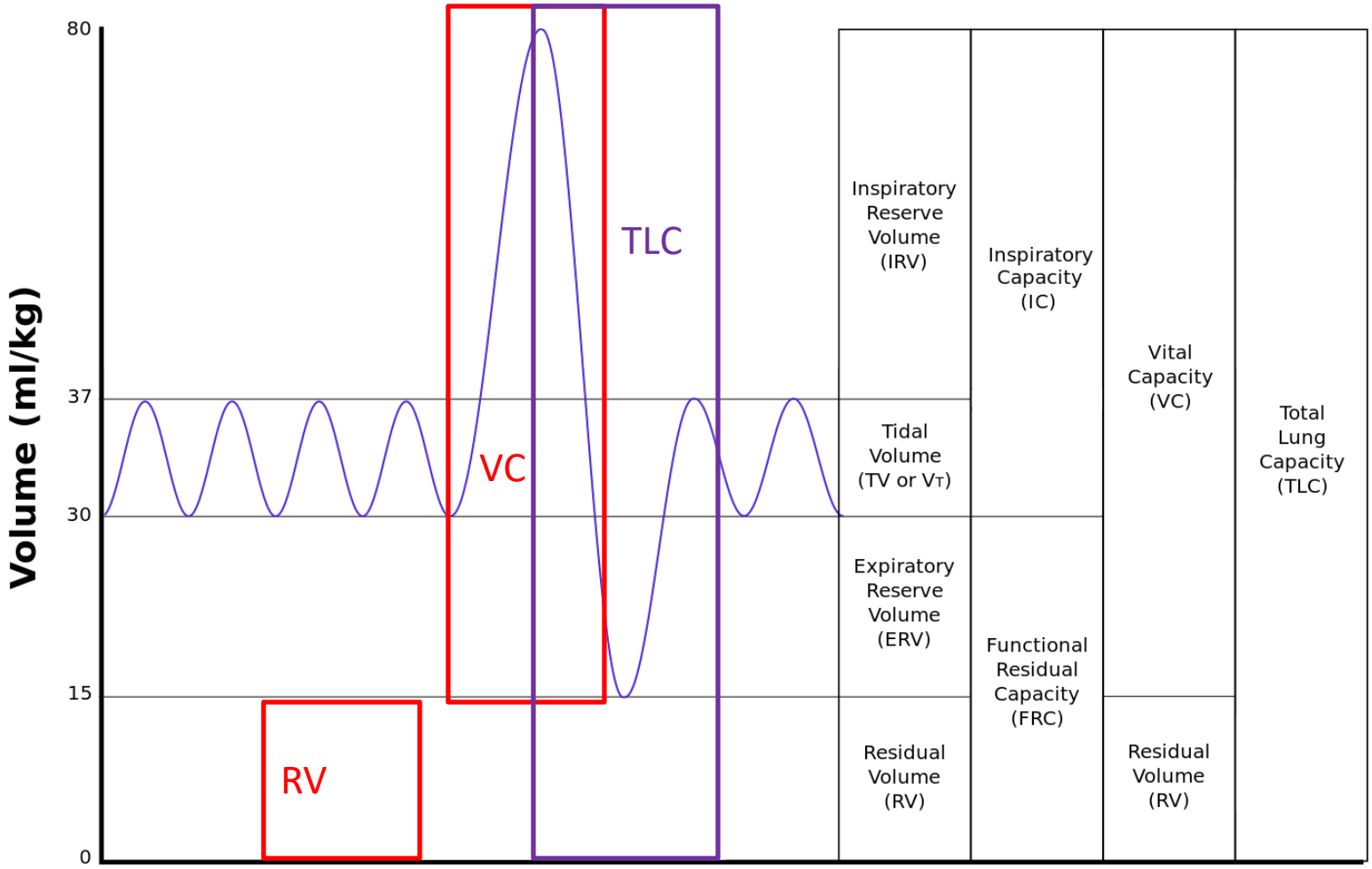
Exhalation still rising after 11 seconds…

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



https://en.wikipedia.org/wiki/File:Lungvolumes_Updated.png

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

https://media.lanecc.edu/users/driscolln/RT127/Softchalk/Diffusion_Softchalk/Diffusion_Lesson_print.html

Diffusing capacity values

DLCO - total CO absorbed

DLCO Hgb -corrected for hemoglobin

-less hemoglobin, less CO absorbed

$\mathbf{V_A}$: alveolar volume (measured using the helium)

DL/ $\mathbf{V_A}$ Absorption per liter lung volume

-smaller breath, less CO absorbed

https://media.lanecc.edu/users/driscolln/RT127/Softchalk/Diffusion_Softchalk/Diffusion_Lesson_print.html

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 sed 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

(Ann Intern Med. 2012;156:684-91).

