



What is Spirometry? A primer

George Su, MD

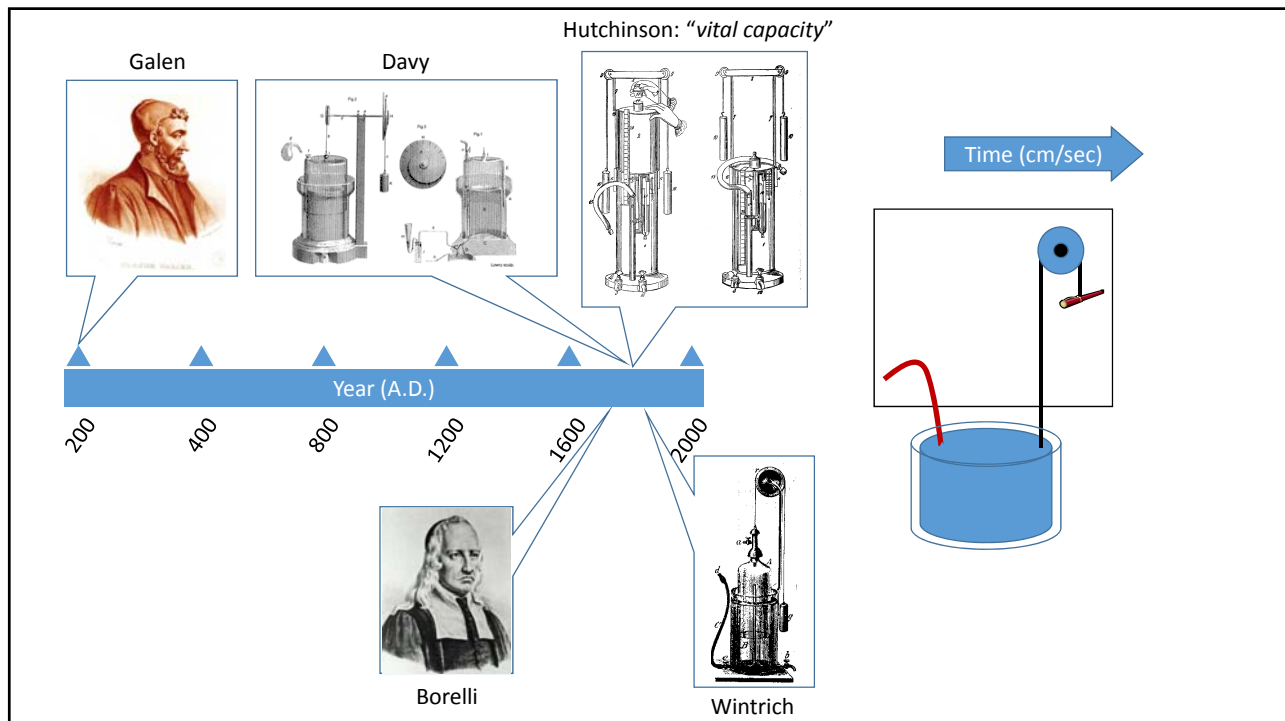
San Francisco Asthma Network Forum
San Francisco, CA
June 7, 2013

Disclosures

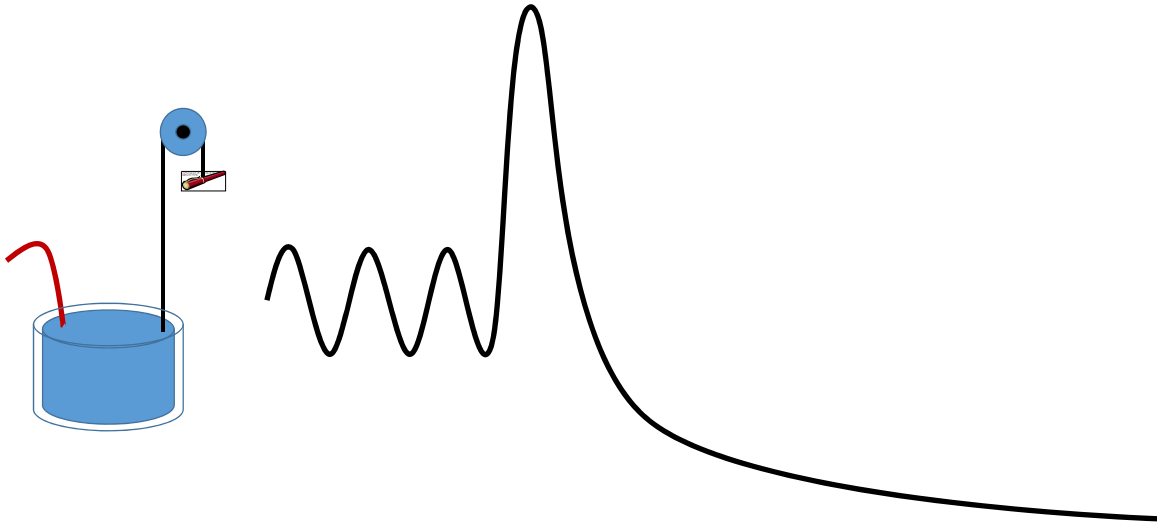
- George Su, MD
- Assistant Professor of Medicine
- SFGH/UCSF

- I have no conflicts of interest

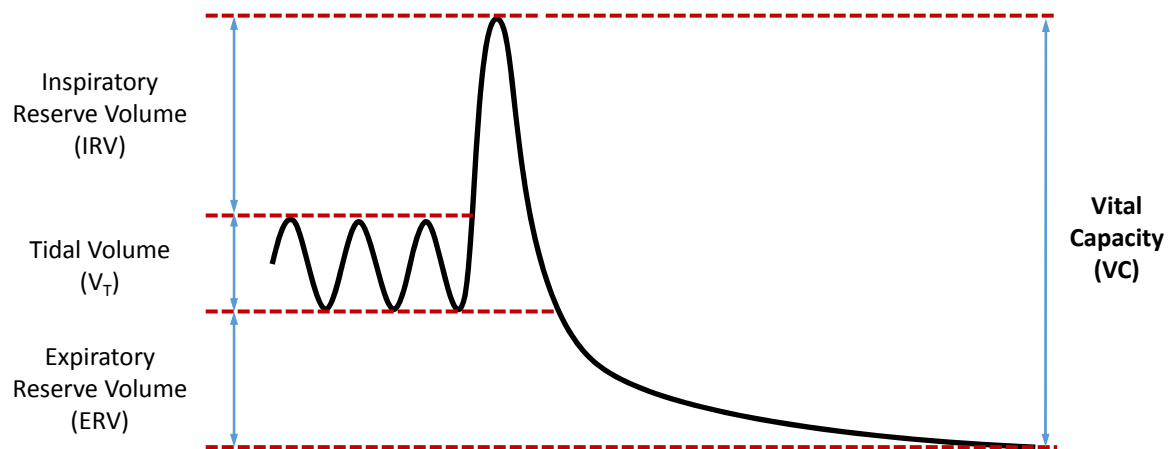
How to quantify/characterize a breath?



Volume changes over time

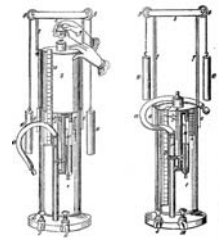


Volume vs. time



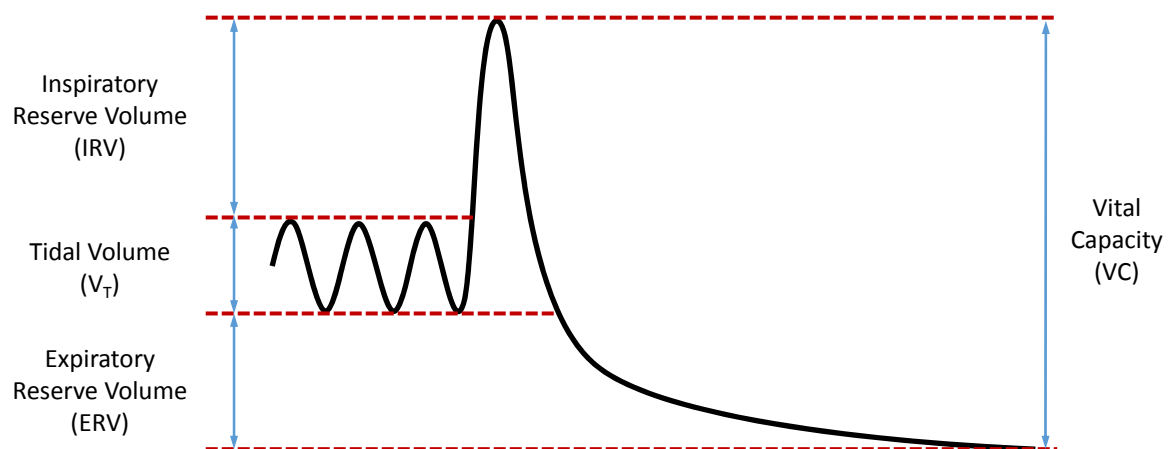
Forced vital capacity (FVC) maneuver

- Full inspiration and forced expiration to limit of emptying
- John Hutchinson (1811-1861)
 - VC related to height, weight
 - Previous TB infections
 - Heart failure
 - Coal miners

