Spirometry and Interpretation of Spirometry

Chicago Asthma Consortium
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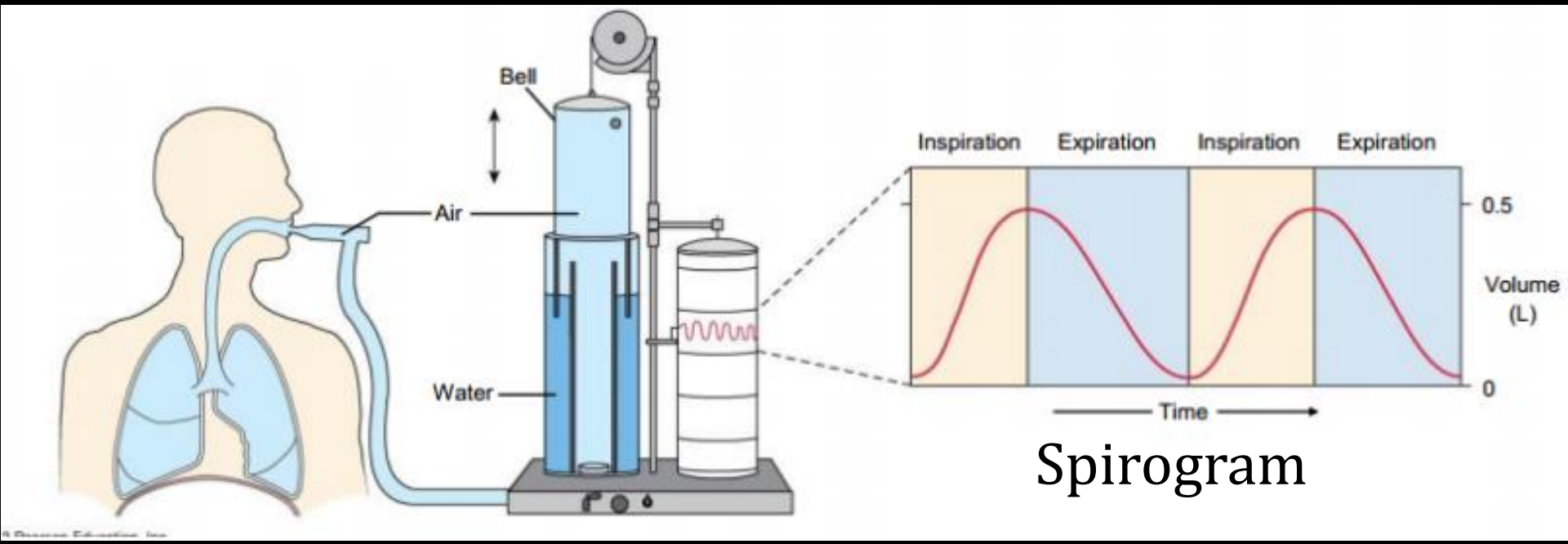
Disclosures

Definitions (working definitions)

- Spirometer: a device that measures the volume of air exhaled or inhaled out of/in to a person's lungs
- Spirometry: the measurement of the volume of air exhaled from a person's lungs
- Spirogram: a graphic depiction of the volume of air exhaled from a person's lungs over a period of time
- VC (vital capacity): the amount of air that can be expelled from the lungs after a person's deepest breath
- FVC (forced vital capacity): the amount of air that can be forcibly expelled from the deepest breath
- FEV1 (forced expiratory volume in 1 second): the amount of air that can be exhaled in 1 second with a forced exhalation
- FEV1/FVC: the ratio of the FEV1 to the FVC.
- FEF 25-75 ("midlflow"): average airflow middle of FVC maneuver
- Flow-volume loop: flow of exhaled air plotted against volume

Spirometer

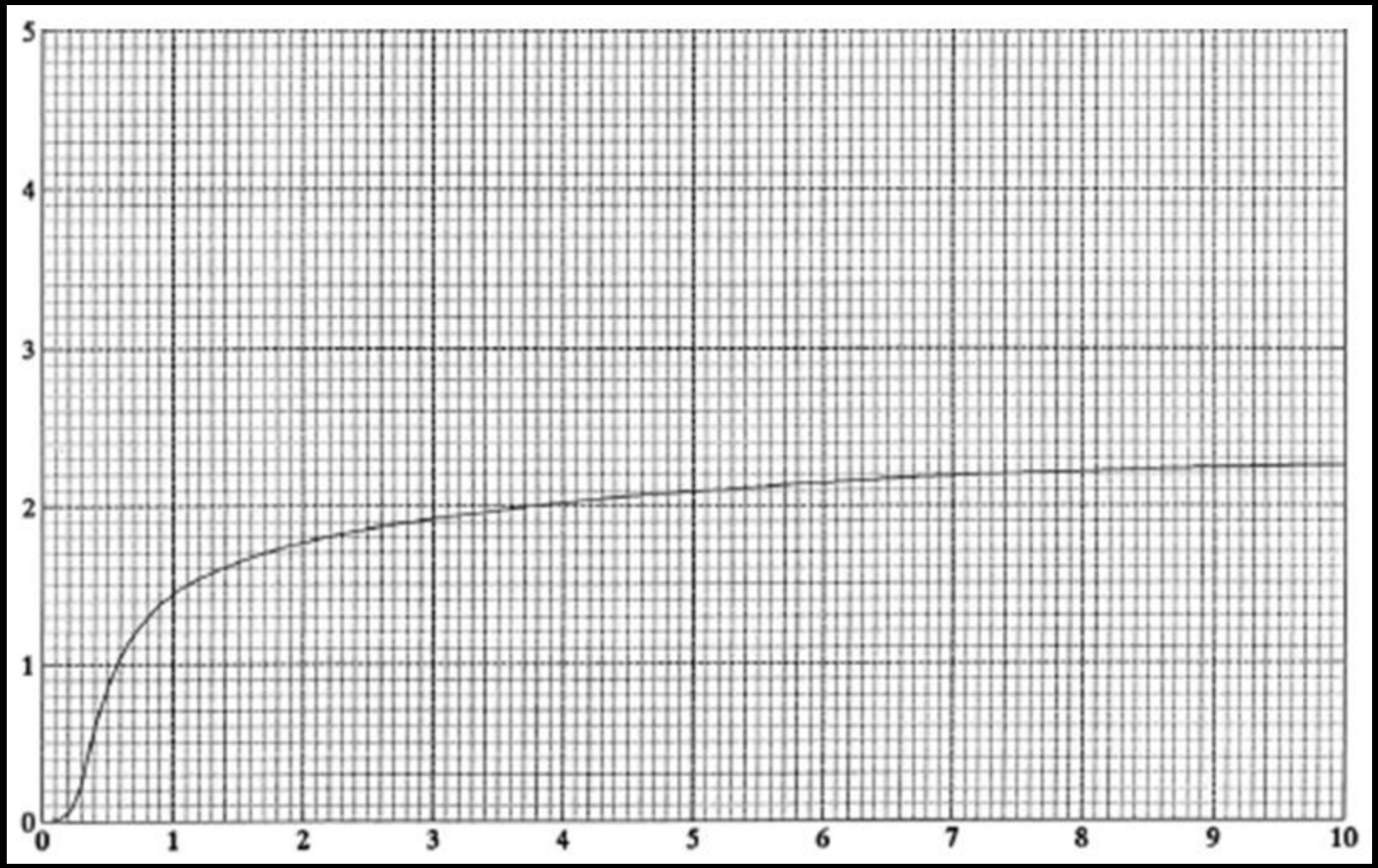


Spirogram

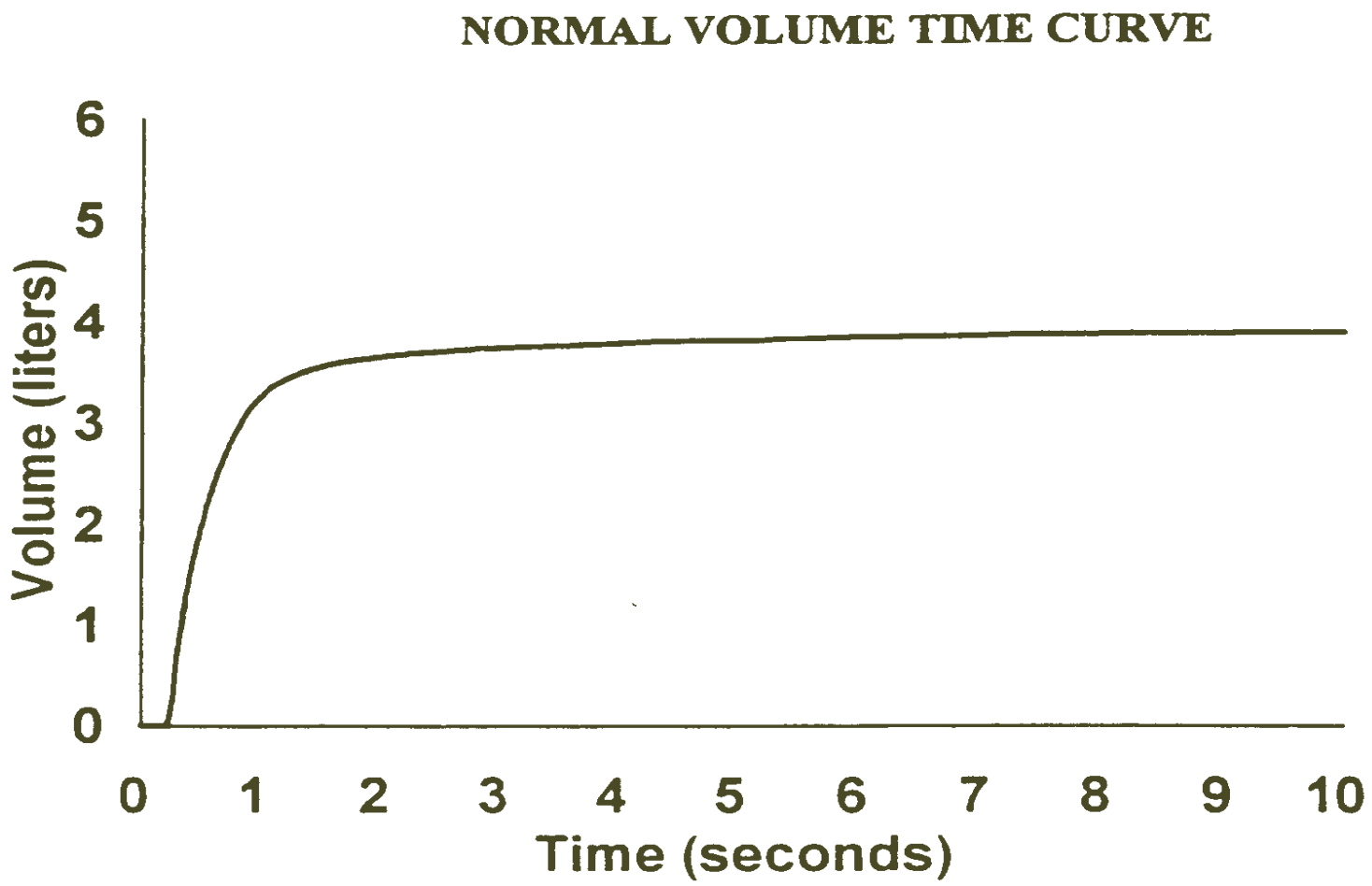
https://www.studyblue.com/#flashcard/view/11665032 (accessed 6/2/17)

Water Seal Spirometer

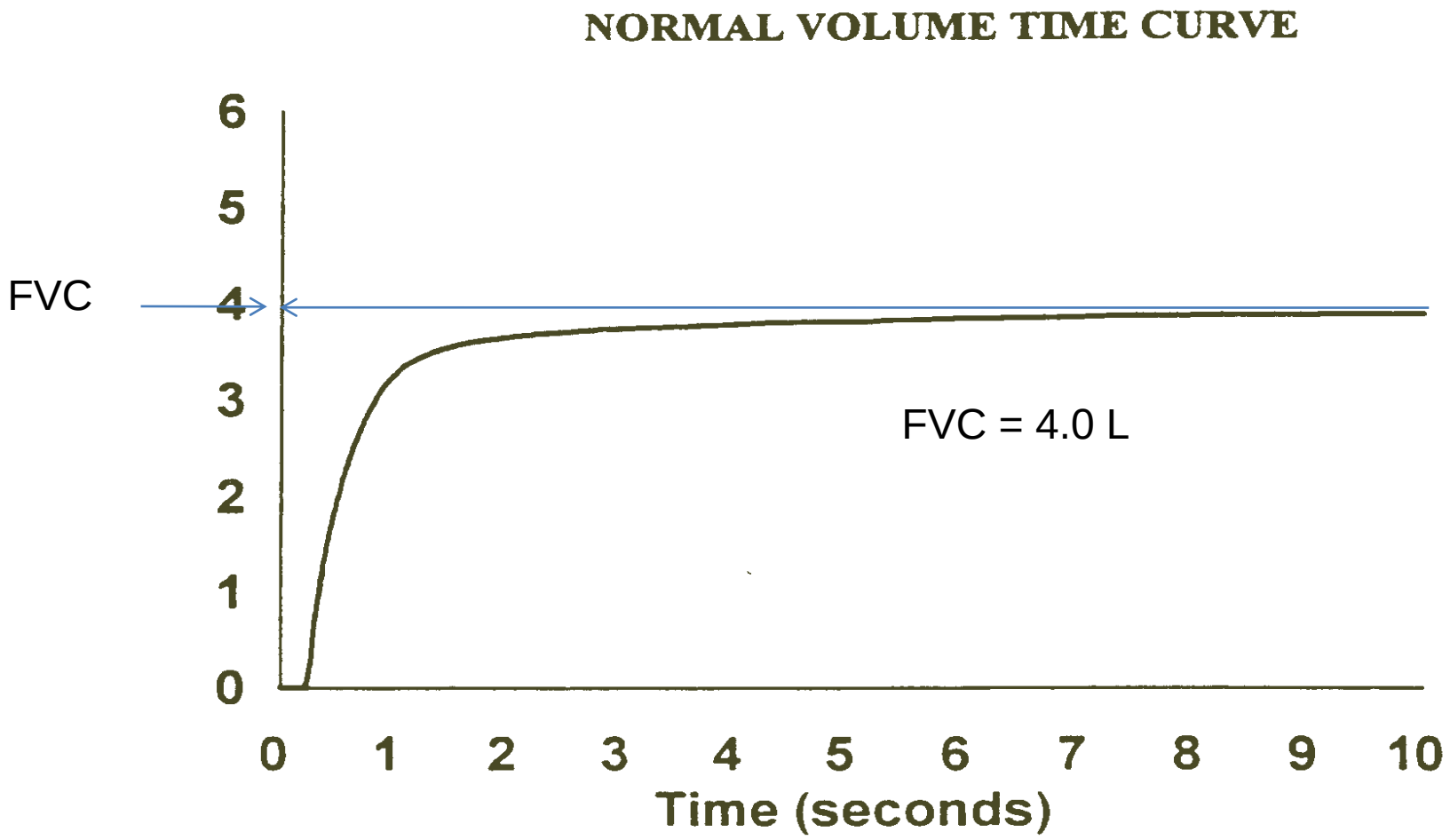
volume-time curve (spirogram)



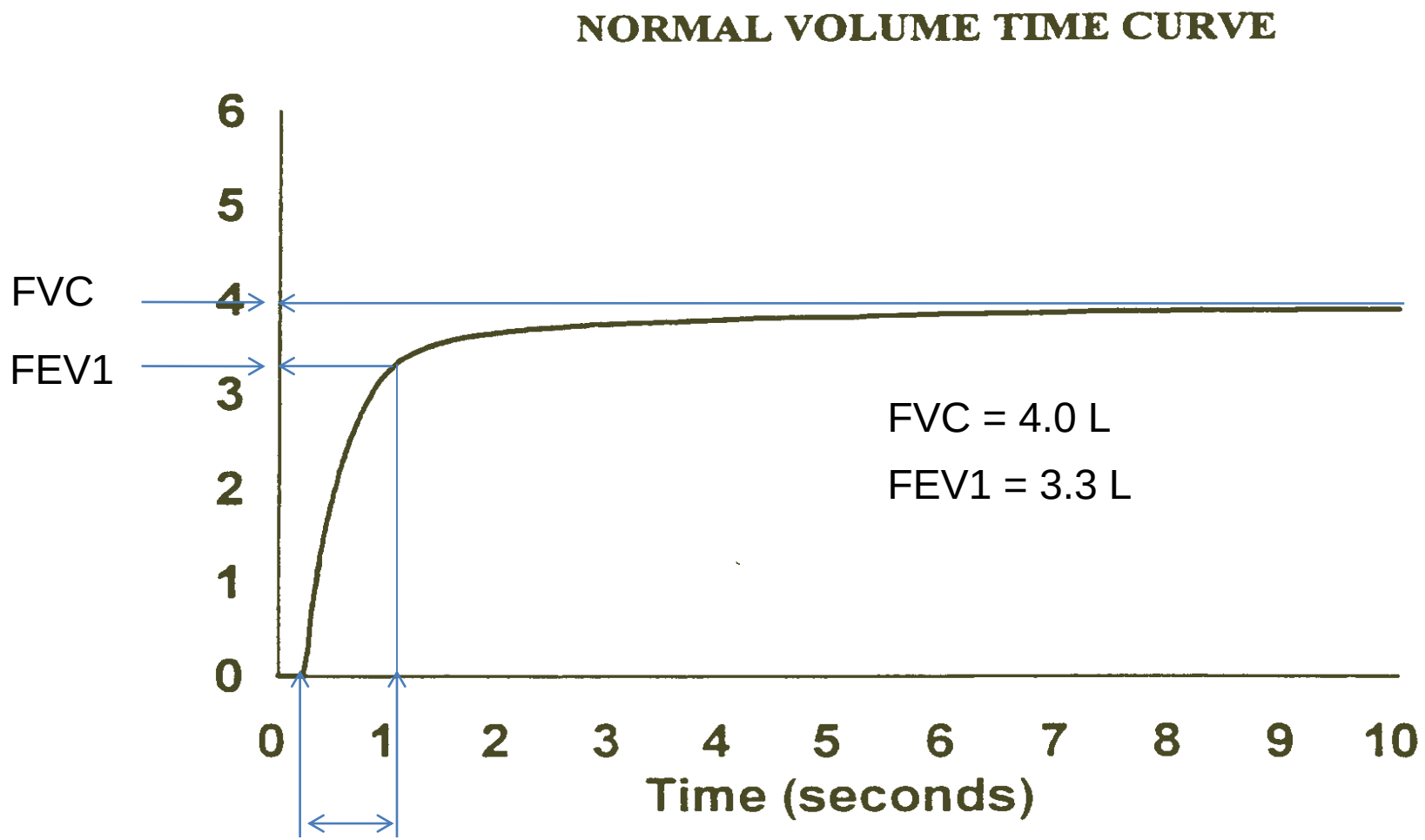
Spirogram


NORMAL VOLUME TIME CURVE
Volume (liters)
0
1
2
3
4
5
6
0 1 2 3 4 5 6 7 8 9 10
Time (seconds)

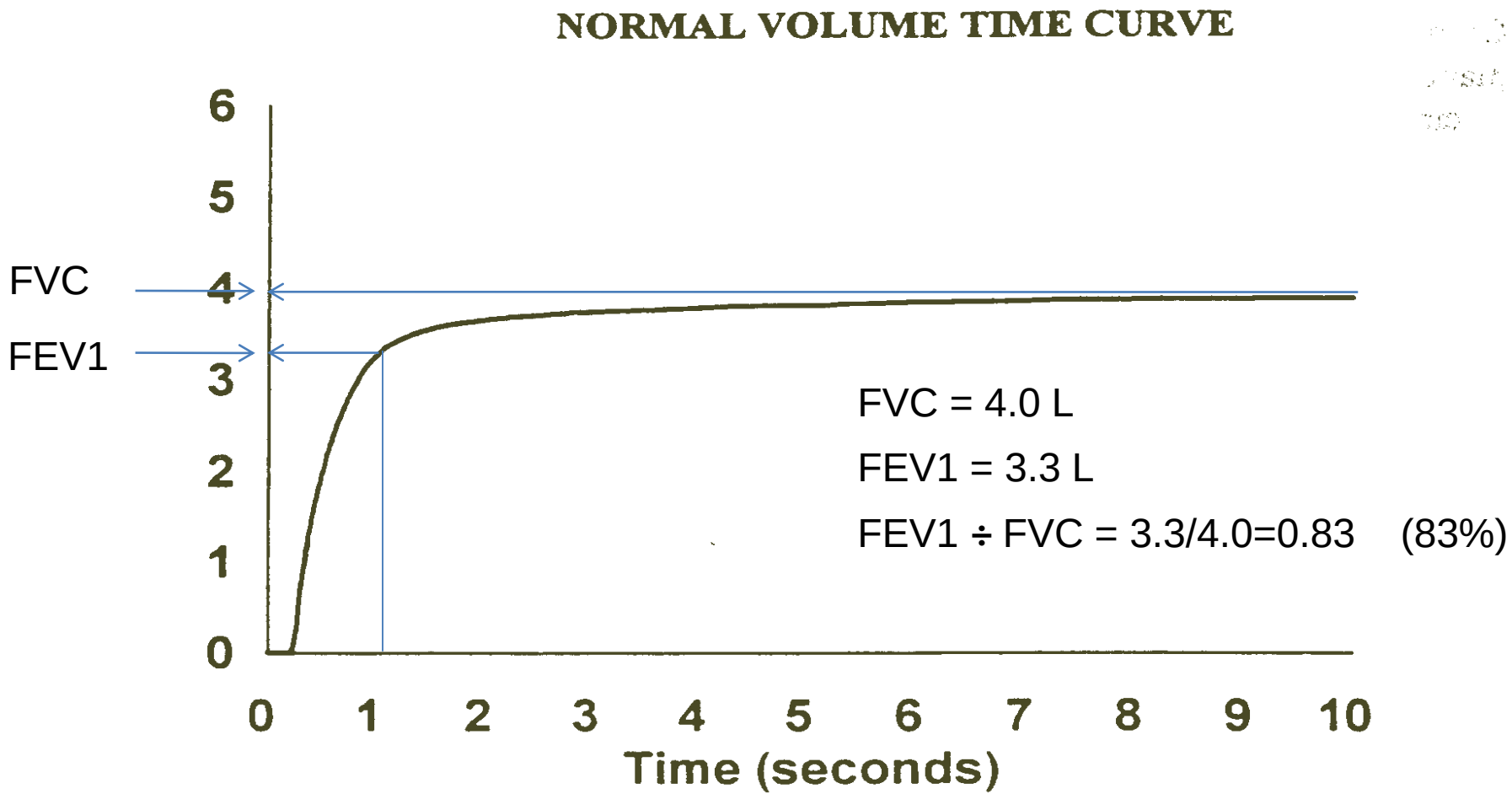
Forced Vital Capacity (FVC)



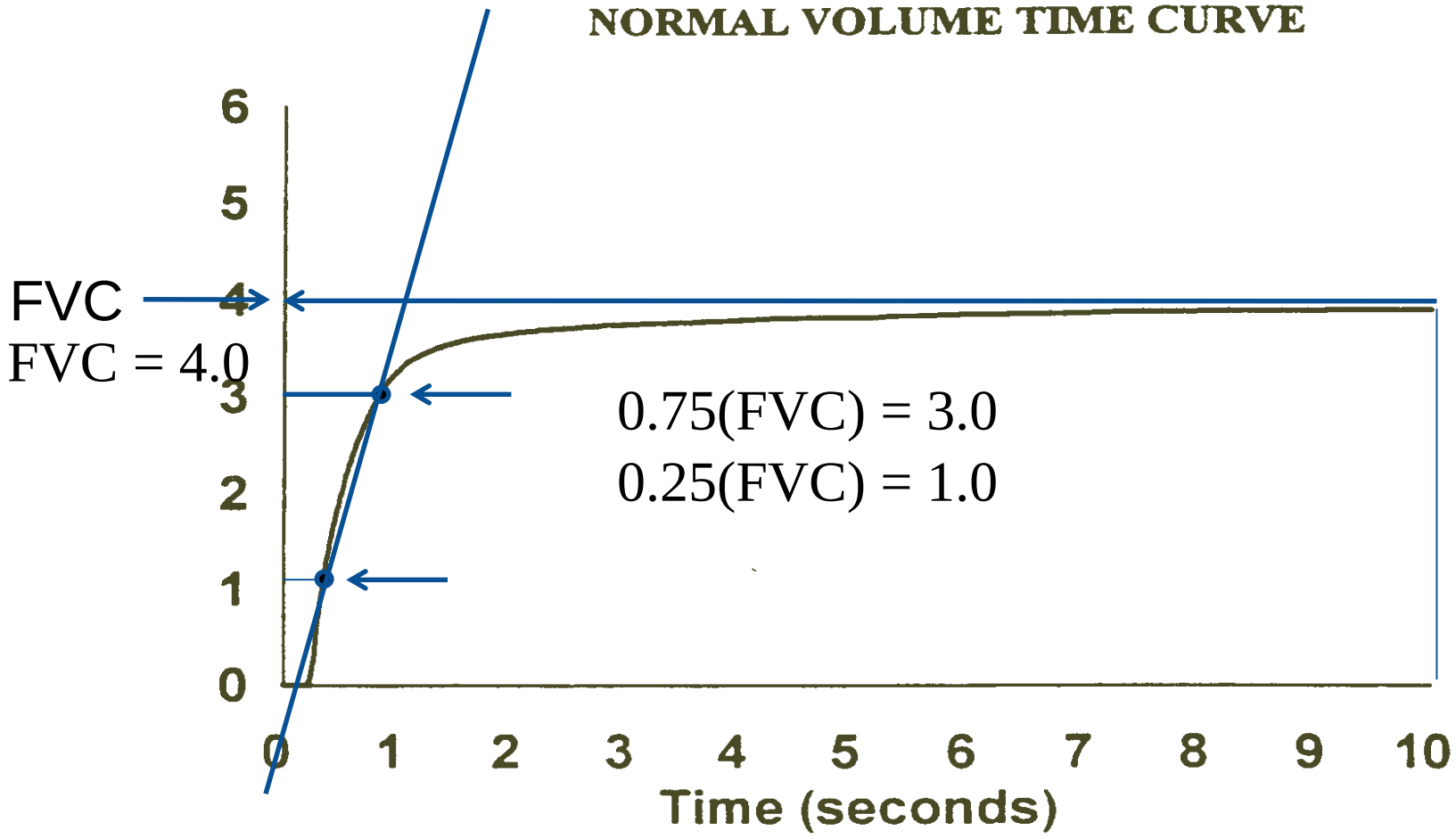
Forced Expiratory Volume at 1 second (FEV1)



FEV1/FVC ratio

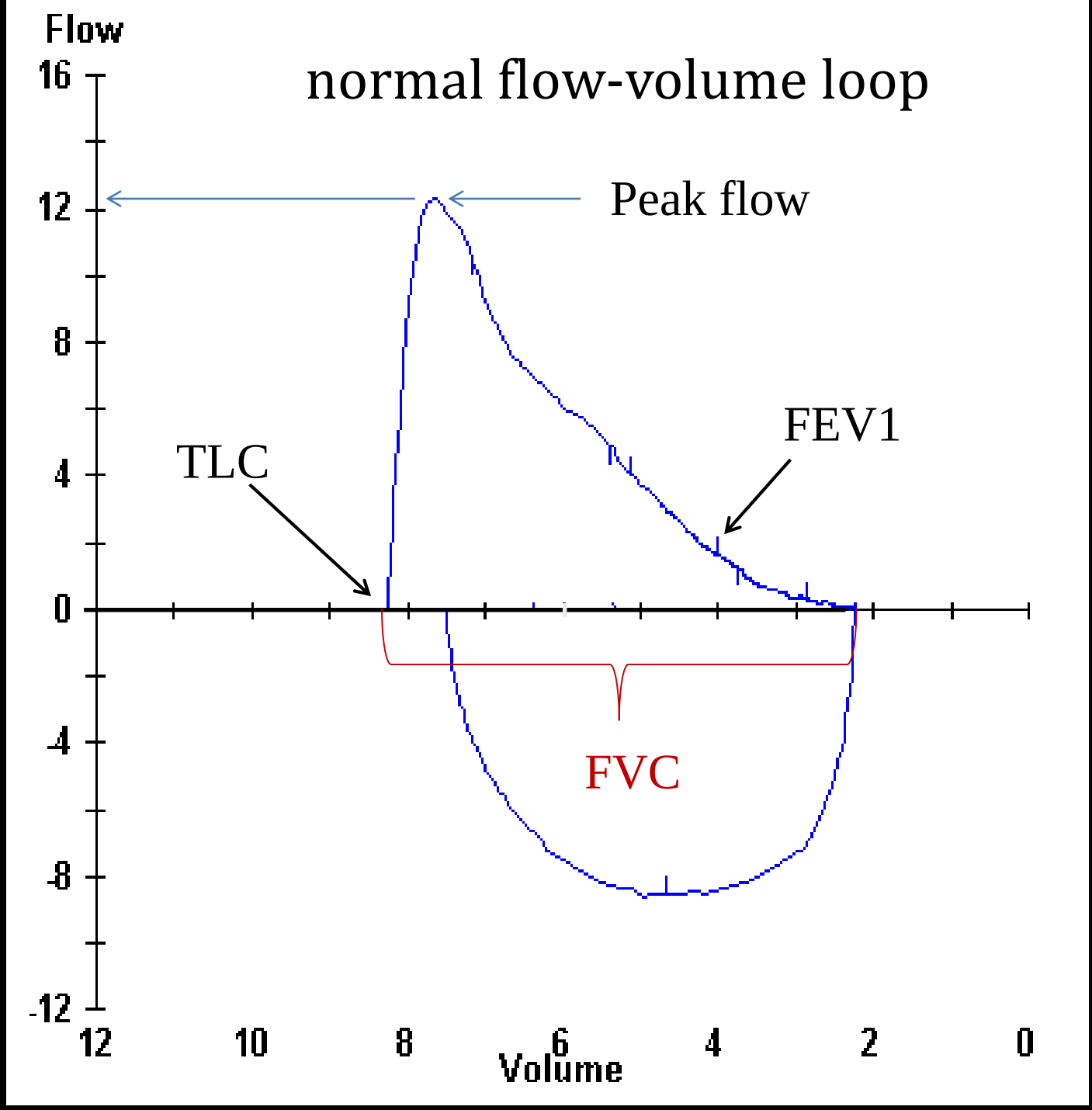


Forced Expiratory Flow 25-75% ($FEF_{25-75\%}$)



Flow Spirometers (pneumotachometer)

- Advantages
  - Measure flow directly
  - Portable
  - Easily cleaned, (often disposable)
- Disadvantages
  - Hypersensitive: small error in zero can produce large error in volume


normal flow-volume loop
Flow
16
12
8
4
0
-4
-8
-12
Peak flow
TLC
FEV1
FVC
12
10
8
6
4
2
0
Volume

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John Hutchinson

http://www.healthline.com/health- slideshow/copd-history#5. Accessed 7/1/2013

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.

1. The subject which I have the honour to bring before this Society, is the consideration of the functions of the organs of respiration, with reference both to health and disease, as deduced from the result of an extensive research.