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

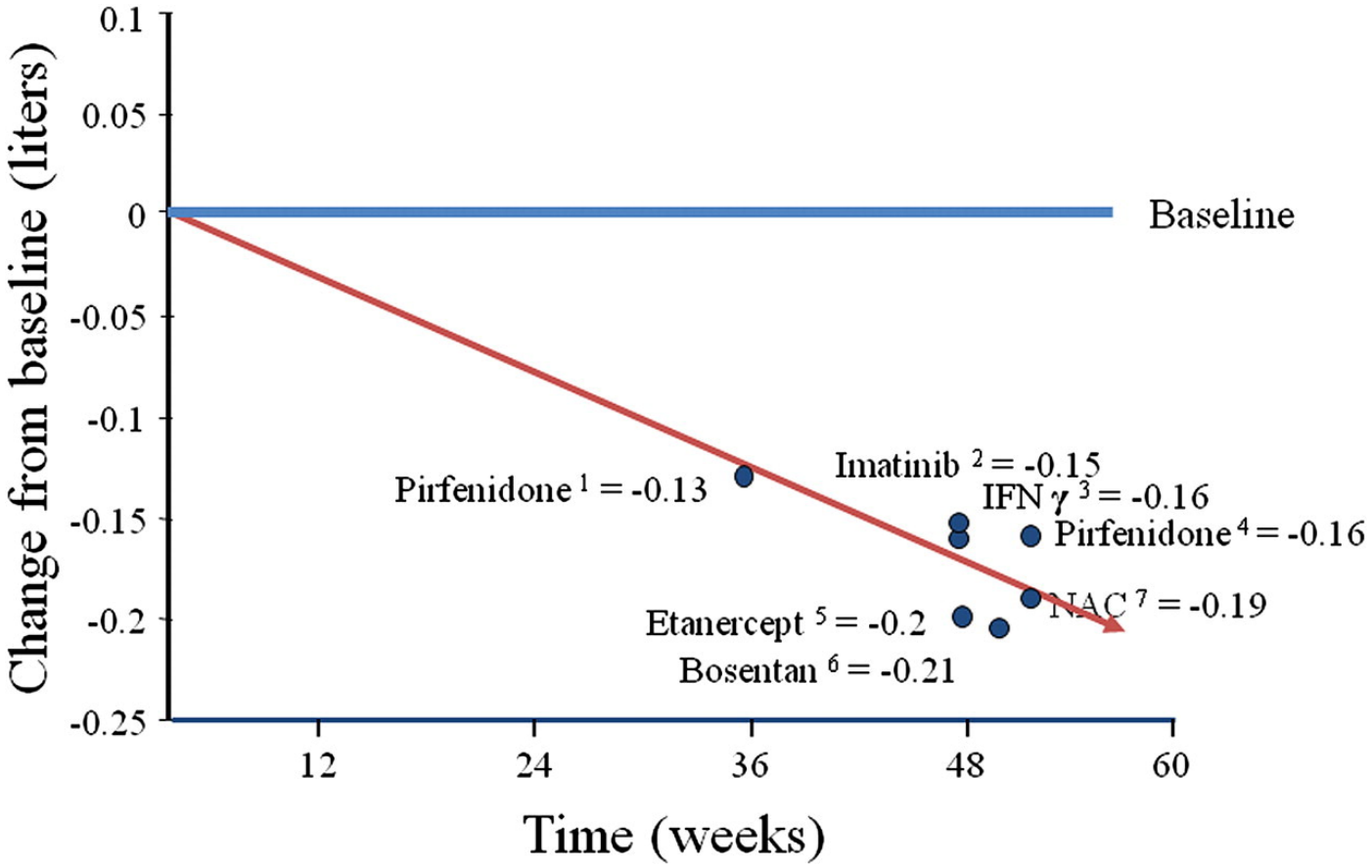
GAP index 8 (7 if DLCO<35%)

One year mortality: 39.2

Ann Intern Med. 2012;156:684-91).