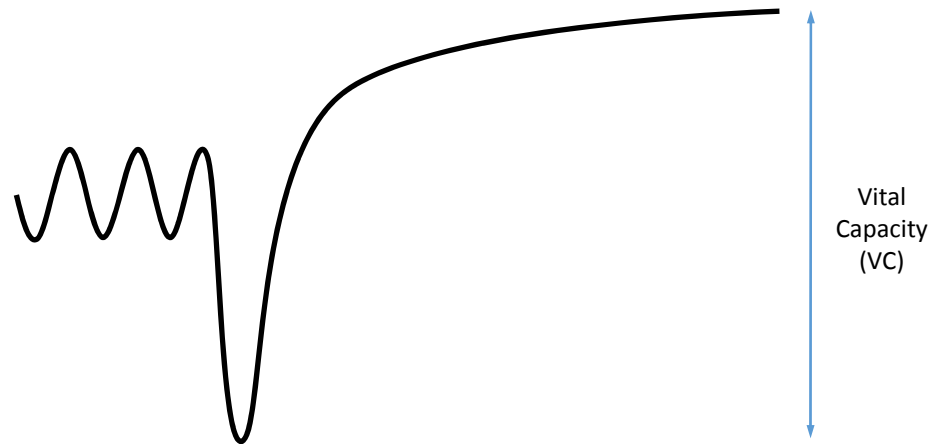


Hutchinson, 1846

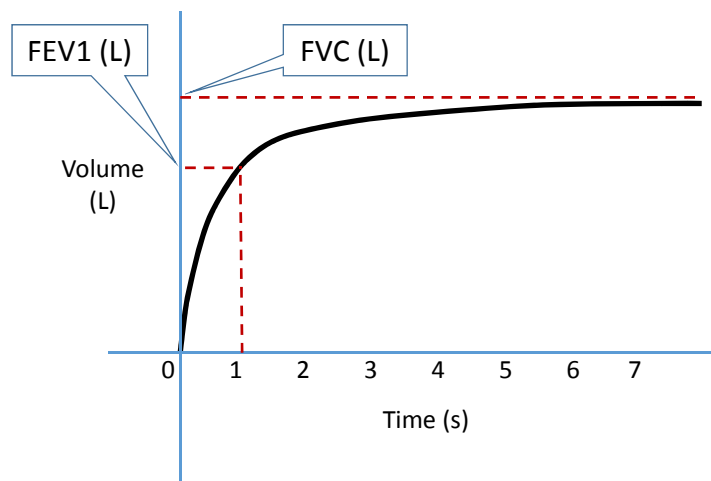
Volume vs. time



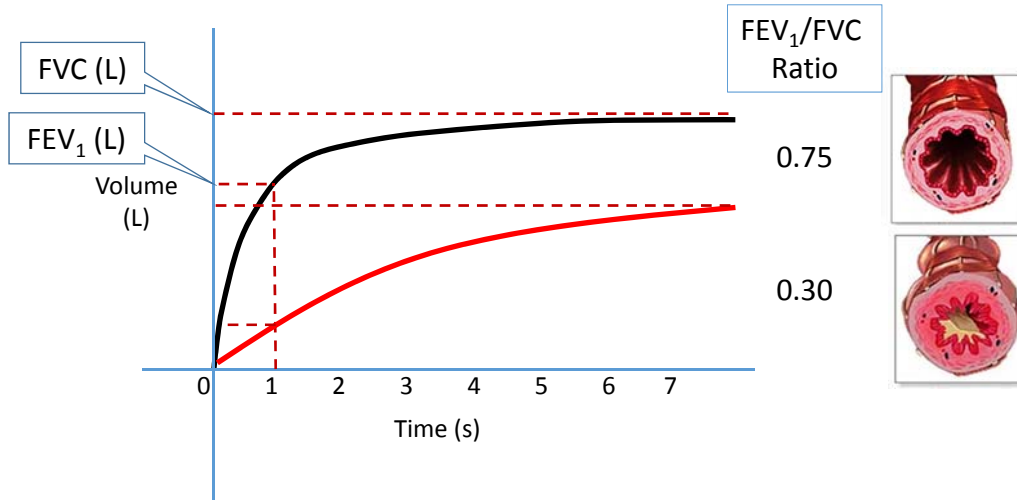
Volume vs. time



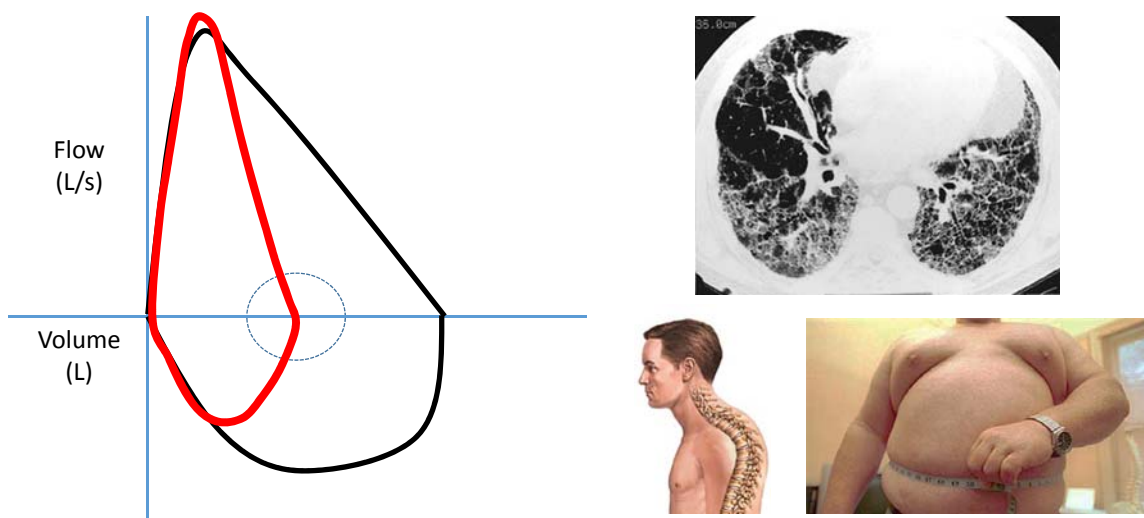
Volume vs. time (VT curve)



VT curve measurements

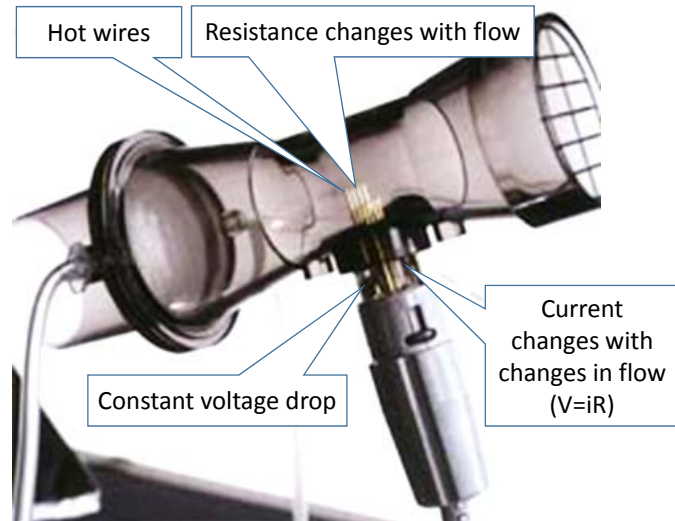


FV loop: Restrictive ventilatory defect

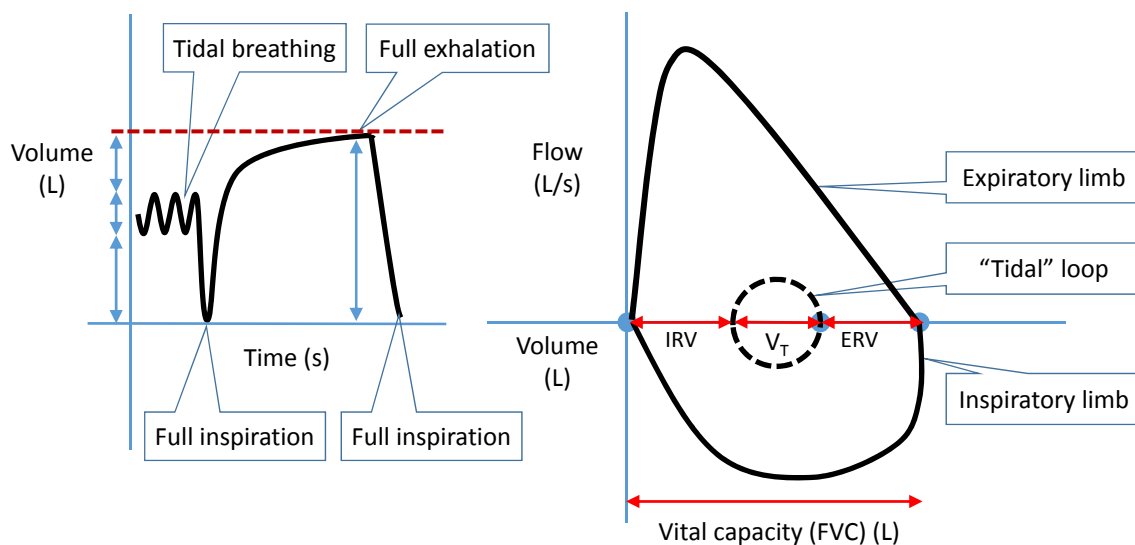


Measure FLOW (volume per time)

