Vitalograph sponsored webinar
History and Application of GLI Norms
Speaker: Carl D. Mottram

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In this video the topics represented by the speaker do not necessarily represent the view of Vitalograph

For the correct use of all devices, please refer to the instruction for use manual.

04757_3

Vitalograph®

Clinical Trials Focus

Pediatric Pulmonary Function Testing

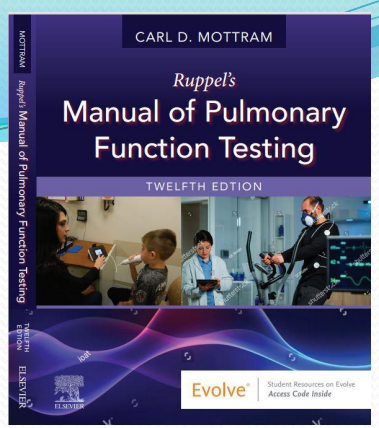
"They're not just little adults"

Carl D Mottram

Associate Professor of Medicine

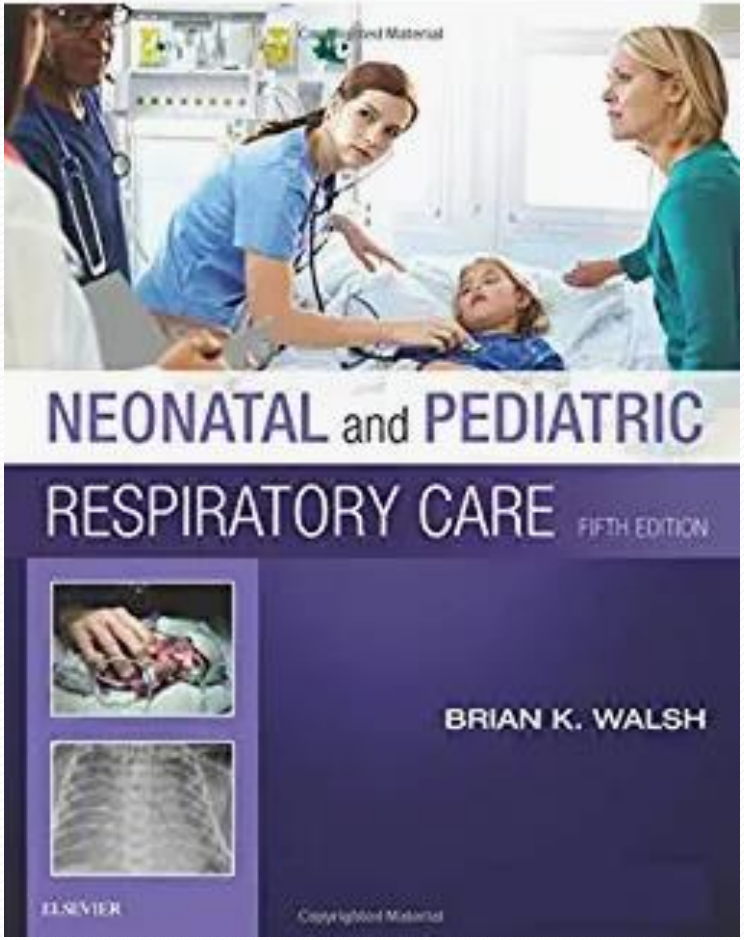
President – PFWConsulting LLC

Carl D. Mottram RRT RPFT FAARC



- President – PFWConsulting LLC
- Associate Professor of Medicine - Emeritus
- Author-Editor – 10-12th Eds Ruppel's Manual of Pulmonary Function Testing
- ATS-ERS Standards Lung Volume Task Force
- ATS, ACCP, CTS, AARC Task Force on "The effects of ethnicity on the interpretation of PFTs
- Board member - Clinical and Laboratory Standards Institute
- Board member - National Board for Respiratory Care

Other Disclosures

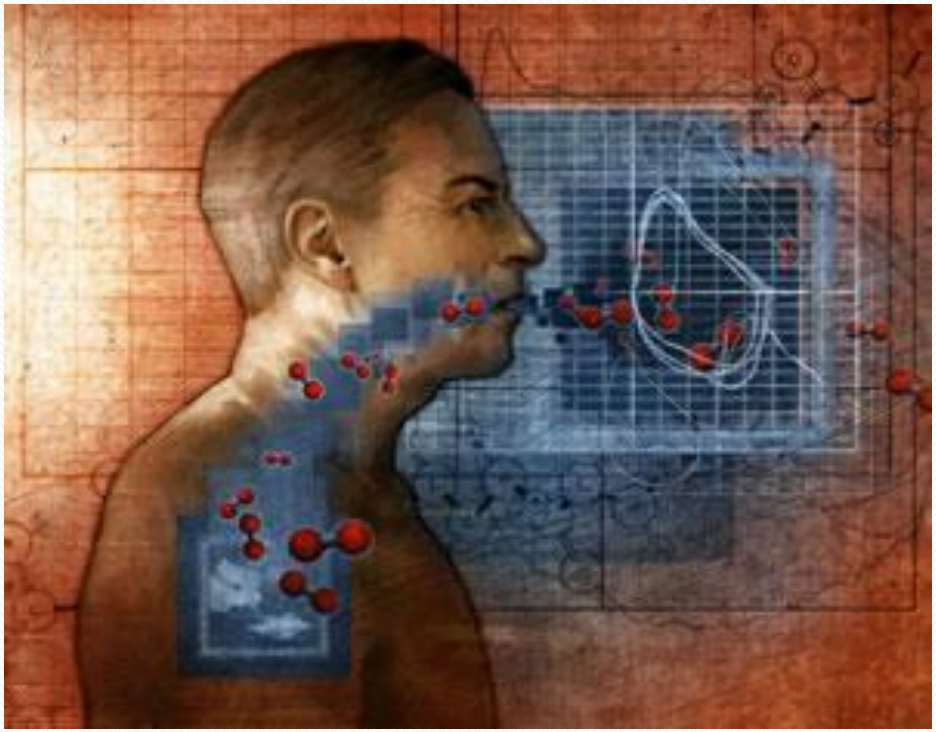


- Author - Chapter on Pediatric PFT testing
  - Walsh 4th – 6th Editions

Objectives

- Describe the various tests that might be used in accessing lung function in pediatric subjects
- Understand current testing standards and specific adjustments that may be applied for testing in this patient population
- Review strategies that enhance testing and aid in a successful testing experience.

Measurement of Lung Function is Complex



My #1 and #2 Key Elements to Success

#1 = Environmental Fears

Environmental Fears

- PFT laboratories are filled with complex testing systems
- Even simple spirometry can appear to be threating!

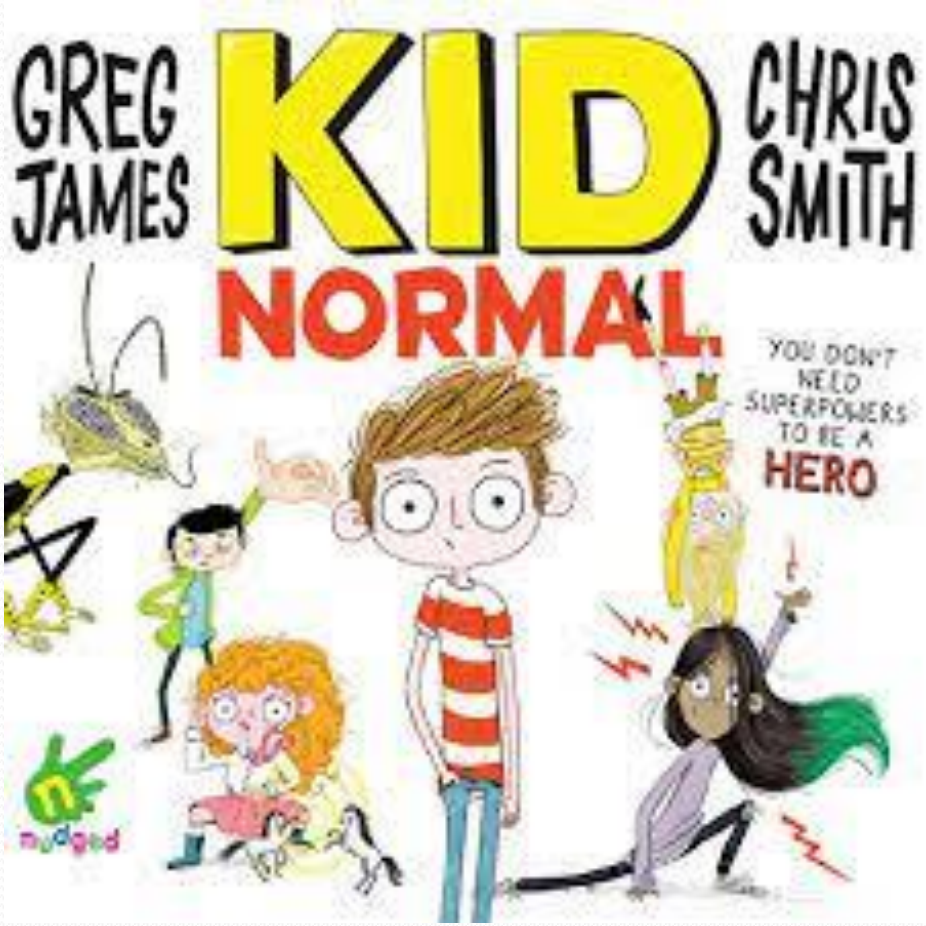
Techniques to Reduce Environmental Fears

- Technologist/operator
  - Calming voice and demeanor
    - Smiling, upbeat attitude
  - “Nothing in here will hurt you”