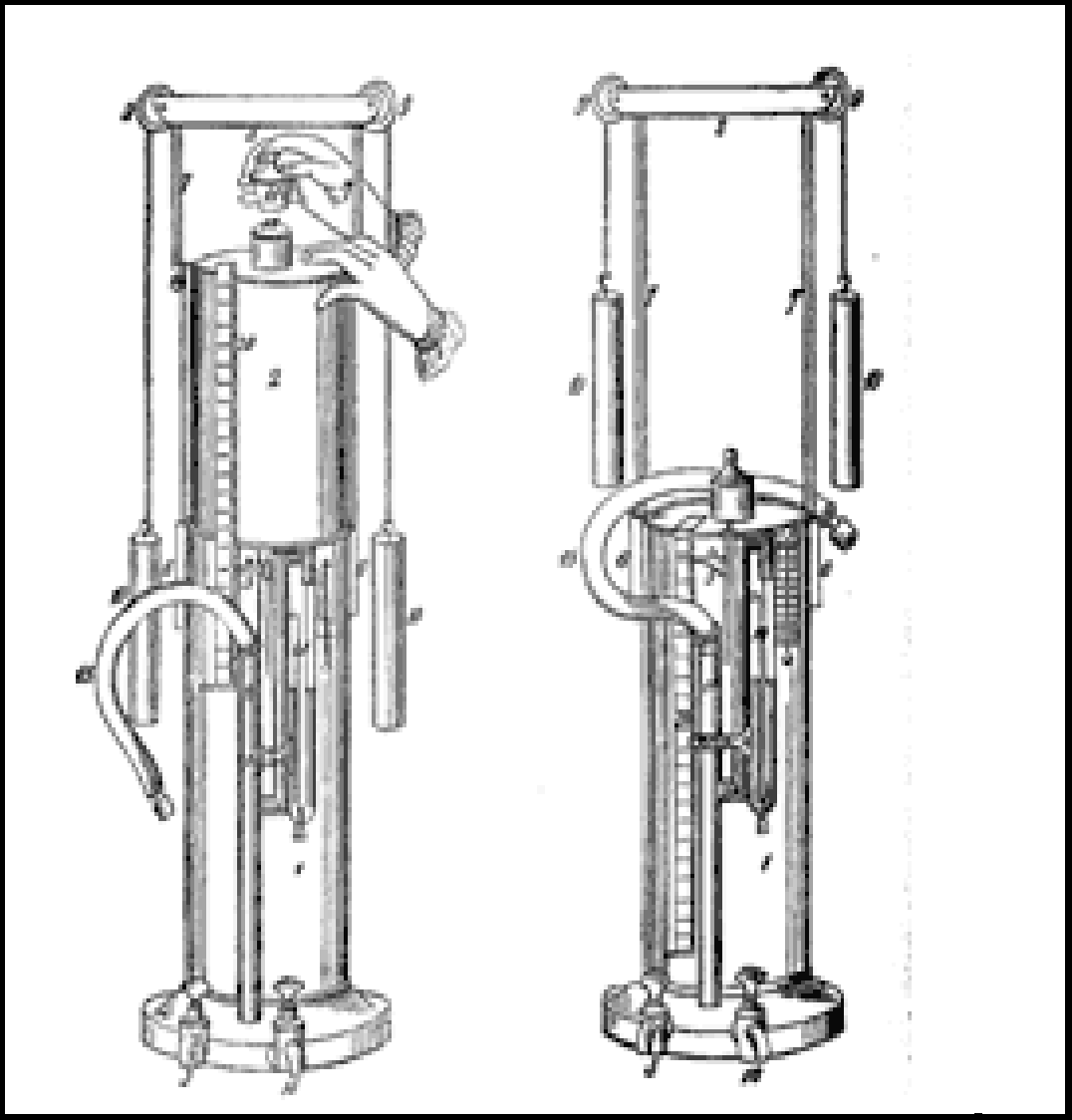
Before commencing this investigation, it is advisable to ascertain what has been already done by others upon the same subject, in order that the observer may be directed to the points which most require examination, and be enabled to render more apparent the results of his own experiments.

To understand the mechanism and function of the thorax and its contents, demands essentially a knowledge of the circulation of the blood, the composition and pressure of the atmosphere. These subjects were so unknown to the ancients, that we are not surprised to find from their writings how little accurate knowledge they possessed respecting the functions of the respiratory organs.

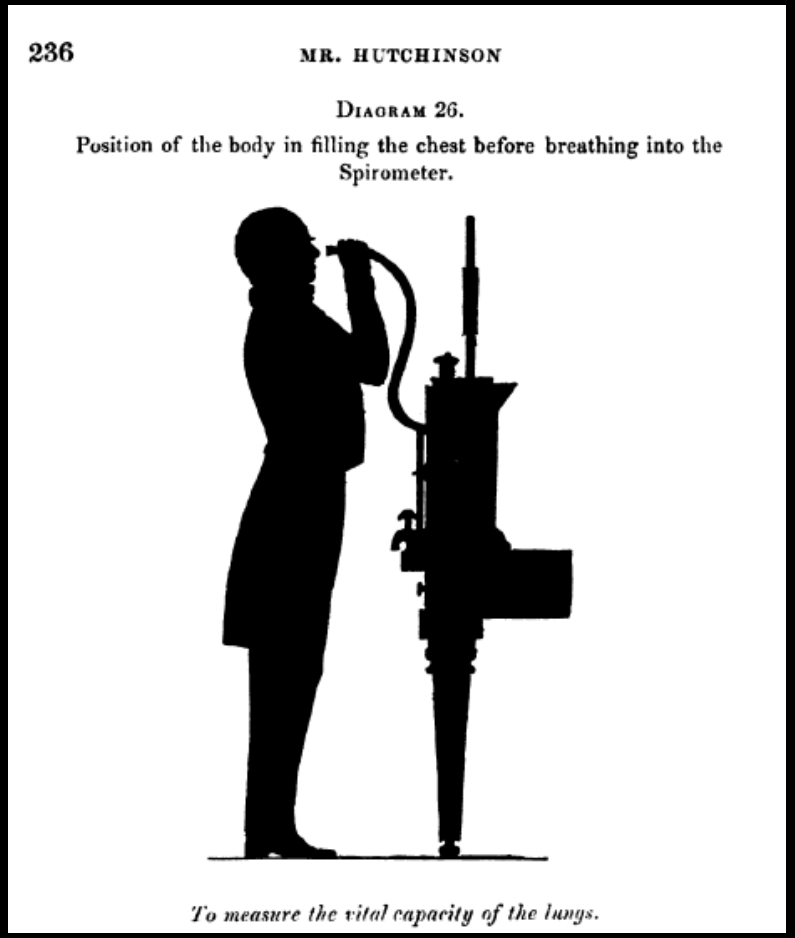
It is no less curious than instructive to observe, that while their writings teem with refined and absurd hypotheses, how tenacious they were of yielding to the truth when light first began to glimmer upon the subject.

Med Chir Trans 1846; 29: 137-252

Hutchinson's Spirometer



https://wiki.engr.illinois.edu/display/BIOE414/History+of+Spirometry Accessed 7/1/2013



236 MR. HUTCHINSON

DIAGRAM 26.

Position of the body in filling the chest before breathing into the Spirometer.

To measure the vital capacity of the lungs.

Med Chir Trans 1846; 29: 137-252

DIAGRAM 1.

The division of the thoracic movements.

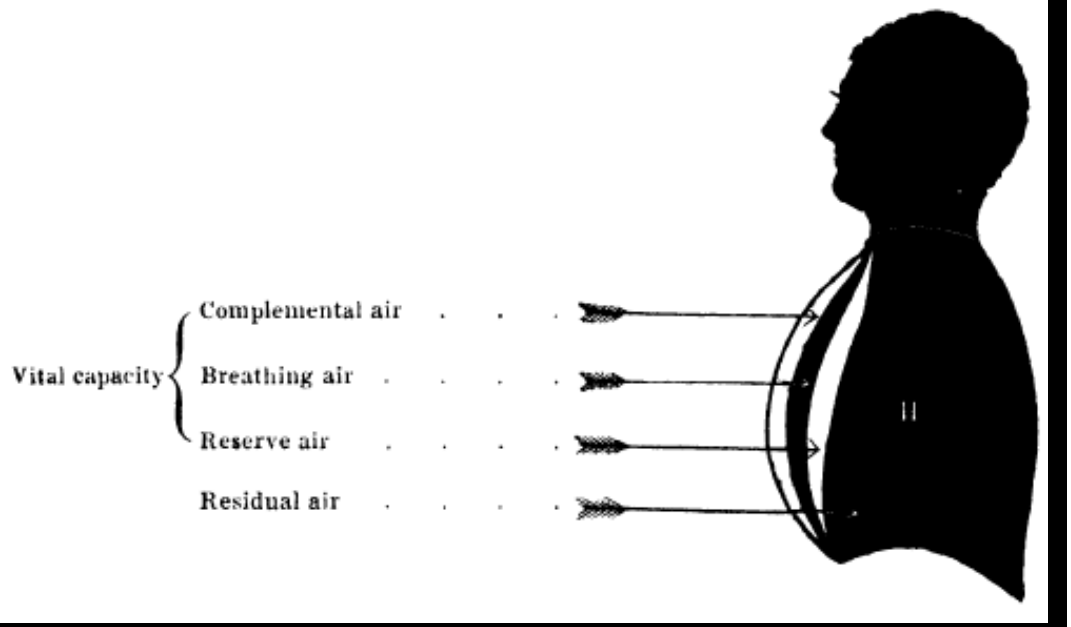
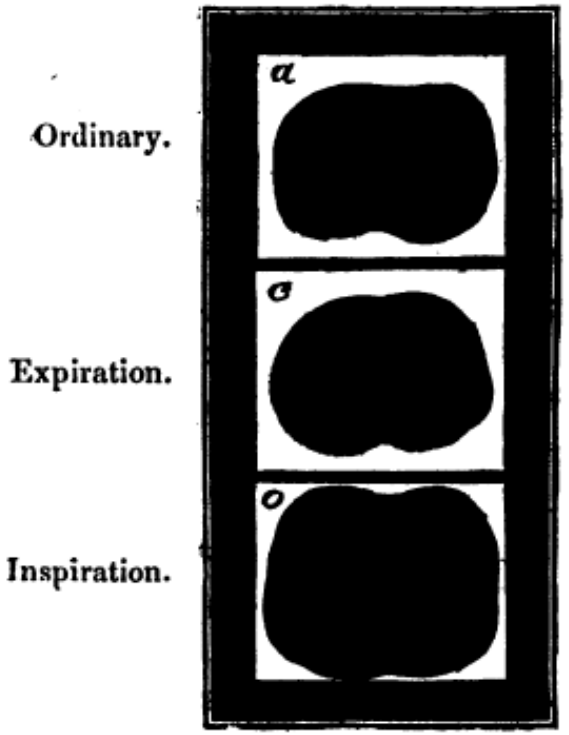


DIAGRAM 15.

Relative difference in the three stages of respiration.



Med Chir Trans 1846; 29: 137-252

W.—Table of the Vital Capacity in relation to Height.

Height.	From Observation.	Regular Progression.	Height.	From Observation.	Regular Progression.
ft. in. ft. in.	cub. in.	cub. in.	ft. in. ft. in.	cub. in.	cub. in.
5 0 to 5 1	174	174	5 6 to 5 7	229	222
5 1 to 5 2	177	182	5 7 to 5 8	228	230
5 2 to 5 3	189	190	5 8 to 5 9	237	238
5 3 to 5 4	193	198	5 9 to 5 10	246	246
5 4 to 5 5	201	206	5 10 to 5 11	247	254
5 5 to 5 6	214	214	5 11 to 6 0	259	262

Med Chir Trans 1846; 29: 137-252

Low Lung Function in Young Adult Life Is Associated with Early Mortality

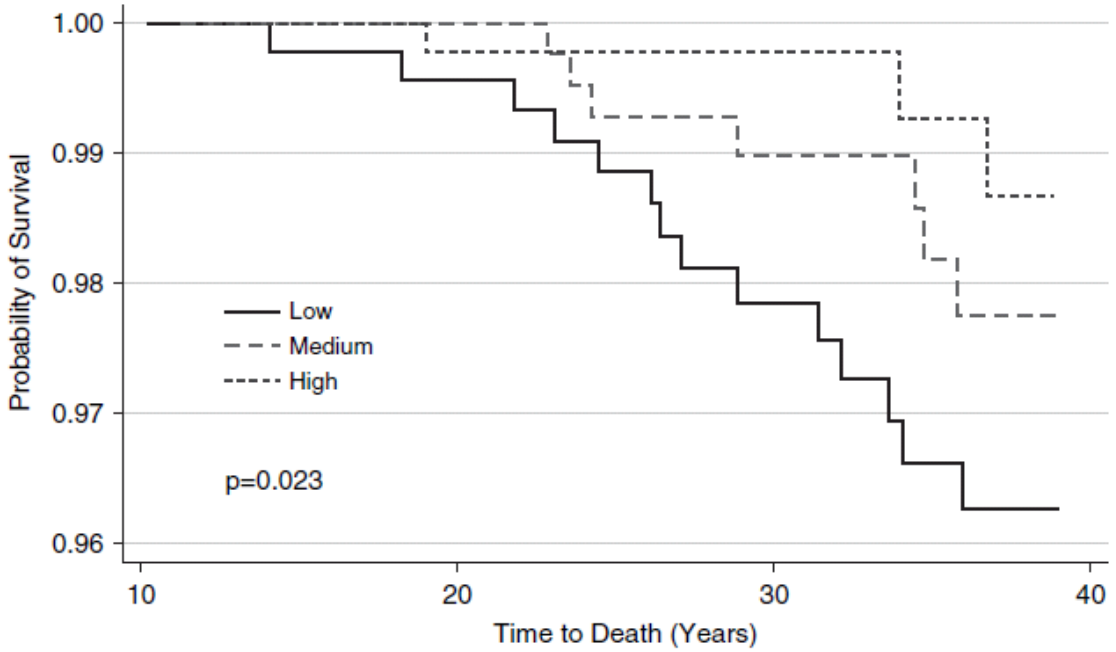


Figure 1. Survival curves for cardiopulmonary mortality by tertiles of FEV_1 percentage predicted at baseline. Low tertile: FEV_1 percentage predicted, <95.19%; medium tertile: FEV_1 percentage predicted, ⩾95.19% and <106.36%; high tertile: FEV_1 percentage predicted, ⩾106.36%.

In conclusion, in a long-term population-based cohort, we found that low levels of FEV_1 and, to a lesser extent, FVC achieved by the age of 21–35 years predict risk of early cardiopulmonary mortality.

AJRCCM 2017. 195:1399-1401

Indications for Spirometry

Diagnosis

- evaluate symptoms
  - cough
  - dyspnea
  - wheezing
- evaluate signs
  - cyanosis
  - abnormal breath sounds
  - chest deformity
- evaluate abnormal laboratory tests
  - hypoxemia
  - hypercarbia
  - polycythemia
  - abnormal chest imaging

Indications for Spirometry

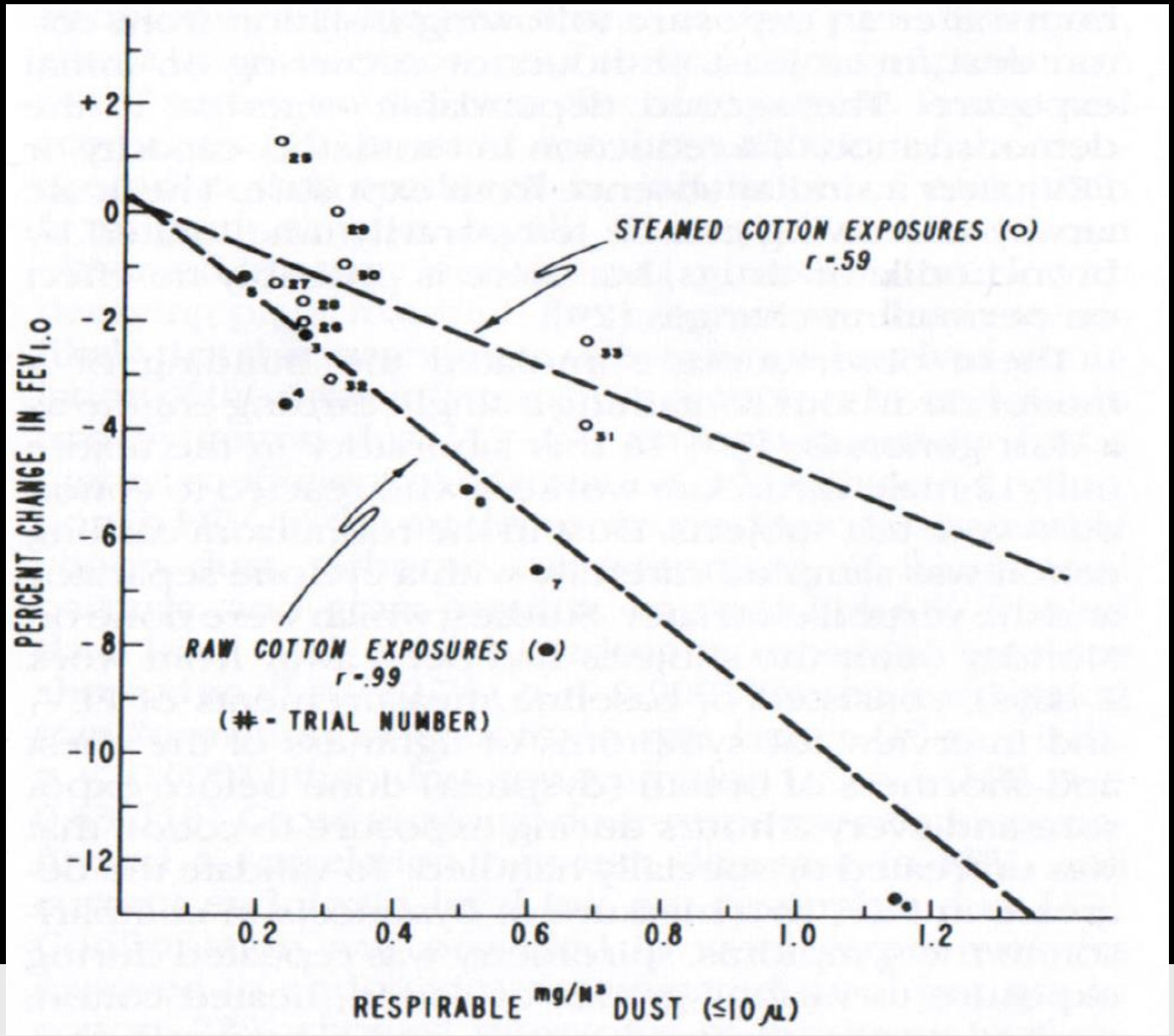
- measure the effect and progression of disease on pulmonary function
- assess therapeutic intervention
  - inhalers
  - systemic medications (corticosteroids, immunomodulators)
- assess pre-operative risk
  - lung resection
  - pneumonectomy
- assess health status before beginning strenuous physical activity programs
- screening individuals at risk for the development of pulmonary disease
  - toxic exposures (occupational, disasters, medications)
  - Smokers (with symptoms and/or if > 45 y.o.)

National Lung Health Education Program

"COPD is easily detected in its preclinical phase using spirometry, and successful smoking cessation (a cost-effective intervention) prevents further disease progression. This consensus statement recommends the widespread use of office spirometry by primary-care providers for patients ≥ 45 years old who smoke cigarettes."

Ferguson GT et al. Chest. 117:4, 1146 2000

Byssinosis



% change FEV1 by respirable dust level in a 16-man panel of cotton cardroom workers exposed to raw cotton and steamed cotton, 1971-1972.

Merchant, JA et al. Br J Ind Med 1973, 30:237-47

Occupational Safety and Health Cotton Dust Standard (29 CFR 1910.1043)

- 1978 – Cotton Dust Standard established
- Based on exposure – response relationship between cotton dust particle concentration and lung function impairment

Permissible Exposure Limit (PEL)

- the amount of dust that a person can be exposed to in an 8-hour work shift over their working life without adverse health effects

PEL Cotton Dust (29 CFR 1910.1043)

- 200 micrograms per cubic meter of lint-free respirable dust averaged over an eight-hour period in yarn manufacturing
- 750 micrograms per cubic meter of lint-free respirable dust over an eight-hour period of slashing and weaving
- 500 micrograms per cubic meter of lint-free respirable dust over an eight-hour period in waste houses and yarn manufacturing areas where exposure to lower grade washed cotton occurs.

A Guide for Persons Employed in Cotton Dust Environments: 2007 North Carolina Department of Labor

Medical Monitoring (29 CFR 1910.1043)

"In any workplace where cotton dust is present there must be a medical surveillance program for all employees exposed to cotton dust. Examinations must be done by or under the direction of a licensed physician. People administering the pulmonary function breathing tests must have attended a course approved by the National Institute for Occupational Safety and Health (NIOSH)."

A Guide for Persons Employed in Cotton Dust Environments: 2007 North Carolina Department of Labor

Medical Monitoring (29 CFR 1910.1043)

Test results are compared to a set of predicted tables based on a person's age, height, sex and race. Generally, tests are considered to be within the normal range if they are 80 percent or greater of the predicted value. The initial determinations should be made *prior to entering the workplace on the first day worked and after having no cotton dust exposure for* at least 35 hours. The pulmonary function tests will be repeated during the shift, at least four hours, but not longer than 10 hours after the first test. These tests are then compared for changes. If there is a decrease of 5 percent or greater on the second after-exposure test, it may indicate a reaction to cotton dust. Each employee will be assigned a byssinosis grade based on his or her response to the respiratory questionnaire.

A Guide for Persons Employed in Cotton Dust Environments: 2007 North Carolina Department of Labor

Other occupational exposures that require assessment of lung function

- Title 29, Part 1915.1001: Asbestos. If possible exposure, surveillance including spirometry
- Title 29, Part 1910.1028: Benzene containing petrochemicals. if respirators required more than 30 days per year, then spirometry required every 3 years.
- Title 20 CFR part 718.204 : Coal dust exposure.

Section 37.3 Chest Radiographs Required for Miners

Existing § 37.3 requires mine operators to provide miners an opportunity to receive a chest radiograph. This section is amended to remove the word ''underground'' and remove obsolete dates and examples. The section is also amended to specify that evidence of decreased lung function demonstrated by a spirometry exam conducted pursuant to § 37.92(b)(2) may trigger a third chest radiograph.

Section 37.4 Plans for Chest Radiographic Examinations

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Section

Section 37.8 Radiographic Examination at Miner's Expense

Existing § 37.8 allows that the miner may pay for an X-ray exam himself or herself, and NIOSH will provide the classification and report as if the exam was conducted pursuant to a mine operator's plan. This section is removed from this subpart and moved to new § 37.103; specific amendments are discussed below.

Section 37.40 General Provisions

Existing § 37.40 outlines general provisions for chest X-rays. This section is amended to update the terminology.

heading and paragraph (a) are amended to replace the words ''interpretation'' and ''interpretations'' with ''classification'' and ''classifications.'' Paragraph (b) is amended to strike an obsolete reference to standards established in 1978.

B. Subpart—Spirometry Examinations

This subpart is added to Part 37 and establishes standards for spirometry testing for all coal miners, working in both underground and surface mines. The new MSHA rule reduces permissible exposure and increases requirements for dust monitoring, however MSHA acknowledges that in

New § 37.90 provides the scope of the provisions in Subpart—Spirometry Examinations, and is amended to clarify the purpose of this subpart. Under this subpart, coal mine operators are required to provide spirometry examinations to each current and new coal miner, using medical facilities approved by NIOSH according to the standards established in this subpart.

20 CFR 718.204

(2) *Medical criteria.* In the absence of contrary probative evidence, evidence which meets the standards of either paragraphs (b)(2)(i), (ii), (iii), or (iv) of this section **shall establish a miner's total disability:**

(i) Pulmonary function tests showing values equal to or less than those listed in Table B1 (Males) or Table B2 (Females) in Appendix B to this part for an individual of the miner's age, sex, and height for the **FEV1** test; if, in addition, such tests also reveal the values specified in either paragraph (b)(2)(i)(A) or (B) or (C) of this section:

(A) Values equal to or less than those listed in Table B3 (Males) or Table B4 (Females) in Appendix B of this part, for an individual of the miner's age, sex, and height for the **FVC** test, or

(B) Values equal to or less than those listed in Table B5 (Males) or Table B6 (Females) in Appendix B to this part, for an individual of the miner's age, sex, and height for the MVV test, or

(C) A percentage of 55 or less when the results of the FEV1 test are divided by the results of the FVC test (**FEV1/FV**C equal to or less than 55%),

Indications for Spirometry

- disability
  - assess individuals for medical/legal reasons
  - assess patients as part of a rehabilitation program
  - assess risks as part of an insurance evaluation
- public health
  - epidemiological surveys
  - clinical research
  - derivation of reference equations

Pulmonary Dysfunction

CLASS	CLASS 0	CLASS 1	CLASS 2	CLASS 3	CLASS 4
WHOLE PERSON IMPAIRMENT RATING (%)	0	2%-10%	11%-23%	24%-40%	45%-65%
SEVERITY GRADE (%)		2 4 6 8 10 (A B C D E) (Minimal)	11 14 17 20 23 (A B C D E) (Mild)	24 28 32 36 40 (A B C D E) (Moderate)	45 50 55 60 65 (A B C D E) (Severe)
HISTORY	No current symptoms *and/or* intermittent Dyspnea that does not require treatment	Dyspnea controlled with intermittent or continuous treatment *or* intermittent, mild Dyspnea despite continuous treatment	Constant mild Dyspnea despite continuous treatment *or* intermittent, moderate Dyspnea despite continuous treatment	Constant moderate Dyspnea despite continuous treatment *or* intermittent, severe Dyspnea despite continuous treatment	Constant severe Dyspnea despite continuous treatment *or* intermittent, extreme Dyspnea despite continuous treatment
PHYSICAL FINDINGS	No current signs of disease	Physical findings not present with continuous treatment *or* intermittent, mild physical findings	Constant mild physical findings despite continuous treatment *or* intermittent, moderate findings	Constant moderate physical findings despite continuous treatment *or* intermittent, severe findings	Constant severe physical findings despite continuous treatment *or* intermittent, extreme findings
OBJECTIVE TESTS					
FVC	FVC ≥80% of predicted	FVC between 70% and 79% of predicted	FVC between 60% and 69% of predicted	FVC between 50% and 59% of predicted	FVC below 50% predicted
	and	*or*	*or*	*or*	*or*
FEV_1	FEV_1 ≥80% of predicted	FEV_1 between 65% and 79% of predicted	FEV_1 between 64% and 55% of predicted	FEV_1 between 45% and 54% of predicted	FEV_1 below 45% of predicted
	and				
FEV_1/FVC (%)	FEV_1/FVC (%) > lower limits of normal and/or (>75% of predicted)				
	or	*or*	*or*	*or*	*or*
DLco	*and* DLco ≥75% of predicted	DLco between 65% and 74% of predicted	DLco between 55% and 64% of predicted	DLco between 45% and 54% of predicted	DLco below 45% of predicted
	or	*or*	*or*	*or*	*or*
$\dot{V}o_2$ max	>25mL/(kg·min) or >7.1 METs	between 22 and 25 mL/(kg·min)	between 21 and 18 mL/(kg·min)	between 17 and 15 mL/(kg·min)	<15mL/(kg·min)
		or	*or*	*or*	*or*
		6.1–7.1 METs	5.1–6.0 METs	4.3–5.0 METs	<4.3 METs

* FVC indicates forced vital capacity; FEV_1, forced expiratory volume in the first second; DLco, diffusion capacity for carbon monoxide; Vo_2 max, maximum oxygen consumption; and METs, metabolic equivalents (multiples of resting oxygen uptake).

Guides to the evaluation of permanent impairment. 6th ed. 2008. American Medical Association. p.88.

CLASS	CLASS 0	CLASS 1	CLASS 2	CLASS 3	CLASS 4
WHOLE PERSON IMPAIRMENT RATING (%)	0	2%-10%	11%-23%	24%-40%	45%-65%
SEVERITY GRADE (%)		2 4 6 8 10 (A B C D E) (Minimal)	11 14 17 20 23 (A B C D E) (Mild)	24 28 32 36 40 (A B C D E) (Moderate)	45 50 55 60 65 (A B C D E) (Severe)
OBJECTIVE TESTS					
FVC	FVC ≥80% of predicted	FVC between 70% and 79% of predicted	FVC between 60% and 69% of predicted	FVC between 50% and 59% of predicted	FVC below 50% predicted
	and	*or*	*or*	*or*	*or*
FEV_1	FEV_1 ≥80% of predicted	FEV_1 between 65% and 79% of predicted	FEV_1 between 64% and 55% of predicted	FEV_1 between 45% and 54% of predicted	FEV_1 below 45% of predicted
	and				
FEV_1/FVC (%)	FEV_1/FVC (%) > lower limits of normal and/or (>75% of predicted)				

Guides to the evaluation of permanent impairment. 6th ed. 2008. American Medical Association. p.88.

Indications for Spirometry

Diagnosis

- evaluate symptoms
  - cough
  - dyspnea
  - wheezing
- evaluate signs
  - cyanosis
  - abnormal breath sounds
  - chest deformity
- evaluate abnormal laboratory tests
  - hypoxemia
  - hypercarbia
  - polycythemia
  - abnormal chest imaging

"All That Wheezes Is Not Asthma" (or COPD)!

David A. Kaminsky, MD, FCCP
Burlington, VT

This famous quote was made by Chevalier Jackson in the *Boston Medical Quarterly* in 1865.[1] At the time, Jackson, an otolaryngologist, was concerned about foreign body aspiration causing wheezing and being misdiagnosed as asthma. Today, this adage reminds us that there are many causes of wheezing and shortness of breath besides the common and classic diagnosis of asthma. Among

where spirometry is normal. Nevertheless, we need to remember that spirometry remains one of the best available, objective measures we have of defining the "O" in COPD so that we may render the most accurate and appropriate diagnosis in our patients who are short of breath or wheeze.

147#2 CHEST FEBRUARY 2 0 1 5

P140 Is it really Asthma? - appropriate assessment and testing is important for accurate diagnosis.

S. Toor; S. Akram; K. Al Mazrouei; A. Al Zaabi; I. Saleem
▸ Author and Funding Information

Chest. 2017;151(5_S):A37. doi:10.1016/j.chest.2017.04.041

Article

Asthma is common in United Arab Emirates with an estimated prevalence of 10%. A significant area of country comprises of desert and dust storms are common. Weather is extremely hot/ humid and exposure to dust is a risk factor for air ways disease. There is no objective evidence to back up estimated prevalence of 10%. General practitioners have a tendency to over diagnose asthma without appropriate testing. A significant number of patients are wrongly diagnosed with Asthma in early childhood and they carry this diagnosis throughout their life.

National military service has been made mandatory for young Emirati males, aged 19 to 34 years. During health screening we have come across a huge patient population who has been labeled with a diagnosis of Asthma.

Aim of this study was to identify patients who have been wrongly diagnosed with Asthma and to document true prevalence of Asthma in this group.

Methods: Patients with Asthma identified during health screening for national service are referred to the Pulmonology department in Zayed Military Hospital for further assessment. These patients underwent clinical assessment by consultant pulmonologists who arranged for pre and post bronchodilator spirometry. Clinical assessment included symptoms of cough, wheeze, chest tightness, night time symptoms, exercise tolerance, use of rescue inhalers, hospitalization and smoking history. Patients who had a high clinical suspicion but no bronchodilator response on spirometry were subjected to Methocholine challenge test.

TABLE 2 Diagnosis from primary-care notes before spirometry testing and the change made to the diagnosis as a result of testing

Diagnosis before spirometry	Diagnosis after spirometry	Patients n
No diagnosis	Asthma	22
	COPD	60
	Other	2
Asthma	Asthma	34
	COPD	31
COPD	Asthma	15
	COPD	48
Bronchiectasis	Bronchiectasis	5
All diagnoses	Asthma	71
	COPD	139
	Bronchiectasis	5
	Other	2

COPD: chronic obstructive pulmonary disease.