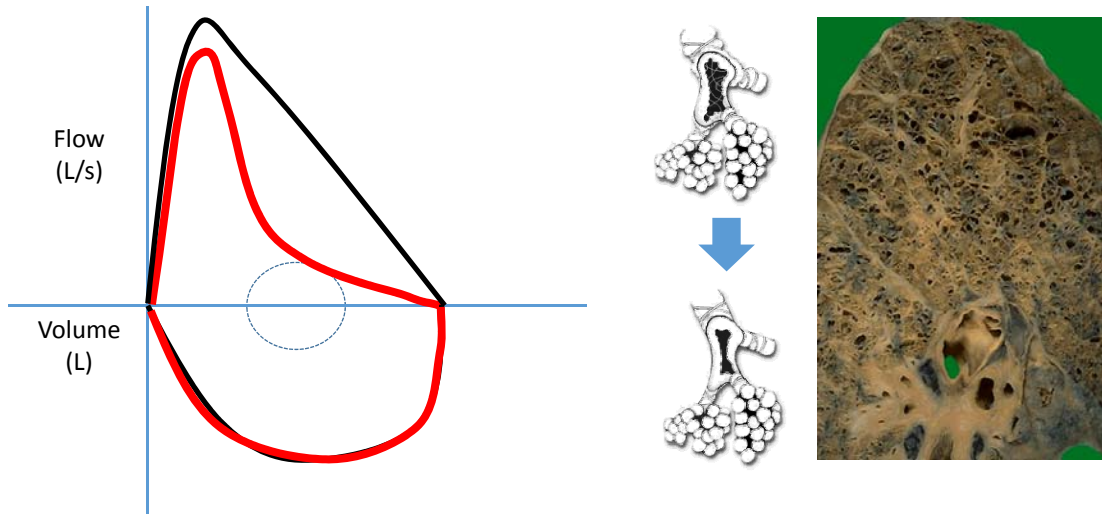
- Fleisch-pneumotach
- Lilly (screen) pneumotach
- Turbine
- Pitot tube
- Hot-wire anemometer
- Ultrasound



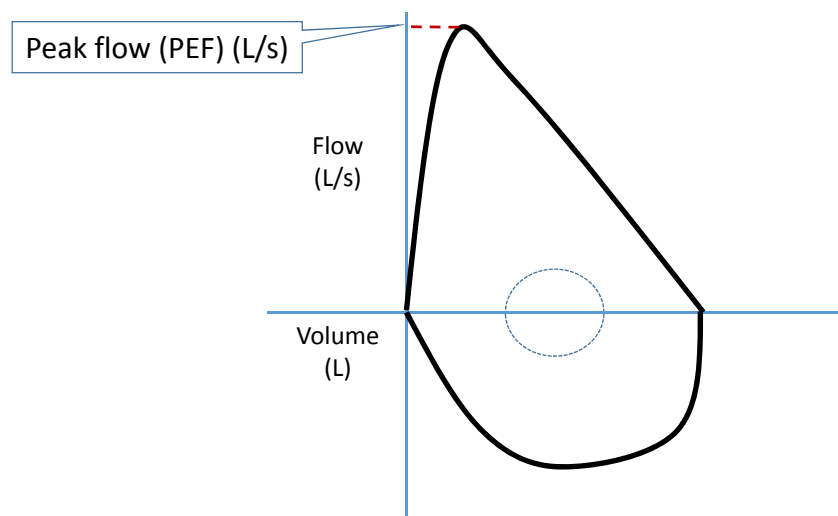
FLOW vs. volume (Flow-volume (FV) loop)



FV loop: Obstructive ventilatory defect



FV loop: additional measurements



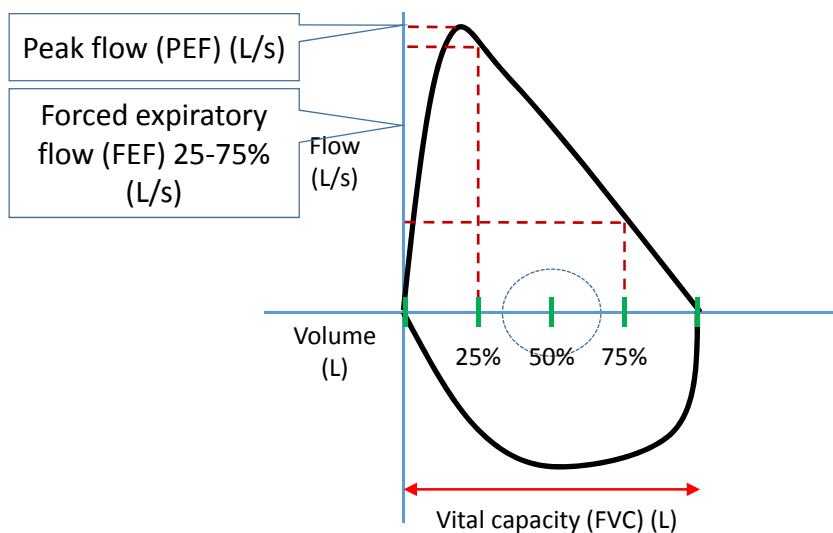
Peak flow meter (PEF)?

- Insensitive relative to spirometry (mild or early disease)
- Dependent on patient effort
- 2x inter- and intra-subject variability ¹
- Less accurate²
- Not calibrated



1. Gardner et al., 1992; 2. ATS Statement, 1995

FV loop: additional measurements



Spirometry measurements

1. **FVC** (L)
2. **FEV₁** (L)
3. **FEV₁/FVC ratio**
 - Sensitive for obstruction
 - >0.70 is normal in adults
4. **FEF_{25-50%}** (L/s)
 - More sensitive measure of small airways narrowing than FEV₁
 - Wide range of “normal” (to 50% children 8-18 yo and to 35% in older adults)
 - Less reproducible than FEV₁
 - Difficult to interpret if the VC (or FVC) is reduced or increased
5. **PEF** (L/s)
 - Highly effort-dependent (marker for effort)

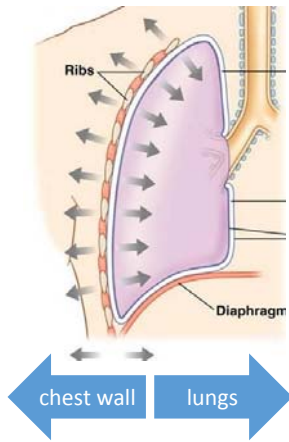
Bronchodilator reversibility testing

- Post-bronchodilator FVC or FEV₁ increases by 12% and 200 ml
- Generally not helpful when lung function is normal at baseline
- Evaluation of asthma
- Sorting out COPD vs. asthma (fixed vs. reversible)

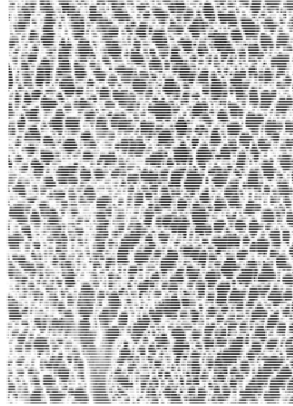
What do these numbers mean?



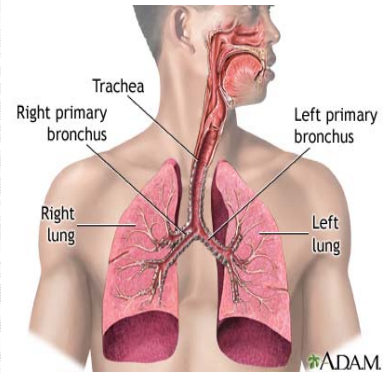
Muscular effort



Elastic recoil

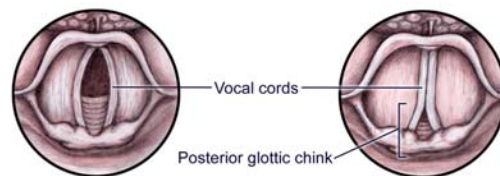
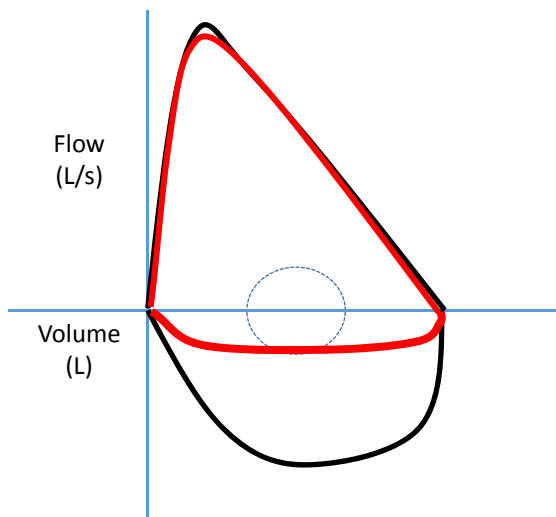


Dynamic interaction:
airways and alveoli



Large airways and
respiratory system

FV loop: Variable extrathoracic outlet obstruction



Vocal cords

Posterior glottic chink



COPD

- Airflow limitation that is not fully reversible
- Progressive inflammatory response to noxious substances
- Tobacco smoke
- Chronic bronchitis: 3 months productive cough for each of 2 successive years
- Emphysema: pathologic destruction of alveoli

COPD

- Currently third leading cause of death in U.S. and worldwide by 2020
- (2008) 13.1 million with COPD diagnosis, with 24 million with evidence of impaired lung function
- Why?