- Equipment and laboratory set-up
  - Pictures
  - Equipment adjunct

Techniques to Reduce Environmental Fears

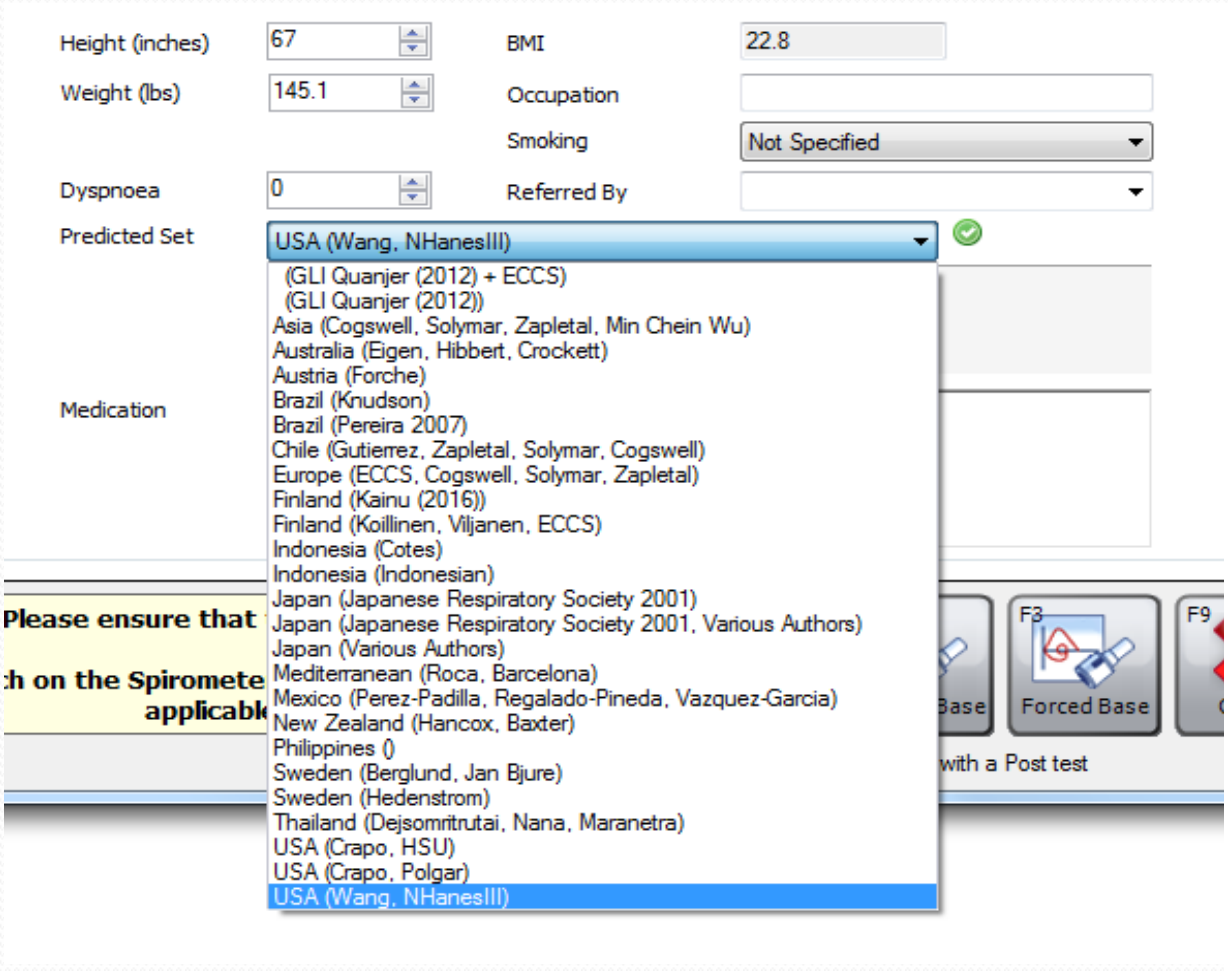
#2 - Selecting a reference set.



What reference values are you currently using?

Never assume a lab knows!!

Reference Sets



DLCO references

Peds:

- Ayers
- Bucci
- Bucci (obs VA)
- Fallat
- Fallat (obs VA)
- Gaensler (obs VA)
- GLI DLco 2020
- Gutierrez (obs VA)
- Iowa
- JohnsHopkins
- Miller
- Nasr
- Polgar
- Weng
- Zapletal2

Reference Sets
Introduction to GLI

Global Lung Function Initiative

About

The Global Lung Function Initiative (GLI) has collected respiratory function outcomes from researchers and health care professionals from around the world. To date, the GLI Network has produced reference equations for Spirometry and

- European Respiratory Society initiative supported by ATS and other professional organizations.
- Charge: Development and validation of new updated reference equations
  - Spirometry, diffusion of the lungs (DLCO), lung volumes

ERS/ATS technical standard on interpretive strategies for routine lung function tests

Sanja Stanojevic, David A. Kaminsky, Martin Miller, Bruce Thompson, Andrea Aliverti, Igor Barjaktarevic, Brendan G. Cooper, Bruce Culver, Eric Derom, Graham L. Hall, Teal S. Hallstrand, Joerg D. Leuppi, Neil MacIntyre, Meredith McCormack, Margaret Rosenfeld, Erik R. Swenson

Eur Respir J. January 2022

Comparison of Measured Values to a Healthy Population

Global Lung Function Initiative (GLI) reference equations for spirometry (10), diffusing capacity (11) and lung volumes (12) should be used to define the expected range of values in healthy individuals.

Tests used to characterize lung function?

- Standard pulmonary function tests
  - Spirometry, diffusion of the lung (D_{LCO}/T_{LCO}), lung volumes (plethysmography and MBW)
- Respiratory Muscle Strength Testing
- Challenge testing
  - Direct and Indirect
- Exhaled nitric oxide
- Forced oscillatory technique

ATS-ERS Standards/Statements

Standardization of Spirometry 2019 Update

An Official American Thoracic Society and European Respiratory Society Technical Statement

Am J Respir Crit Care Med Vol 200, Iss 8, pp e70–e88, Oct 15, 2019

An Official American Thoracic Society/European Respiratory Society Statement: Pulmonary Function Testing in Preschool Children

Am J Respir Crit Care Med Vol 175. pp 1304–1345, 2007

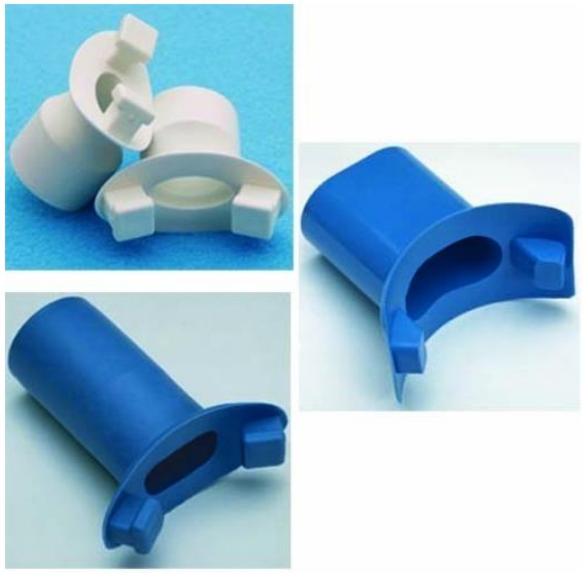
2019 ATS-ERS Spirometry: Indications

- Diagnostic
  - To evaluate symptoms, signs, or abnormal laboratory test results
  - To measure the physiologic effect of disease or disorder
  - To screen individuals at risk of having pulmonary disease
  - To assess preoperative risk
  - To assess prognosis
- Monitoring
  - To assess response to therapeutic intervention
  - To monitor disease progression
  - To monitor patients for exacerbations of disease and recovery from exacerbations
  - To monitor people for adverse effects of exposure to injurious agents
  - To watch for adverse reactions to drugs with known pulmonary toxicity
- Disability/impairment evaluations
  - To assess patients as part of a rehabilitation program
  - To assess risks as part of an insurance evaluation
  - To assess individuals for legal reasons
- Other
  - Research and clinical trials
  - Epidemiological surveys
  - Derivation of reference equations
  - Preemployment and lung health monitoring for at-risk occupations
  - To assess health status before beginning at-risk physical activities

2019 ATS-ERS Standardization of Spirometry,

Spirometers

Spirometry

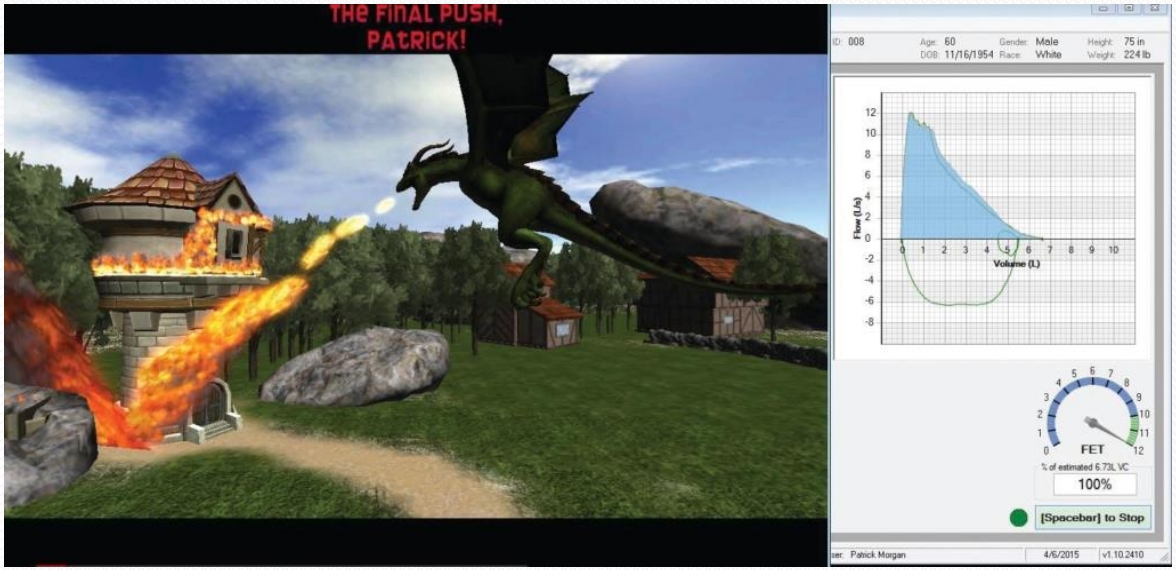


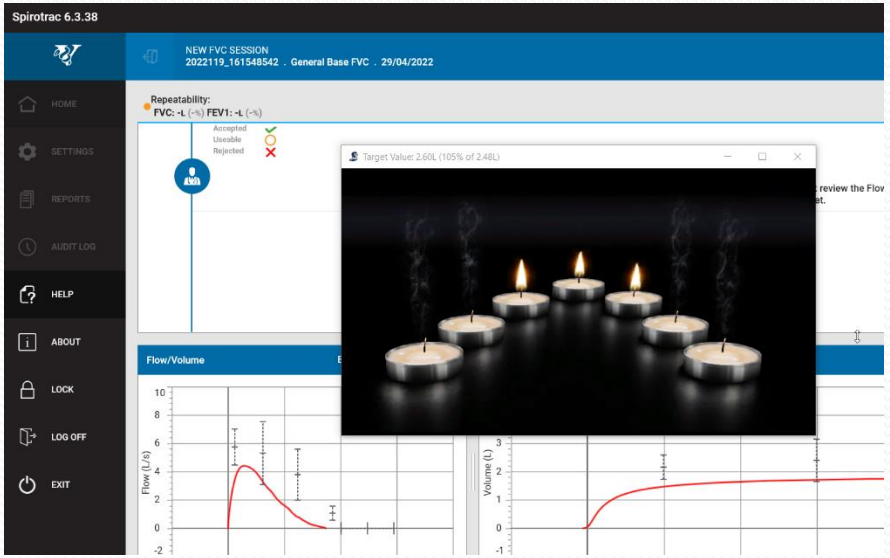
- Device interface
  - Mouthpieces
  - Masks
- Stay consistent throughout the study