Eur Respir J 2006; 28: 945–952

SUMMARY REPORT 2007

National Asthma Education and Prevention Program Expert Panel Report 3

Guidelines for the

Diagnosis and Management of Asthma

Diagnosis of Asthma

osis of asthma, the clinician
hat symptoms of recurrent
obstruction or airway
s are present; airflow
st partially reversible; and
es are excluded.

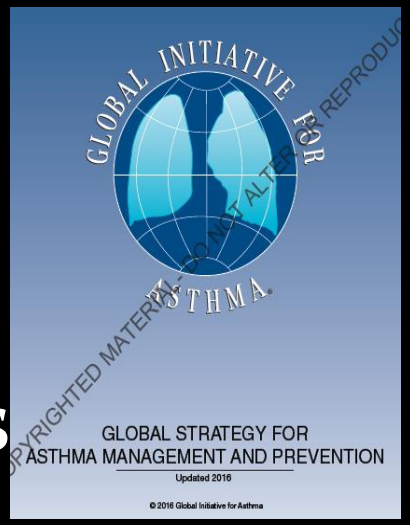
CATORS FOR CONSIDERING THMA

ble key indicators increases the
out spirometry is needed to establish

- Episodic symptoms of airflow obstruction or airway hyperresponsiveness are present.
- Airflow obstruction is at least partially reversible, measured by spirometry. Reversibility is determined by an increase in FEV_1 of >200 mL and ≥12 percent from baseline measure after inhalation of short-acting $beta_2$-agonist (SABA). Some studies indicate that an increase of ≥10 percent of the predicted FEV_1 after inhalation of a SABA may have higher likelihood of separating patients who have asthma from those who have chronic obstructive pulmonary disease (COPD).

Asthma:

- Recurring and variable symptoms
- Airflow limitation with reduced FEV1/FVC
- Positive bronchodilator reversibility test
- Positive bronchial challenge test



Global Initiative for Asthma. Global Strategy for Asthma Management And Prevention, 2016. Available from: www.ginasthma.org.

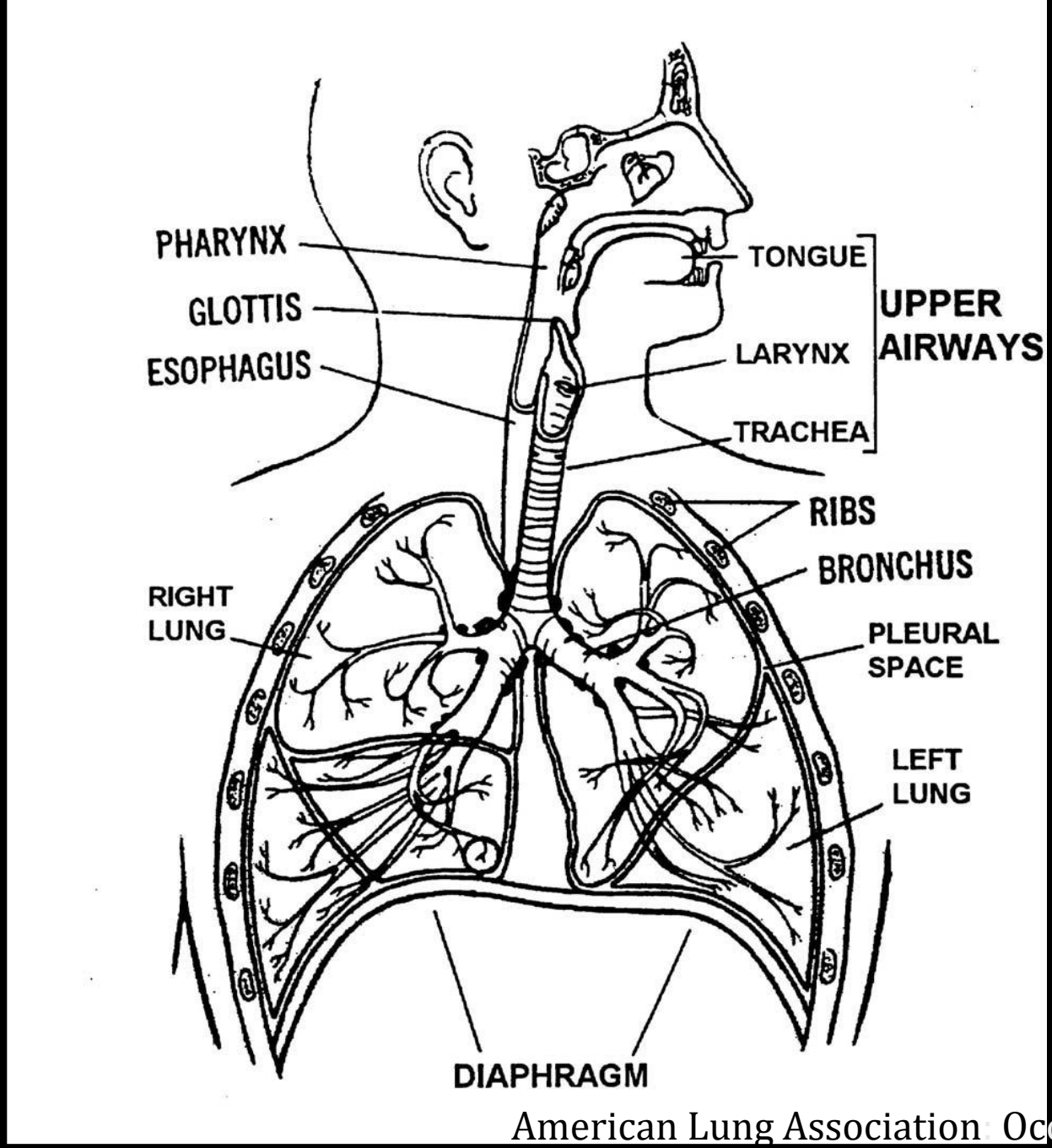
Global Initiative for Chronic Obstructive Lung Disease

GLOBAL ST
MANAGE
CHRONIC OBS

Figure 2.1. Pathways to the diagnosis of COPD

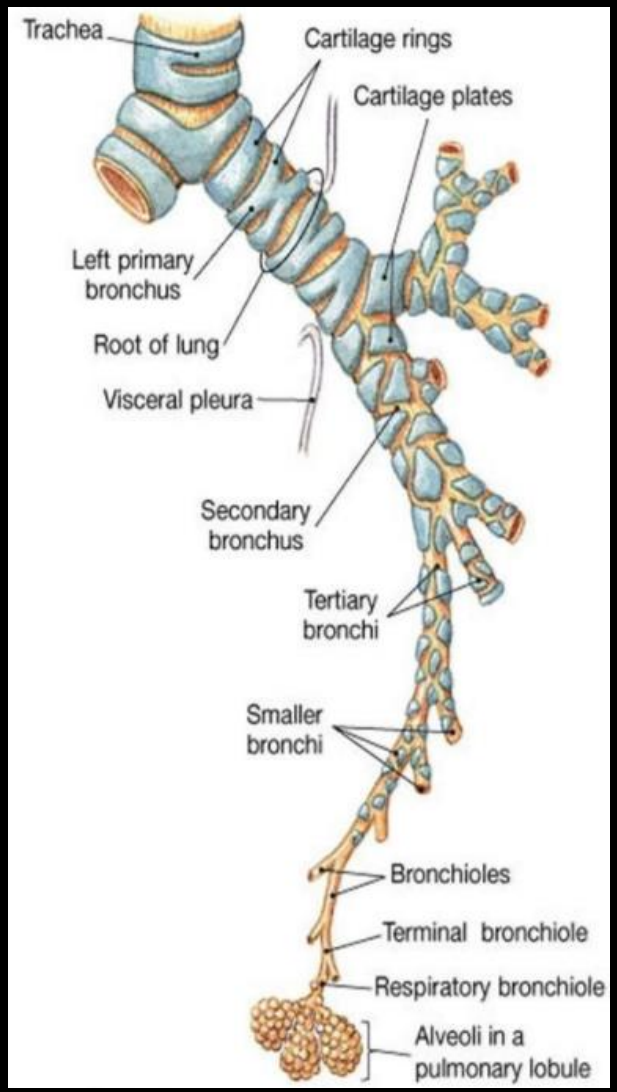
SPIROMETRY: Required to establish diagnosis

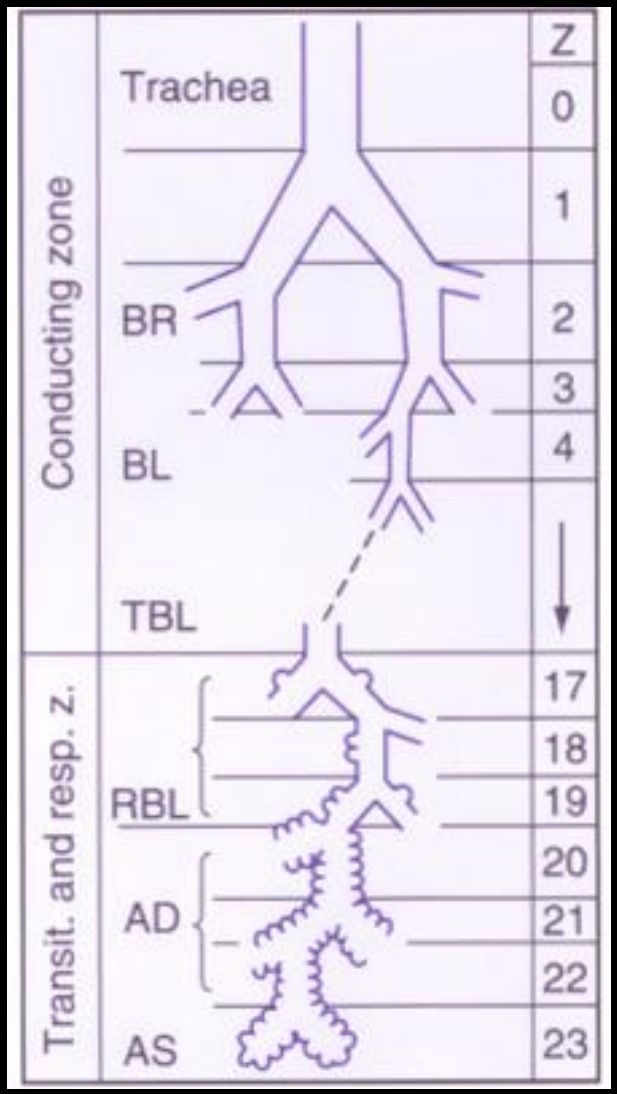
http://goldcopd.org/gold-2017-global-strategy-diagnosis-management-prevention-copd/. Accessed 6/14/2017



American Lung Association. Occupational Lung Diseases: An Introduction. New York, NY. Macmillan. 1979: pp 10. (5)

Conducting Airways





E.P. Horvath Jr., S.M. Brooks, and J.L. Hankinson [1981]. Manual of Spirometry in Occupational Medicine, U.S. Department of Health and Human Services, p. 5.

Physiology: FVC

- Flow (Pouiseuille's law)
  - Airway diameter
    - Asthma: thickened basement membrane, matrix, hypertrophic musculature
    - Airway compliance
      - Airway structure (abnormal in bronchiectasis and tracheomalacia)
      - Supporting parenchymal stroma (abnormal in emphysema)
  - Laminar vs turbulent flow
    - Secretions
  - Dynamic compression

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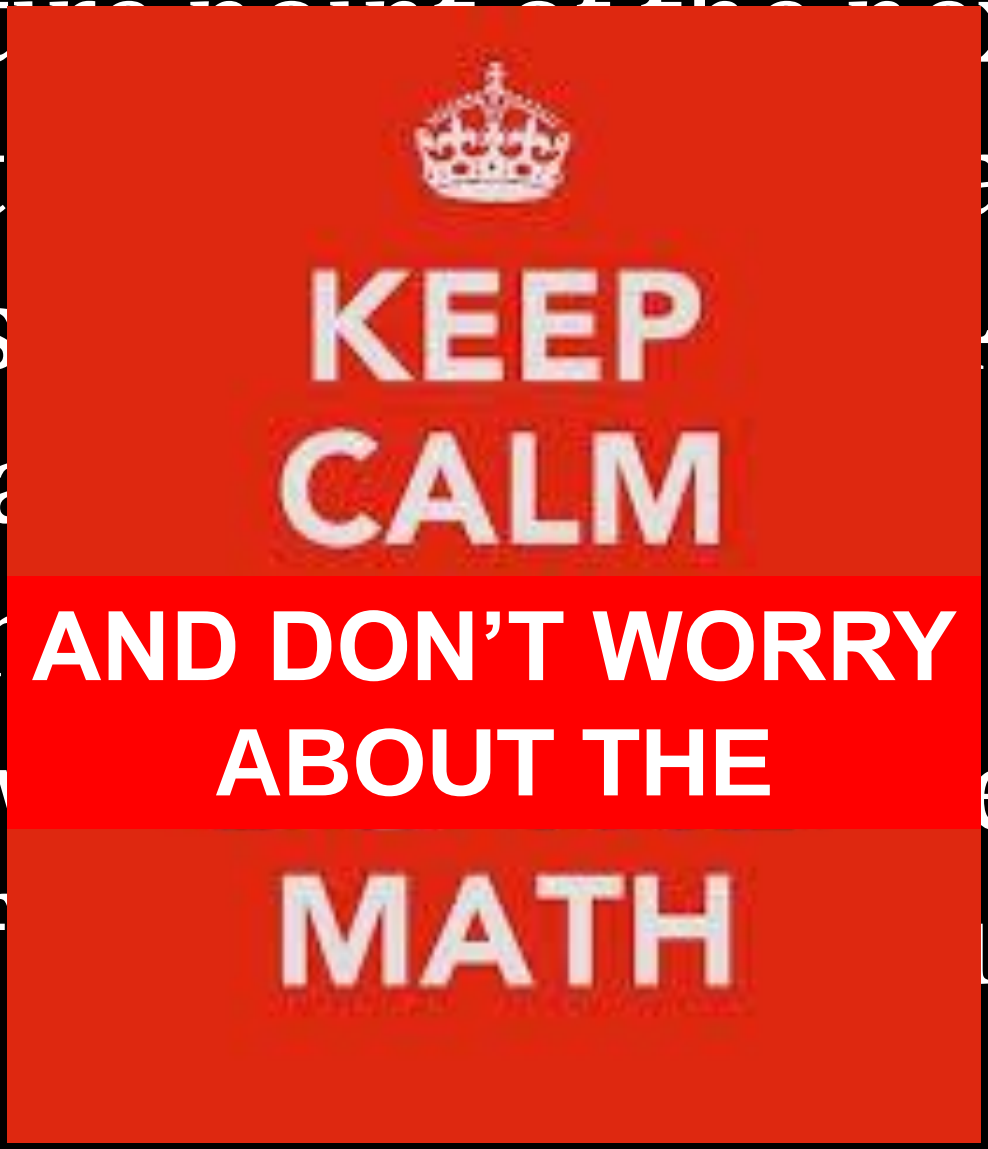
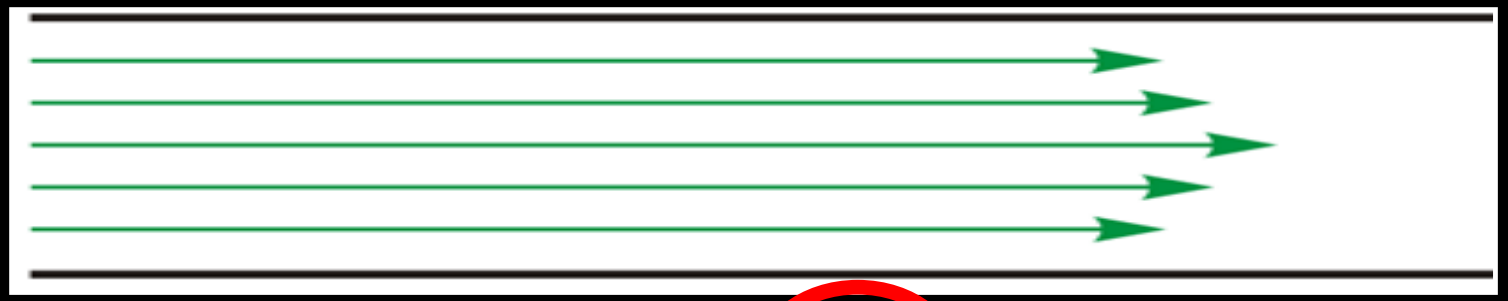


Laminar Flow and Pouiseuille's Law

Laminar Flow



$$Volume\ Flowrate = \frac{p_1 - p_2 \times r^4}{\frac{8}{\pi} v \times L}$$

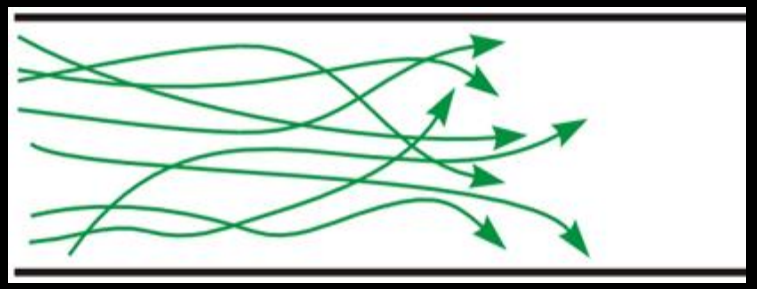
p1-p2 = pressure difference

r = radius

v = *viscosity*

L = *length of tube*

Turbulent Flow



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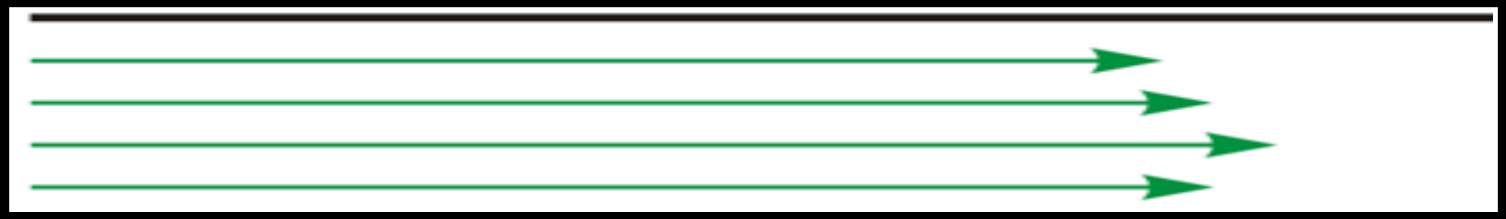
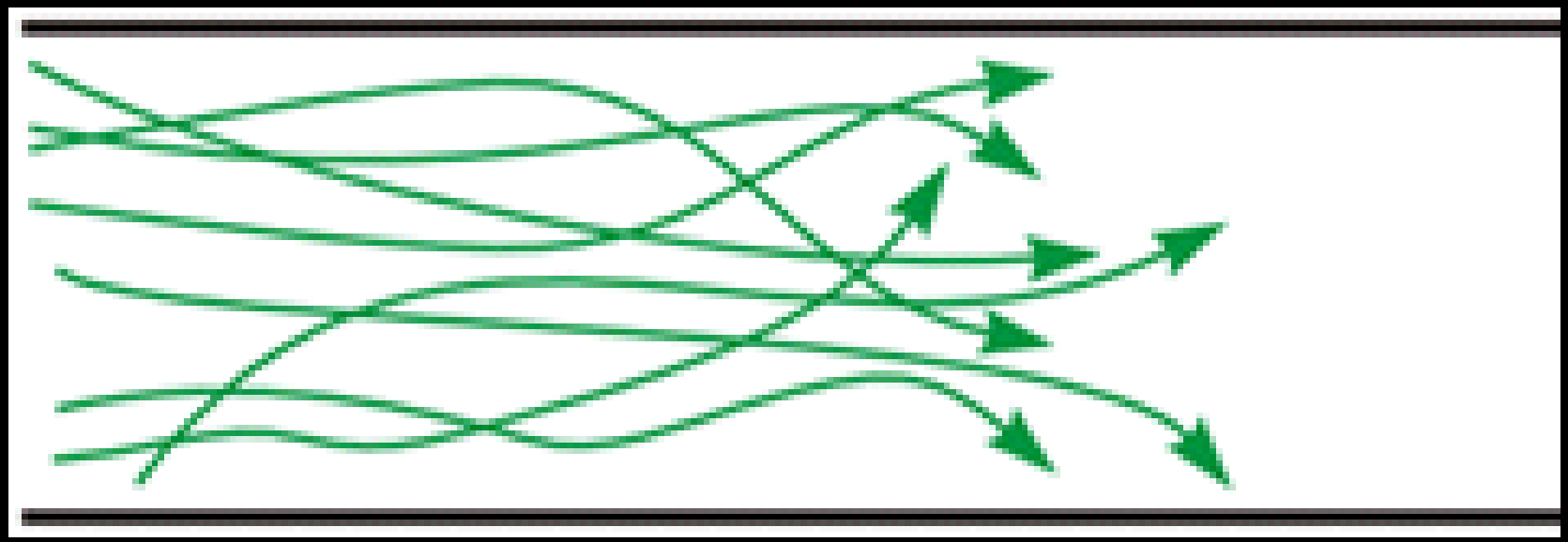
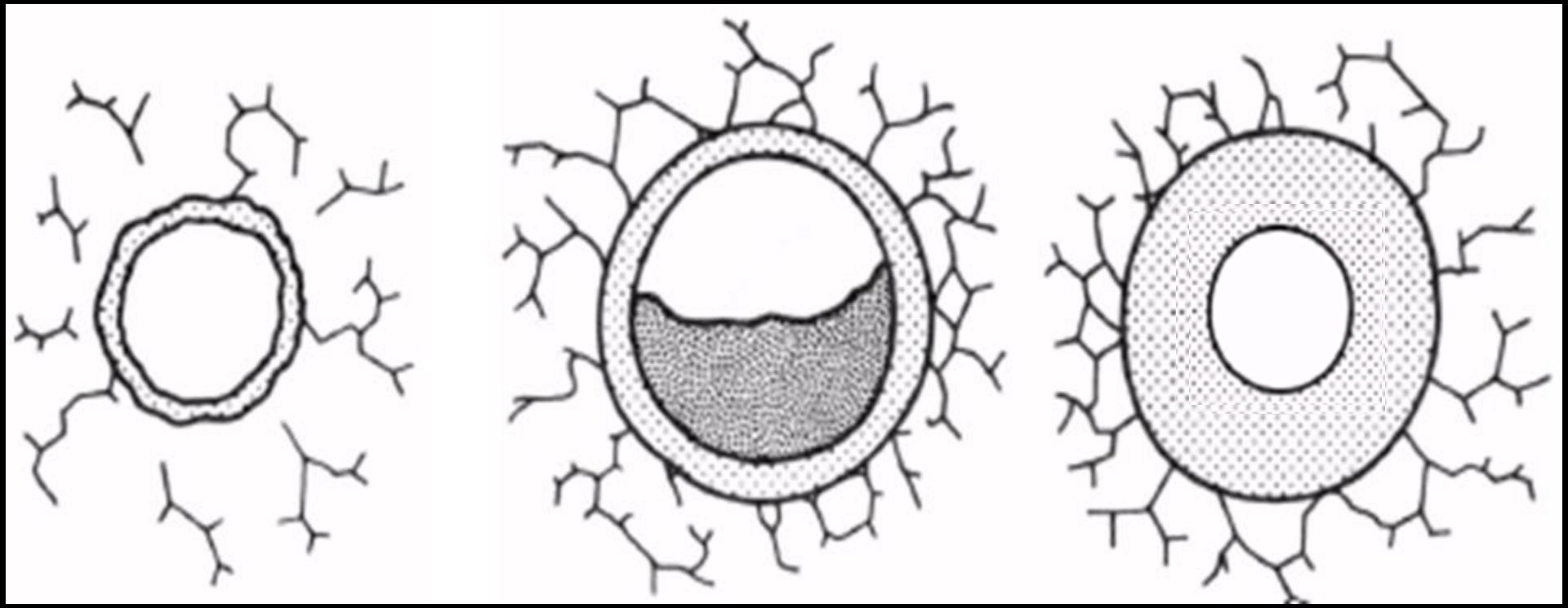


Turbulent Flow

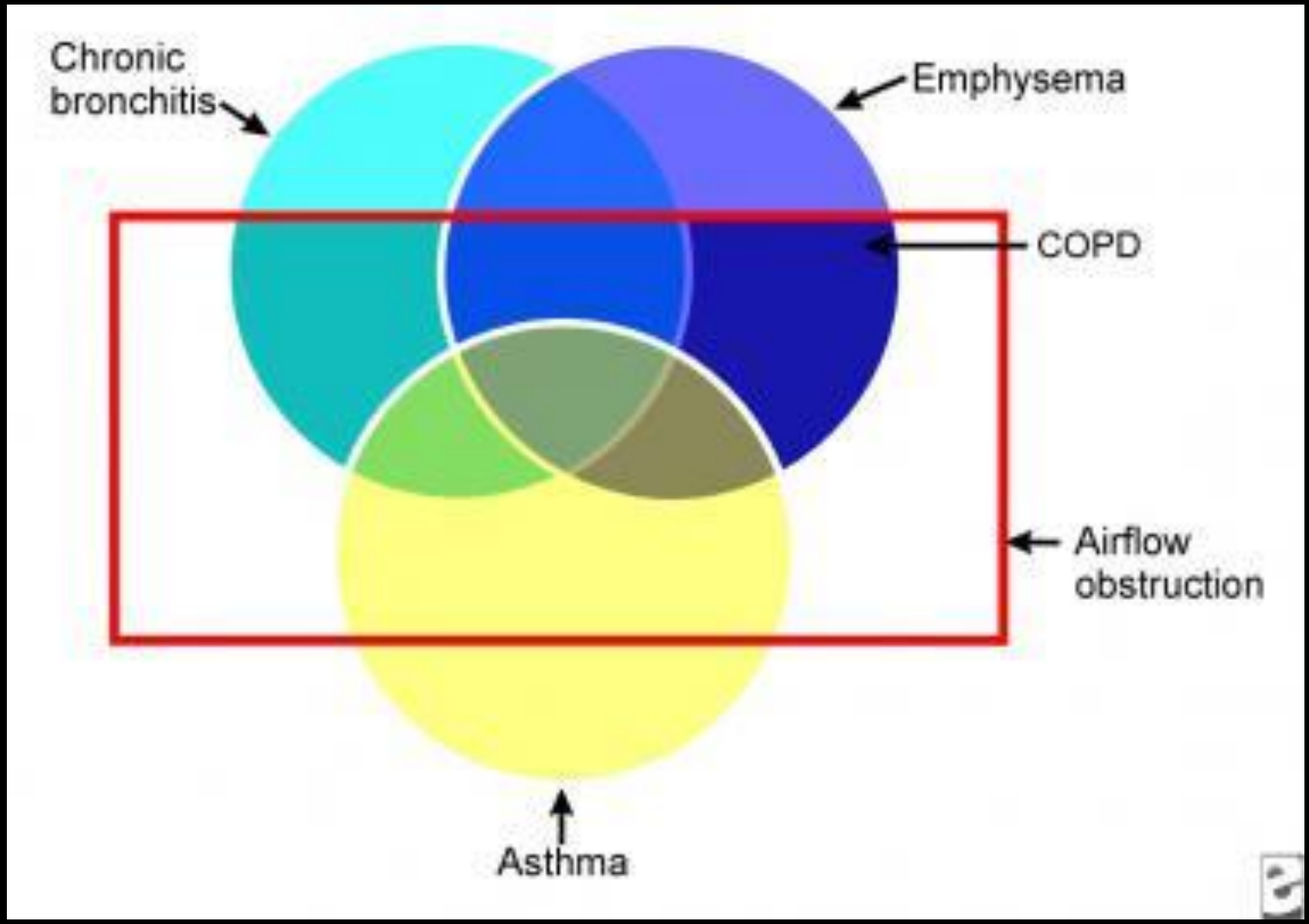


Obstructive lung diseases



emphysema bronchitis asthma

West, JB. Pulmonary Pathophysiology – the essentials. 1987



http://emedicine.medscape.com/article/297664-overview

Performing Valid Spirometry

Relative and absolute contraindications to PFTs

- Infectious risk (TB, Influenza)
- Hemoptysis (coughing blood)
- Severe SOB - (Can't hold breath for 10 seconds)
- Severe cough
- Chest, abdominal, oral, or facial pain
- Stress Incontinence
- Inability to cooperate (dementia/confusion/language barrier)
- Medically unstable

Relative and absolute contraindications to Spirometry

Table 3 Summary of contraindications and the main reason to avoid testing

Contraindication	Reason to avoid lung function testing*	Recommendation
Thoracic/abdominal surgery	Rupture site of injury, avoid pain, discomfort	Relative
Brain, eye, ear, ENT surgery	Rupture site of injury, avoid pain, discomfort	Relative
Pneumothorax	Worsen pneumothorax, avoid discomfort and pain	Relative
Myocardial infarction	Induce further infarction leading to cardiac arrest	Absolute/relative
Ascending aortic aneurysm	Rupture of aneurysm, catastrophic/fatal event	Absolute/relative
Haemoptysis	Pulmonary emboli or myocardial infarction	Relative
Pulmonary embolism	Death, hypoxia leading to respiratory failure	Absolute/relative
Acute diarrhoea	Discomfort, embarrassment, infection risk	Relative
Angina	May lead to cardiac arrest in severe cases. discomfort	Absolute/relative
Severe hypertension (systolic >200 mm Hg, diastolic >120 mm Hg)	Risk of blackout/collapse, rupture of cerebral blood vessels, etc.	Measure blood pressure before tests if suspected
Confused/demented patients	Lung function tests are volitional and need patient cooperation	Balance need for test against difficult in obtaining results
Patient discomfort	Vomiting, diarrhoea, cold sores, common cold	Wait until main symptoms abate
Infection control issue	Contagious infections (norovirus, tuberculosis, flu)	Wait until main symptoms abate

*Sometimes the risk may be necessary as a preoperative assessment for life-saving surgery.
Recommendation: absolute, lung function testing should be avoided in most cases; relative, judge each case on its merits.