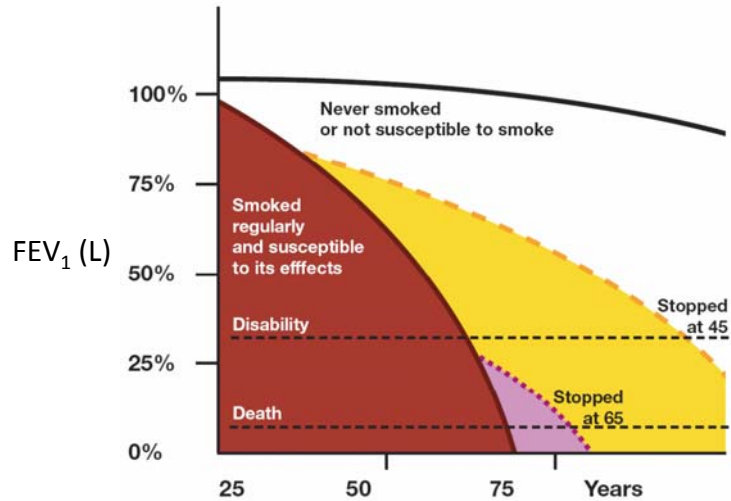
CDC, 2002

Spirometry and COPD

- Low **FEV1/FVC** strong predictor for progression¹
- Degree of obstruction correlates with pathologic changes²
- Independent predictor of morbidity and mortality (COPD, cardiovascular disease, lung CA, all-cause mortality)³⁻⁸
- Utilization of healthcare resources⁹

1. Anthonisen et al., 1994; et al., 2. Anthonisen, et al., 1989; 3. Kerstjens, et al., 1996; 4. Beaty, et al., 1982; 5. Tockman, et al., 1987; 6. Kuller et al., 1990; 7. Traver, et al., 1979; 8. Hole et al., 1996; Silverman, et al., 1996

Accelerated decline in FEV₁ in smokers



Fletcher and Peto, et al., 1977

Clinical staging of COPD

I: Mild	II: Moderate	III: Severe	IV: Very Severe
Chronic cough and sputum	SOB typically c exertion	Greater SOB, ↓ QOL, ↓ exercise, repeated exacerbations	CRF, RHF, severely impaired QOL, life-threatening exacerbations
$FEV_1/VC < 70$ $FEV_1 \geq 80\%$	$FEV_1/VC < 70$ $FEV_1 50\%-80\%$	$FEV_1/VC < 70$ $FEV_1 30\%-50\%$	$FEV_1/VC < 70$ $FEV_1 < 30\%$ $FEV_1 < 50\% \text{ c CRF}$

GOLD, 2007

Spirometry and COPD

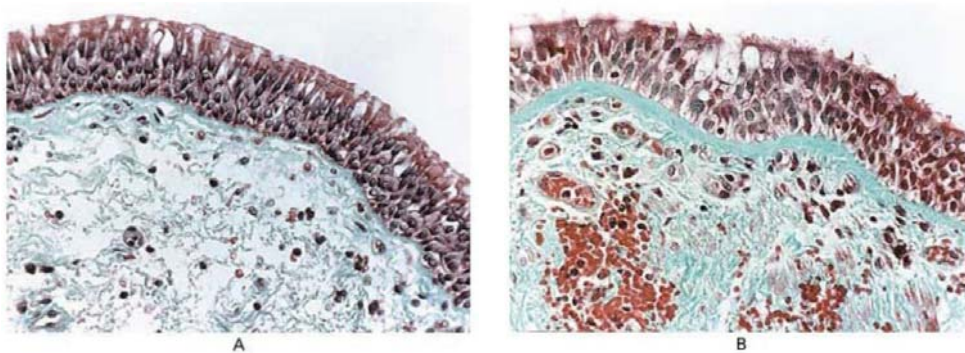
- Healthcare Effectiveness Data and Information Set (HEDIS)



- Spirometry testing must occur 730 (~2 years) days prior to or 180 days (6 months) after the diagnosing event for COPD
- Screening all smokers?
- “Targeted case-finding”, e.g. >40 y.o. with tobacco history and symptoms

ACP, 2011

Asthma



Jarjour, et al., 2001

Asthma

- Highly-prevalent disease
- Disproportionately affects underserved
- Bulk of diagnosis and management occurs in primary care setting

Spirometry and asthma

- Adults and children > 5 in whom diagnosis of asthma is being considered
- Degree of airway obstruction (**impairment** and **risk**)
- Patients' perceptions of obstruction are inaccurate
- Clinical symptoms alone underestimate severity ~30% of the time in primary care

Stout, et al., 2006; Cowen, et al., 2007; Fuhlbrigge, et al., 2001

EPR-3: Asthma and spirometry

- At the time of initial diagnosis
- Document airflow obstruction and reversibility
- When reducing the dosage of medications
- After treatment is initiated and symptoms (and peak flows) have stabilized
- During periods of progressive or prolonged loss of control
- At least every 1 – 2 years in moderate to severe disease

NHLBI Guidelines for the Diagnosis and Treatment of Asthma (Expert Panel Report-3) July 2007 <http://www.nhlbi.nih.gov/guidelines/asthma/>

EPR-3: Clinical severity of asthma

	Days With Symptoms	Nights With Symptoms	PEF or FEV ₁ *	PEF Variability
Step 4 Severe Persistent	Continual	Frequent	≤60%	>30%
Step 3 Moderate Persistent	Daily	≥5/month	>60%–<80%	>30%
Step 2 Mild Persistent	3–6/week	3–4/month	≥80%	20–30%
Step 1 Mild Intermittent	≤2/week	≤2/month	≥80%	<20%

NHLBI Guidelines for the Diagnosis and Treatment of Asthma (Expert Panel Report-3) July 2007 <http://www.nhlbi.nih.gov/guidelines/asthma/>

Primary care spirometry

- Valuable test in point-of-service setting
- Indications: shortness of breath, wheeze, chronic cough, following volumes (FVC surrogate for total lung capacity), positional testing (diaphragmatic weakness)
- Formally recommended for COPD and asthma testing
 - Targeted case-finding (COPD >40 yo with tobacco hx and symptoms)
 - Diagnosis of obstructive ventilatory defect
 - Degree of impairment/severity
 - Prognosis
 - Response to therapy
- Fundamentally based on well-performed FVC maneuver (effort-dependent)



Primary Care Spirometry in the SFDPH

George Su, MD

San Francisco Asthma Network Forum

San Francisco, CA

June 7, 2013

Primary care spirometry - SFDPH

- San Francisco's "safety net system"--Community Health Network (CHN)
- Patient-centered medical home (point-of-service diagnostic testing)
- Constituency suffers from disproportionately severe asthma and COPD
- Pilot projects supported by Proposition 10 and the Medi-Cal Plan/Practice Improvement Project (PIIP) (2005)

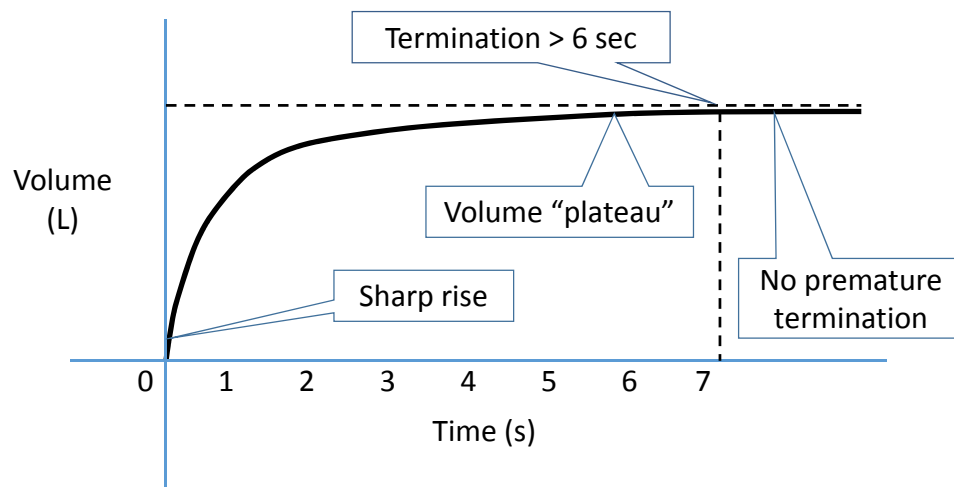
SFDPH CHN spirometry needs assessment

- FHC, GMC, SEHC, CPHC, Curry Senior Center, Tom Waddell (46 primary providers, 5 administrators, 4 medical directors, and 6 coaches)
- Gail Herrick, Karen Cohn
- Lack of clarity of testing indications **(46%)**
- Variable provider confidence in ability to interpret tests **(45%)**
- Lack of confidence in test quality **(38%)**
- Lack of standardized training **(45%)**
- Not enough patients **(35%)**
- Testing skills erosion (maintenance training, support, turnover) **(34%)**
- Too much time and effort to maintain program **(30%)**