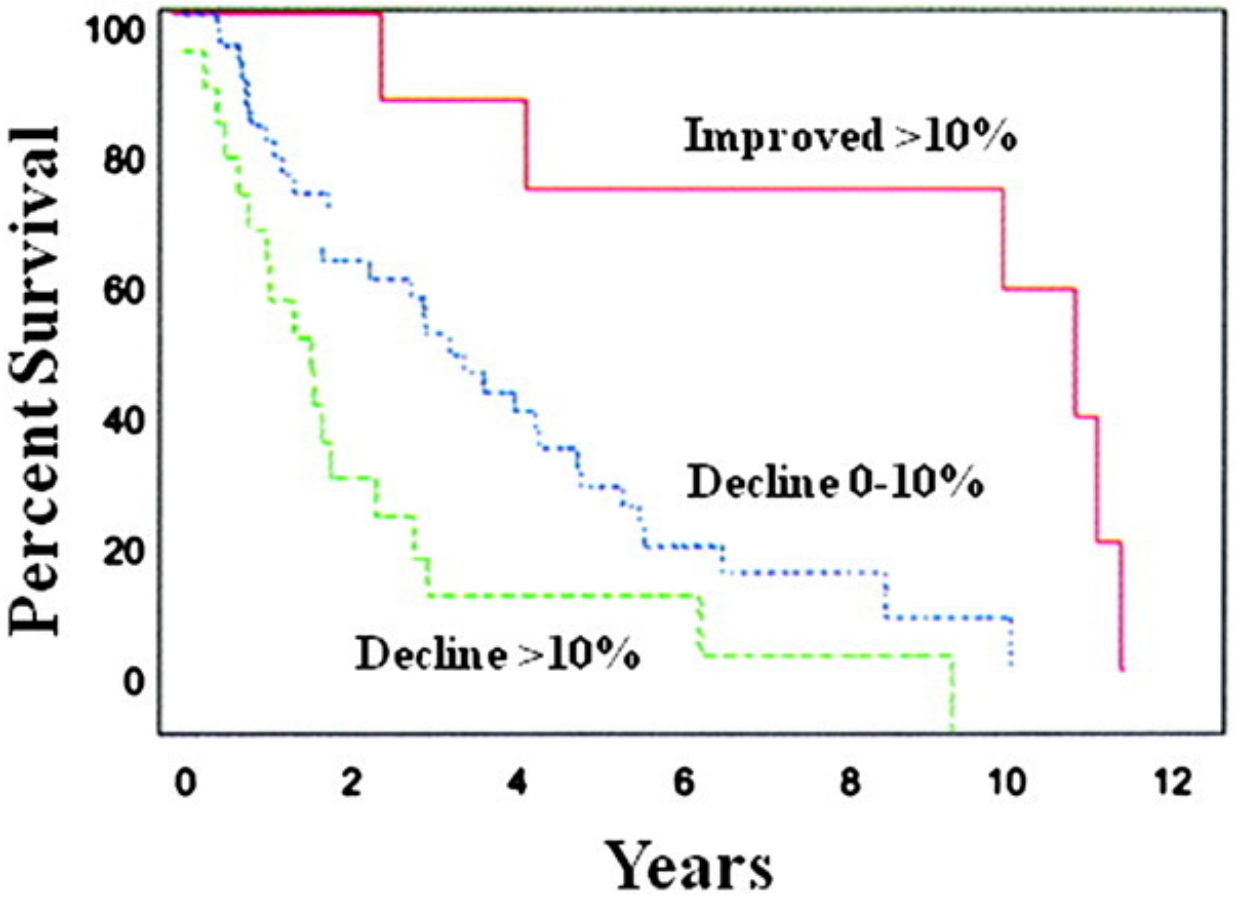
Typical FVC falls 150- 200 mL/year in IPF

Fall in FVC over time in placebo arm of drug trials



Brett Ley; Harold R. Collard; Talmadge E. King Jr.; *Am J Respir Crit Care Med* **2011,** 183, 431-440