Patient preparation for PFTs

- Instructions to patient prior to the study:
  - Do not use LABA w.in 12 hours (Spiriva 24 hrs), SABA w/in 4 hours
  - Avoid smoking (at least 1 hour prior to study)
  - No heavy meal w/in 2 hours of the test
  - Avoid heavy exercise (w/in 30 min before the test)
  - Avoid tight clothing
- Technician to review these issues, delay the study if necessary
  - Medical issues/symptoms
  - URI – delay by 4 weeks
  - Document steroids, bronchodilators and last use of bronchodilators

Optimal Conditions for Spirometry

- Patient and tech:
  - speak same language,
  - have good rapport, and
  - are both highly motivated
- Excellent equipment, calibration verified
- Previous study before patient was exposed or became ill for comparison

FVC Maneuver

- Instructions – explain the test
- Before starting:
  - Standing vs sitting (standing FVC > Sitting FVC)
  - Loosen tight clothing
  - Sit straight and don't slump
  - Feet flat on floor
  - Elevated chin and neck
  - Nose clip
  - Be sure teeth and tongue are not blocking mouthpiece
  - Tight seal with lips

FVC Maneuver

- Demonstrate
- Emphatic coaching
- Several systems and ways to do this
  - Closed systems – with loop
    - Breath in and out slowly, then take as deep a breath as you can and ***blast it out!!!!!*** – when I tell you, suck the air back in as hard as you can until your lungs are completely filled again
  - Open systems - FVC with no loop
    - Take as deep a breath as you can, put the mouthpiece in you mouth ***and blast it out!!!!!!!***

Valid spirometry must meet criteria for:

- Acceptability
- Repeatability

Eur Respir J 2005; 26: 948–968

Forced Vital Capacity Maneuver (FVC)

Acceptability

- vigorous effort –usually requires:
  - maximal inspiration
  - vigorous encouragement by tech
- start of test criterion: no hesitation
  - explosive ("blast it out!!!!!") exhalation
  - "extrapolated volume"
- middle of test: smooth expiratory effort
  - no cough in 1st second,
  - no leak,
  - no obstruction
- end of test criteria:
  - ≥ 6 seconds long – to maximal exhalation
  - plateau (< 0.025 liters in the last second)

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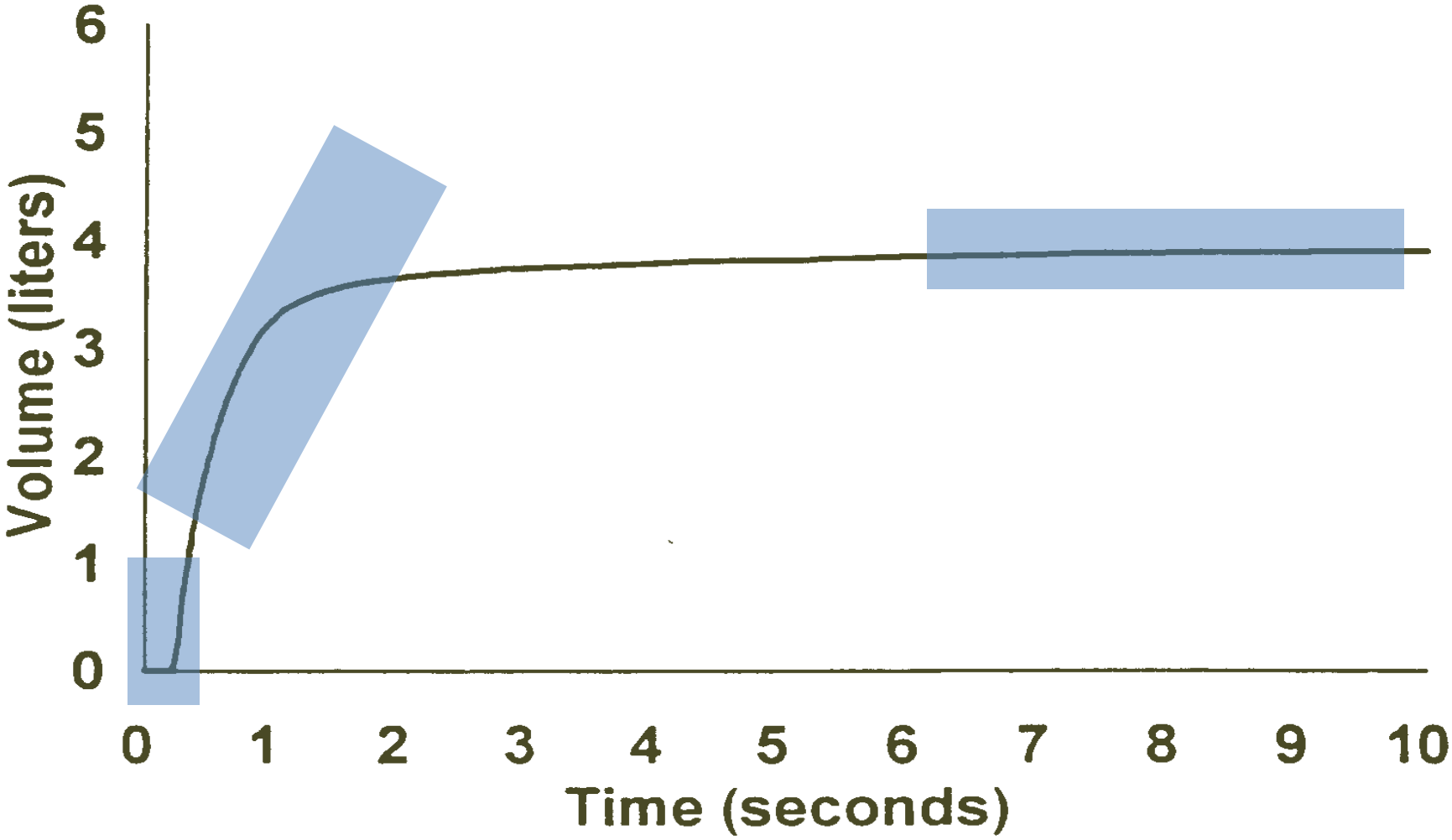
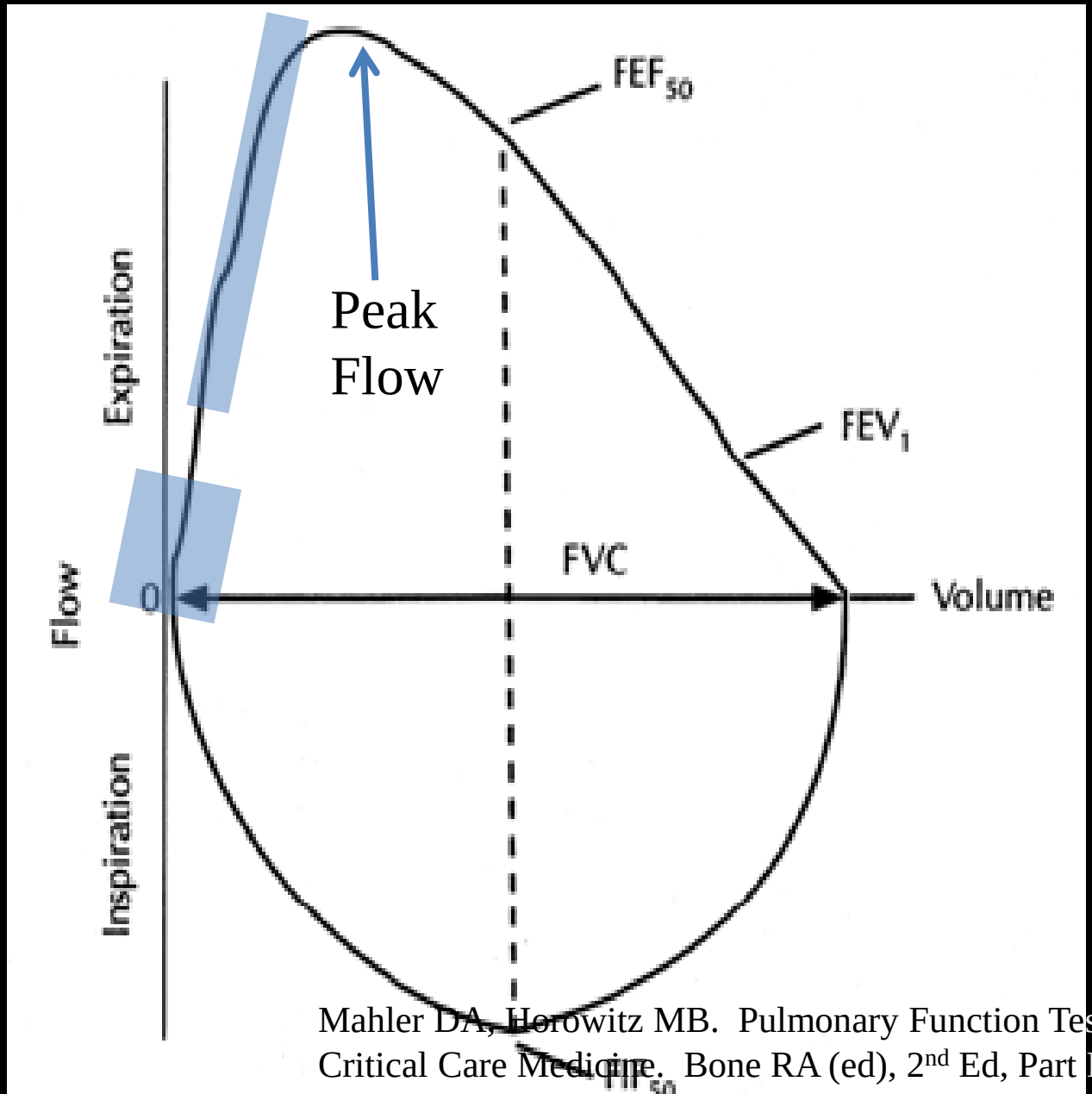
Eur Respir J 2005; 26: 948–968

Acceptable VT Curve

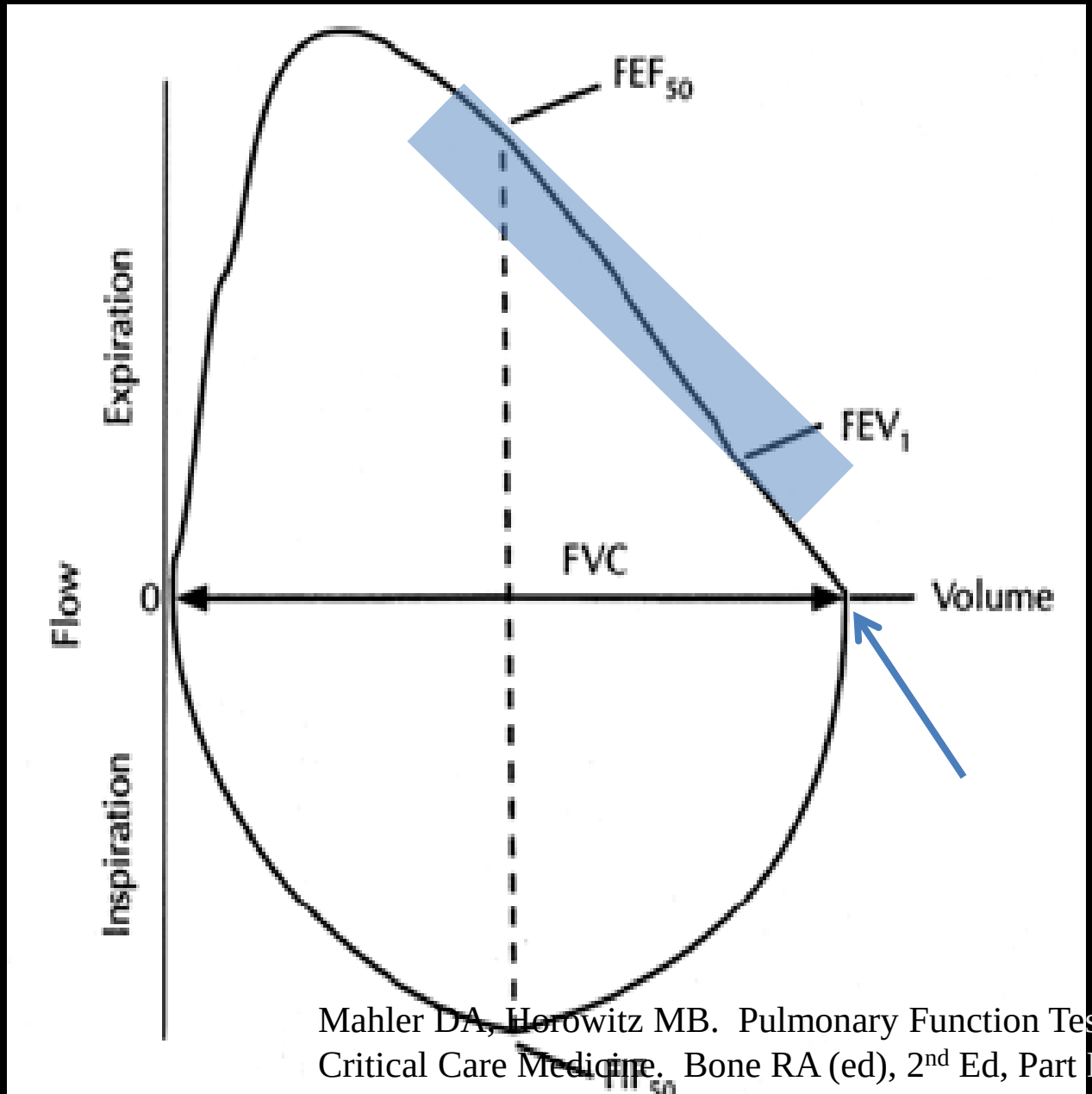


Acceptable FV Loop



Mahler DA, Horowitz MB. Pulmonary Function Testing. In Pulmonary and Critical Care Medicine. Bone RA (ed), 2nd Ed, Part F, Ch 6, p7. St. Louis MO

Acceptable FV Loop



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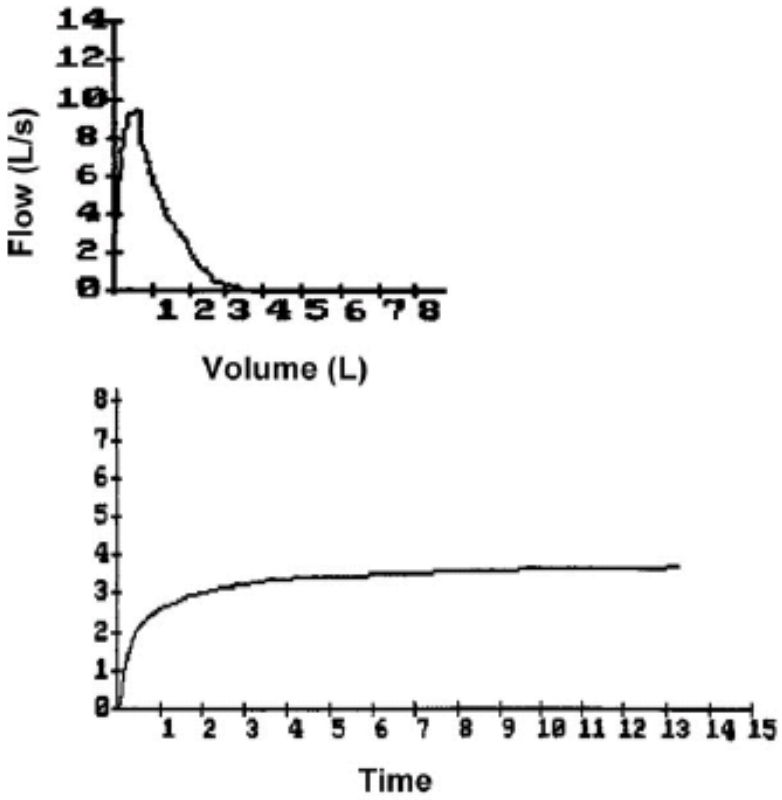
ACOEM Guidance Statement

Spirometry in the Occupational Health Setting—2011 Update

ATS/ERS Minimum Size Instrument Display *

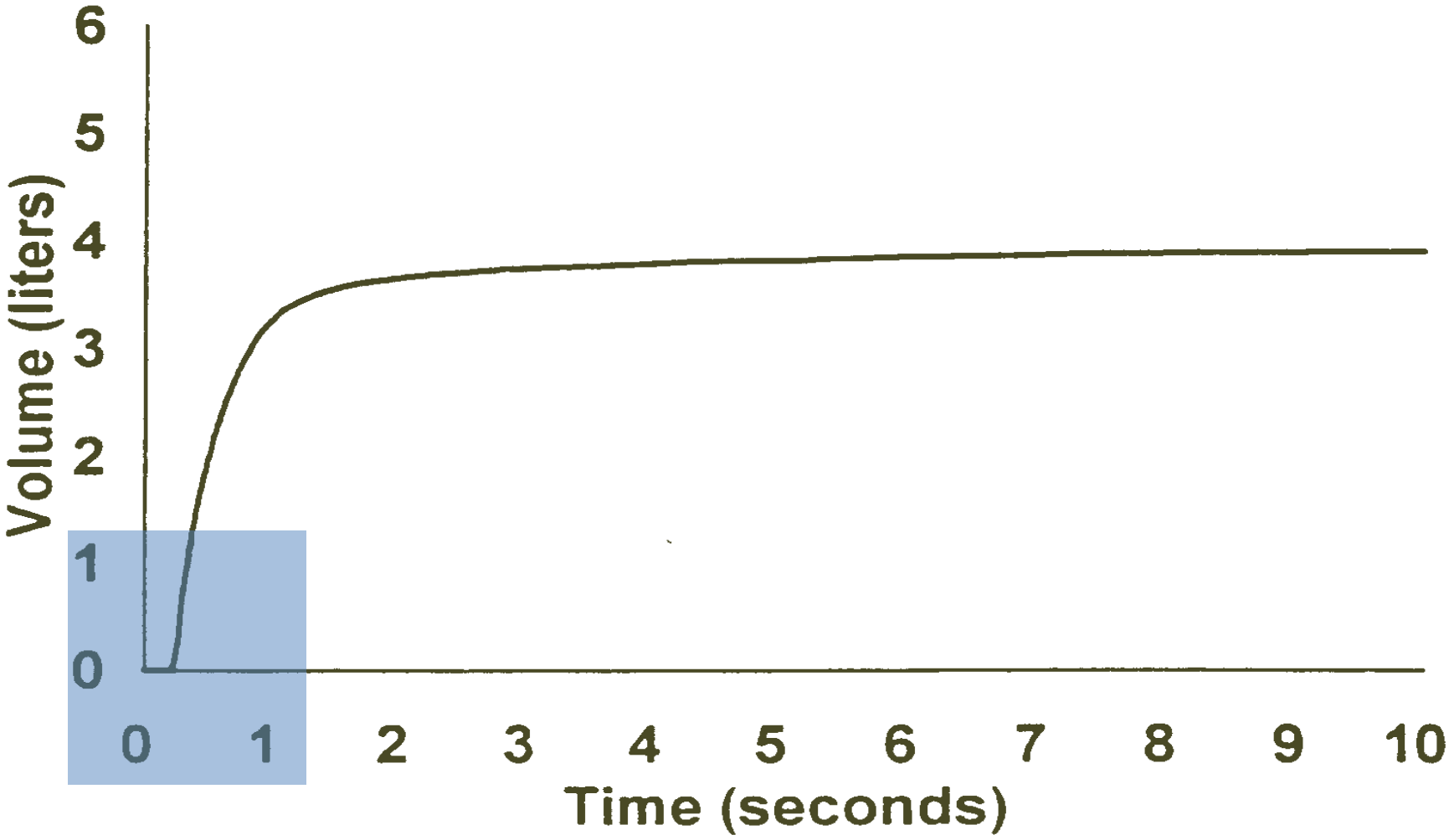


- Volume Scale ≥ 5 mm/ L
- Flow Scale ≥ 2.5 mm/ L/s
- Time Scale ≥ 5 mm/ s

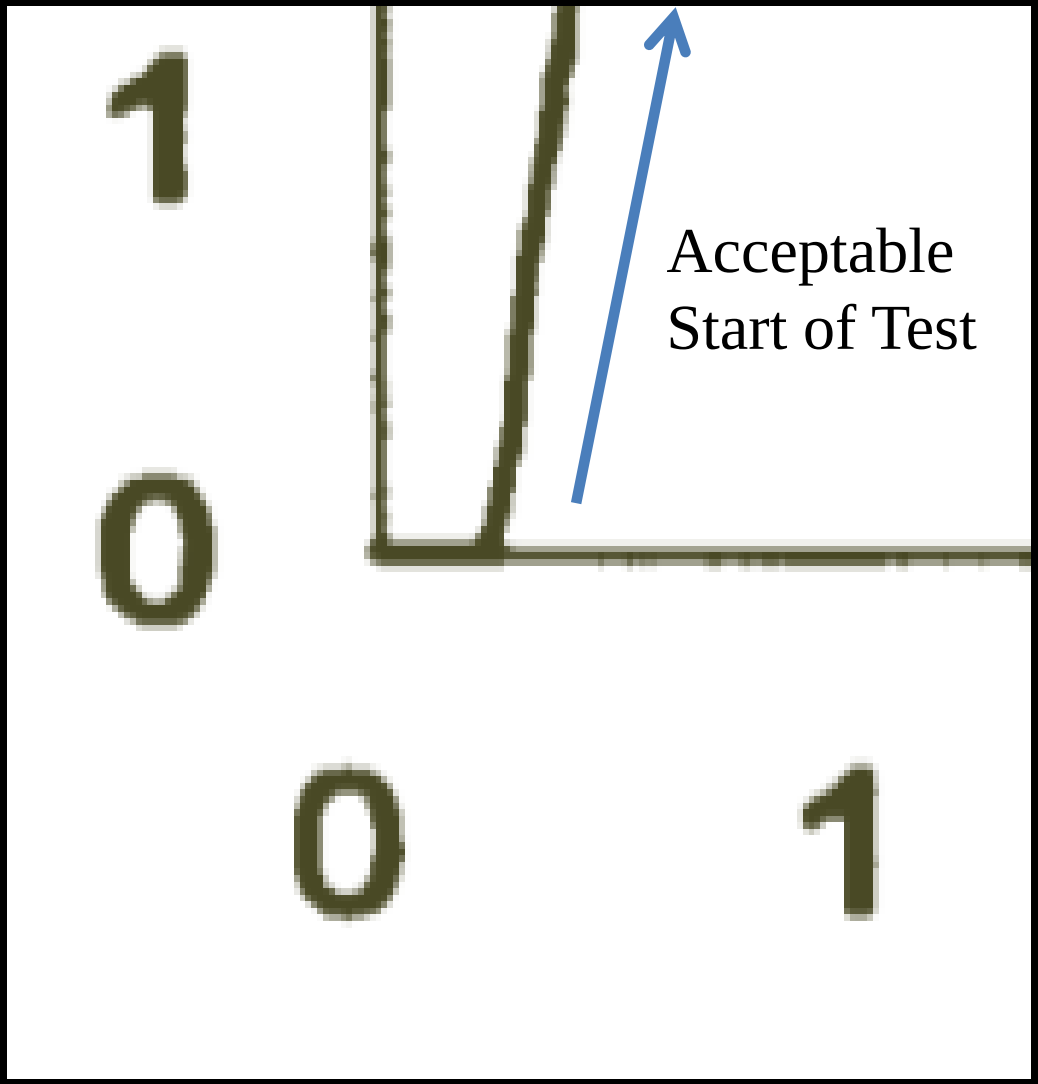
* Complies with ANSI ISO 25672 aspect ratio requirements.

Townsend, MC. 2011. JOEM 53:569-84

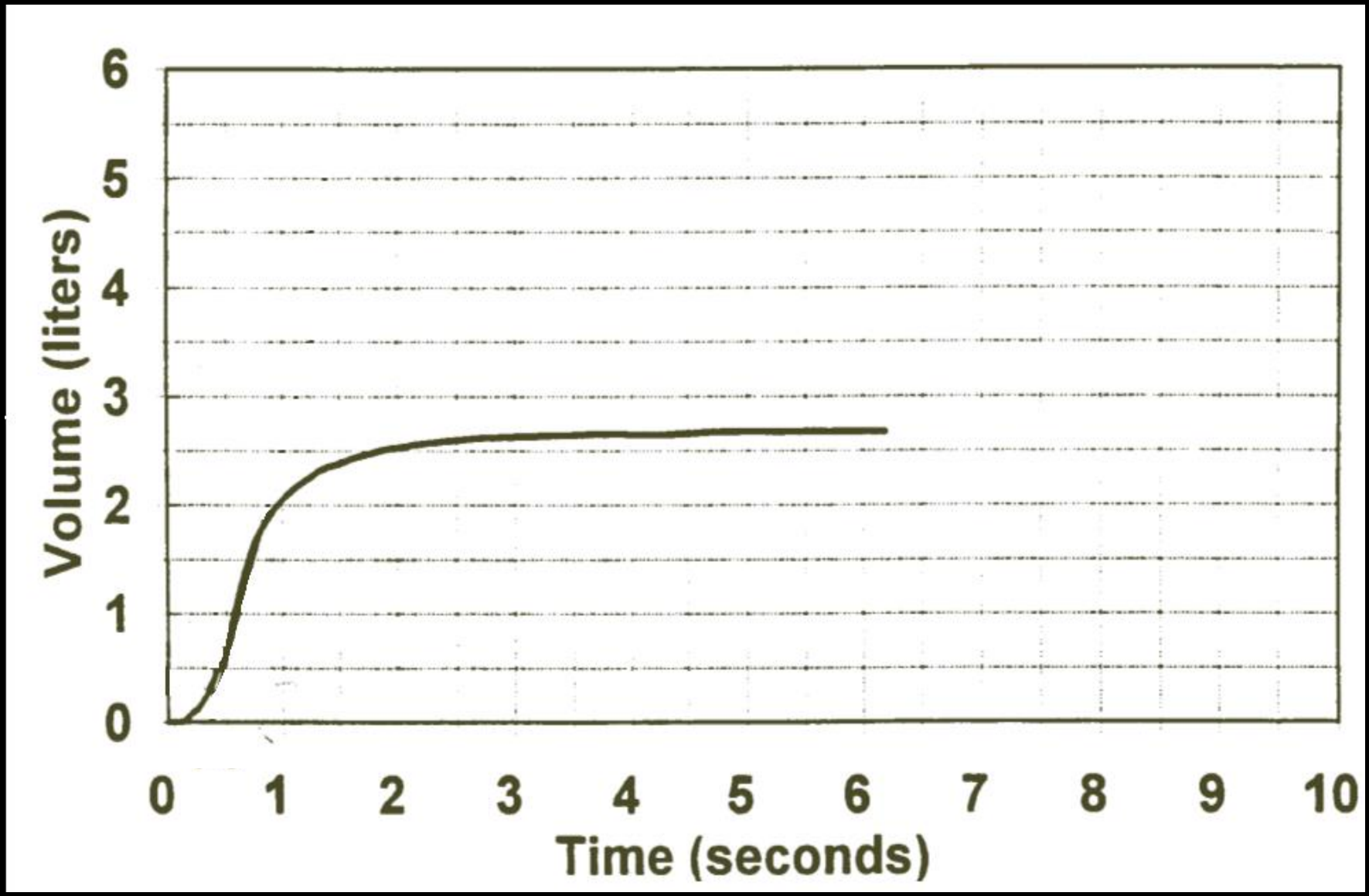
Acceptable VT Curve



Acceptability (start of test): extrapolated volume – hesitation



Acceptability (start of test): extrapolated volume – hesitation - error



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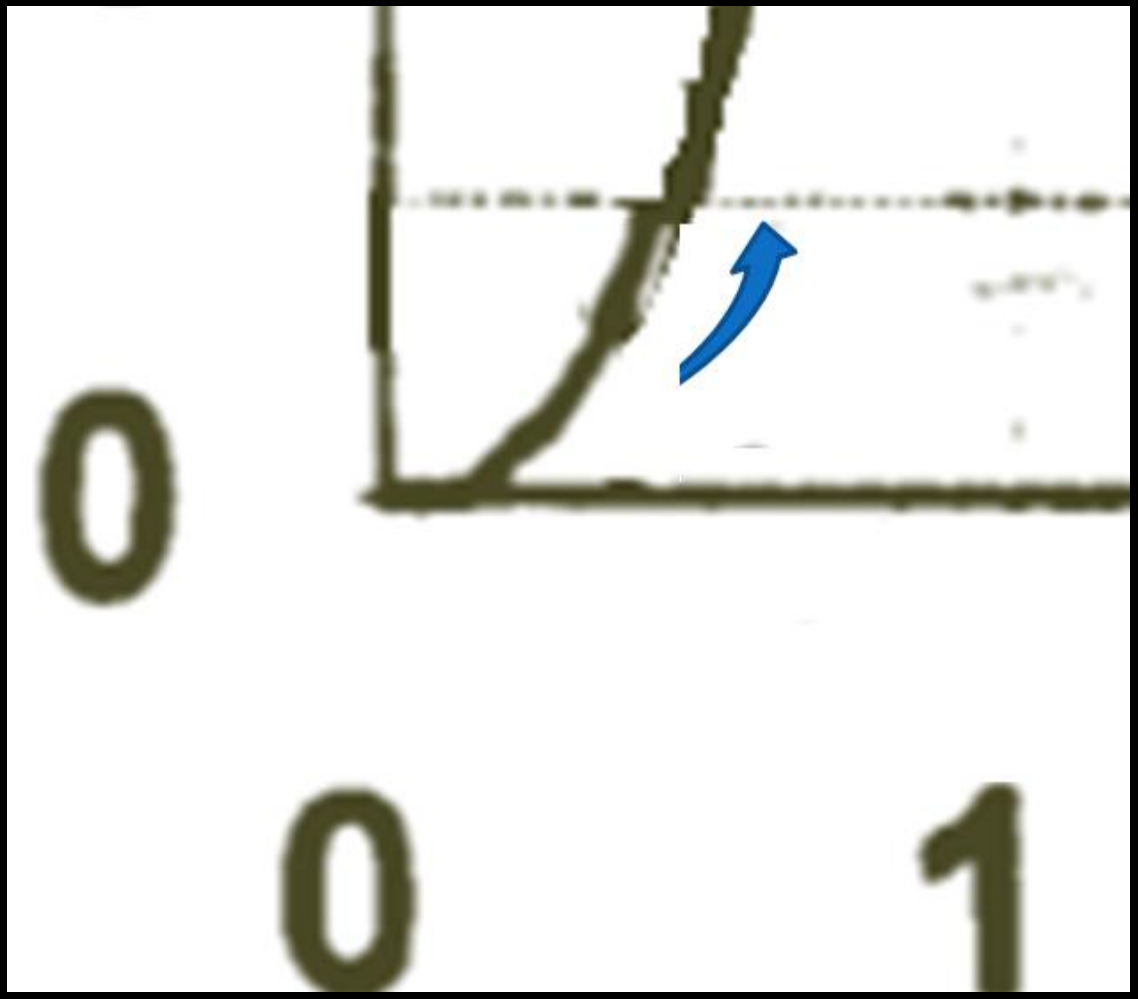