Test quality

- Acceptability
- Reproducibility

Volume-time curve: acceptability

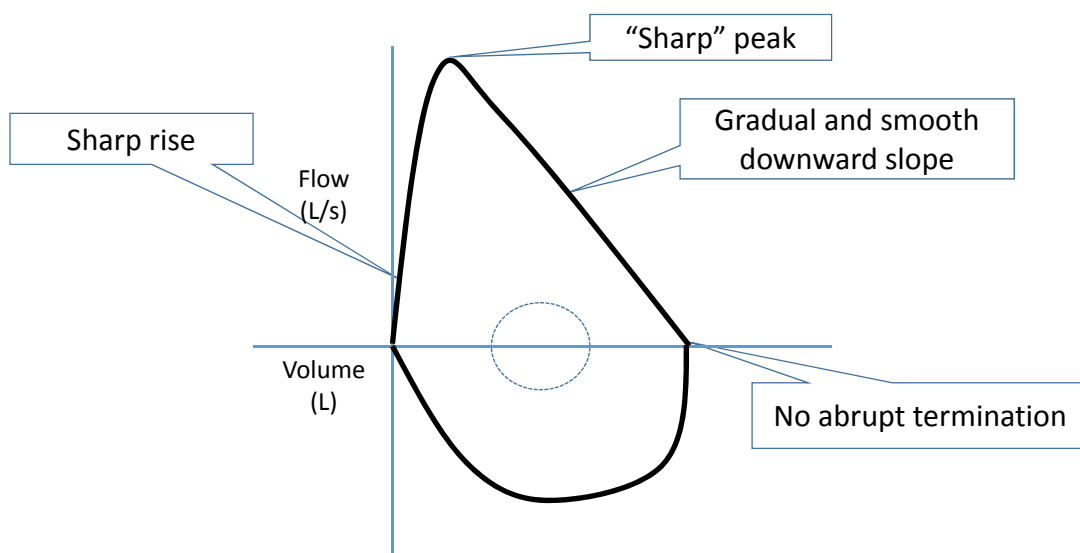


Volume-time curve: acceptability

- Sharp rise
 - Indicates a good, fast start
- Termination of the maneuver after ≥ 6 seconds of exhalation
 - < 6 seconds is acceptable as long as the volume plateaus for at least 1 second

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Flow-volume loop: acceptability

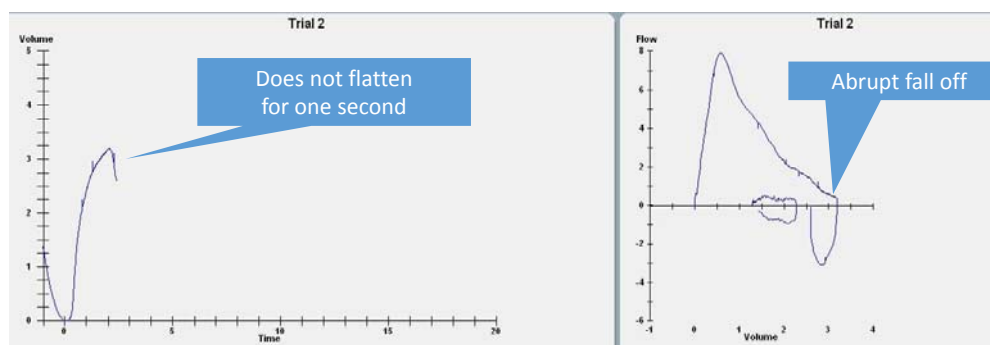


Flow-volume loop: acceptability

- Sharp rise
 - Indicates a good, fast start
- Gradual downward slope of the flow
 - Indicates a full and complete exhalation

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Acceptability 1



Early termination

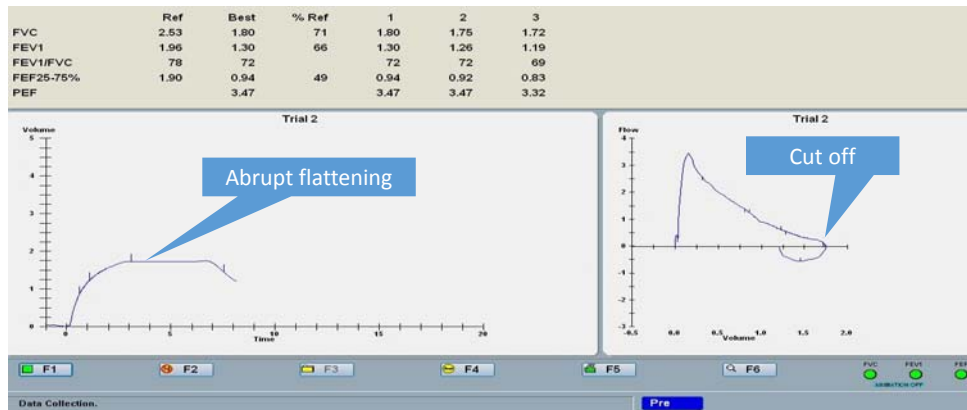
- VT curves with short or absent plateaus
- FV curves show abrupt drop off at the end

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Correcting early termination

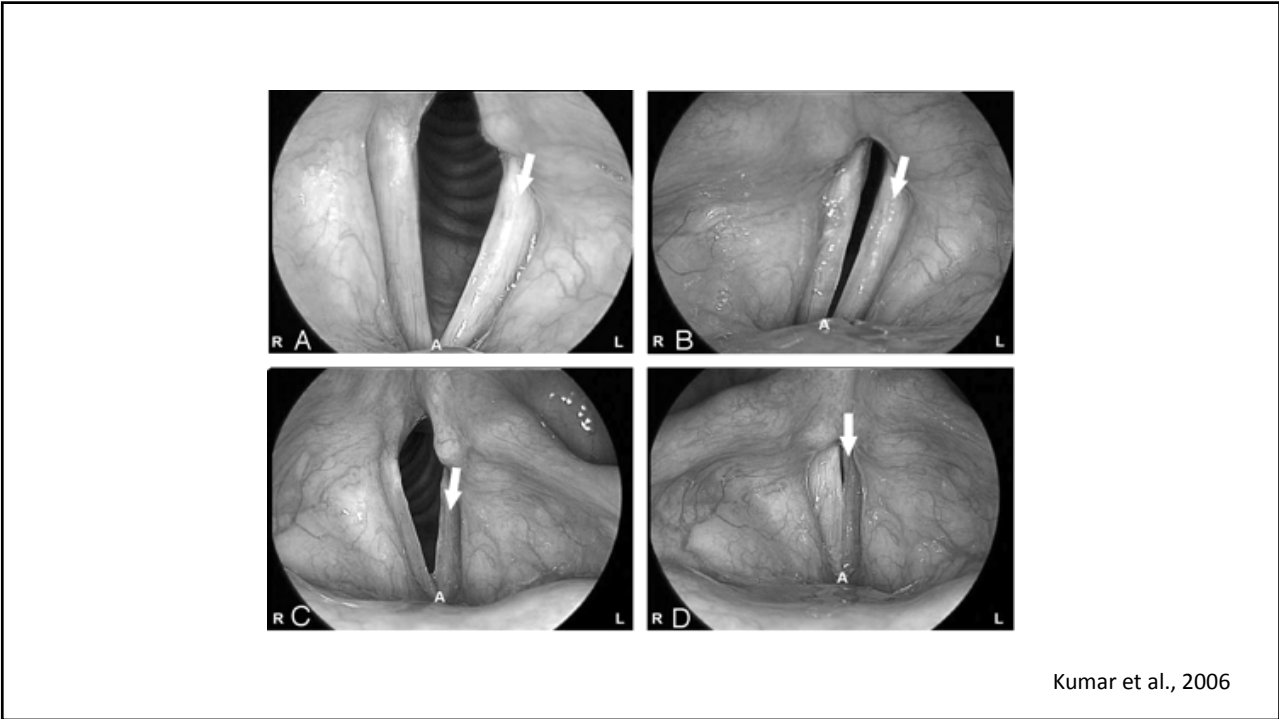
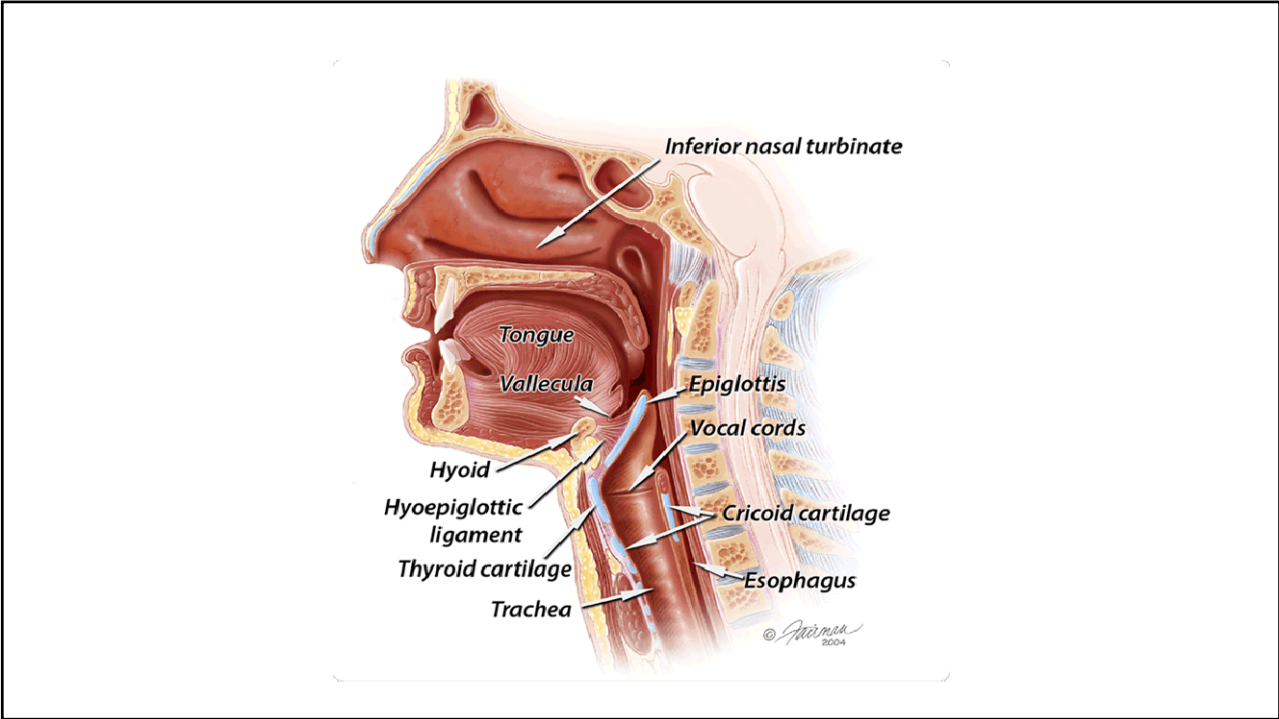
- Focus on END of TEST, blowing long and hard
- Coach patient to make a sustained effort
- Make sure the patient understands to empty lungs
- Cue the patient counting with six fingers
- “1...2...3...4...5...6”
- Use incentive screen