Stable FVC suggests better survival



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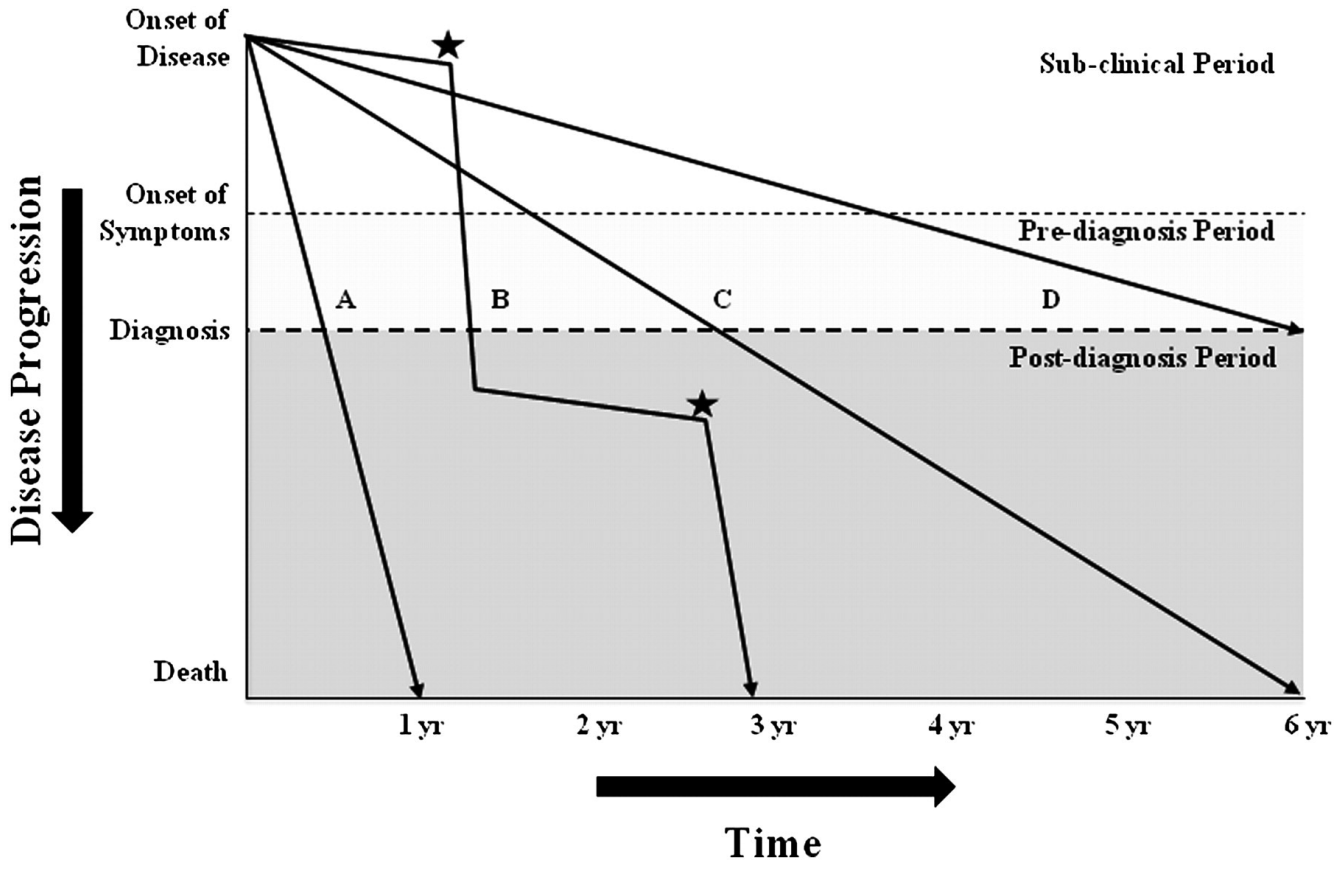