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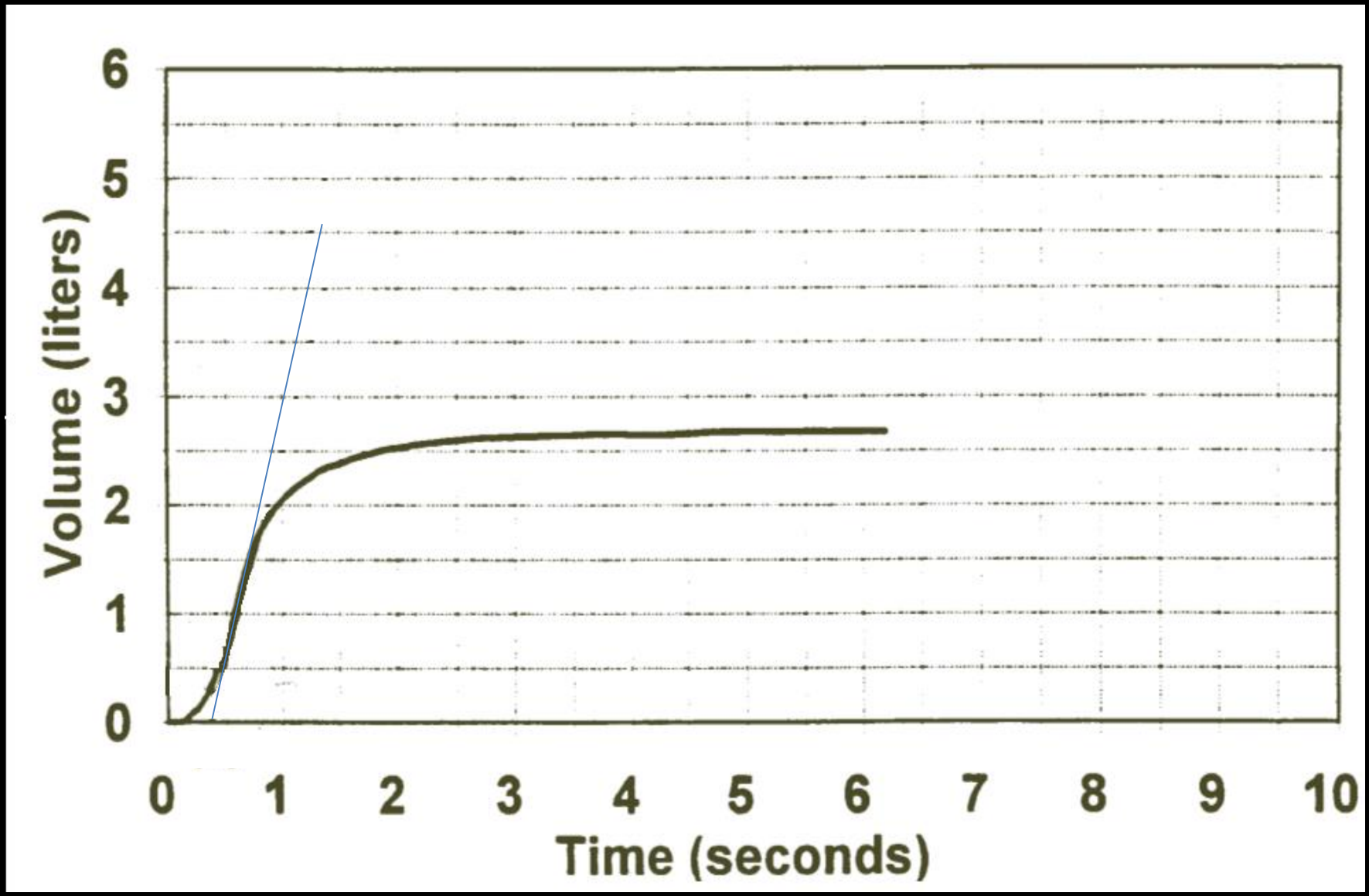

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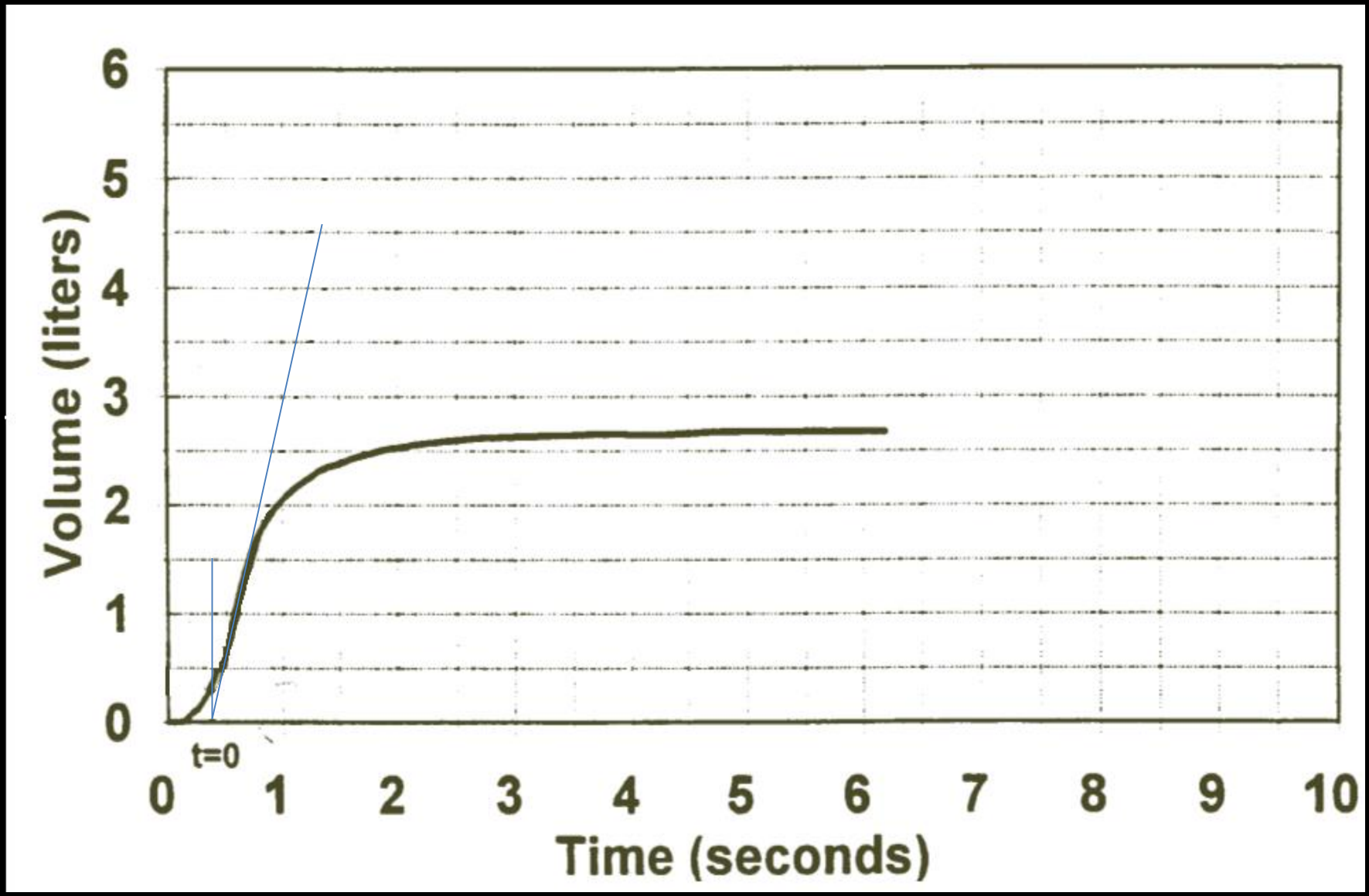

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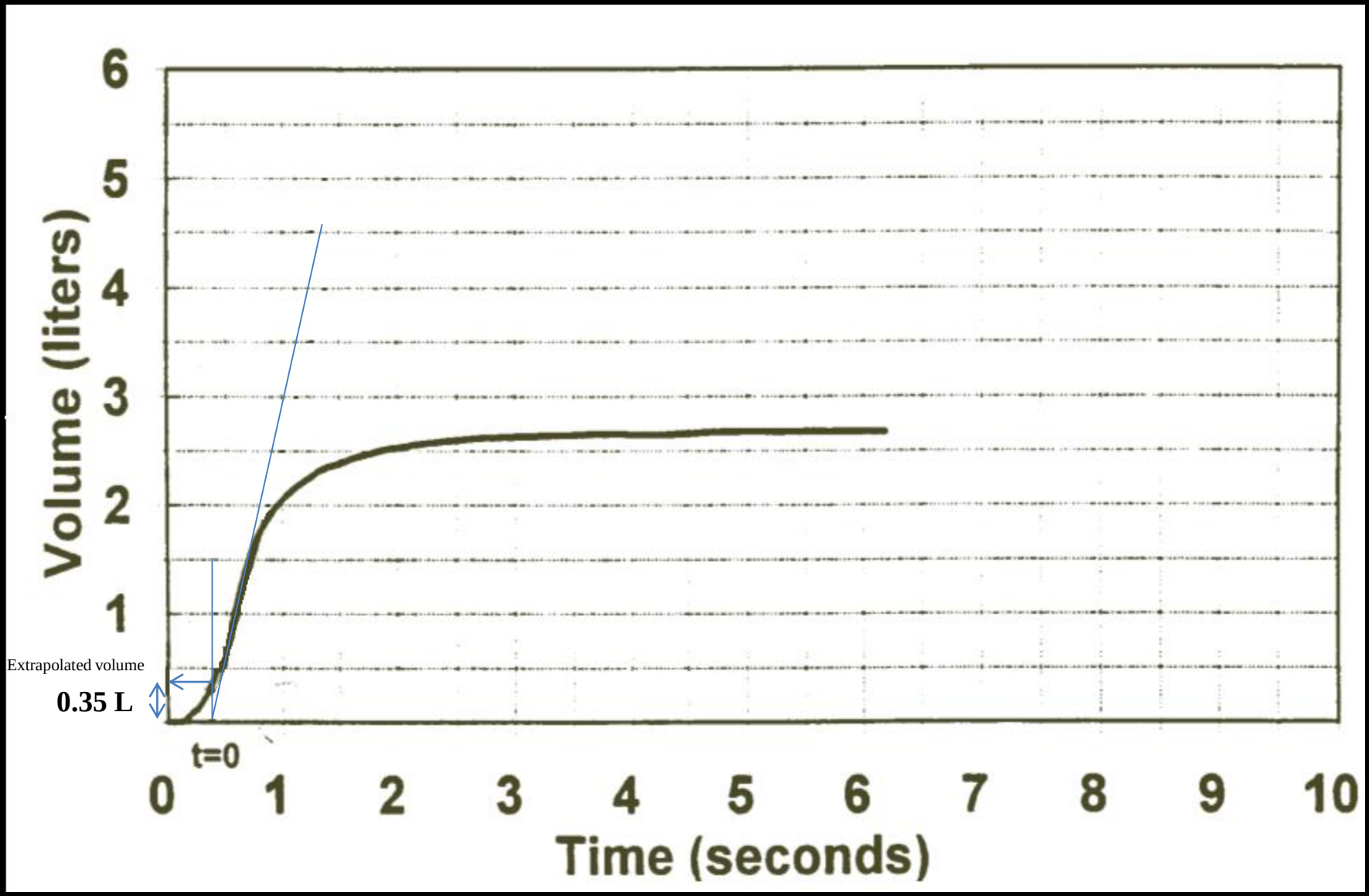

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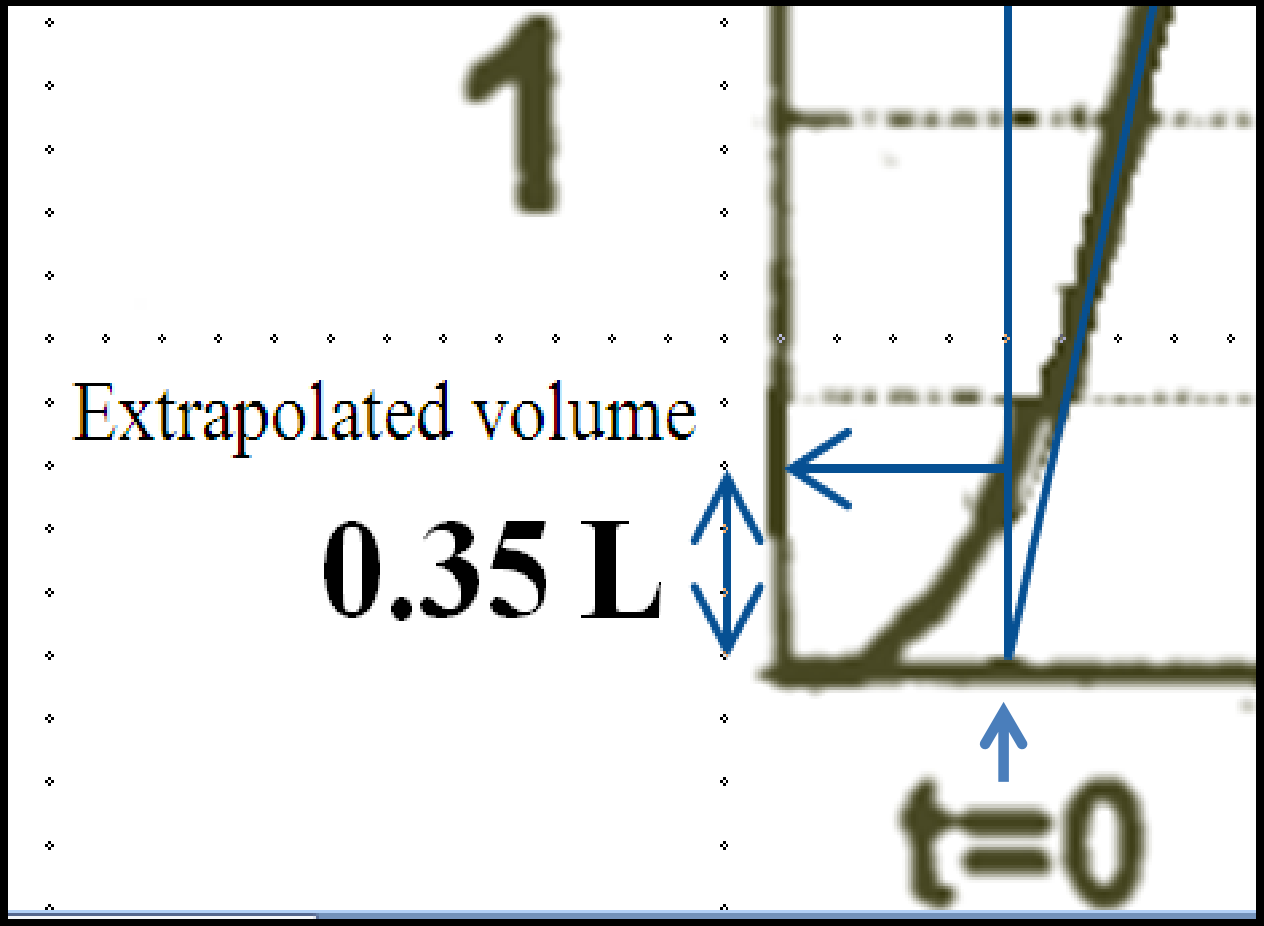
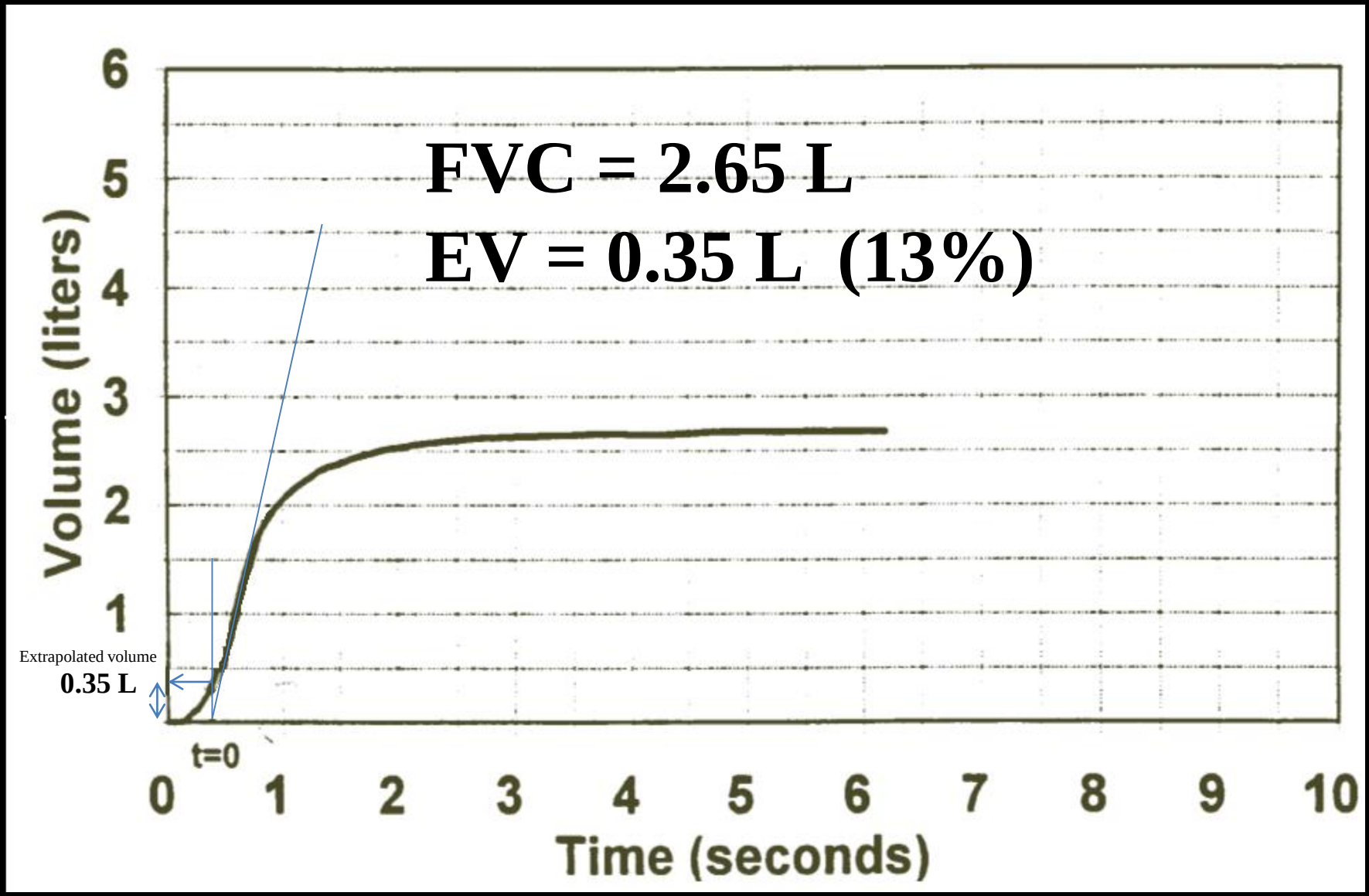


Acceptability (start of test): extrapolated volume – hesitation - error

- The “blast it out” criterion (hesitation)
- The extrapolated volume should be less than:
  - 0.15 L or….
  - 5% of the FVC (whichever is greater)

Eur Respir J 2005; 26: 948–968

Acceptability (start of test): extrapolated volume – hesitation - error



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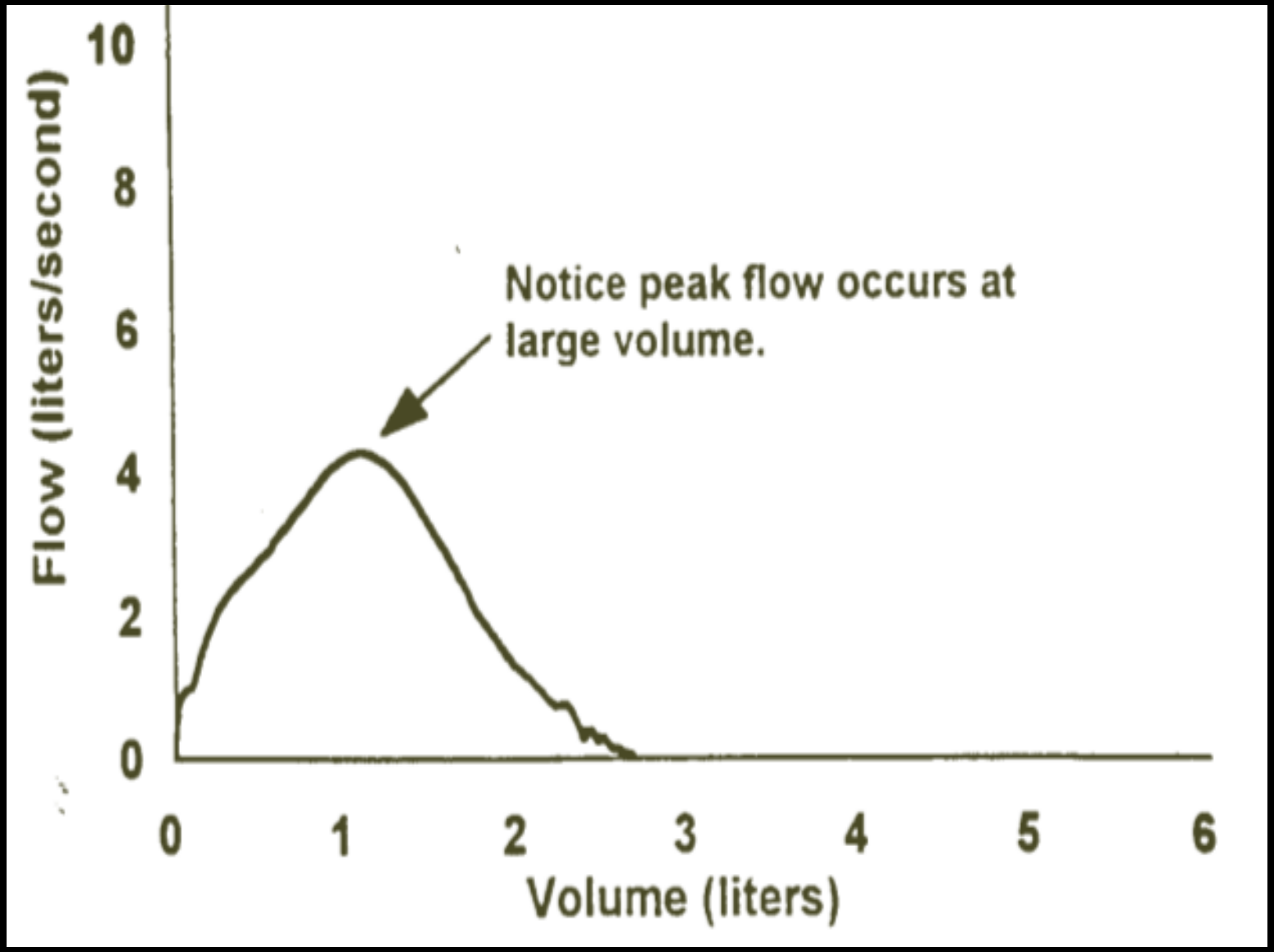

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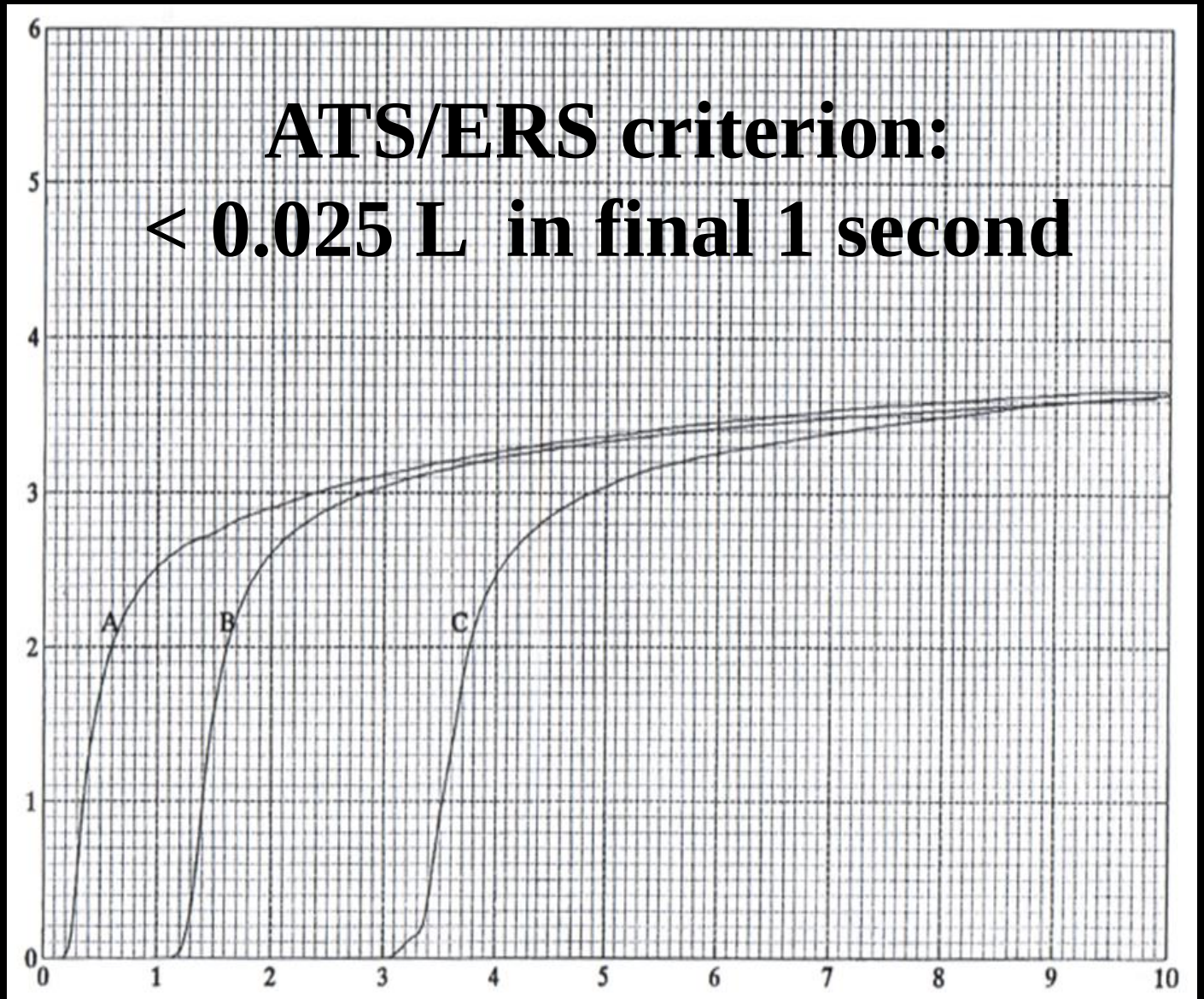
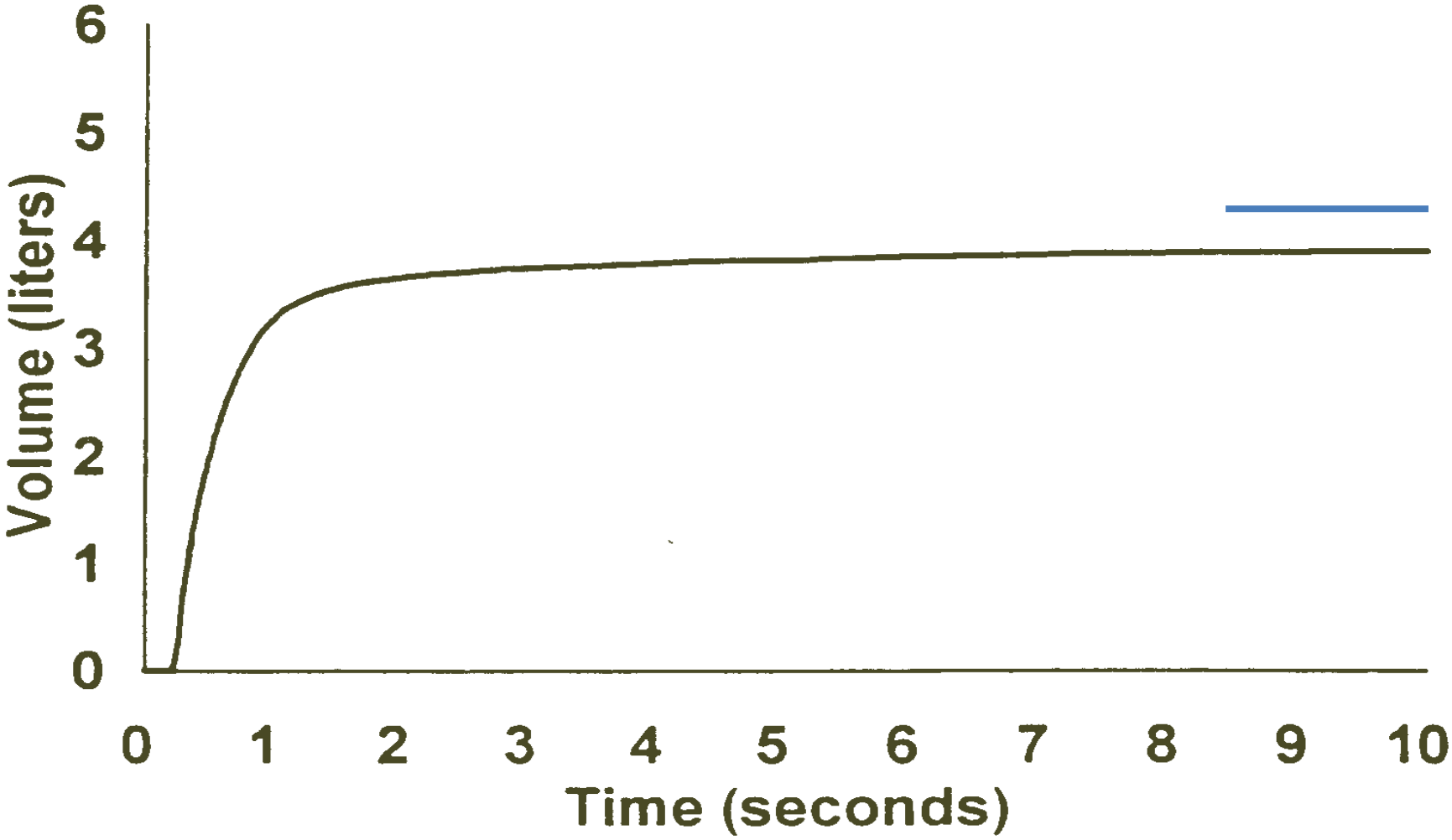
Eur Respir J 2005; 26: 948–968