Acceptability 2



Glottic closure

- Appears like early termination on FV curve
- VT curve looks like it is drawn with a ruler
- Patient may report sudden tightening near larynx



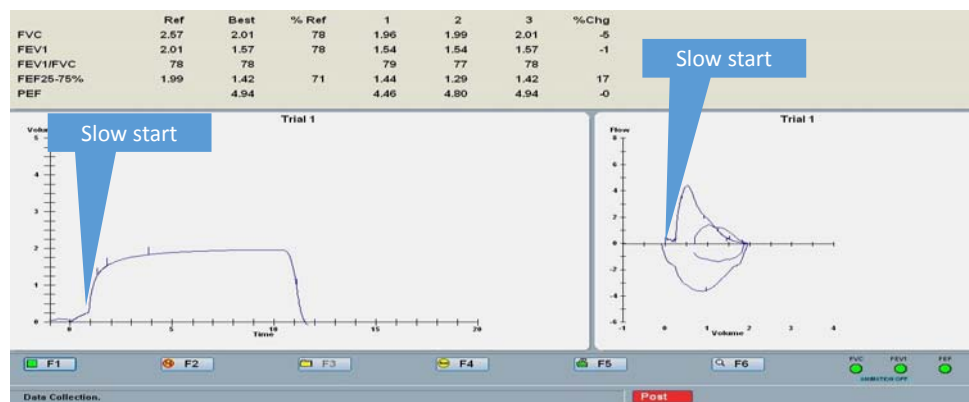
Kumar et al., 2006

Correcting glottis closure

- Instruct patient to try to relax upper airway
- Instruct patient to relax, holding their head in a slightly sniff position
- The patient should continue to blow until being told to stop

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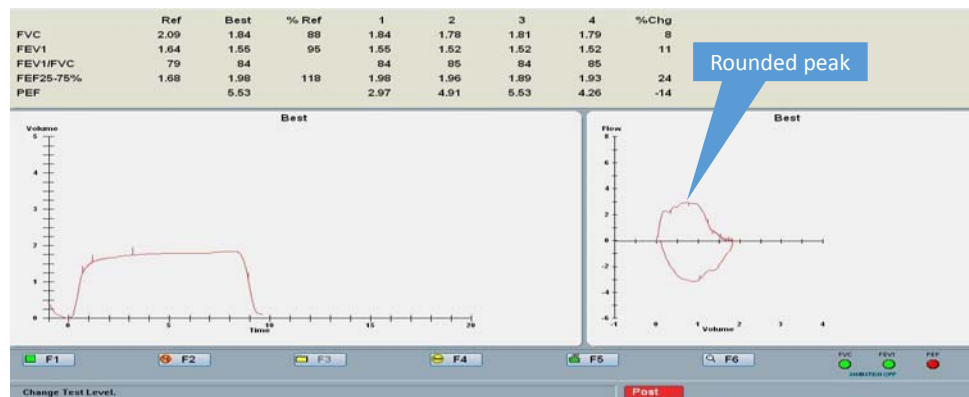
Acceptability 3



Correcting slow start

- Concentrate on a fast blast immediately after a full inhalation

Acceptability 4



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Poor initial blast/submaximal effort

- FV loop will display a rounded or flat peak
- VT curve will display decreased rise/slope

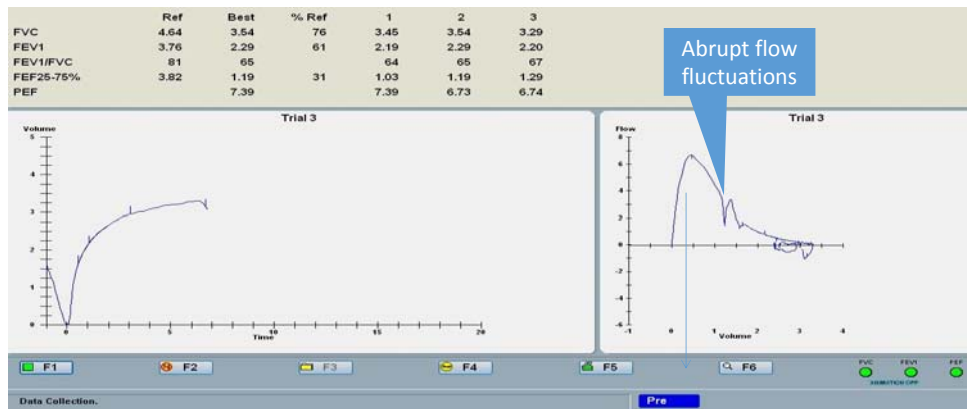
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Correcting poor initial blast

- Reinstruct and demonstrate
- “As hard and as fast as you can...”
- Use examples

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Acceptability 5



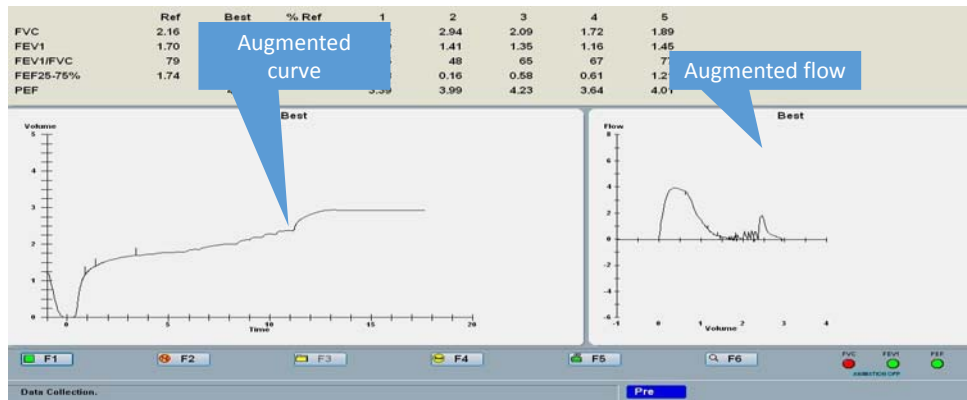
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Cough

- Cough in first second invalidates effort
- Stop and reassess (patient may be unable to continue)
- Some efforts may still be valid (if cough occurs > 1 second after start)

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Acceptability 6



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Extra breath

- VT curve: will see the start of a plateau and then another rapid rise
- FV loop: will see the flow start to increase again after it is first declining

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Correcting extra breaths

- Instruct the patient to fully exhale in one long maneuver without stopping to pull more air in
- A nose clip may also be necessary to prevent the patient from breathing in through their nose and breathing out through their mouth