2019 ATS-ERS Spirometry Update: Spirometry Technique

1. Well-trained staff are quintessential!!
2. Explain the procedure
    1. Proper mouthpiece placement
    2. Noseclip (FVL)
    3. Maximum inhalation (Phase I)
    4. “Blast” the air out quickly (Phase II)
    5. Complete exhalation (Phase III)
    6. Complete the FVL (Phase IV)
3. Demonstrate procedure

Using Incentive Software

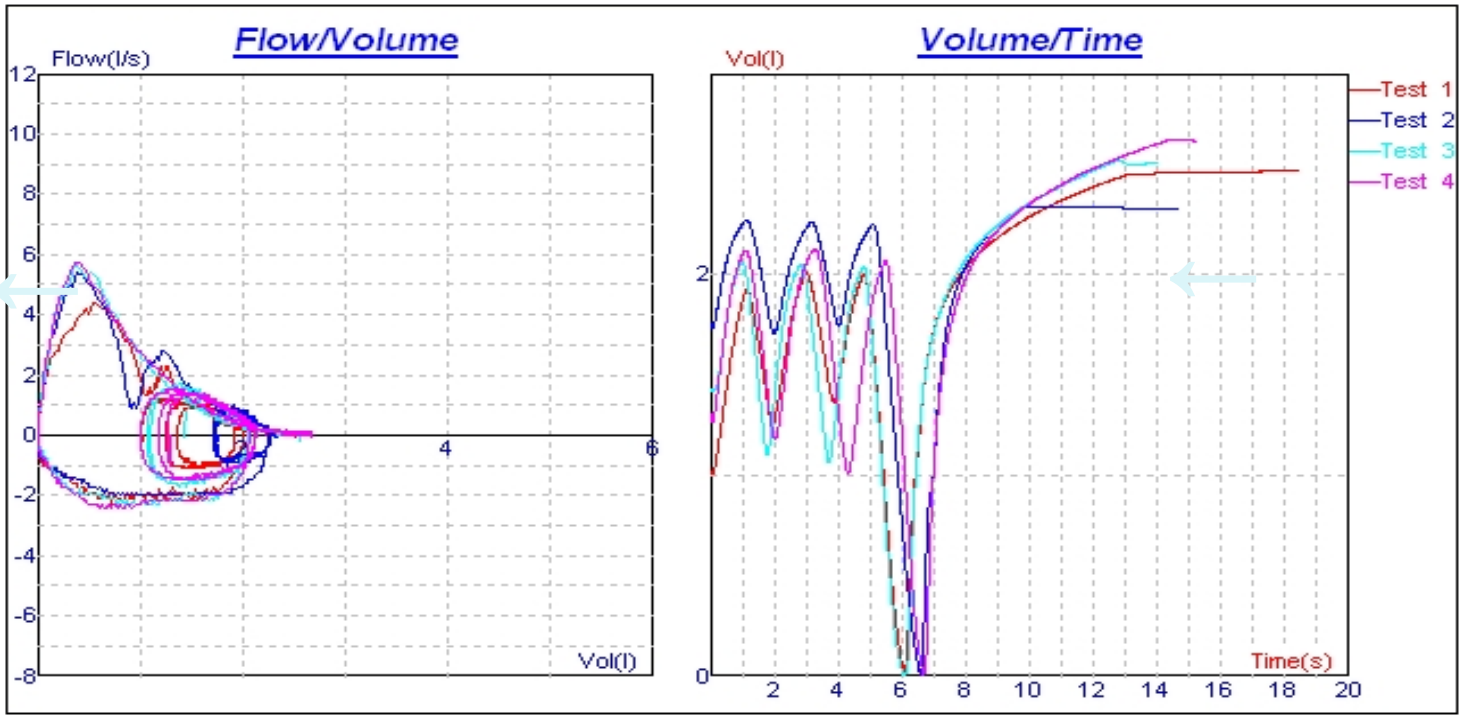




2019 ATS/ERS Acceptability

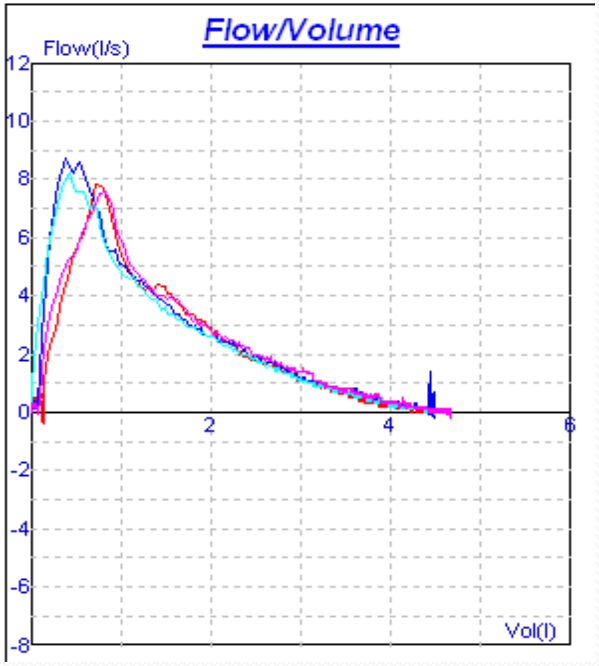
Free from artifacts

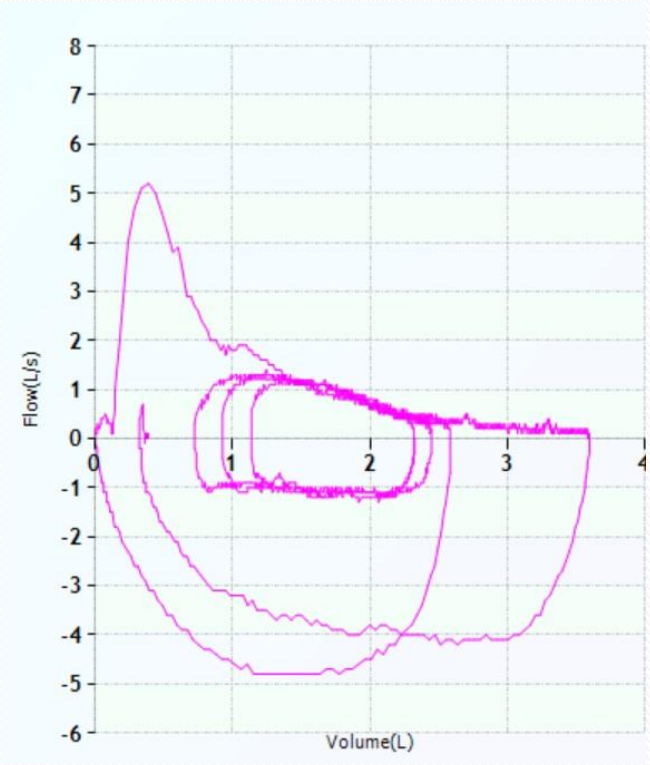
No cough in the first second



2019 ATS/ERS Acceptability

Slow starts or excessive back extrapolated volume (5% of FVC or 100 mls)



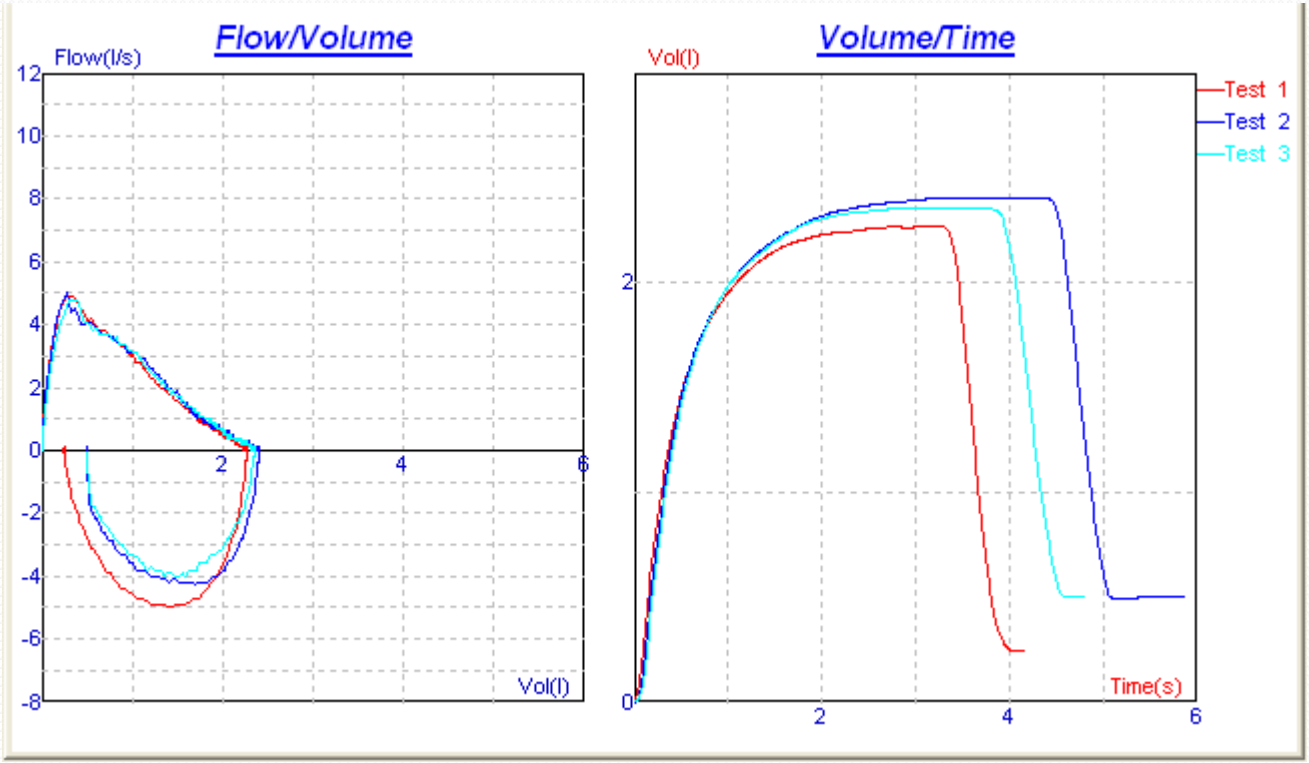


2019 ATS/ERS Acceptability

End of forced expiration (EOFE) - no set time limit

*Less than a 0.025-L change in volume for at least 1 second

*terminate maneuver at 15 seconds



2005 Spirometry TS ≥6 seconds ≥10 y.o. and ≥3 seconds for <10 y.o.

Success in Young Children

Prim Care Respir J 2013; 22(2): 221-229

Primary Care RESPIRATORY JOURNAL
www.thepcrj.org

CLINICAL REVIEW

Spirometry in children

*Kana Ram Jat[1]