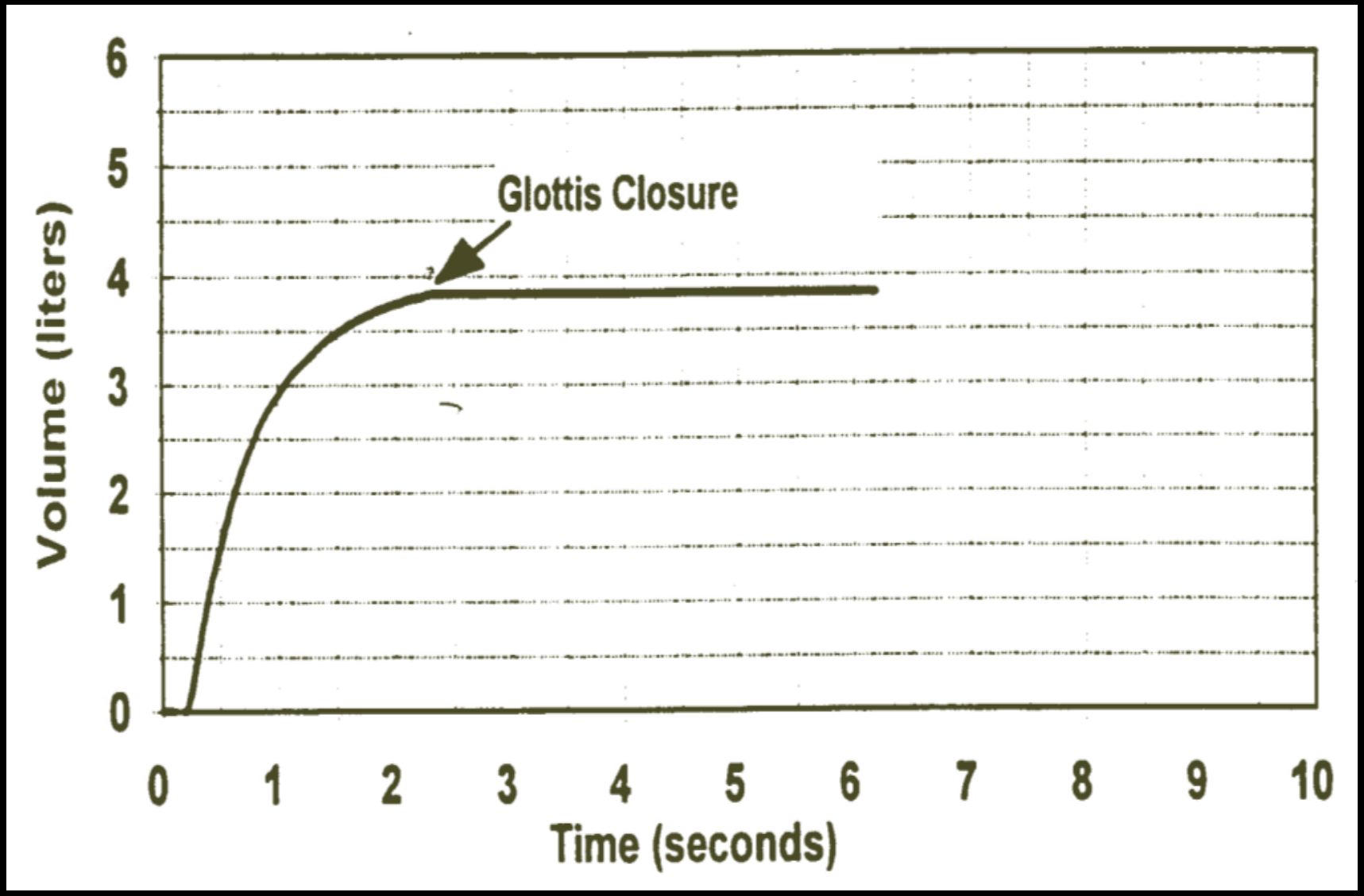
Acceptability (end of test): plateau



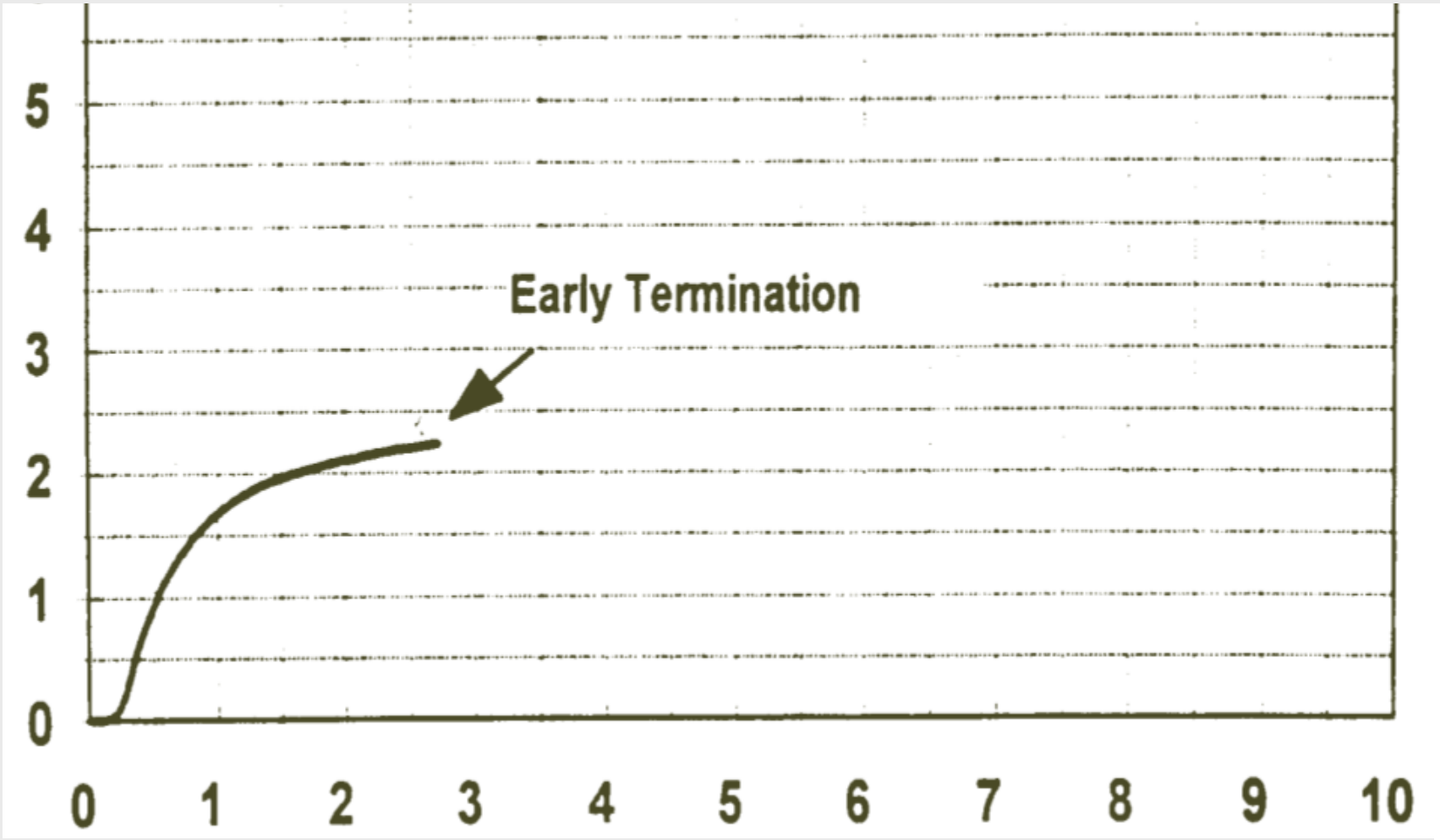
Normal VT Curve



Acceptability: glottic closure



Acceptability (end of test): early termination (< 6 sec)



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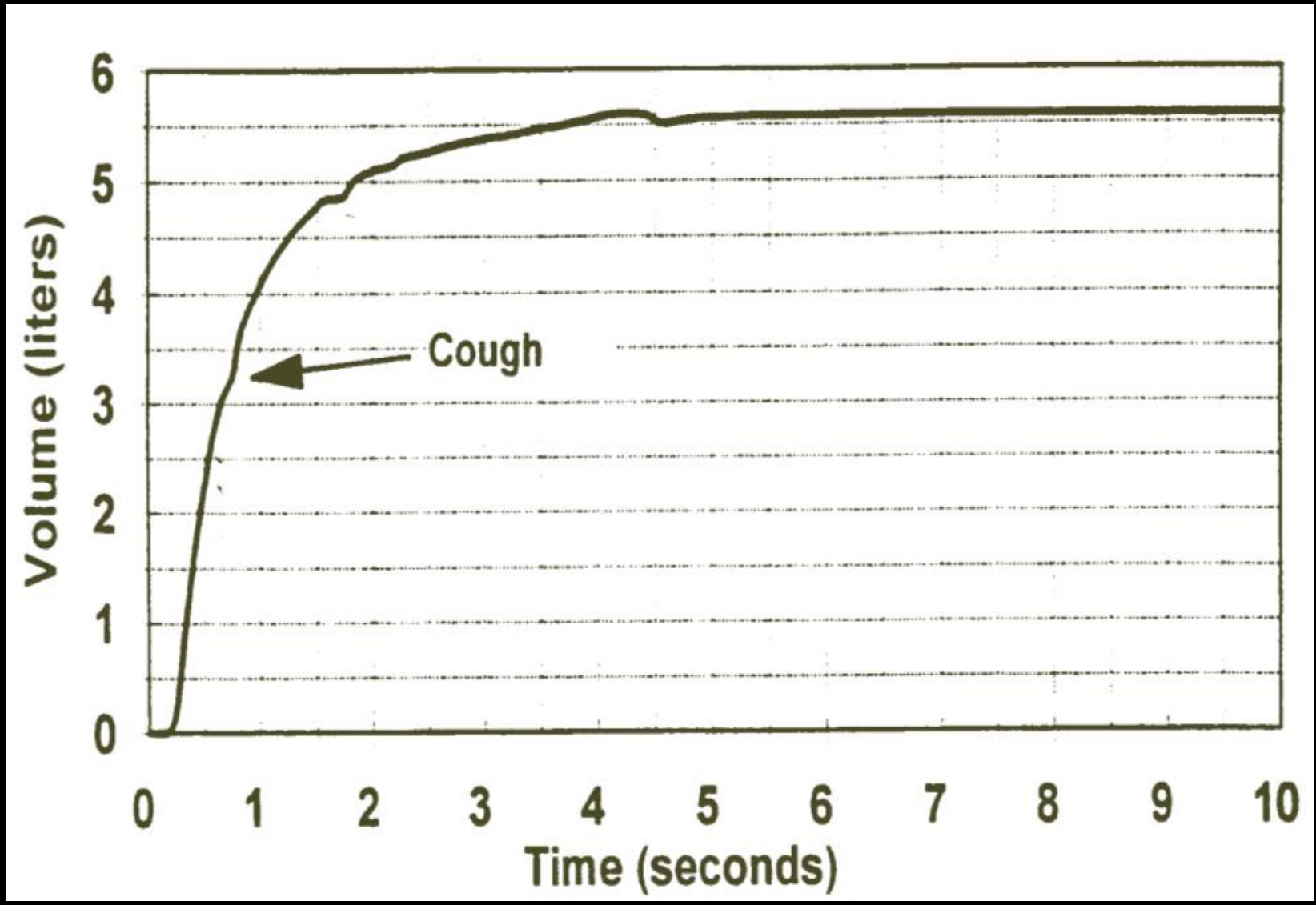
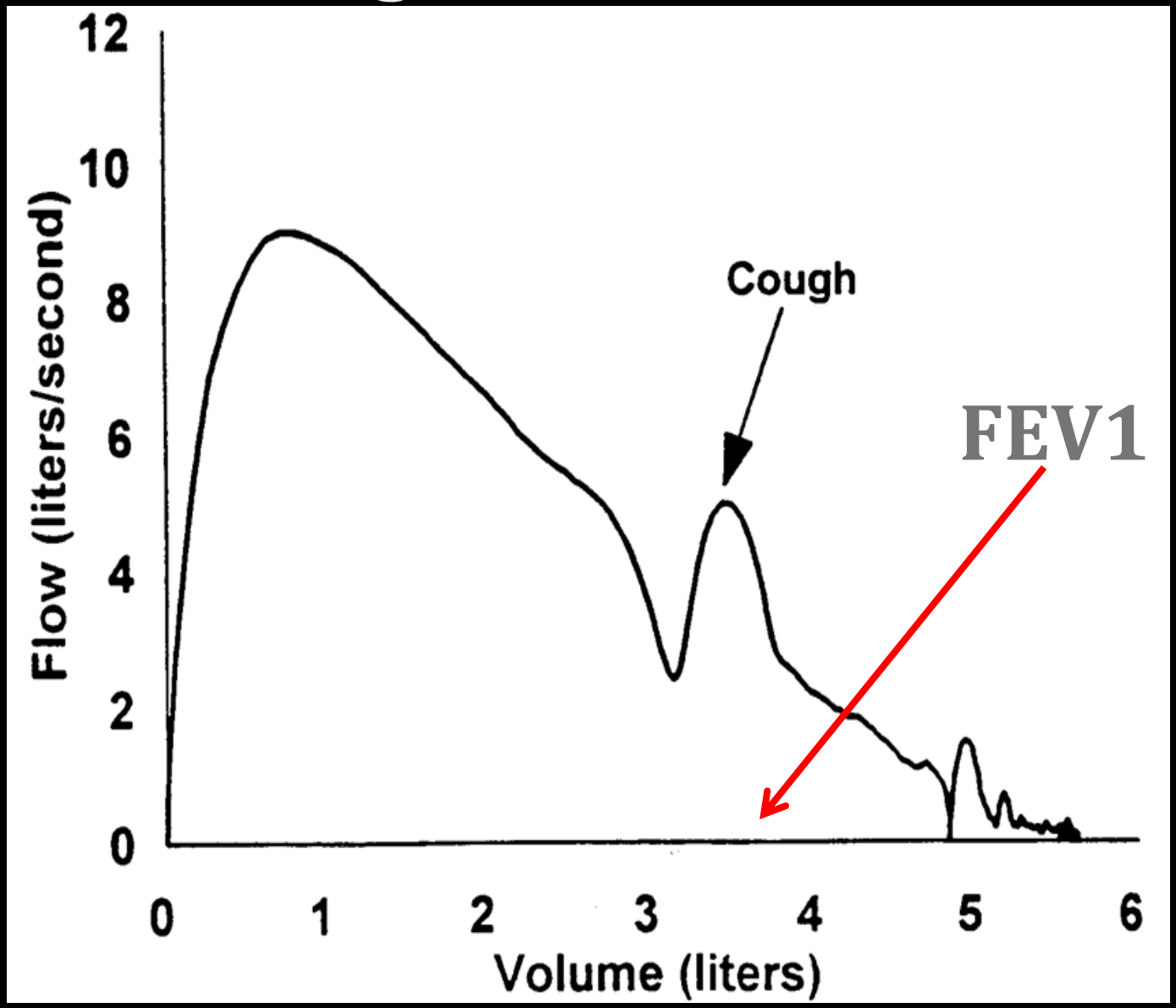
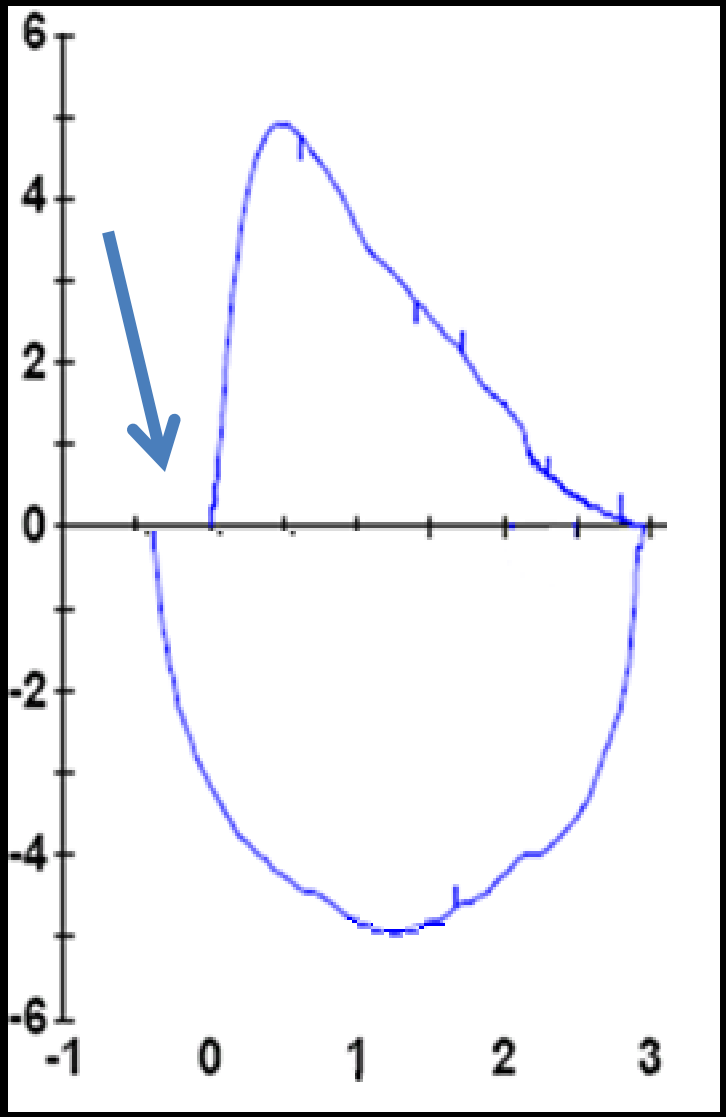
Acceptability: cough in 1st second



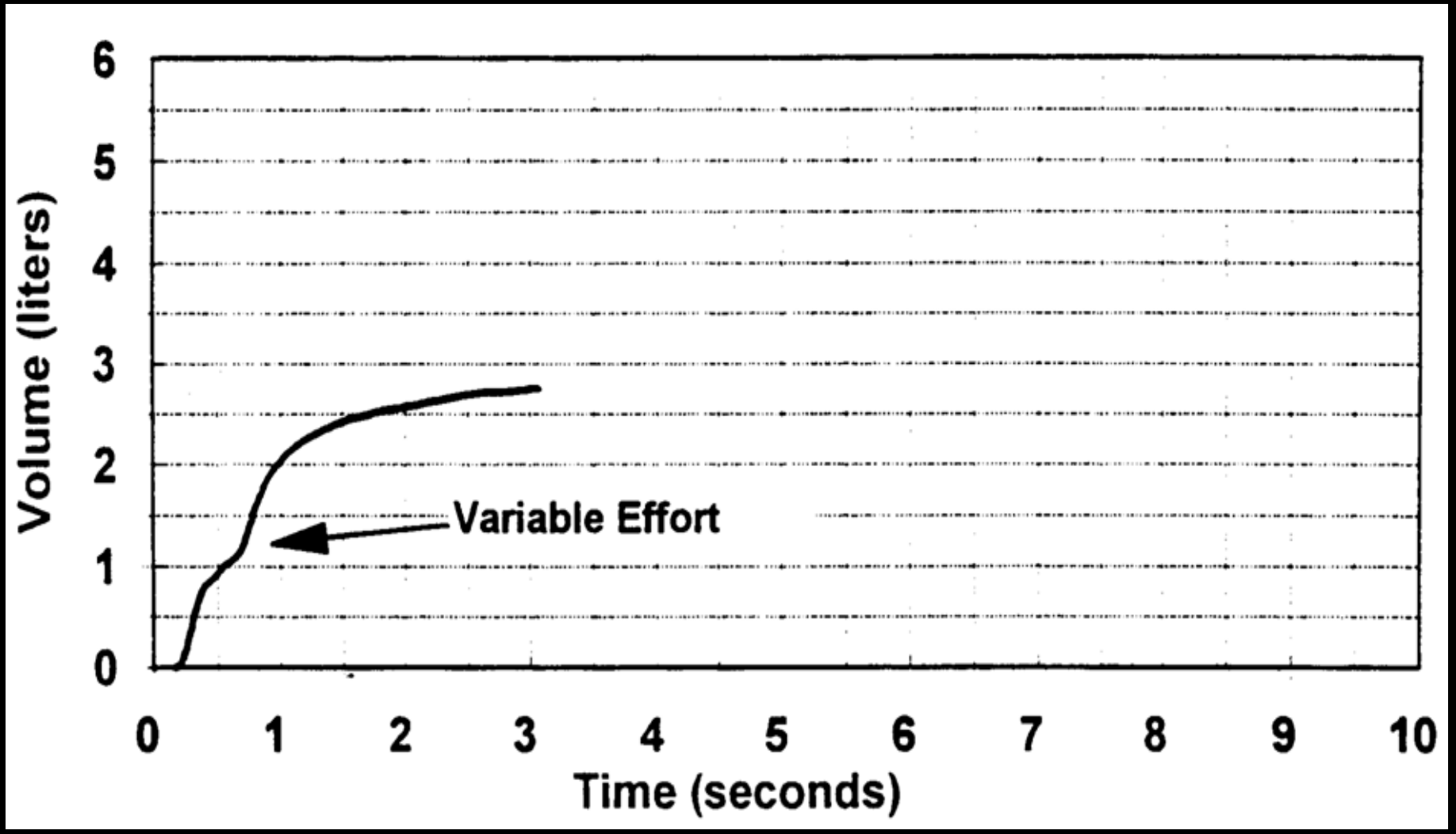
Acceptability: cough in 1st second



Acceptability: Inadequate inhalation



Acceptability: variable effort



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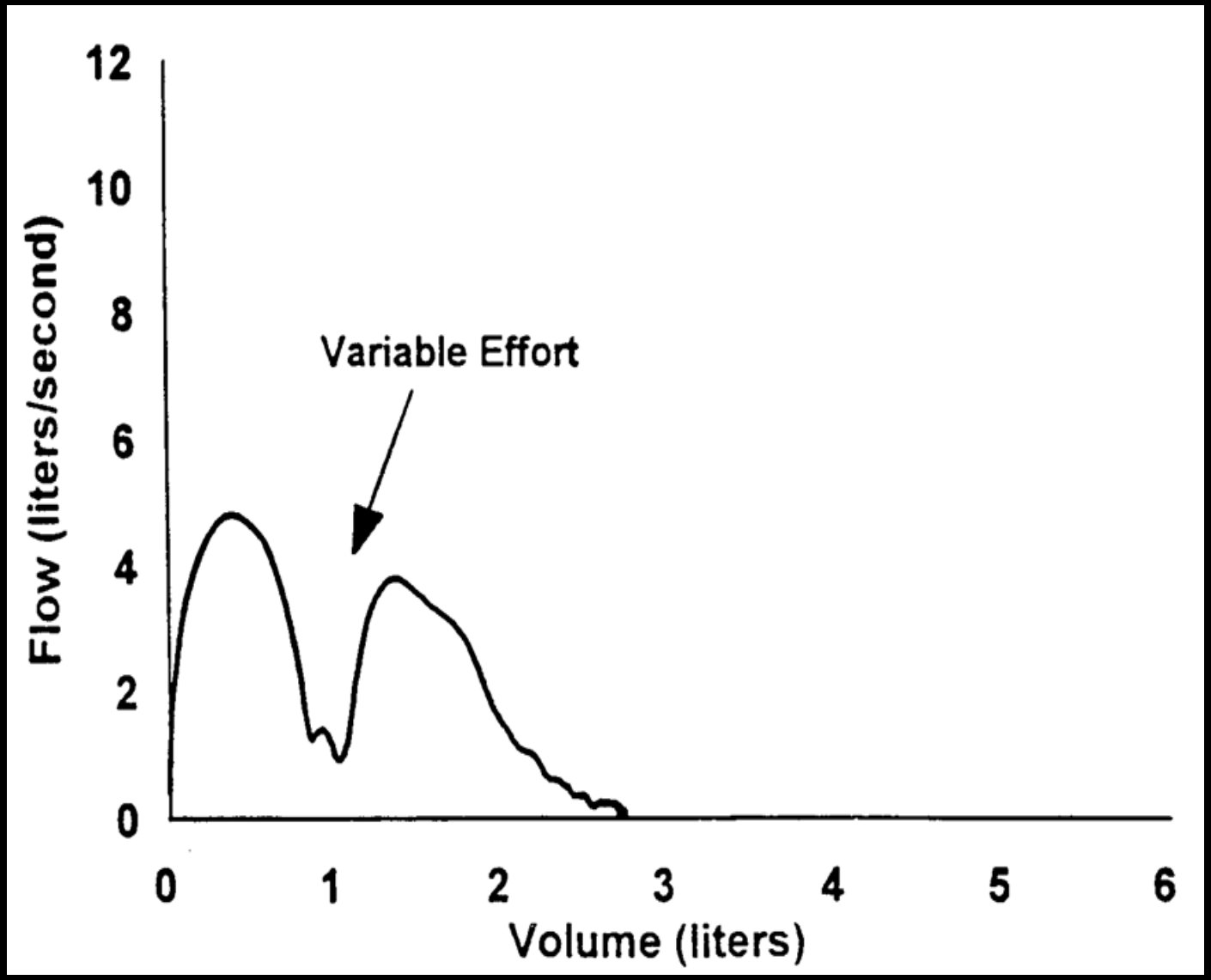
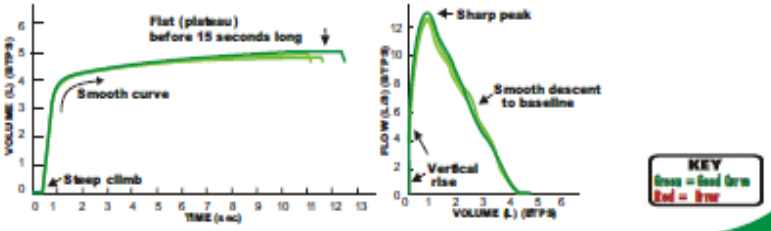


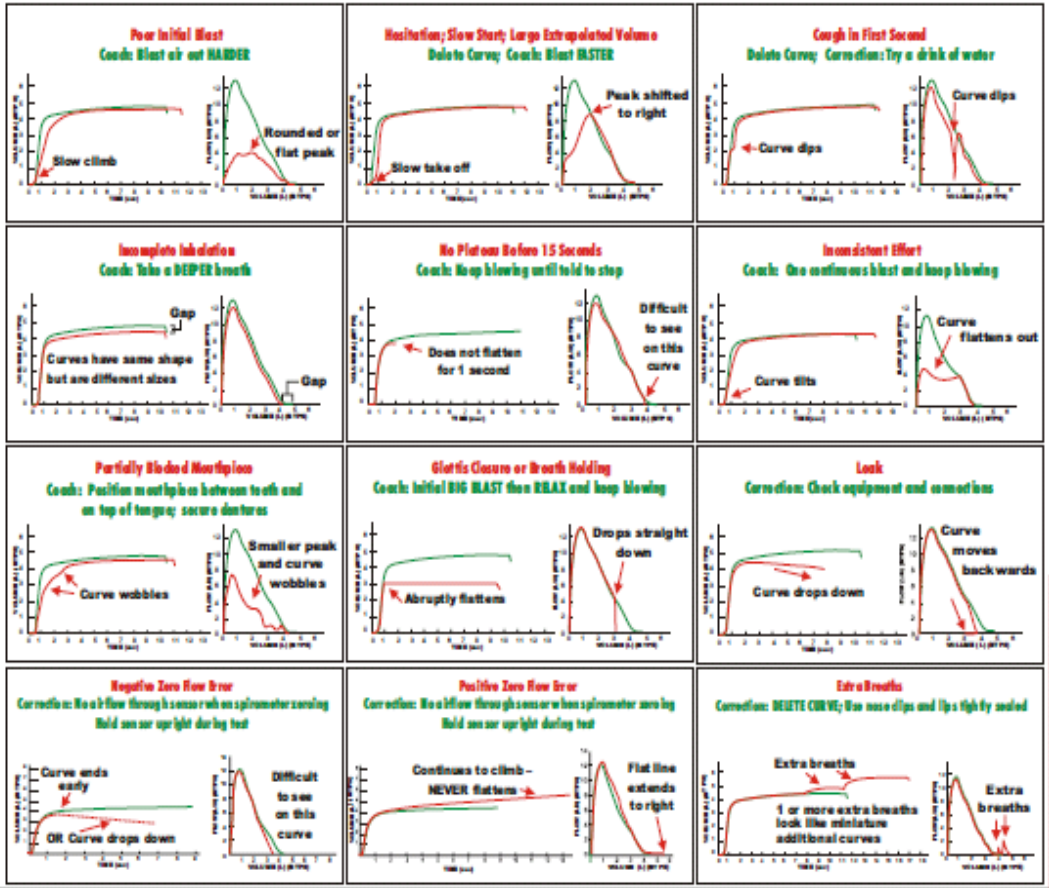
Get Valid Spirometry Results EVERY Time

A Valid Test has:
3 or More Good Curves
and Repeatable FVC and FEV1*

*Use most current American Thoracic Society/ European Respiratory Society (ATS/ERS) standards



HOW TO CORRECT TEST ERRORS



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For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting www.cdc.gov/niosh/eNews. For more information about NIOSH-Approved Spirometry Training go to http://www.cdc.gov/niosh/topics/spirometrytraining.html

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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DHHS (NIOSH) Publication No. 2011-135

Valid spirometry must meet criteria for:

- Acceptability
- Repeatability

Eur Respir J 2005; 26: 948–968

Forced Vital Capacity Maneuver (FVC)

Repeatability

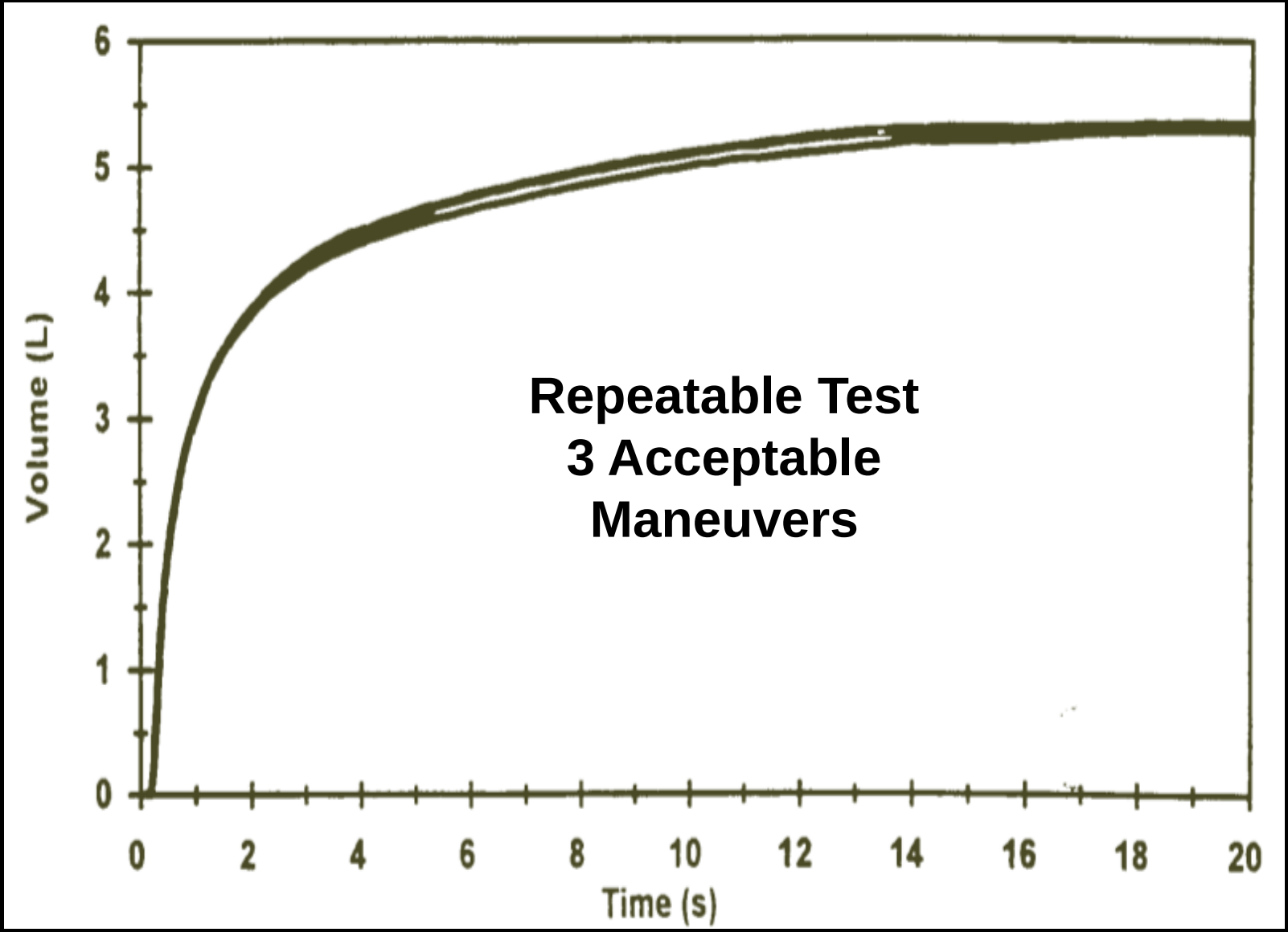
- Need 3 acceptable maneuvers (though only 2 used):
- Largest FVC and second largest FVC must not vary by more than 0.15 Liters

AND

- Largest FEV1 and second largest FEV1 must not vary by more than 0.15 Liters
- (If FVC is < 1.0 Liters volumes need to be within 1.0 liter)