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Reproducibility criteria

- After 3 acceptable maneuvers have been obtained, assess whether the following reproducibility criteria are met:
- The 2 largest FVC values are within 0.15 L of each other
- Or, the 2 largest FEV₁ values are within 0.15 L of each other

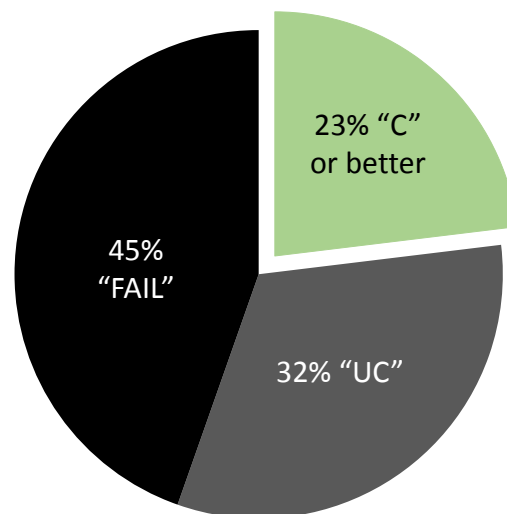
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Spirometry 360™ Grading System



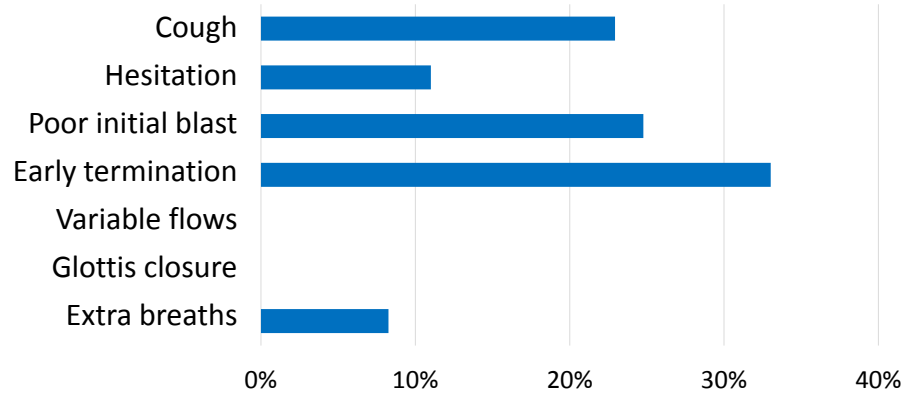
Spirometry 360 Grade	Age Seven Years or Older
A (meets ATS rules)	3 acceptable efforts <i>and</i> variance \leq 150 ml
B (meets ATS rules)	2 acceptable efforts <i>and</i> variance \leq 150 ml
C (still Clinically useful)	2 acceptable efforts <i>and</i> variance \leq 200 ml
UC (Use with extreme Caution)	1 acceptable effort
NP (Not Passing)	No acceptable efforts

SFDPH spirometry grades (prior to 2010)



n=132 study sample
SEHC, SFGH 1M, Tom Waddell

SFDPH acceptability errors (prior to 2010)



n=132 study sample
SEHC, SFGH 1M, Tom Waddell

SFDPH CHN spirometry

- Low percentage of acceptable studies
- Low provider confidence in indications, quality, interpretations
- Difficulty maintaining testing skills
- Barriers to program sustainability



The San Francisco Community Primary Care Spirometry Program

George Su, MD

San Francisco Asthma Network Forum
San Francisco, CA
June 7, 2013

SFDPH CHN spirometry needs assessment



- Lack of clarity of testing indications
- Variable provider confidence in ability to interpret tests
- Lack of confidence in test quality
- Lack of standardized training
- Not enough patients
- Testing skills erosion (maintenance training, support, turnover)
- Too much time and effort to maintain program

Program Provisions



1. Careful selection of partner clinics
2. Superior training program
3. Centralized support (SFGH Pulmonary and RCS)
4. Quality assurance
5. Formal interpretation services
6. Posting of test results to the DPH electronic medical record (EMR)

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Community spirometry center



- Committed leadership and coaching staff
- Dedicated time for training
 - **10 hours** for clinical and technical training
 - **7.5 hours** for Spirometry 360™ training
- Computer, printer, and internet (DPH Network)
- Secure storage space
- 10 spirometry tests per month per coach for training

Site Recruitment

- 1M Chest Clinic
- FHC Ward 92
- FHC Ward 85
- SAFMC
- CPHC
- SEHC



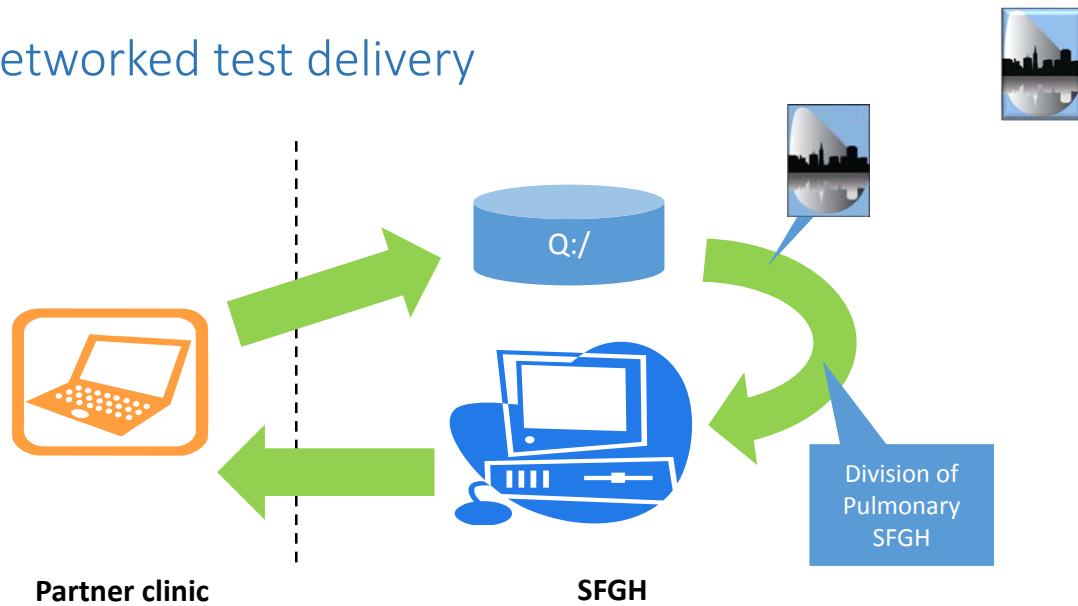
Training



iMTR
Interactive Medical Training Resources |
University of Washington



Networked test delivery

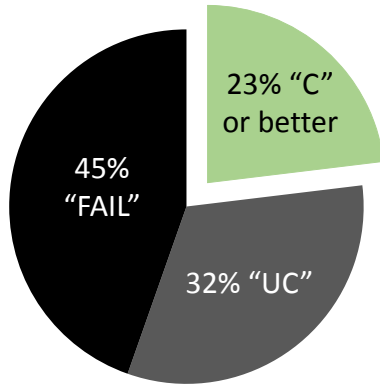


Spirometry 360™ Grading System

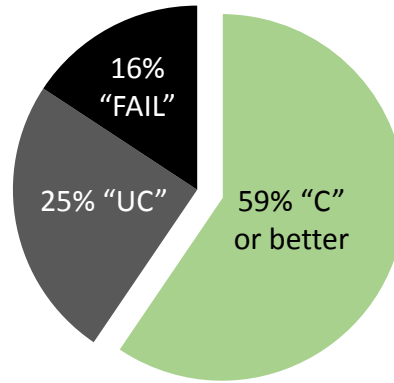


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SFDPH spirometry (pre- & post- comparison)