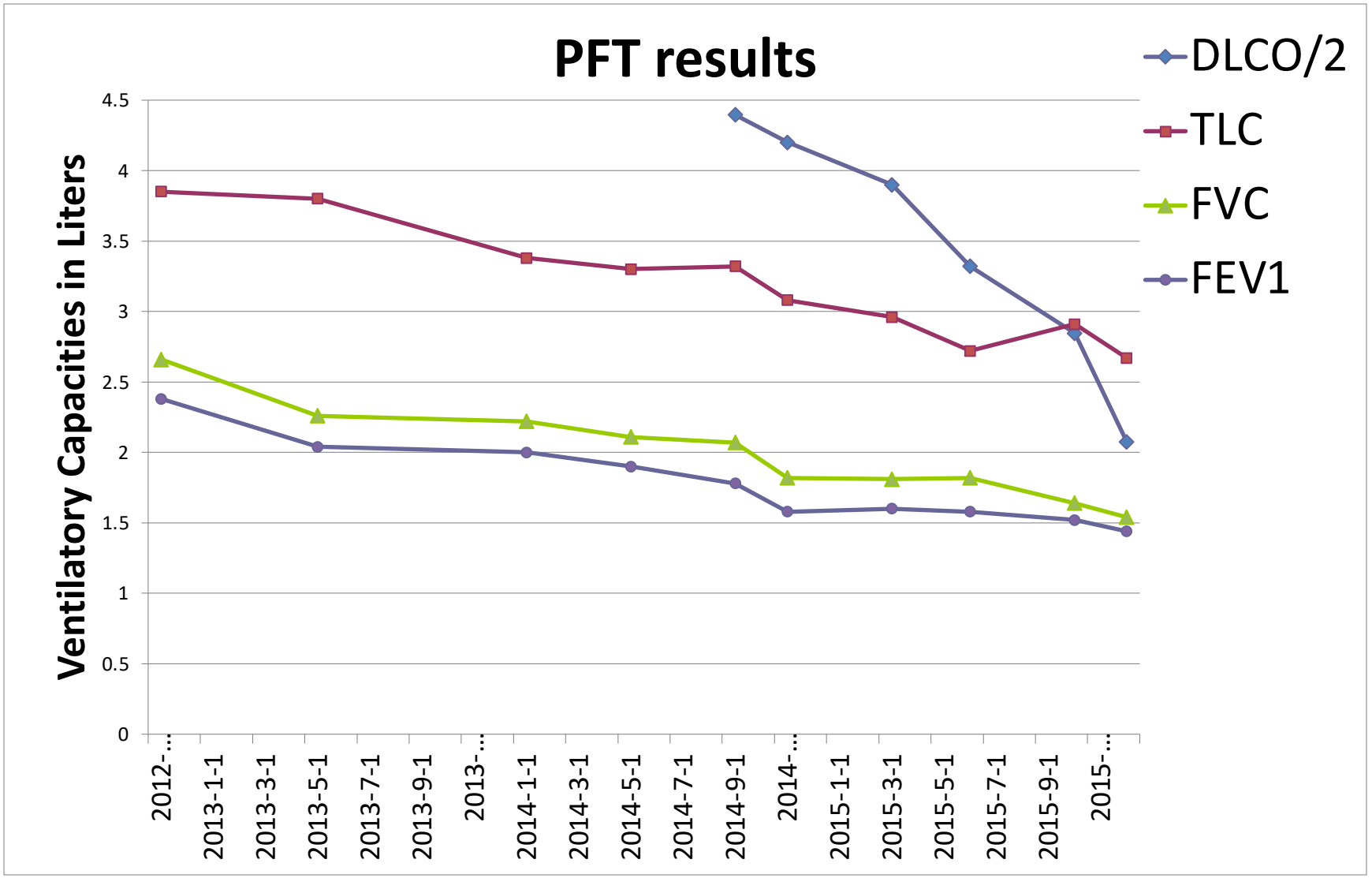
Recent changes in PFTs may be more significant than specific values