Eur Respir J 2005; 26: 948–968

Repeatability



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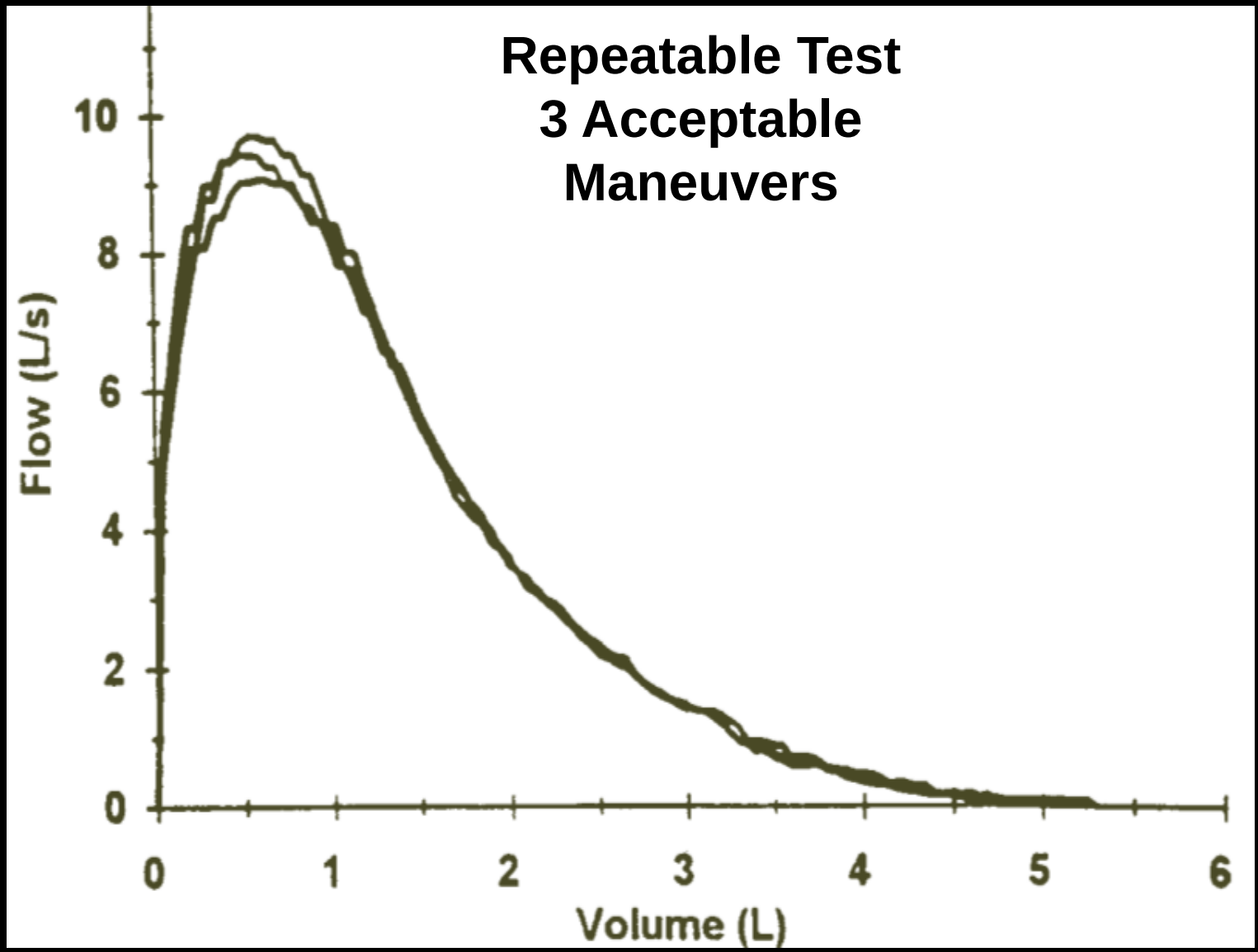

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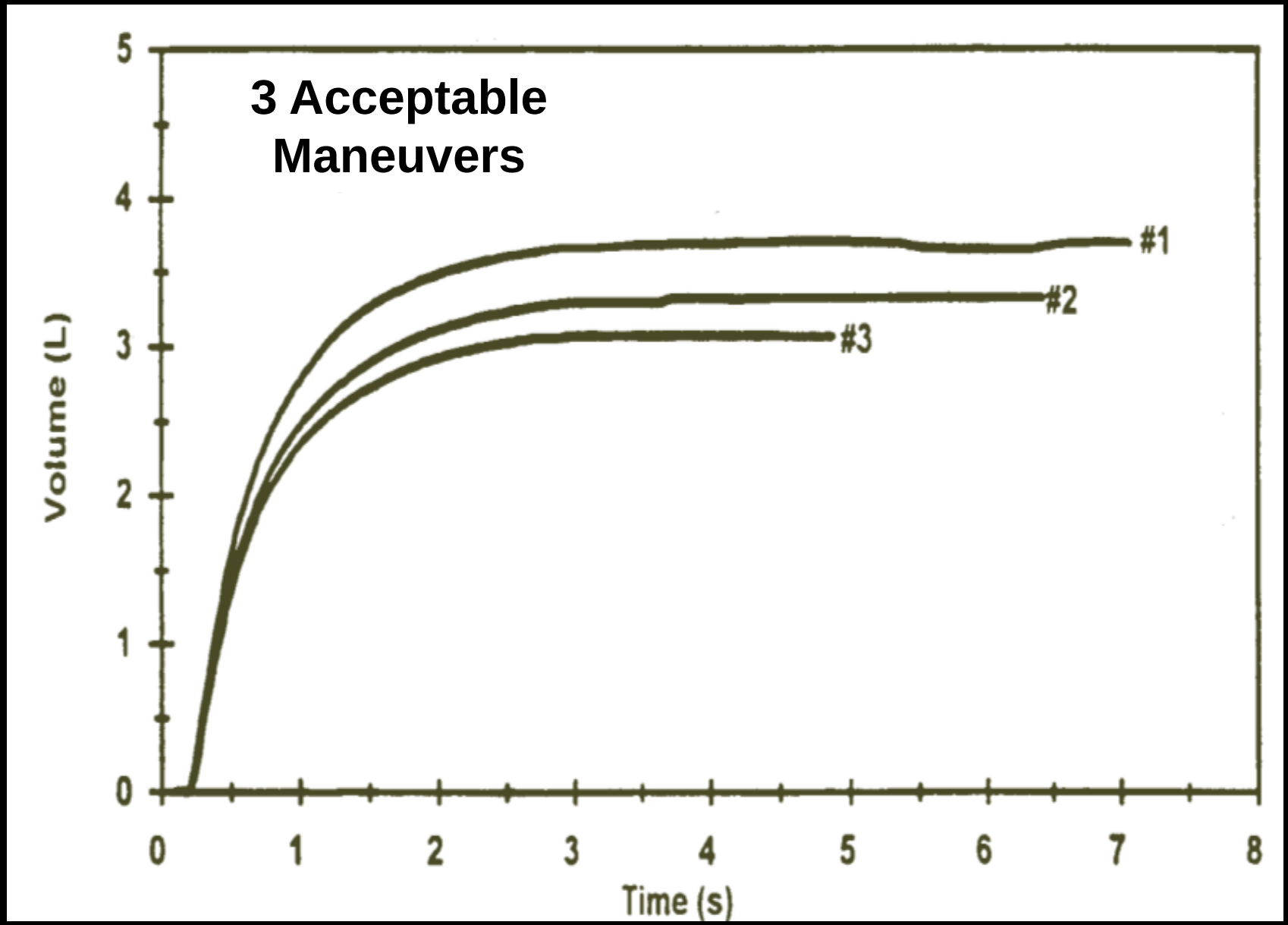

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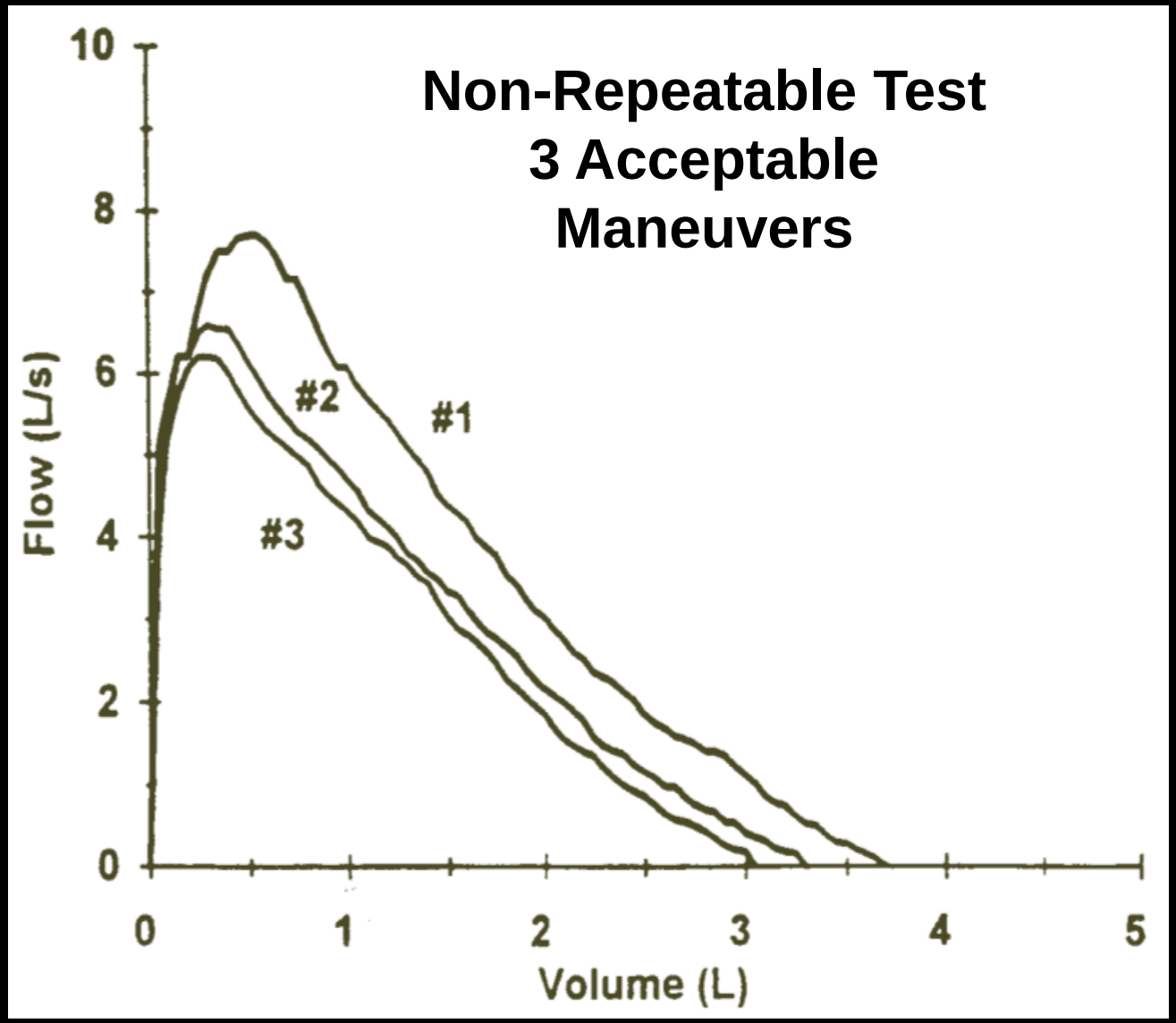
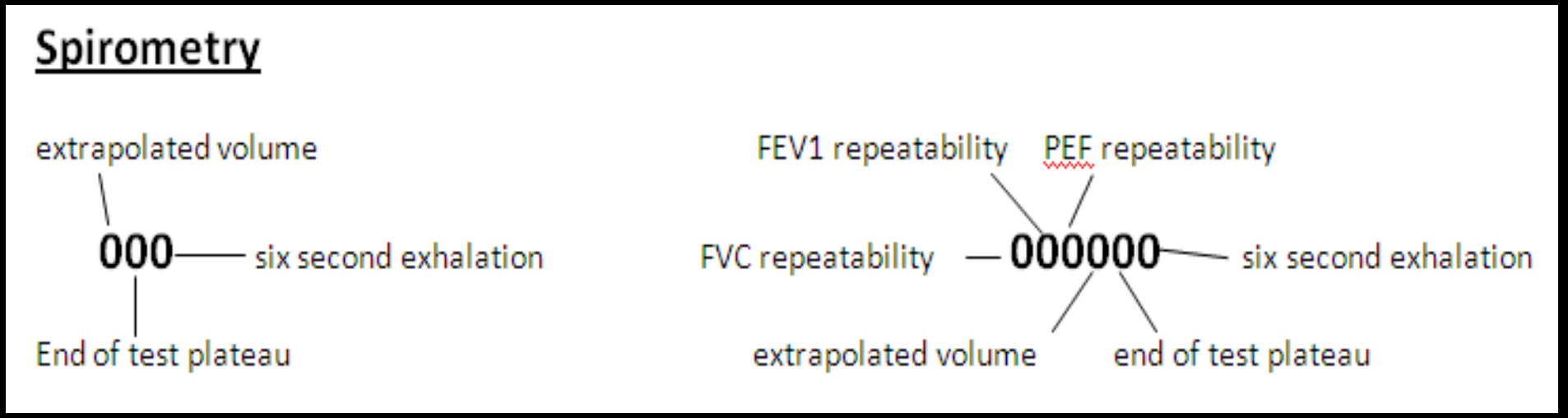


Error Codes


Spirometry
extrapolated volume
000
six second exhalation
End of test plateau
FEV1 repeatability
PEF repeatability
FVC repeatability
000000
six second exhalation
extrapolated volume
end of test plateau

Error Codes

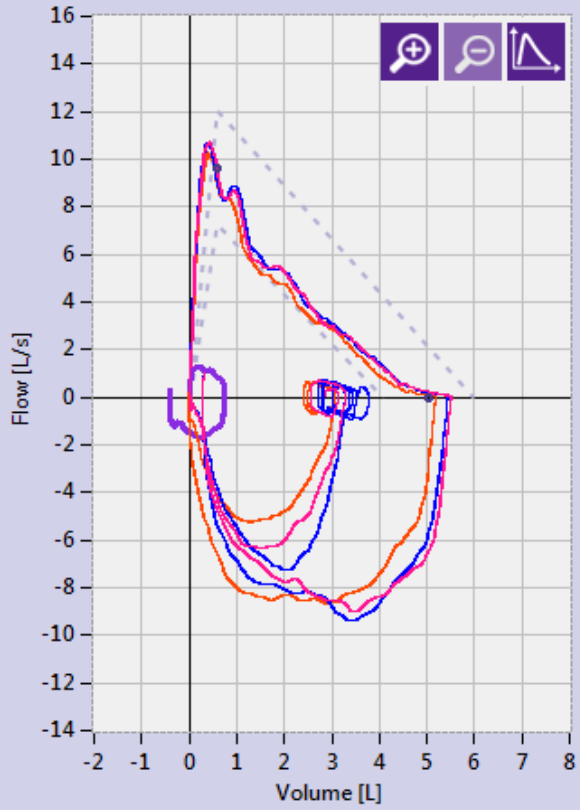
Date: 08/27/10

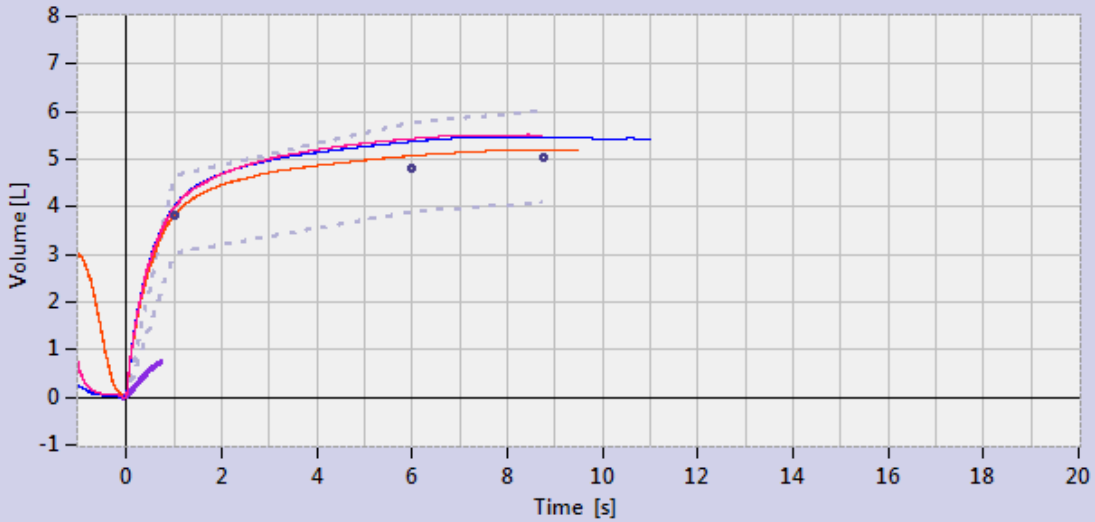
Age: 55 Birth Date: 03/25/55 Gender: Male Temp: 23
Height(in): 70 Weight(lb): 245 BMI: 35.16 Physician: Mahapatra
Race: African-American Technician: Jocelyne
Diagnosis: COPD Quit: No
Smoker: Yes How Long: 23 Medication Set 1: Albu

Spirometry

		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	4.12	3.70	90	0.94
FEV1	Liters	3.78	** 2.12	** 56	0.79
FEV1/FVC	%	79	** 57		10
FEV1/SVC	%	79	** 57		10
FEF25-75%	L/sec	3.13	** 0.81	** 26	1.79
PEF	L/sec	9.58	** 5.11	** 53	2.32
FEF/FIF50		<1.00	0.24		
FET100%	Sec		9.53		
Vol Extrap	Liters		0.09		
FVL ECode			000010		

FVL (ex/in) 10/22/2015





Test Information

Session Quality: Pre: A; FEV1 Var=0.02L (0.5%); FVC Var=0.05L (0.9%) System Interpretation: Pre:

Normal Spirometry (Interpretation: GOLD(2008)/Hardie)

Comment

Click to e

Test Results: NHANES III

	Pred	LLN	Pre Best	%Pred	Trial 1	Trial 2	Trial 3	Trial 4
Trial Rank			I<<		4	3	2	1
Time								
FVC [L]	5.04	4.07	5.51	109				
FEV1 [L]	3.83	3.01	3.99	104				
FEV1/FVC	0.760	0.664	0.724	95				
FEF25-75% [L/s]	3.19	1.53	2.85	89				
PEF [L/s]	9.64	7.24	10.83	112				

Trial 1 - Ranking based on acceptability and results

Problem: Patient may not have exhaled completely. Detailed criteria: Expiration time less than 2 seconds. OR volume in the last 0.5 seconds of the expiration more than 100 ml. (Message ID=4)

Solution: The patient must exhale longer and force as much air as possible out of his or her lungs.

Acceptable

Highest Ranked

Reset All

Clapp, William / 9101320

12:30:33 AM

Patterns of impairment

- Restrictive
- Obstructive
- Mixed

Restrictive Defects
size of lung reduced to the point of impairment

- Interstitial lung disease (reduced compliance - ”stiff”)
  - Interstitial pneumonitis
  - Pulmonary fibrosis
  - Pneumoconiosis
  - Granulomatous
  - Pulmonary edema
- Infiltrative
  - malignancy

Adapted: WM Gold, 1994

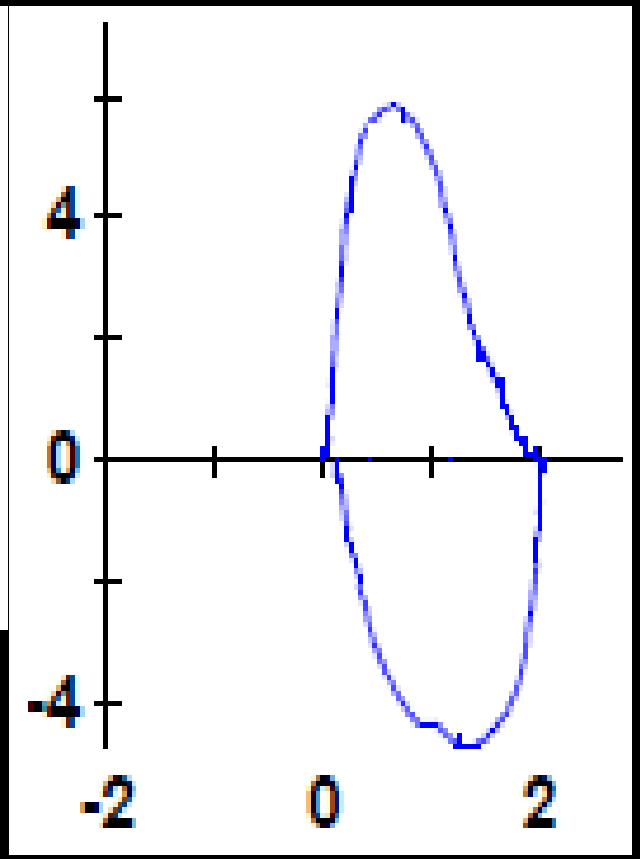
Restrictive Defects
size of lung reduced to the point of impairment

- Space occupying lesions
  - tumor
  - cyst
- Pleural
  - pneumothorax,
  - effusion
  - fibrothorax
- Chest Wall
  - scoliosis
  - kyphosis
  - obesity
- Abdominal
  - ascites
  - pregnancy

Adapted: WM Gold, 1994

Patterns of Impairment Restrictive Defects

Spirometry		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	4.26	** 2.05	** 48	0.86
FEV1	Liters	4.26	** 1.89	** 44	0.72
FEV1/FVC	%	85	92		10
FEV1/SVC	%	85	91		10
FEF25-75%	L/sec	4.24	3.63	86	1.63
PEF	L/sec	9.46	8.77	93	2.12
FEF/FIF50		<1.00	1.20		
FET100%	Sec		6.36		
Vol Extrap	Liters		0.07		



- FEV1 low
- FVC usually low
- FEV1/FVC normal or high
- Midflows normal or high

Patterns of Impairment Restrictive Defects

- "…the pattern of a reduced VC and a normal or even slightly increased FEV1/VC is often caused by submaximal inspiratory or expiratory efforts and/or patchy peripheral airflow obstruction, and a reduced VC by itself does not prove a restrictive ventilatory defect. It is associated with a low TLC no more than half the time."

- "A restrictive ventilatory defect is characterized by a reduction in TLC below the 5th percentile of the predicted value, and a normal FEV1/VC."

Eur Respir J 2005; 26: 948–968

Patterns of Impairment
Obstructive Defects

Lower/peripheral (small and medium) airways

- Intrinsic obstruction (lumen) small and medium airways
  - Asthma
  - Bronchitis
- Airway collapse
  - Emphysema
  - *Bronchiectasis*

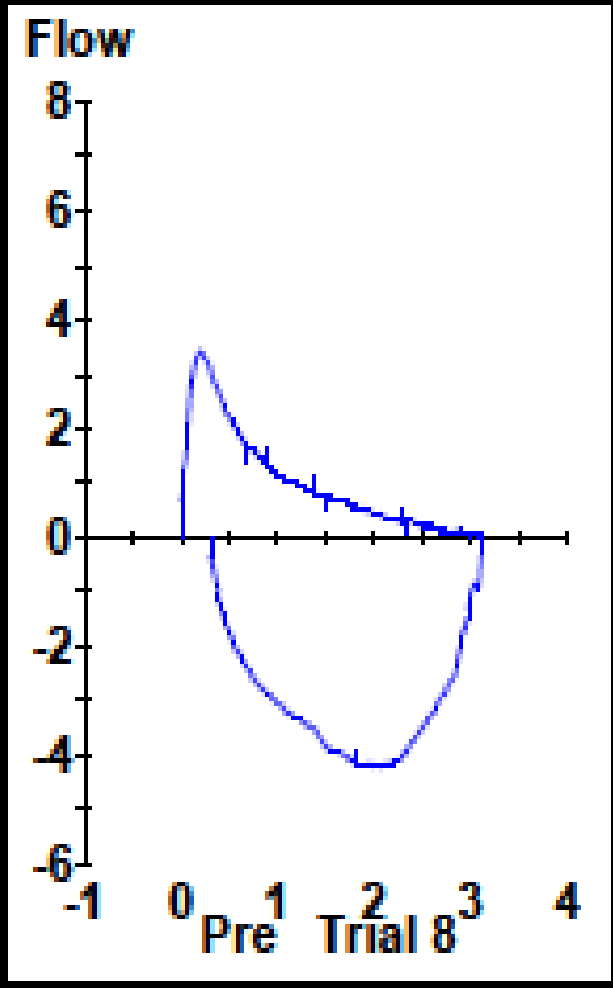
Upper airway – large airways

- Trachea/mainstem bronchi: tumor, stenosis, collapse
- Pharynx: tumor, infection, edema, foreign body

Adapted: WM Gold, 1994

Obstructive defects (lower/peripheral airways)

Spirometry		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	4.58	** 3.13	** 68	0.88
FEV1	Liters	3.50	** 1.45	** 41	0.75
FEV1/FVC	%	76	** 46		10
FEV1/SVC	%	76	** 39		10
FEF25-75%	L/sec	3.00	** 0.56	** 19	1.51
PEF	L/sec	9.08	** 3.77	** 42	2.19
FEF/FIF50		<1.00	0.16		
FET100%	Sec		10.42		
Vol Extrap	Liters		0.02		



- FVC normal or low
- FEV1 low (sometime normal)
- FEV1/FVC low
- Midflows low

“Midflows”

- Mean expiratory flow rate at 25-75% FVC ($MEFR_{25-75\%}$)
- Forced expiratory flow rate at 25-27% ($FEF_{25\%-75\%}$)
  - (the average expiratory flow over the middle half of the FVC)

} Same thing

- Highly dependent on the validity of the FVC measurement and the level of expiratory effort.
- When the FEV1 and FEV1/VC are in the normal range, the wide variability of the midflows in healthy subjects must be considered
- Helpful in the presence of a borderline FEV1/FVC

Eur Respir J 2005; 26: 319–338

http://spirxpert.com/indices11.htm. Accessed 7/7/2013

SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING"
Edited by V. Brusasco, R. Crapo and G. Viegi
Number 5 in this Series

Interpretative strategies for lung function tests

R. Pellegrino, G. Viegi, V. Brusasco, R.O. Crapo, F. Burgos, R. Casaburi, A. Coates, C.P.M. van der Grinten, P. Gustafsson, J. Hankinson, R. Jensen, D.C. Johnson, N. MacIntyre, R. McKay, M.R. Miller, D. Navajas, O.F. Pedersen and J. Wanger

"…abnormalities in these mid-range flow measurements during a forced exhalation are not specific for small airway disease in individual patients."

Eur Respir J 2005; 26: 948–968

FEF_{25-75} and FEV_1/FVC in Relation to Clinical and Physiologic Parameters in Asthmatic Children with Normal FEV_1 Values

Michael R. Simon, MD[a], Vernon M. Chinchilli, PhD[b], Brenda R. Phillips, MS[b], Christine A. Sorkness, PharmD[c], Robert F. Lemanske Jr., MD[c], Stanley J. Szefler, MD[d], Lynn Taussig, MD[e], Leonard B. Bacharier, MD[f], and Wayne Morgan, MD[g] for the Childhood Asthma Research and Education (CARE) Network of the National Heart, Lung, and Blood Institute

FEF25-75 % predicted was well correlated with bronchodilator responsiveness in asthmatic children with normal FEV1. FEF25-75 % predicted should be evaluated in clinical studies of asthma in children, and may be of use in predicting the presence of clinically relevant reversible airflow obstruction.

J Allergy Clin Immunol. 2010. 126(3): 527–534.e8

The Utility of Forced Expiratory Flow between 25% and 75% of Vital Capacity in Predicting Childhood Asthma Morbidity and Severity

Devika R. Rao, Jonathan M. Gaffin, Sachin N. Baxi, William J. Sheehan, Elaine B. Hoffman & Wanda Phipatanakul

"…childhood asthmatics with a normal FEV1, FEF25–75 should be considered as a potentially important spirometric variable that can be used as a marker of BDR, asthma severity, and asthma exacerbations both in the clinical and research settings."

Journal of Asthma, 2012. 49:6, 586-592.

Asthma in children younger than 12 years: Initial evaluation and diagnosis

Authors: Gregory Sawicki, MD, MPH, Kenan Haver, MD
Section Editors: Robert A Wood, MD, Gregory Redding, MD
Deputy Editor: Elizabeth TePas, MD, MS

Contributor Disclosures

"Forced expiratory flow between 25 and 75 percent of vital capacity (FEF25-75) less than 65 percent correlates with reversible airflow obstruction in children with normal FEV_1 and may be a useful measure in this subgroup, although further studies are needed ... "

UpToDate. Accessed 6-18-2017

Office spirometry

Author: Meredith C McCormack, MD, MHS
Section Editor: James K Stoller, MD, MS
Deputy Editor: Helen Hollingsworth, MD

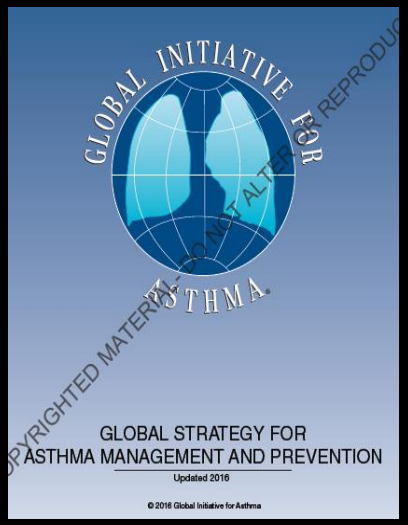
Contributor Disclosures

All topics are updated as new evidence becomes available and our peer review process is complete.
Literature review current through: Apr 2017. | **This topic last updated:** Jun 06, 2016.

Other flow measures — The transition from normal function to moderate airflow obstruction is generally gradual. Physiologists have searched for a test that is more sensitive than the FEV_1 for detection of airflow obstruction in its early stages. None has proven to be as reliable as the index obtained by dividing the FEV_1 by the FVC. The forced expiratory flow between 25 and 75 percent of the FVC (also known as FEF25-75 or maximal mid-expiratory flow rate) should not be used to detect "small airways disease" in adults, due to poor reproducibility [13].

UpToDate. Accessed 6-18-2017

Asthma:

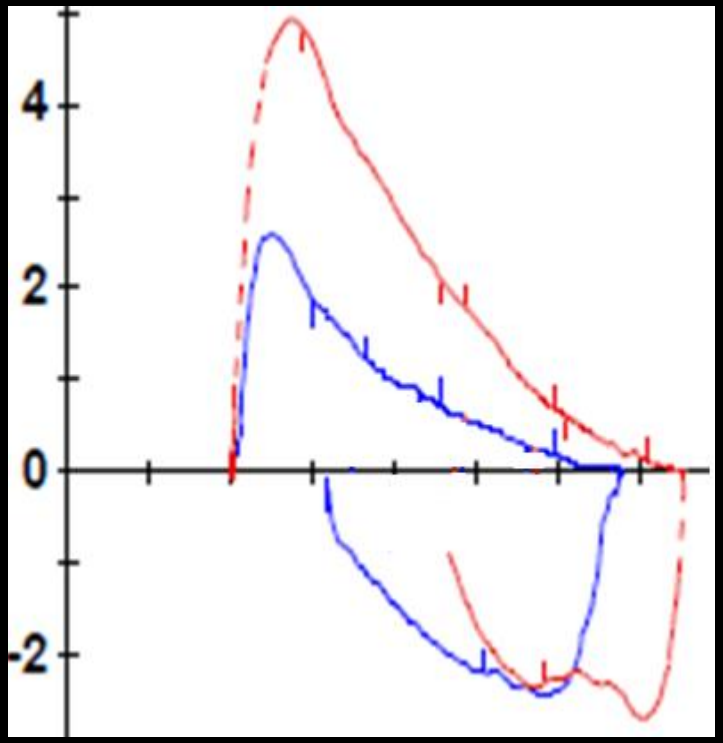


- Recurring and variable symptoms
- Airflow limitation with reduced FEV1/FVC
- Positive bronchodilator reversibility test
- Positive bronchial challenge test (bronchial hyperresponsiveness)

Global Initiative for Asthma. Global Strategy for Asthma Management And Prevention, 2016. Available from: www.ginasthma.org.