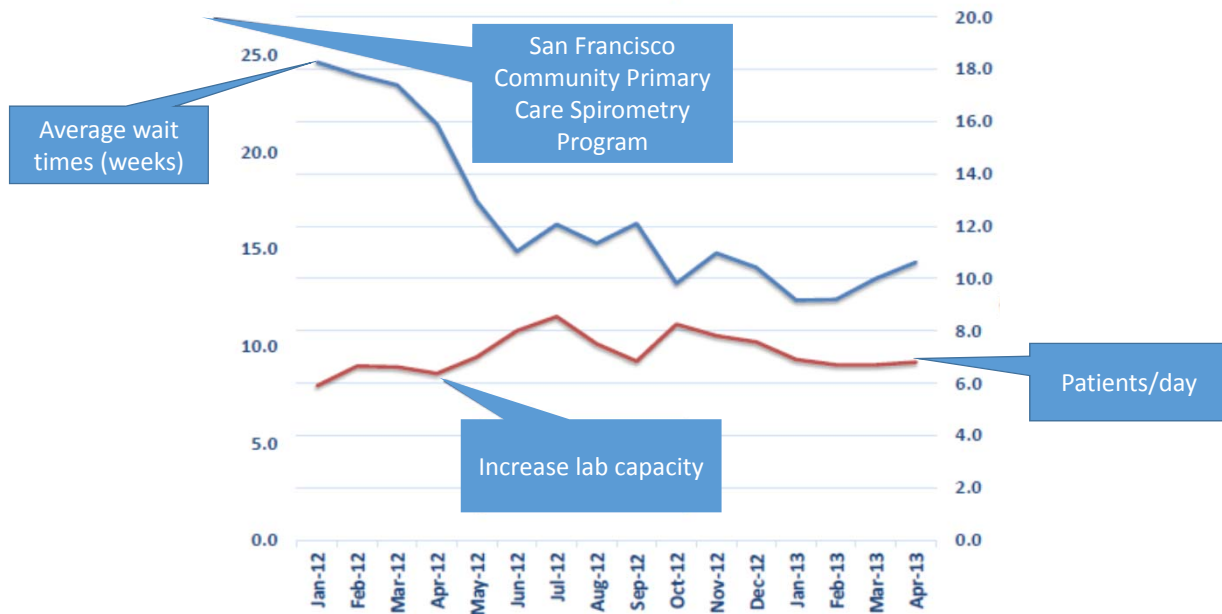


n=132 study sample
SEHC, SFGH 1M, Tom Waddell



n=985 study sample
SEHC, CPHC, SFGH FHC, SFGH 1M

SFGH PFT Laboratory Wait Times



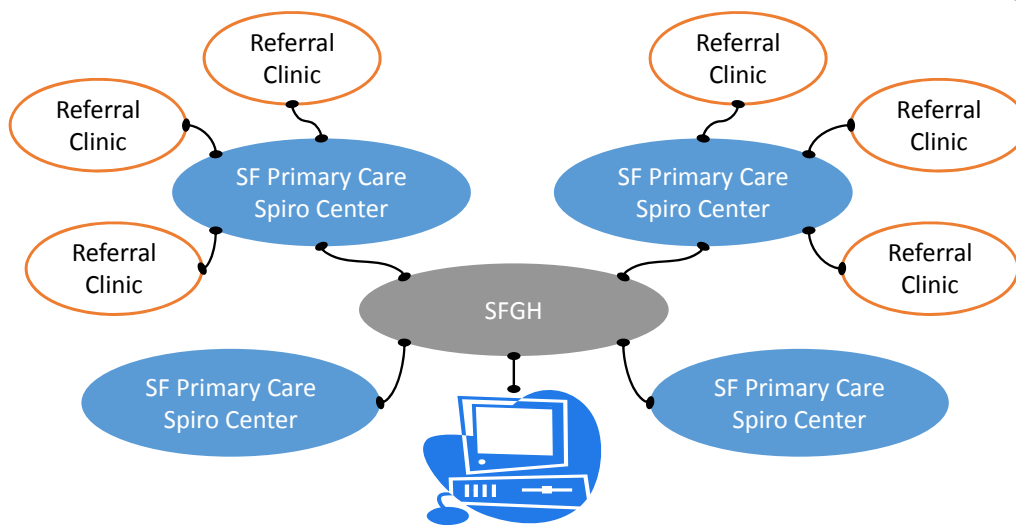
Maintenance training



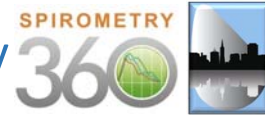
- Spirometry 360™ “refresher courses”
- Recertification (PFT laboratory SFGH)
- Ongoing evaluation of curves (overreading)

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SFDPH safety net spirometry centers



SF Community Primary Care Spirometry



- Novel partnerships
- Primary-specialty (pulmonary and RCS)
- Spirometry 360™
- SFDPH CHN IT
- Novel quality assurance program
- Integrated delivery system
- Better POS care
- Increased delivery system efficiencies

Who we are



- Eula Lewis – Program Director
- Katie Allen – Research/QI Director
- Stephanie Tsao – Director Healthy San Francisco Asthma and COPD Program
- George Su – Medical Director
- SAFMC: Sonia Bledsoe, Ana Valdez, Zeke Montejano, Jackie Mojigo, Katy Broner, Zoe Arends-Derning
- SEHC: Elsa Tsutaoka, Judy Lizardo, Mikaela Merchant, Tracy Shaw-Senigar, Ricardo Duarte
- CPHC: Albert Yu, Ben Lui, Kit Chan, Jessica Wong, Sarena Li, Consuelo Yan
- Marta Diaz, Rosemarie Fejerang, Byron Decuire, Myron Fong, Robert Ennis, Pik Wah Ho, Aya Matsushima, Michelle Murrell, Isabel McGregor-Crane

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- Oliver Beech
- Mario Talavera



San Francisco General Hospital

Foundation

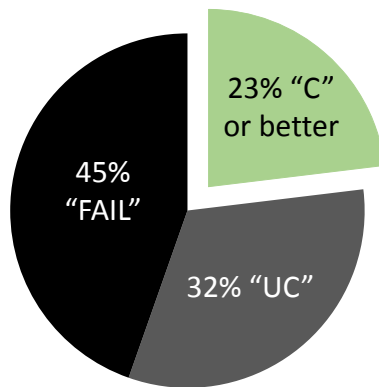


“Tele-spirometry”

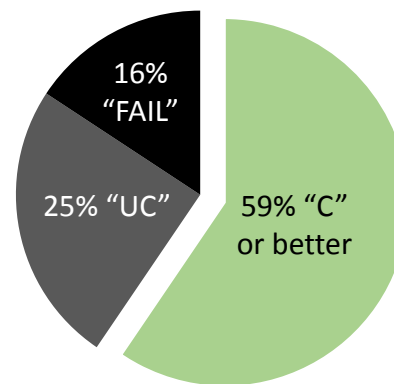
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SFDPH spirometry (pre- & post- comparison)



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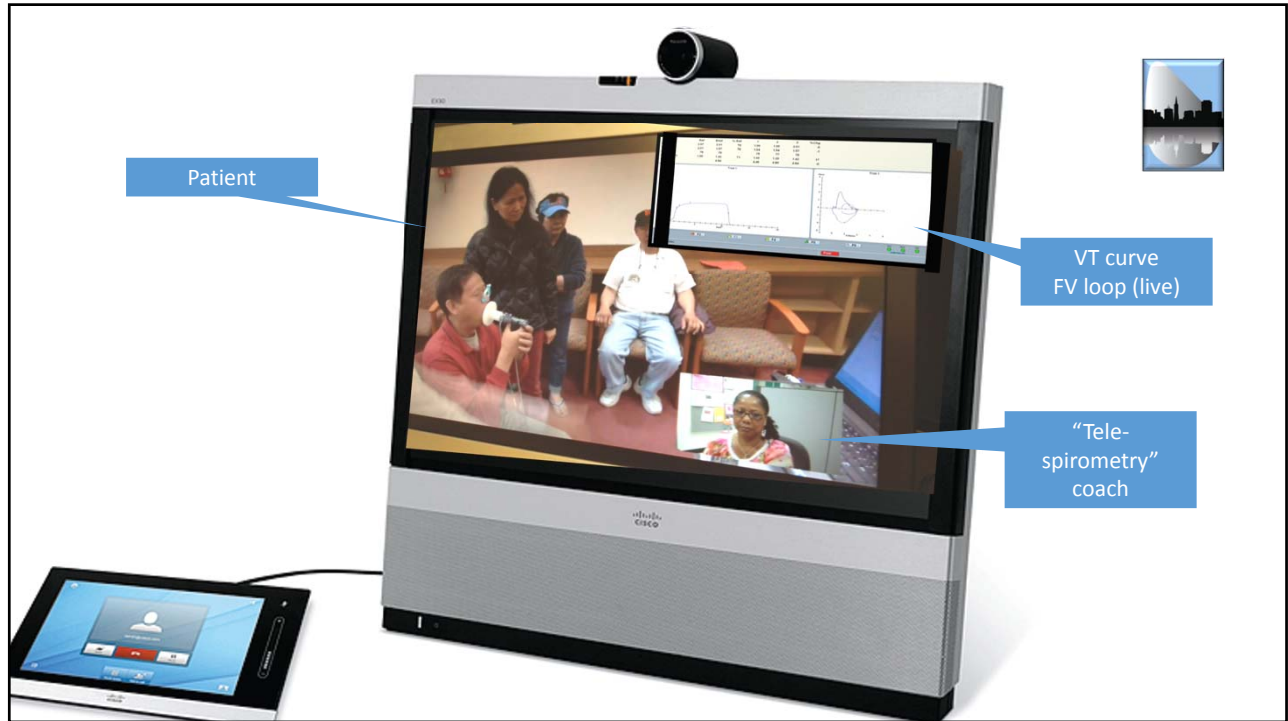
n=985 study sample
SEHC, CPHC, SFGH FHC, SFGH 1M

Poor quality testing



- Incorrectly diagnosed
- Incorrectly "ruled out"
- Inappropriate pulmonary function testing laboratory referral
- Patients forced to return for repeat testing

Live spirometry support



Tele-spirometry



- Standard telehealth technologies
- Leverages specialist effort and time
- Active or “fly-on-the-wall” support
- Decrease rates of low quality testing and need for repeat studies
- Enhance feedback and coach training
- Single site pilot (CPHC)

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- Jeff Jorgenson
- David Kelegian
- Ben Lui
- Albert Yu
- Kit Chan
- Roland Pickens
- Alice Chen
- John Applegarth
- Tim Greer
- Ron Alvarez



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