- In preschool children nearly 82.6% (214/259) of children aged 3–6 years – Eigen et al
- 75% of children aged 2–5 years - Aurora et al
- 55% (196/355) of children aged 3–5 years Crenesse et al

"were able to perform technically acceptable and reproducible spirometry manoeuvres"

Diffusion of the Lung (DLCO/TLCO)

- Evaluates how well oxygen moves into and out of the lungs (alveolar capillary interface)
  - Carbon monoxide is used as a surrogate for O_2
  - "Gas exchange"

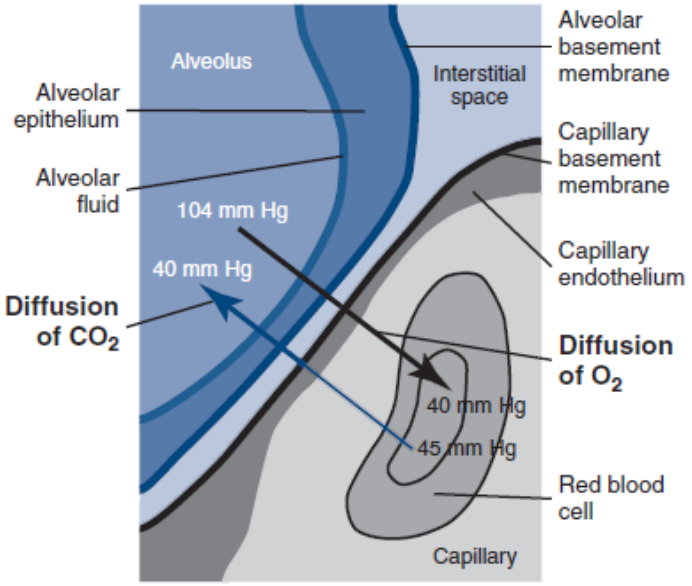


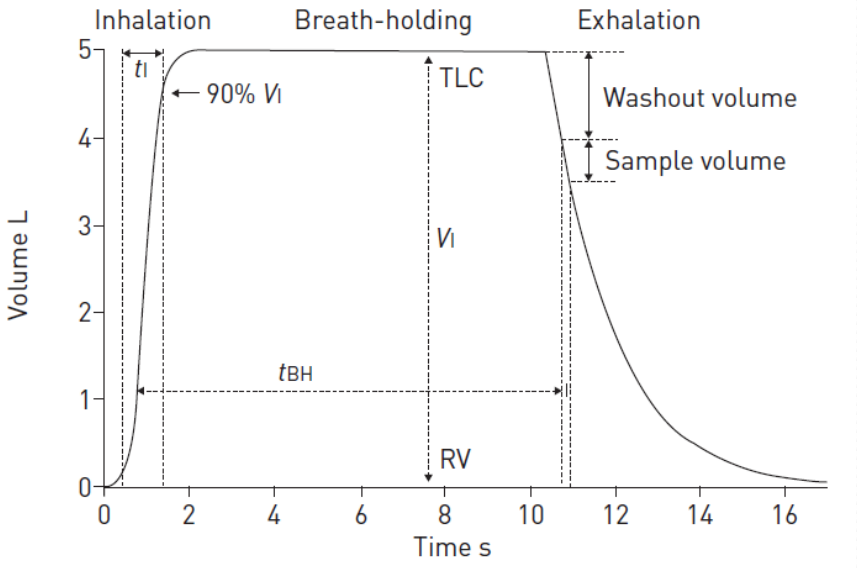
FIGURE 3-1 Diffusing capacity is performed to evaluate the alveolar capillary interface where gas exchange occurs.

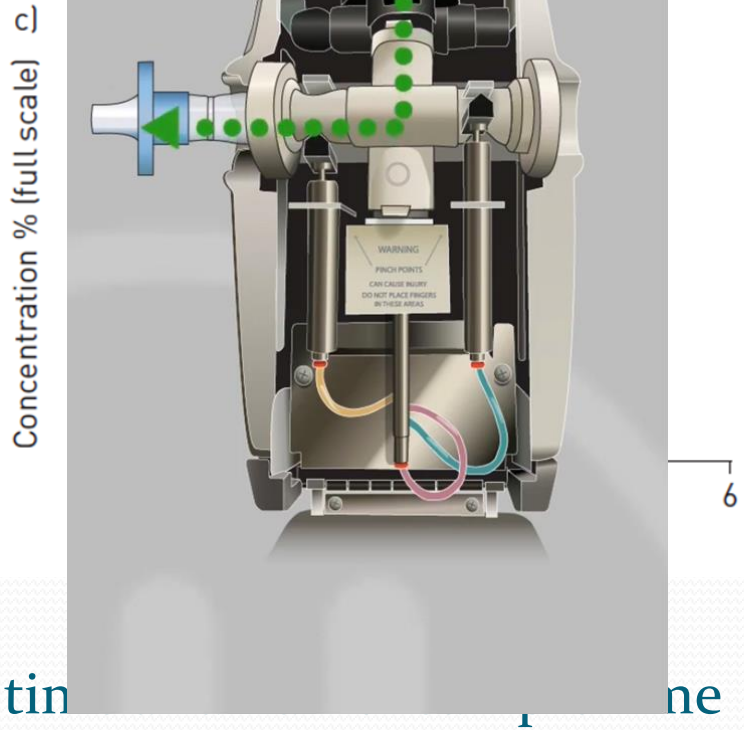
Mottram CD Manual of PFT. 12th Ed 2022

2017 ERS/ATS Technical Standards

Diffusion of the Lung – Breath Hold Time (10s ±2)

Classic Systems





- Jones - Meade - 0.70 of inspiratory tin ne

Lung Volumes: *Know the Technique*

- Gas techniques
  - Helium dilution
  - Nitrogen washout
- Body plethysmography
  - "Gold standard"
- Other methods
- Known to yield different results in certain diseases

Plethysmography

Patience and pretest instructions are essential to a successful test session

Multiple Breath Washout

ERS/ATS CONSENSUS STATEMENT

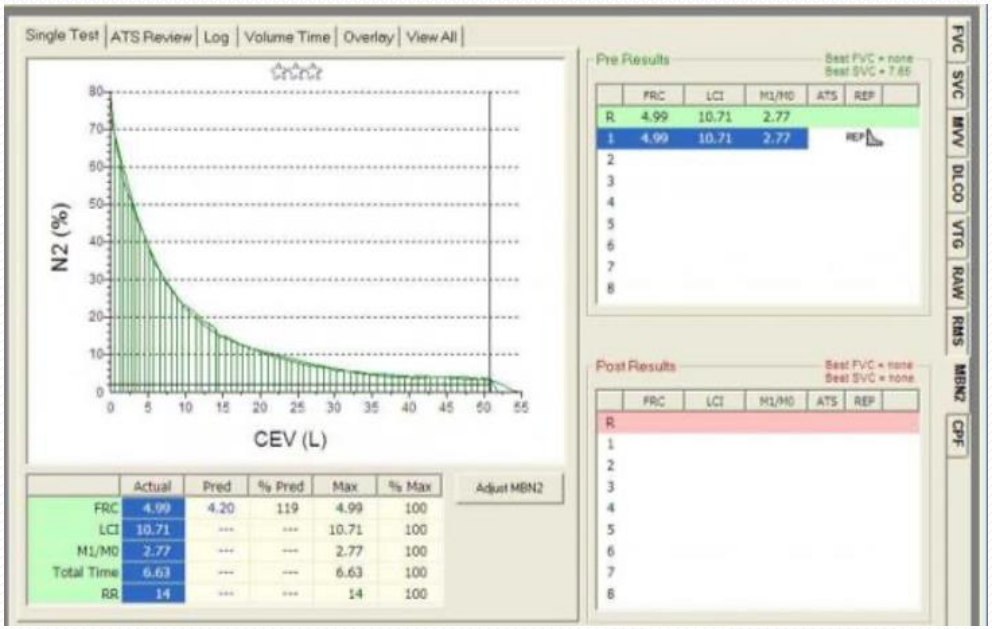
Consensus statement for inert gas washout measurement using multiple- and single-breath tests

Eur Respir J 2013; 41: 507–522

- Nitrogen washout
  - 100% Oxygen
  - Dry gas = dry mouth and cough
- Lung Clearance Index (LCI)

Lung Clearance Index (LCI)

- Commonly measured/followed in subjects with cystic fibrosis
- Cumulative expired volume (CEV), the total sum of gas expired during the washout, divided by functional residual capacity (FRC).
- An LCI $\leq$ 7 is normal with changes in LCI >15% considered to be physiologically relevant



Respiratory Muscle Strength

Measurement Techniques and Clinical Indications

- Guidelines

ATS/ERS Statement on Respiratory Muscle Testing

THIS JOINT STATEMENT OF THE AMERICAN THORACIC SOCIETY (ATS), AND THE EUROPEAN RESPIRATORY SOCIETY (ERS) WAS ADOPTED BY THE ATS BOARD OF DIRECTORS, MARCH 2001 AND BY THE ERS EXECUTIVE COMMITTEE, JUNE 2001

ERS statement on respiratory muscle testing at rest and during exercise

Eur Respir J 2019; 53

Non-invasive voluntary tests of respiratory muscle strength

Respiratory Muscle Strength

Measurement Techniques and Clinical Indications

Voluntary tests of respiratory muscle strength (RMS)

Common RMS indices

- Maximal Inspiratory Pressures (MIP or $P_I max$)
- Maximal Expiratory Pressures (MEP or $P_E max$)