Bronchodilator reversibility

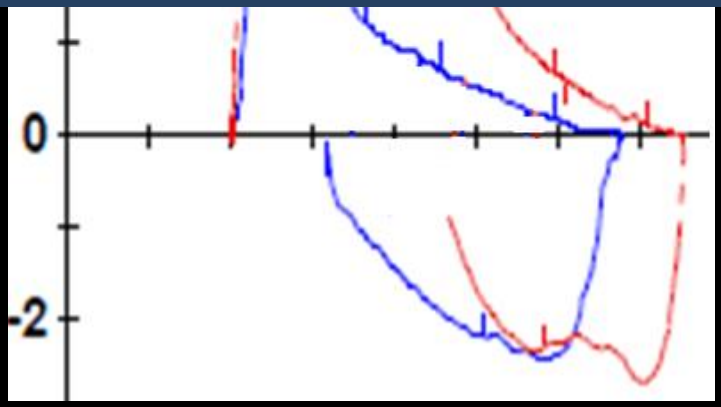
- Salbutamol 100 ug X 4 (or Ipratropium)
- 15 minutes
- Increase FEV1 or FVC of 200 ml and ≥ 12%



Spirometry		Ref	Pre Meas	Pre % Ref	CI	Post Meas	Post % Ref	Post % Chg
FVC	Liters	2.61	2.40	92	0.66	2.77	106	16
FEV1	Liters	2.09	** 1.30	** 62	0.57	2.00	96	54
FEV1/FVC	%	81	** 54		11	72		
FEF25-75%	L/sec	2.22	** 0.65	** 29	1.28	1.43	64	120
PEF	L/sec	5.73	** 3.26	** 57	1.87	5.31	93	63
FEF/FIF50			0.36			0.84		134
FET100%	Sec		9.82			7.67		-22
Vol Extrap	Liters		0.05			0.02		-56

Obstructive ventilatory defect with moderately severe reduction in FEV1, with significant increases in, and normalization of, FVC and FEV1 after administration of bronchodilators

- Increase FEV1 or FVC of 200 ml and ≥ 12%



Spirometry		Ref	Pre Meas	Pre % Ref	CI	Post Meas	Post % Ref	Post % Chg
FVC	Liters	2.61	2.40	92	0.66	2.77	106	16
FEV1	Liters	2.09	** 1.30	** 62	0.57	2.00	96	54
FEV1/FVC	%	81	** 54		11	72		
FEF25-75%	L/sec	2.22	** 0.65	** 29	1.28	1.43	64	120
PEF	L/sec	5.73	** 3.26	** 57	1.87	5.31	93	63
FEF/FIF50			0.36			0.84		134
FET100%	Sec		9.82			7.67		-22
Vol Extrap	Liters		0.05			0.02		-56

TABLE 9 Summary of the procedures relating to bronchodilator response

Procedures suggested to minimise differences within and between laboratories

- Assess lung function at baseline
- Administer salbutamol in four separate doses of 100 μg through a spacer
- Re-assess lung function after 15 min. If you want to assess the potential benefits of a different bronchodilator, use the same dose and the same route as used in clinical practice. The wait time may be increased for some bronchodilators

An increase in FEV_1 and/or FVC ⩾12% of control and ⩾200 mL constitutes a positive bronchodilator response

In the absence of a significant increase in FEV_1 and/or FVC, an improvement in lung function parameters within the tidal breathing range, such as increased partial flows and decrease of lung hyperinflation, may explain a decrease in dyspnoea

The lack of a bronchodilator response in the laboratory does not preclude a clinical response to bronchodilator therapy

FEV_1: forced expiratory volume in one second; FVC: forced vital capacity.

Bronchodilator response?

Eur Respir J 2005; 26: 948–968

Reversible with bronchodilator?

Date: 06/16/09 Time: 12:37

Age: 51 Birth Date: 07/01/57 Gender: Female
Temp: 24 PBar: 753 Relative Humidity: 25
Height(in): 59 Weight(lb): 148 BMI: 29.91
Physician: SHIM / 7405648
Race: Caucasian
Technician: BROWN
Diagnosis: ASTHMA
Quit: No Stopped:
Smoker: No How Long:
Medication Set 1: ATROVENT / QVAR ALBUTEROL

Spirometry		Ref	Pre Meas	Pre % Ref	CI	Post Meas	Post % Ref	Post % Chg
FVC	Liters	2.94	** 1.94	** 66	0.59	** 2.18	** 74	12
FEV1	Liters	2.33	** 1.48	** 64	0.50	** 1.62	** 69	9
FEV1/FVC	%	80	** 69		10	74		
FEF25-75%	L/sec	2.45	** 1.25	** 51	1.05	** 1.21	** 49	-3
PEF	L/sec	5.97	** 3.77	** 63	1.46	4.74	79	26
FEF/FIF50			0.85			0.87		2
FET100%	Sec		7.10			7.39		4
Vol Extrap	Liters		0.07			0.09		38
FVL ECode			000000			001000		

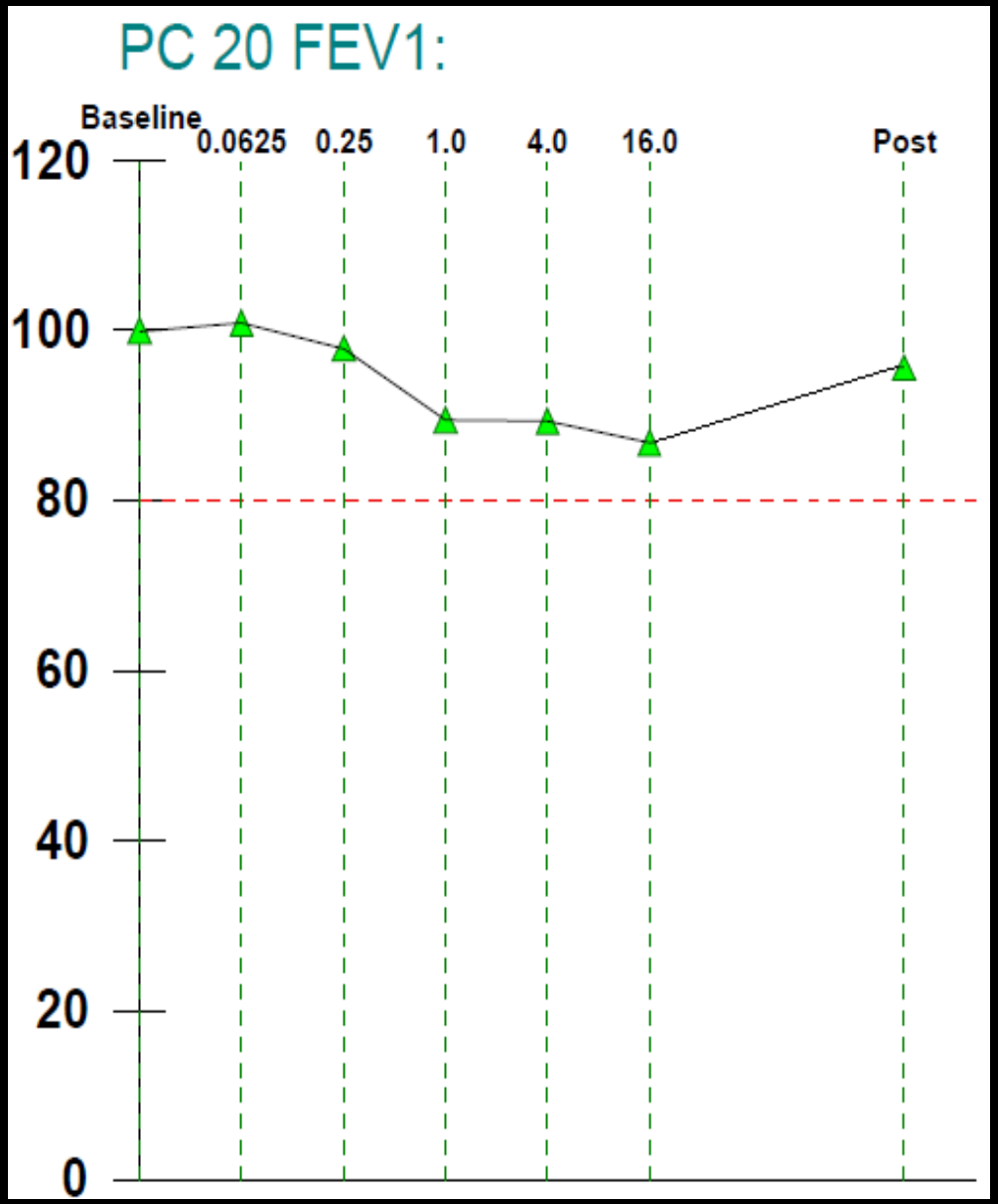
Methacholine Challenge Testing: Bronchial Hyperresponsiveness - Indications

- Diagnosis of Asthma when:
  - Traditional methods, i.e. spirometry with pre and post BD have not been diagnostic
  - Strong clinical suspicion
- Symptoms of cough, wheeze, chest tightness
  - Exposure to cold air
  - Exercise
  - Exposure to allergens
  - Workplace exposure
  - Respiratory viral infections

Bronchoprovocation: Methacholine Challenge (five breath dosimeter protocol)

	Ref	Pre Meas	Level 1 Meas	Level 2 Meas	Level 3 Meas	Level 4 Meas	Level 5 Meas	Level 6 Meas	Level 7 Meas	Post Meas
Dose			0.0625	0.25	1.0	4.0	16.0			
FVC Liters	5.21	4.64	4.81	4.63	4.32	4.37	4.26			4.53
%Ref		89	92	89	83	84	82			87
%Change			2	-2	-9	-8	-10			-4
Dose			0.0625	0.25	1.0	4.0	16.0			
FEV1 Liters	4.04	3.89	4.03	3.92	3.58	3.57	3.47			3.82
%Ref		96	100	97	89	88	86			95
%Change			1	-2	-10	-11	-13			-4
Dose			0.0625	0.25	1.0	4.0	16.0			
FEF25-75%	3.55	4.34	4.53	4.47	4.05	3.76	3.63			4.49
%Ref		122	127	126	114	106	102			126
%Change			0	-1	-10	-17	-20			-1

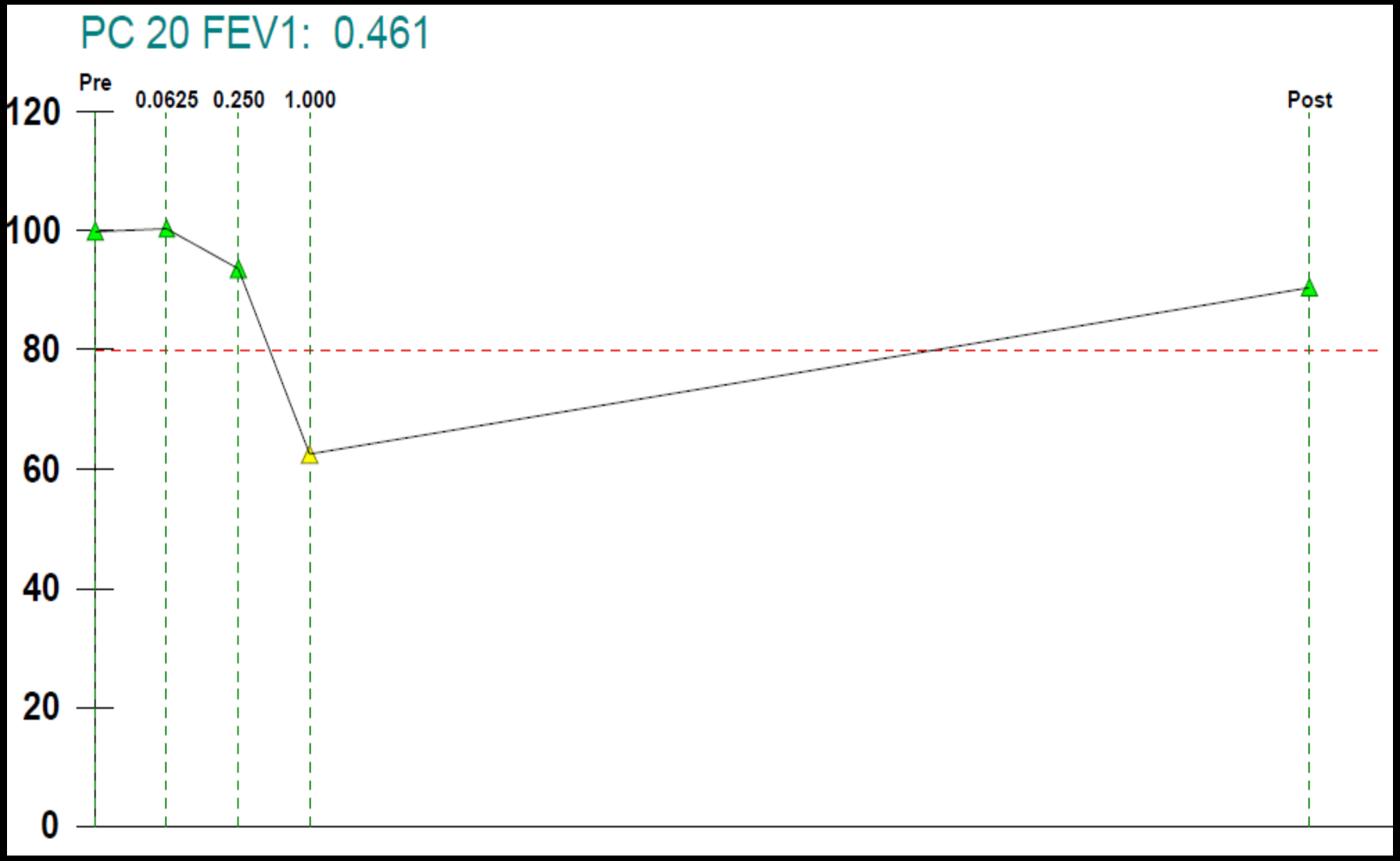
Bronchoprovocation: Methacholine Challenge



Bronchoprovocation: Methacholine Challenge (five breath dosimeter) protocol

	Ref	Pre	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Post
		Meas	Meas	Meas	Meas	Meas	Meas	Meas	Meas	Meas
Dose			0.0625	0.250	1.000					
FVC Liters	3.08	2.69	2.67	2.50	** 2.08					2.68
%Ref		88	87	81	** 67					87
%Change			-1	-7	-23					-1
Dose			0.0625	0.250	1.000					
FEV1 Liters	2.49	1.94	1.95	** 1.82	** 1.21					** 1.75
%Ref		78	78	** 73	** 49					** 70
%Change			1	-6	-38					-9
Dose			0.0625	0.250	1.000					
FEF25-75%	2.62	1.29	1.41	1.28	** 0.52					** 0.88
%Ref		49	54	49	** 20					** 33
%Change			9	-1	-60					-32

Bronchoprovocation: Methacholine Challenge



Bronchoprovocation interpretation

TABLE 5

CATEGORIZATION OF BRONCHIAL RESPONSIVENESS

PC_{20} (mg/ml)	Interpretation*
> 16	Normal bronchial responsiveness
4.0-I 6	Borderline BHR
1.0–4.0	Mild BHR (positive test)
< 1.0	Moderate to severe BHR

. Before applying this interpretation scheme, the following must be true: (I) baseline airway obstruction is absent; (2) spirometry quality is good; (3) there is substantial postchallenge FEV_1 recovery.

Am J Respir Crit Care Med
Vol 161. pp 309-329, 2000

TABLE 5-5 Criteria for Rating Permanent Impairment due to Asthma[a]

G Asthma

CLASS	CLASS 0	CLASS 1	CLASS 2	CLASS 3	CLASS 4
WHOLE PERSON IMPAIRMENT RATING (%)	0	2%-10%	11%-23%	24%-40%	45%-65%
SEVERITY GRADE (%)		2 4 6 8 10 (A B C D E) (Minimal)	11 14 17 20 23 (A B C D E) (Mild)	24 28 32 36 40 (A B C D E) (Moderate)	45 50 55 60 65 (A B C D E) (Severe)
CLINICAL PARAMETERS (MINIMUM MEDICATION NEED, FREQUENCY OF ATTACKS, ETC)	No medication required	Occasional bronchodilator use (not daily use)	Daily low-dose inhaled steroid (<500 mcg per day of beclomethasone or equivalent)	Daily medium or high-dose (500 to 1000 mcg per day) inhaled steroid and/or short periods of systemic steroids and a long acting bronchodilator Daily use of steroids, systemic and inhaled, and daily use of maximum bronchodilators	Asthma not controlled by treatment
MAXIMUM POSTBRONCHODILATOR FEV_1	>80%	70%–80%	60%–69%	50%–59%	<50%
OBJECTIVE TESTS FOR DEGREE OF AIRWAY HYPERRESPONSIVENESS		Minimal	Mild	Moderate	Severe
PC_{20} mg/mL[b]	6–8	3–5	3–>0.5	0.5–0.25	0.24–0.125

[a] Percent predicted FEV_1 after albuterol therapy

impairment. 6th ed. 2008

Spirometry/PFTs - what is normal?

Spirometry		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	3.07	2.54	83	0.78
FEV1	Liters	2.43	2.04	84	0.66
FEV1/FVC	%	80	80		11
FEV1/SVC	%	80	79		11
FEF25-75%	L/sec	2.40	2.18	91	1.50
PEF	L/sec	6.29	6.95	111	2.19
FEF/FIF50			0.65		
FET100%	Sec		7.14		
Vol Extrap	Liters		0.04		
FVL ECode			000000		

Derivation of Predicted Values

- Large numbers of measurements in an asymptomatic, nonsmoking population
- Development of regression equations
  - spirometry
  - lung Volumes
  - DLCO
  - VO_2max
- Populations change over time
  - cohort effect (changes of the population)
  - health of the society (nutrition, survival of less healthy infants, etc)

Spirometry Reference Sets/Equations

- Morris 1971
- Knudson 1976 (predicteds mandated by the Cotton Dust Standard)
- Crapo 1981,
- Knudson 1983
- Miller 1986
- Hankinson et. al. 1999 (NHANES III).
- ATS/ERS 2005
  - NHANES III
  - ERS 1993 – European Community for Steel and Coal
- *Global Lung Initiative (GLI)*

National Health and Nutrition Examination Survey (NHANES III)

Spirometric Reference Values from a Sample of the General U.S. Population

JOHN L. HANKINSON, JOHN R. ODENCRANTZ, and KATHLEEN B. FEDAN

Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, West Virginia

AM J RESPIR CRIT CARE MED 1999;159:179–187.

- Data collected 1988-1994
- 81 counties across U.S.
- Spirometry on 20,627 participants ≥ 8 y.o.
- Caucasian-Americans, African-American and Mexican-American
- Use of equipment and procedures meeting ATS standards

Use of Reference (predicted) Values

- Predicted values should be obtained from studies of “normal” or “healthy” subjects with the same anthropometric (e.g. sex, age and height) and ethnic characteristics of the patient being tested
- Height and weight should be measured for each patient at the time of testing
- When using a set of reference equations, extrapolation beyond the size and age of the investigated subjects should be avoided

Also

- Mixed race – use the race the patient most closely identifies with (but consider in the interpretation)
- Asian – Americans correction factor of 0.88 (Hankinson, 2010)

Eur Respir J 2005;26:948-968

Eur Respir J 2012; 40: 1324–1343
DOI: 10.1183/09031936.00080312

ERS TASK FORCE

Multi-ethnic reference values for spirometry for the 3–95-yr age range: the global lung function 2012 equations

Philip H. Quanjer, Sanja Stanojevic, Tim J. Cole, Xaver Baur, Graham L. Hall, Bruce H. Culver, Paul L. Enright, John L. Hankinson, Mary S.M. Ip, Jinping Zheng, Janet Stocks and the ERS Global Lung Function Initiative

TABLE 2 Subjects in the groups for which prediction equations were derived#

Group	Males		Females		Total
	N	Age range yrs	N	Age range yrs	
Caucasian	25827	2.5–95	31568	2.5–95	57395
African–American	1520	6–85	2025	6.1–87	3545
North East Asian	1414	16–91	3578	16–88	4992
South East Asian	3095	3.3–86	5160	3.2–92	8255
Total	31856		42331		74187

#: the countries of origin are listed in table E1 in the online supplementary data.

Eur Respir J 2005; 26: 948–968
DOI: 10.1183/09031936.05.00035205

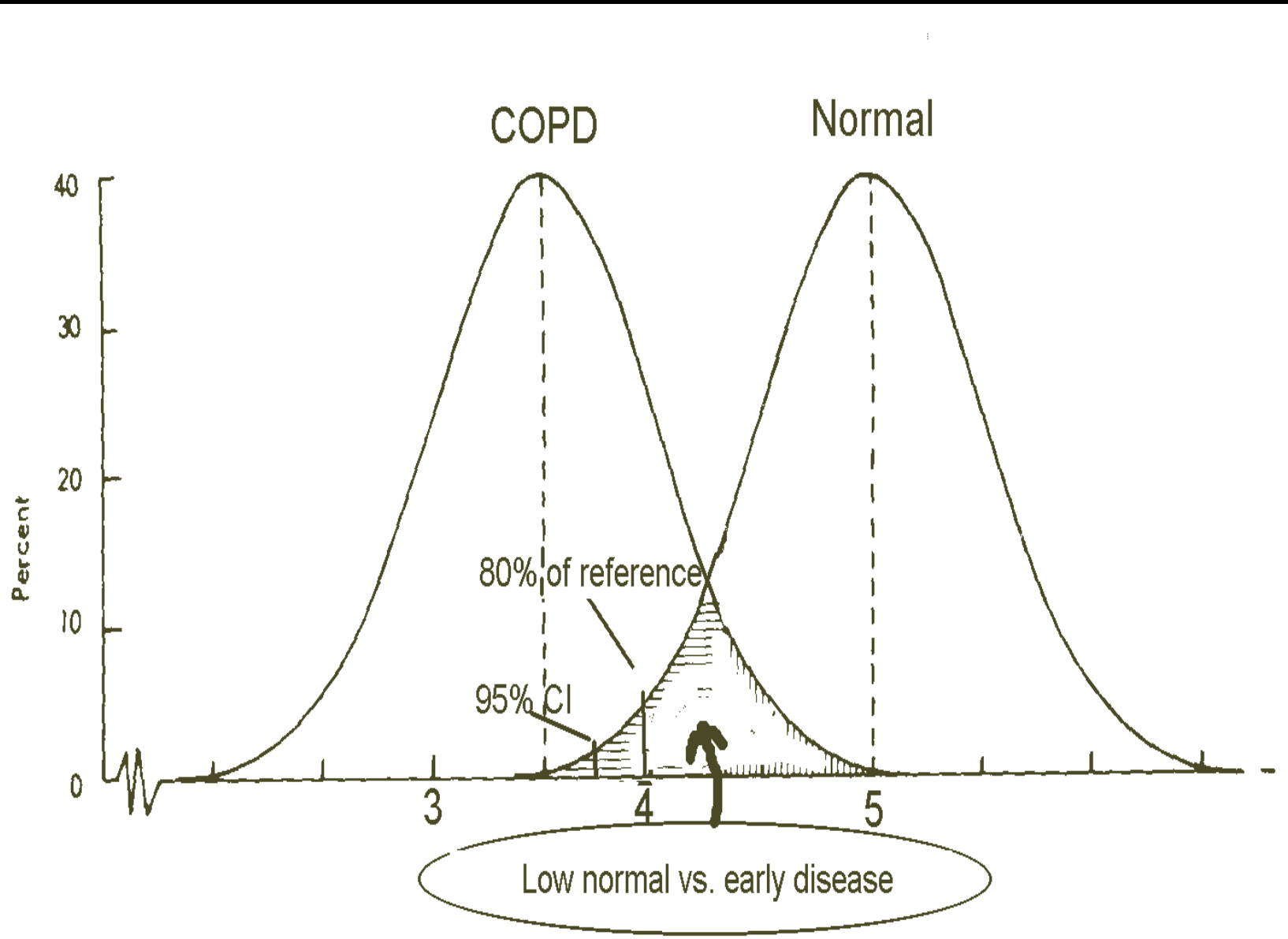
SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING"
Edited by V. Brusasco, R. Crapo and G. Viegi
Number 5 in this Series

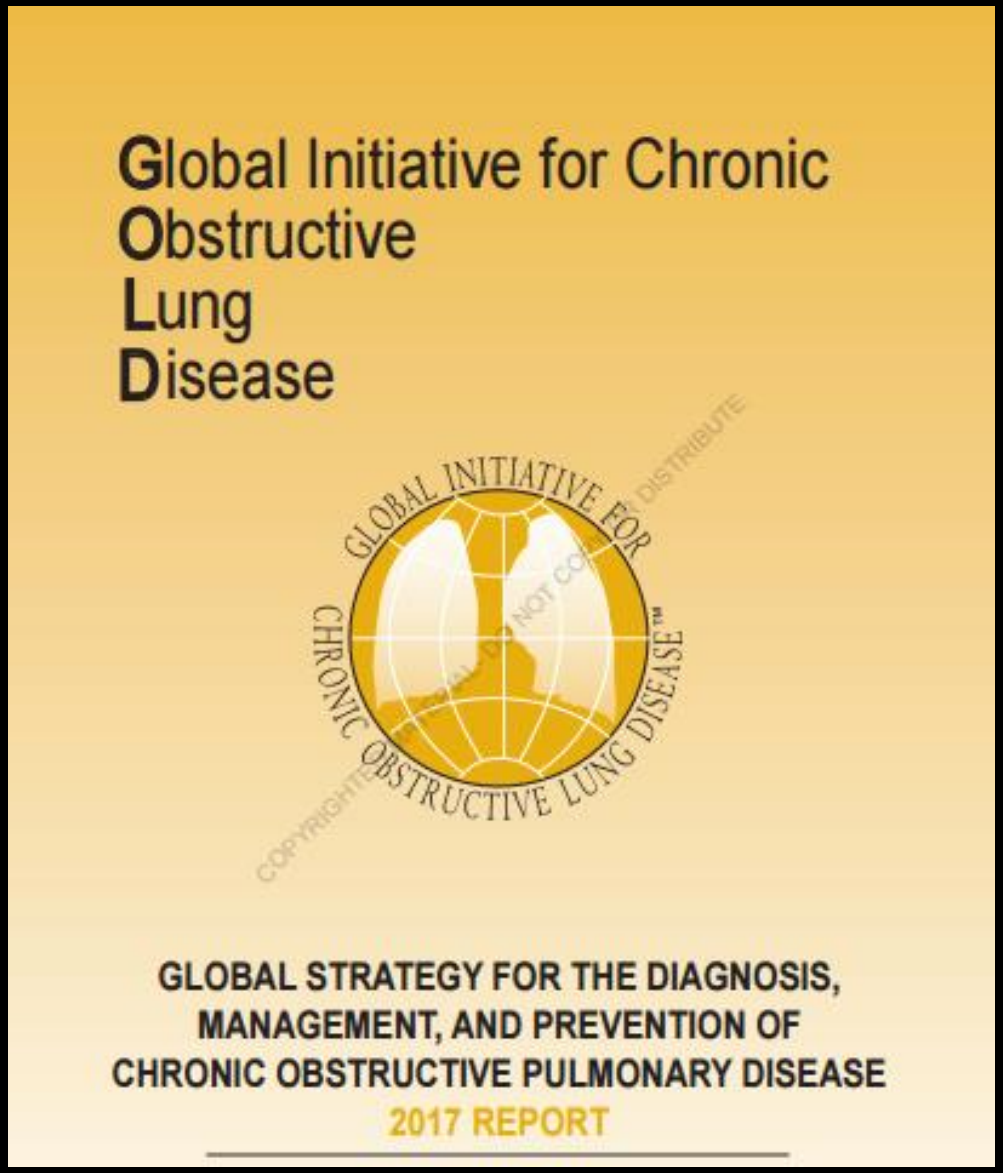
Interpretative strategies for lung function tests

R. Pellegrino, G. Viegi, V. Brusasco, R.O. Crapo, F. Burgos, R. Casaburi, A. Coates, C.P.M. van der Grinten, P. Gustafsson, J. Hankinson, R. Jensen, D.C. Johnson, N. MacIntyre, R. McKay, M.R. Miller, D. Navajas, O.F. Pedersen and J. Wanger

"For each lung function index, values below the 5th percentile of the frequency distribution of values measured in the reference population are considered to be below the expected 'normal range' "

(applies to FEV1, FVC, FEV1/FVC, FEF 25-75)


COPD
Normal
40
30
20
10
0
Percent
80% of reference
95% CI
3
4
5
Low normal vs. early disease



Obstruction: FEV1/FVC < 70%

Fixed cut-off controversial

"The practice of using 0.70 as a lower limit of the FEV1/FVC ratio results in a significant number of false positive results in males aged > 40 yrs and females > 50 yrs, as well as in a risk of overdiagnosis of chronic obstructive pulmonary diseases (COPD) in asymptomatic elderly neversmokers."

Eur Respir J 2005;26:948-968

Severity: characterized by the FEV1
(not FEV1/FVC)

TABLE 6 Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV_1)

Degree of severity	FEV_1 % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

Eur Respir J 2005; 26: 948–968

Obstructive defect, moderately severe reduction in FEV1

Spirometry		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	2.76	** 1.81	** 65	0.69
FEV1	Liters	2.21	** 1.19	** 54	0.59
FEV1/FVC	%	81	** 66		11
FEF25-75%	L/sec	2.34	** 0.59	** 25	1.33
PEF	L/sec	5.98	4.47	75	1.94
FEF/FIF50			0.31		
FET100%	Sec		8.73		
Vol Extrap	Liters		0.02		

Severity: characterized by the FEV1
(not TLC or FEV1/FVC)

TABLE 6 Severity of any spirometric abnormality based on the forced expiratory volume in one second (FEV_1)

Degree of severity	FEV_1 % pred
Mild	>70
Moderate	60–69
Moderately severe	50–59
Severe	35–49
Very severe	<35

Eur Respir J 2005; 26: 948–968

Obstructive defect present, but FEV1 is normal

Spirometry		Ref	Pre Meas	Pre % Ref	CI
FVC	Liters	3.51	3.58	102	0.65
FEV1	Liters	2.98	2.57	86	0.55
FEV1/FVC	%	84	** 72		10
FEF25-75%	L/sec	3.34	** 1.79	** 54	1.15
PEF	L/sec	6.67	6.53	98	1.60
FEF/FIF50			0.49		
FET100%	Sec		8.60		
Vol Extrap	Liters		0.10		

Could say “obstructive defect with normal FEV1”

Do not beat a dead horse.

No ACTUAL animals were harmed in the making of this cartoon.

Summary

- Spirometry is used for
  - screening and surveillance in evaluation of individuals exposed to toxic inhalants,
  - evaluation of respiratory impairment,
  - Monitoring therapeutic effect/disease progression
  - Diagnosing obstructive lung disease
  - Suggesting restrictive lung disease
- Spirometry is essential in the diagnostic evaluation of patients with suspected airways disease
- Even small changes in the size of airways have very large effects on the flow of air in the lungs (Poiseuille)
- To be useful diagnostically, spirometry must be valid (3 acceptable, 2 repeatable trials)
- Midflows (FEF 25-75) not helpful in adults, but useful in children

END

Soli Deo Gloria