Brett Ley; Harold R. Collard; Talmadge E. King Jr.; *Am J Respir Crit Care Med* **2011,** 183, 431-440
Collard et al. AJRCCM 168, No. 5 (2003), pp. 538-542.

Following PFTs: an example

	DLCO/2	TLC	FVC	FEV1	DLCOunc
11/30/12		3.85	2.66	2.38	12.55
5/13/13		3.80	2.26	2.04	16.71
1/24/14		3.38	2.22	2.00	12.61
5/28/14		3.30	2.11	1.90	10.85
9/24/14	4.40	3.32	2.07	1.78	8.79
11/12/14	4.20	3.08	1.82	1.58	8.40
3/5/15	3.90	2.96	1.81	1.60	7.80
6/17/15	3.32	2.72	1.82	1.58	6.64
10/26/15	2.85	2.91	1.64	1.52	5.69
12/14/15	2.08	2.67	1.54	1.44	4.15


PFT results
DLCO/2
TLC
FVC
FEV1
Ventilatory Capacities in Liters
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2012-…
2013-1-1
2013-3-1
2013-5-1
2013-7-1
2013-9-1
2013-…
2014-1-1
2014-3-1
2014-5-1
2014-7-1
2014-9-1
2014-…
2015-1-1
2015-3-1
2015-5-1
2015-7-1
2015-9-1
2015-…

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

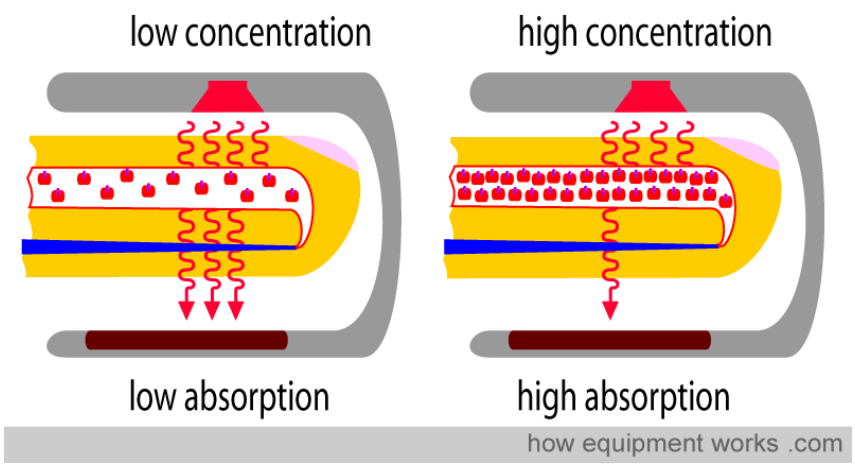
Online resources

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

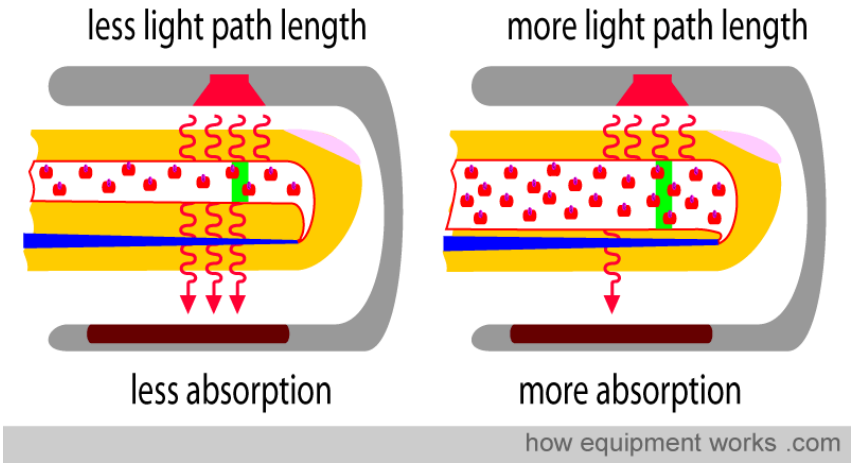
https://www.pulmonaryfibrosis.org/life-with-pf/pff-educational-resources/webinars/understanding-pulmonary-function-tests

https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/pulmonary-function-tests