- Maximal nasal inspiratory Pressure (SNIP)
- Peak Cough Flow (PCF)

Clinical Indications

- Assessment of neuromuscular disorders
  - ALS, myasthenia gravis, DMD, etc.
- Evaluation of reduced muscle strength
  - Emphysema, chest wall deformities
- Evaluation of patients with impaired cough and retained secretions
- Monitoring respiratory muscle strength as an adjunct to mechanical ventilator weaning
- Assessment of inspiratory muscle training

Test Methodology

Instrumentation: RMS and other tests

- Small portable electronic devices
  - Used for MIPs and MEPs
  - Nasal sniff pressures using a nasal olive

Test Methodology and Instrumentation: RMS and other tests

- Pressure transducers - integrated into PF testing systems with a data acquisition/processing programs
- Digital calibration is acceptable; however, a check via water manometer should be done regularly
- Pressure range should be ±300 cmH2O and resolution ⩽0.5 cmH2O

2019 ERS Technical Statement

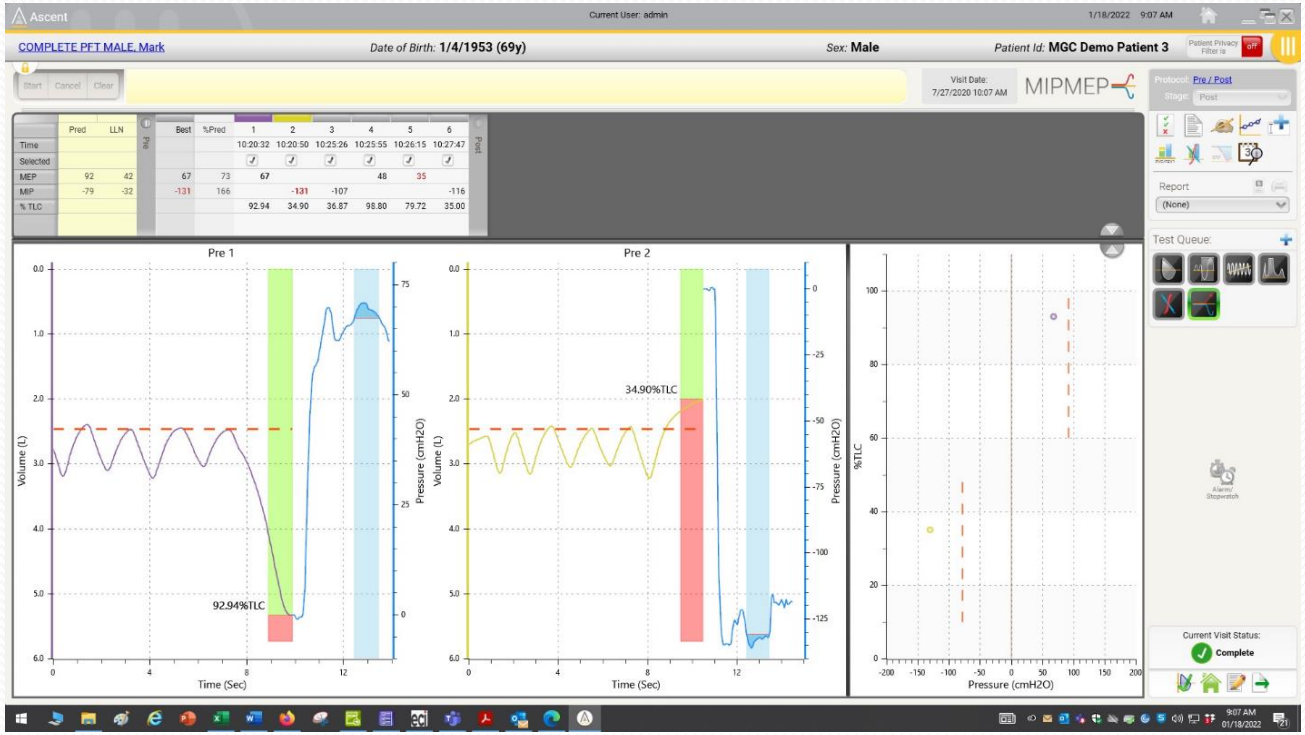
Test Methodology: *MIP's and MEP's*

- During testing, subjects are normally seated.
- Coaching to prevent air leaks around the mouthpiece.
  - Flanged mouthpiece preferred
  - May need to "lip hold"
- Sustain each maneuver for 1-1.5 seconds
- Reliability of the test is good if at least 5 attempts are performed
- Maximum value of three inspiratory maneuvers or three expiratory maneuvers that vary by less than 10% are recorded.

Adapted from 2019 ERS TS RMS

Test Methodology: RMS

- MIP/$P_I$max - Performed near RV
- MEP/$P_E$max - Performed near TLC



Respiration

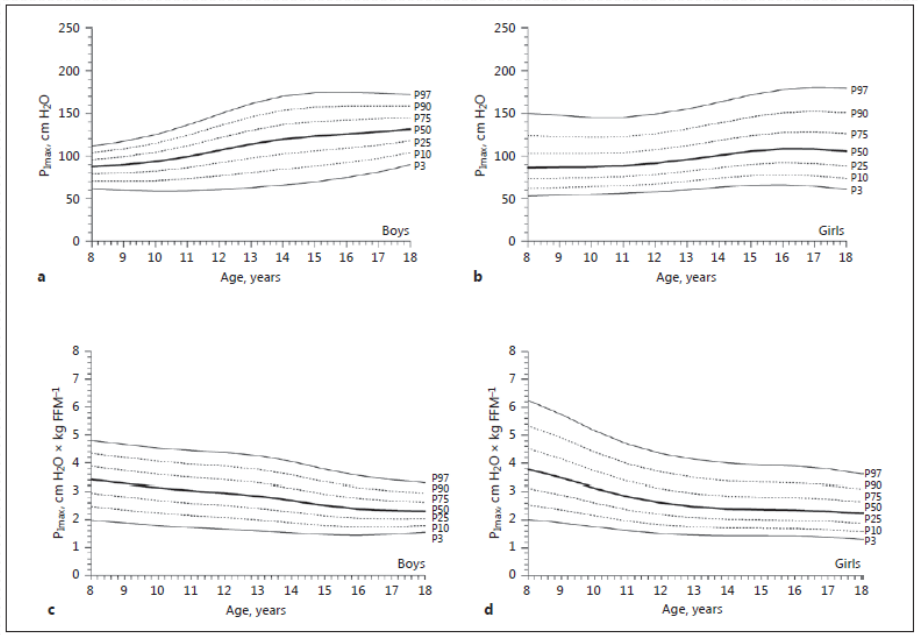
Respiration
DOI: 10.1159/000485464

Received: June 26, 2017
Accepted after revision: November 17, 2017
Published online: January 17, 2018

Reference Values for Respiratory Muscle Strength in Children and Adolescents

Erik Hulzebos[a] Tim Takken[a] Elja A. Reijneveld[b] Mark M.G. Mulder[a]
Bart C. Bongers[c, d]

- 251 children, 8-19 y.o.;117 boys and 134 girls).
- The reference values are presented as reference centiles which were developed using the same lambda, mu, sigma method as used by the ERS Global Lung Initiative taskforce.

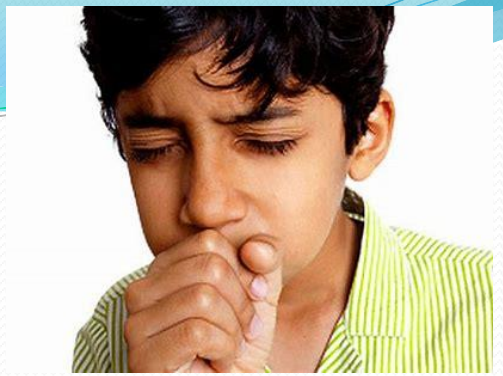


Maximal Inspiratory Sniff Pressures (SNIP)

- SNIP is often recorded in the seated position.
- To avoid air leaks, one nostril is completely occluded by the pressure sensor (plug/olive), while the other nostril is kept open.
  - Often both nostrils are tested with 1 to 3 SNIP runs and the nostril conducive to the higher values is used for further testing.
- Test is performed at FRC
- The subject is instructed to sniff quickly and deeply
  - < 500ms
- Up to 10 trials maybe required.
- Record the highest No repeatability criteria cited.

Eur Respir J 2019; 53

Peak Cough Flow (PCF)



- Performed with subjects seated.
- An oronasal mask/mouthpiece is connected to a pneumotachograph or peak flow meter.
- Subjects are instructed to perform a maximal cough after complete inhalation.
- Perform 3–6 maneuvers
- <5% variability
- Maximum PCF (L/min) should be reported.
- PCF <270 L/min is associated with higher likelihood of pulmonary complications in neuromuscular disorders

Eur Respir J 2019; 53


CHALLENGES
AHEAD

Bronchoprovocation Challenges

Direct stimulus

Indirect stimulus

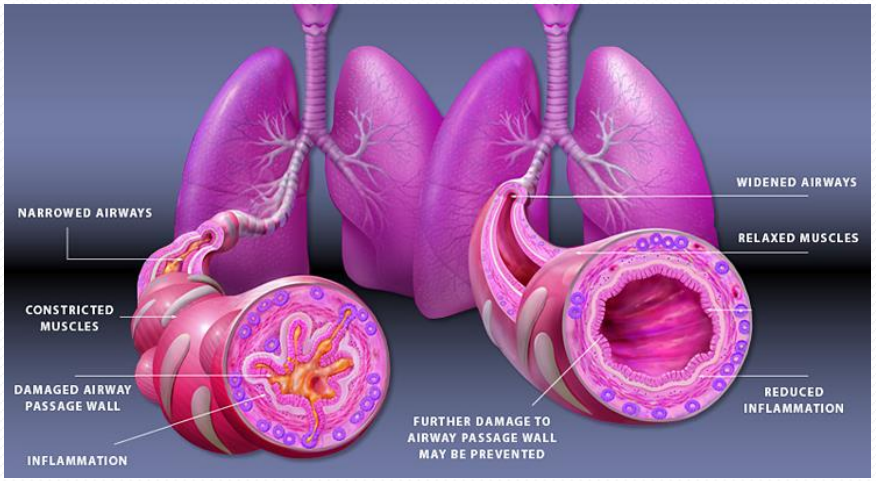
Effector cells

- Airway smooth muscle cells
- Bronchial endothelial cells
- Mucus producing cells

Intermediary cells

- Inflammatory cells
- Neuronal cells

Airflow limitation



Bronchoprovocation Challenges *- Direct vs Indirect*

Direct Stimuli

- Methacholine
- Histamine
- Prostaglandin
- Leukotrienes

Indirect Stimuli

- Adenosine (AMP)
- Metabisulfite / SO_2
- Exercise
- Hyper/hypotonic aerosol
- Isocapnic hyperventilation
- Mannitol

Most common inhalation challenges

Bronchoprovocation - Guidelines

ERS technical standard on bronchial challenge testing: general considerations and performance of methacholine challenge tests

Eur Respir J 2017; 49

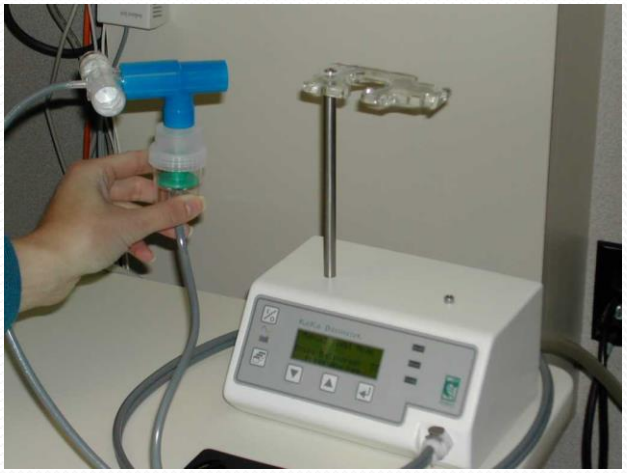
ERS technical standard on bronchial challenge testing: pathophysiology and methodology of indirect airway challenge testing

Eur Respir J 2018; 52

Allan L. Coates[1], Jack Wanger[2], Donald W. Cockcroft[3], Bruce H. Culver[4] and the Bronchoprovocation Testing Task Force: Kai-Håkon Carlsen[5], Zuzana Diamant[6,7], Gail Gauvreau[8], Graham L. Hall[9], Teal S. Hallstrand[4], Ildiko Horvath[10], Frans H.C. de Jongh[11], Guy Joos[12], David A. Kaminsky[13], Beth L. Laube[14], Joerg D. Leuppi[15] and Peter J. Sterk[16]

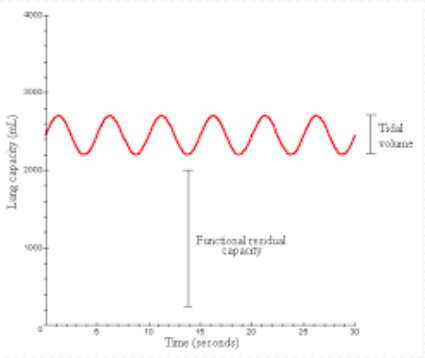
Methacholine Test Methodology/*Protocols*

- 1999 Technical Standard describes two protocols
  - Five-breath dosimeter protocol
  - Two-minute tidal breathing dosing protocol
    - One-minute tidal breathing protocol



Why Tidal Breathing Method?

- More recent data using only methacholine suggests differences, especially in those with mild responsiveness.
- Data suggests those with mild responsiveness using TB method will be considered normal using 5-breath method.
  - Difference due to broncho-protective effect of maximal inspiratory maneuver.



P_{D20} versus P_{C20}

Methacholine Guideline Recommendations[1] and the **AEROECLIPSE® II BREATH ACTUATED NEBULIZER**

1999 Guidelines[2]

PC_{20} – The provocative concentration at which the patient's FEV_1 drops 20% from their baseline measure.

2017 Guidelines[1]

PD_{20} – The provocative dose delivered that results in a 20% drop in the patient's FEV_1 from their baseline measure.

Why the Change?

- Nebulizers have evolved to offer more reproducible delivery profiles, without the need for calibration
- Nebulizer efficiency is much greater than in 1999, requiring less time to deliver the same dose
- Concentration prescribed a specific delivery profile, not common across devices making substitution of nebulizers difficult
- Dose is easy to calculate and allows use of different devices or protocols with the same end result

As a high efficiency nebulizer, the AEROECLIPSE® II BAN should be used with a shorter nebulization time or lower initial concentration or both.[1]

Published Values for the AEROECLIPSE® II BAN[3]

- Rate of output = 2.70 ± 0.22 mg/min (@ 16 mg/mL)
- Respirable Fraction = 76% < 5 µg

Calculation of Delivered Dose for Methacholine

For 20 seconds of tidal breathing using the AEROECLIPSE® II BAN, the delivered dose would be:

2.70 mg/min	x	0.76	x	20/60 secs	=	0.68 mg (680 µg)
Published delivery rate for 16 mg/mL concentration	x	% of particles sized < 5 µm	x	Takes the number from one minute to 20 seconds	=	Total dose delivered in 20 seconds

Example Calculation of Delivered Dose

To determine the dose for other dilutions, the delivered dose would be:

[Conc(mg/mL)/16 mg/mL]	x	680 µg
New dilution concentration divided by the known 16 mg/mL	x	Known dose delivered in 20 seconds

This is delivered dose in 20 seconds. If conducting the test for 1 minute, simply multiply by 3 to arrive at the delivered dose.

Calculate Your Delivered Dose

$$\frac{\text{Your Drug Concentration Here}}{16\ \text{mg/mL}} \times 680\ \mu\text{g} = \text{Delivered dose in 20 seconds}$$

REFERENCES

1. Coates AL, Wanger J, Cockcroft DW, *et al.* ERS technical standard on bronchial challenge testing: general considerations and performance of methacholine challenge tests. Eur Respir J 2017; 49:1601526.
2. Crapo RO, Casaburi R, Coates AL, *et al.* Guidelines for methacholine and exercise challenge testing – 1999. Am J Respir Crit Care Med 2000; 161:309–329.
3. Coates AL, Leung K, Dell SD. Developing alternative delivery systems for methacholine challenge tests. J Aerosol Med Pulmon Drug Deliv 2014; 27:66–70.

Methacholine Test Performance

- Baseline acceptable and repeatable spirometry
  - Calculate a -20% decline for a positive test
    - Multiple baseline FEV1 value by 0.80
    - 0 .90 (target recovery)
- Spirometry at 30 and 90 seconds at each dose
  - Patient doesn't have to empty completely.

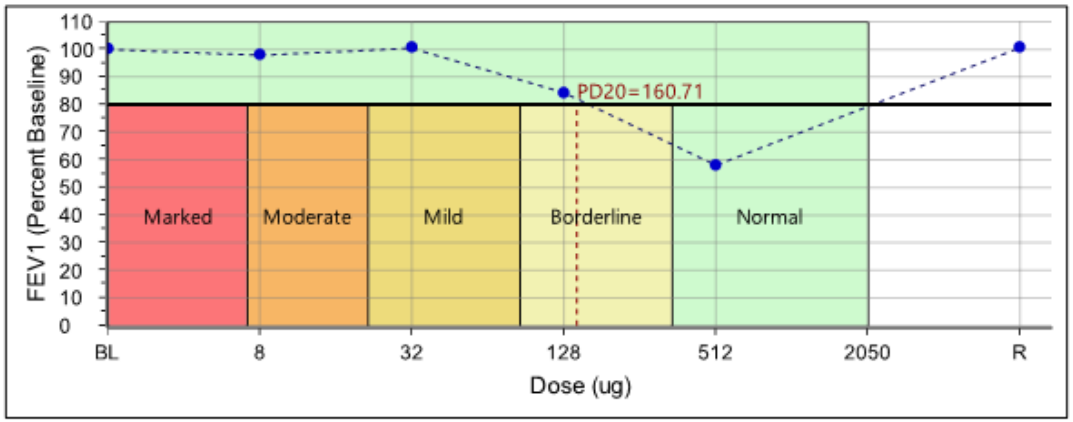
Methacholine Test Procedure

Pulmonary Function Report

Morgan Scientific, Inc.
151 Essex Street
Haverhill, MA 01832 Phone: (978) 521-4440

Patient Information

Name: Philip K. Carcas **ID: 134732** **Test date/time: 7/19/2018 9:47:40 AM**
Height at test: 75 in
Weight at test: 207.9 lb Sex: M Birthdate: 12/20/1960 Age at test: 57
BMI at test: 26.1 Smoking history (pk-yrs): N/A Ethnic group: C
Physician: Colin Chapman, M.D. Estimated Lung Age: N/A Technician: Patrick Morgan
ICD-10: (J45.30) Mild persistent asthma, uncomplicated Referring Physician:
Predicted set



Challenge Grade: *PD20 of 160.71 indicates borderline airway hyper-responsiveness*

Stage	Dosage	FVC	% BL	FEV1	% BL	Level Notes
Baseline		6.99		5.10		
Diluent		---	---	---	---	*0*
Level 1	8	6.96	---	4.99	-2	*1 No response*
Level 2	32	6.94	-1	5.12	---	*2 No response*
Level 3	128	5.92	-15	4.30	-16	*3 Subject feeling tight*
Level 4	512	5.11	-27	2.96	-42	*4 Significant response*
Level 5	2050	---	---	---	---	*5*
Recovery	**Albuterol**	7.06	1	5.13	1	

Mannitol Challenge Test

- Indirect Inhalation Challenge Test
- Aridol Kit
  - Aridol capsules (mannitol)
  - Dry powder inhaler device

Mannitol Challenge Test

Inhaler Technique

- Prepare for Inhalation: Tilt the inhaler so that the mouthpiece faces slightly downward at a 45º angle
  - Allows capsule to fall into spinning chamber
- Inhale: Controlled and deep inhalation, then hold their breath for five seconds

Mannitol Challenge Test

Inhaler Technique

- Inhalation of mannitol can cause coughing
  - Dry power sugar
- Challenge test time is critical and prolonged intervals between doses may affect results

Mannitol Challenge Test
Procedure

- Pre-challenge spirometry
  - FEV_1 at least 60% of predicted
- Administer 0 mg Aridol using Osmohaler
- At 60 seconds perform spirometry

Mannitol Challenge Test

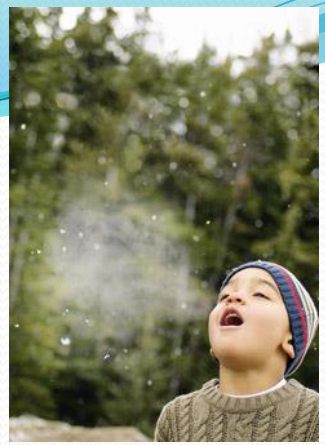
Procedure

- Perform 2 acceptable FVC maneuvers *(according to ATS/ERS Guidelines)*. Use the higher of these two values to calculate the change in FEV_1
- If Baseline FEV_1 is >10% lower than pre-challenge FEV_1 - stop challenge
- Calculate target FEV_1
  - highest Baseline value * 0.85
- Decline of 15% is considered positive