Pulse oximeter: measures absorption of light by hemoglobin

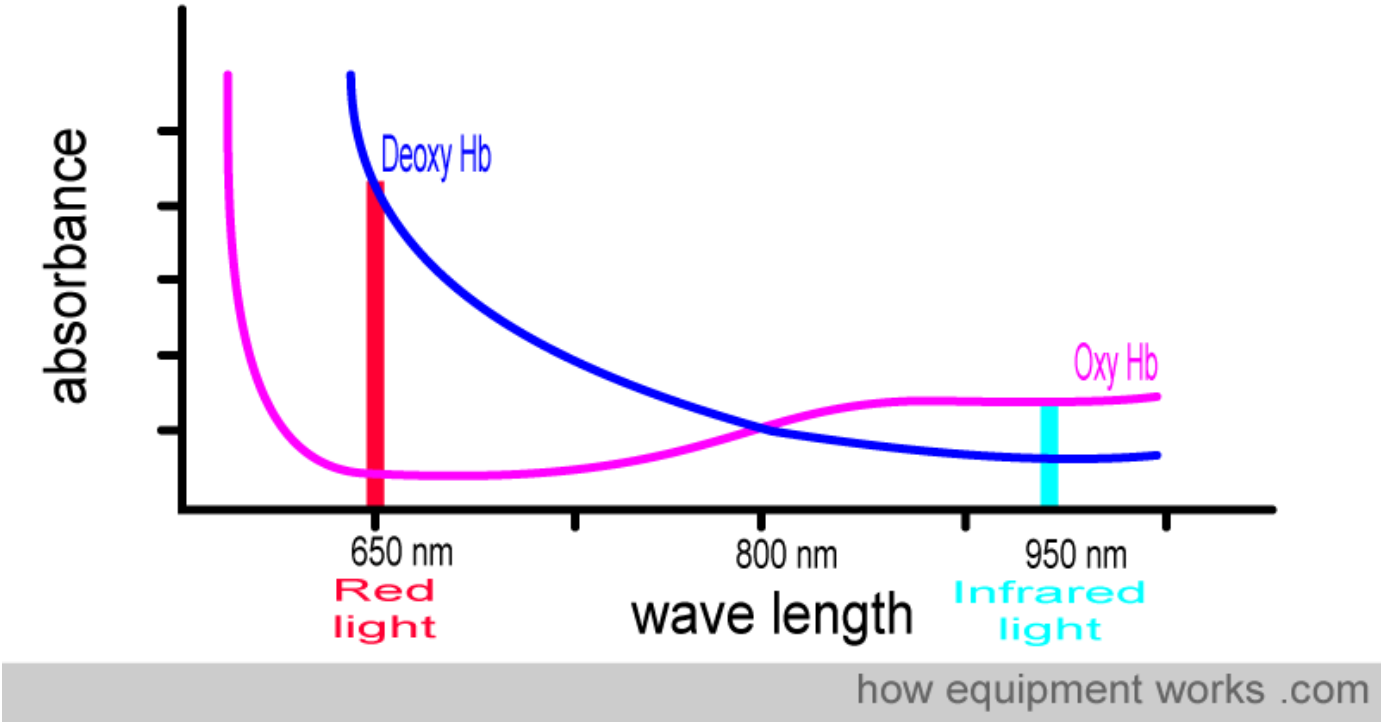


More hemoglobin, more absorption



Wider blood vessel , more absorption

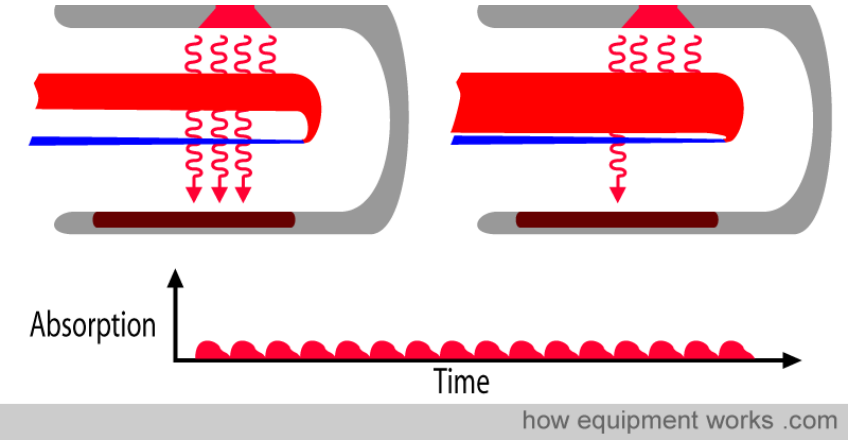
Light sources for red and infrared distinguish oxygenated and deoxygenated hemoglobin



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



Arterial absorption is pulsatile

Oximeter subtracts out the stable absorption

Reports only pulsatile absorption!