Methacholine to Mannitol

Table 8.1 Comparisons of the sensitivity and specificity (calculated relative to exercise challenge) for the Aridol test and methacholine in Study DPM-A-305			
Population	**Treatment**	**Sensitivity % (95% CI)**	**Specificity % (95% CI)**
Overall Population (n=419)			
	Aridol	58 (50, 65)	63 (57, 69)
	Methacholine	53 (46, 51)	68 (62, 73)
	Difference	5 (-4, 13)	-5 (-12, 3)
Age 6-11 years old (n=36)			
	Aridol	67 (47, 87)	47 (21, 72)
	Methacholine	71 (52, 91)	33 (9, 57)
	Difference	-5 (-29, 20)	17 (-29, 62)
Age 12-17 years old (n=70)			
	Aridol	55 (37, 72)	62 (46, 77)
	Methacholine	65 (48, 81)	64 (49, 79)
	Difference	-10 (32, 13)	-3 (-24, 19)

Exhaled Breath

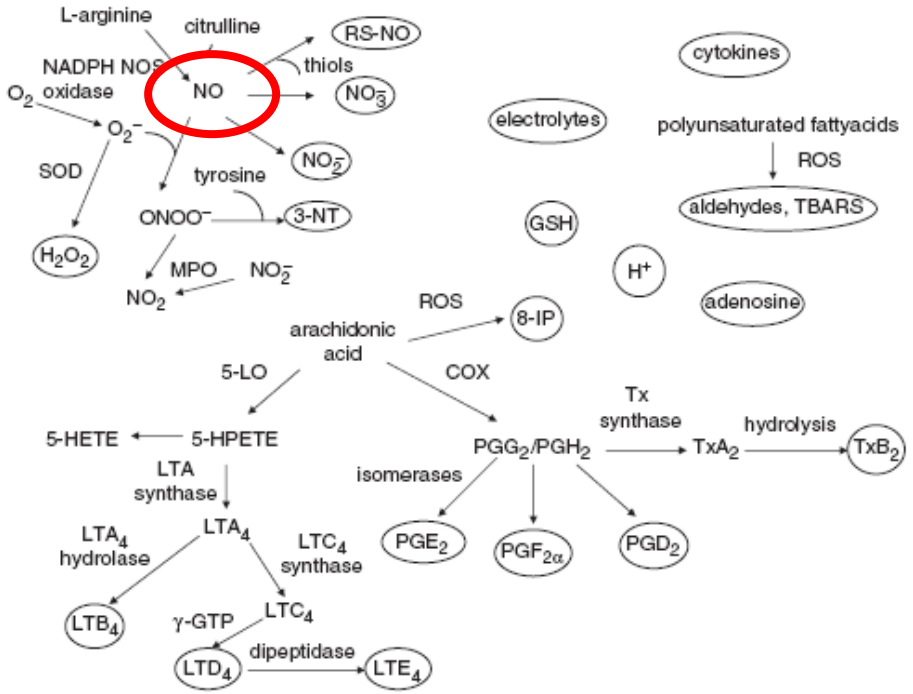


- Numerous biomarkers of inflammation that have been detected in exhaled breath

Analysis of exhaled breath condensate in respiratory medicine: methodological aspects and potential clinical applications

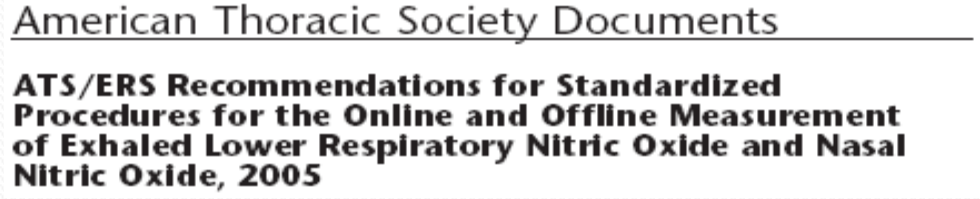
Paolo Montuschi

Therapeutic Advances in Resp Disease 2007 1;5



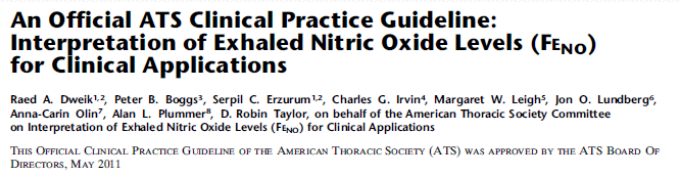
Background and Guidelines

- 1991 – Exhaled nitric oxide first measured
- 1993 – eNO found elevated in asthmatics
- Guidelines
  - 2005 ATS/ERS (www.thoracic.org)


American Thoracic Society Documents

ATS/ERS Recommendations for Standardized Procedures for the Online and Offline Measurement of Exhaled Lower Respiratory Nitric Oxide and Nasal Nitric Oxide, 2005

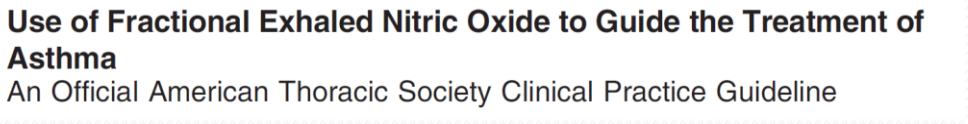
  - 2011 ATS Interpretation Guideline


An Official ATS Clinical Practice Guideline: Interpretation of Exhaled Nitric Oxide Levels (FE_{NO}) for Clinical Applications

Raed A. Dweik[1,2], Peter B. Boggs[3], Serpil C. Erzurum[1,2], Charles G. Irvin[4], Margaret W. Leigh[5], Jon O. Lundberg[6], Anna-Carin Olin[7], Alan L. Plummer[8], D. Robin Taylor, on behalf of the American Thoracic Society Committee on Interpretation of Exhaled Nitric Oxide Levels (FE_{NO}) for Clinical Applications

This Official Clinical Practice Guideline of the American Thoracic Society (ATS) was approved by the ATS Board Of Directors, May 2011

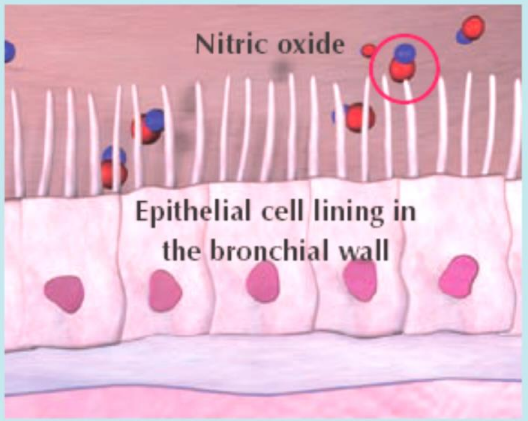
  - 2021 ATS F_{ENO} CPG


Use of Fractional Exhaled Nitric Oxide to Guide the Treatment of Asthma

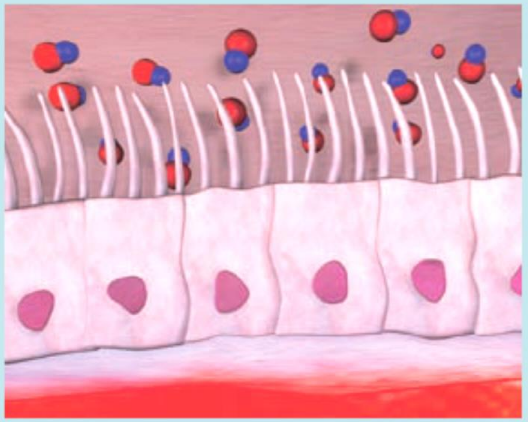
An Official American Thoracic Society Clinical Practice Guideline

Exhaled Nitric Oxide

- eNO = FE_{NO}*
- eNO is an index of eosinophilic (allergic) airway inflammation.
- eNO is *not* increased with bronchospasm.



Normal epithelial cells. Minimal release of NO.



Activated epithelial cells during inflammation demonstrate increased production of NO.

* The abbreviation for fraction of exhaled nitric oxide at a flow of 50mL/sec

Exhaled Nitric Oxide - Indications

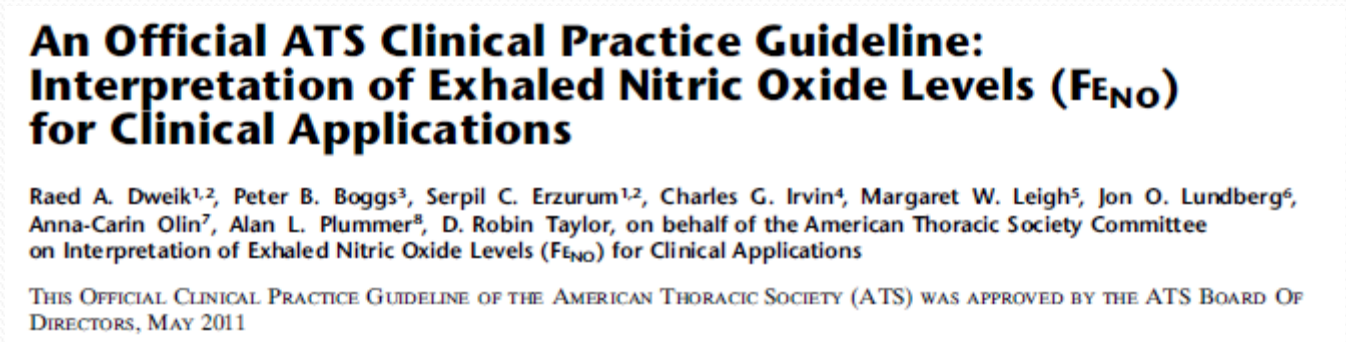
- Establish the correct diagnosis of asthma in corticosteroid-naïve patients
- Differentiate COPD from asthma
- Predict a favorable response to corticosteroids
- Useful in the titration of anti-inflammatory medication in patients with asthma, and in maintenance of asthma control
- Predictive of impending asthma exacerbation
- Monitor asthma medication adherence

The Use of Fraction of Exhaled Nitric Oxide in Pulmonary Practice*

Kaiser G. Lim, MD, FCCP; and Carl Mottram, RRT, RPFT

Invited Article "Topics in Practice Management"
CHEST / 133 / 5 / MAY, 2008

ATS CPG: Interpretation



An Official ATS Clinical Practice Guideline: Interpretation of Exhaled Nitric Oxide Levels (FE_{NO}) for Clinical Applications

Raed A. Dweik[1,2], Peter B. Boggs[3], Serpil C. Erzurum[1,2], Charles G. Irvin[4], Margaret W. Leigh[5], Jon O. Lundberg[6], Anna-Carin Olin[7], Alan L. Plummer[8], D. Robin Taylor, on behalf of the American Thoracic Society Committee on Interpretation of Exhaled Nitric Oxide Levels (FE_{NO}) for Clinical Applications

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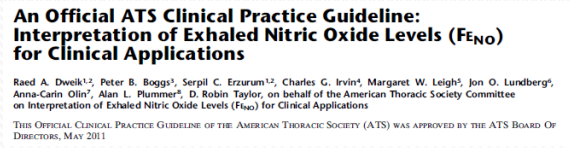
Am J Respir Crit Care Med Vol 184. pp 602–615, 2011

- Recommend the use of FENO in the diagnosis of eosinophilic airway inflammation (strong recommendation)

ATS Recommendations

- Recommend accounting for age as a factor affecting FENO in children younger than 12 years of age (strong recommendation)
- Recommend that FENO greater than 50 ppb (35 ppb in children) be used to indicate that eosinophilic inflammation and, in symptomatic patients, responsiveness to corticosteroids are likely (strong recommendation)
- Recommend that FENO values between 25 ppb and 50 ppb (20–35 ppb in children) should be interpreted cautiously and with reference to the clinical context. (strong recommendation)



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2021 ATS F_{ENO} Clinical Practice Guideline (CPG)

- Only had one question
- To provide evidence-based clinical guidance on whether FENO testing is indicated to optimize asthma treatment in patients with asthma in whom treatment is being considered.

- Conclusion: In patients with asthma in whom treatment is being considered, we suggest that FENO is beneficial and should be used in addition to usual care

2021 ATS F_ENO CPG
Am J Respir Crit Care Med Vol 204, Iss 10, pp e97–e109, Nov 15, 2021

Exhale Nitric Oxide: Pre-test Instructions

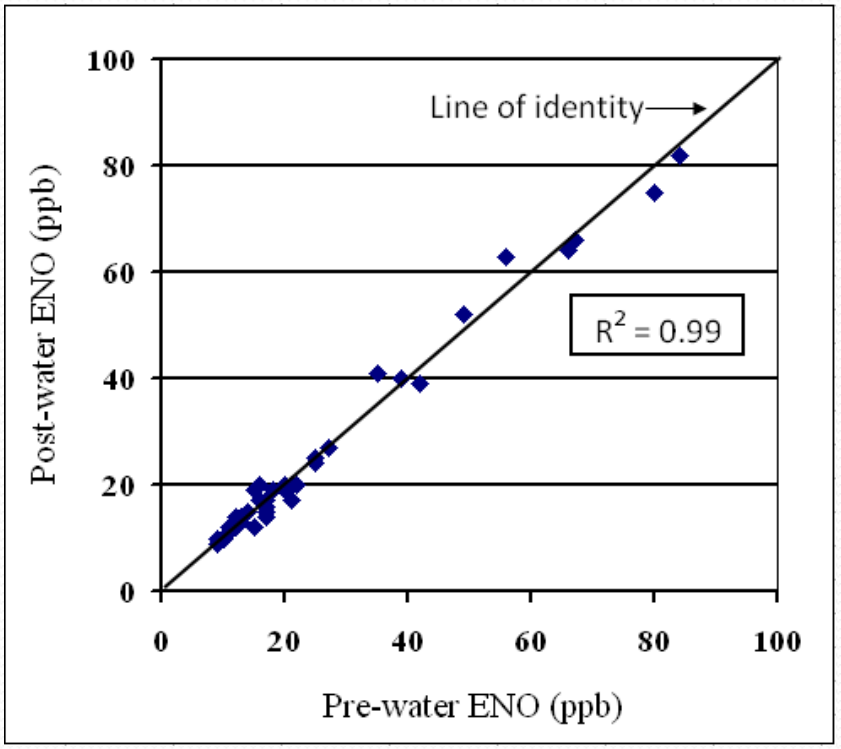
- Avoid meals, drinking, smoking, exercise for 1 hour prior to testing
- No spirometry or BD in prior 30 min
- Determine smoking status
  - Any cigarettes in last week?
  - Consider exhaled CO confirmation
- Ask about recent viral URIs
- Determine asthma controller use
  - Ask ICS, Singulair, & prednisone last 2 weeks

American Thoracic Society Documents

ATS/ERS Recommendations for Standardized Procedures for the Online and Offline Measurement of Exhaled Lower Respiratory Nitric Oxide and Nasal Nitric Oxide, 2005

Exhale Nitric Oxide: Pre-test Instructions

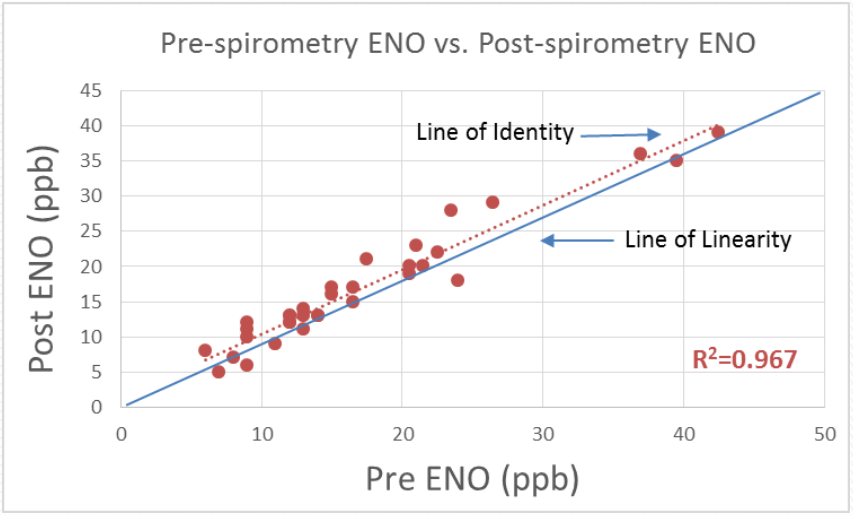
- Problem: Patients showing up for test and having consumed water from a drinking fountain.
- Study: 40 patients
  - Control test
  - 12 oz of water
  - 10-minute post water consumption test
- Statistical comparison

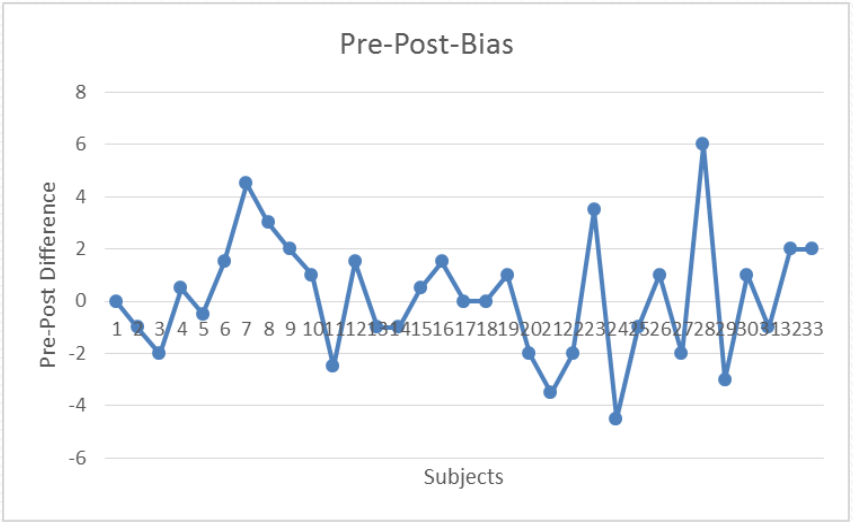


Mottram CD, Hynes KM, et. al. Resp Care Nov 2010 Vol 55 N11 pg 1545

Exhale Nitric Oxide: Pre-test Instructions

- 32 patients studied
- The subjects performed an ENO according to standard laboratory procedures before and 15 minutes after spirometry.





Exhaled Nitric Oxide Before and After Spirometry

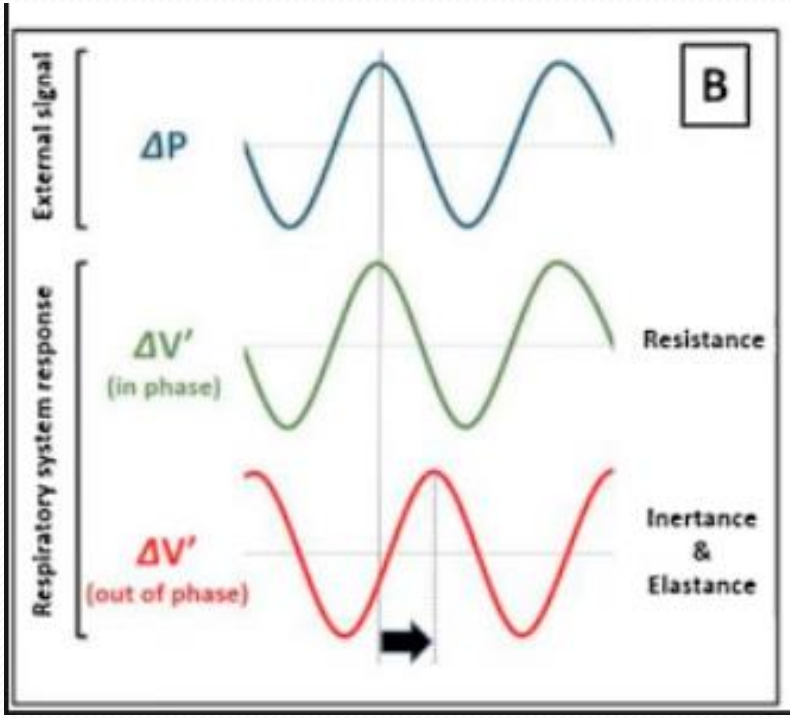
Carl D Mottram, Rosemary Dicke, Katrina M Hynes and Paul D Scanlon

Respiratory Care October 2018, 63 (Suppl 10) 3020139;

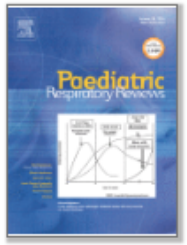
Exhaled Nitric Oxide: Procedure

- Constant flow of 50mL/sec
- No repeatability criteria

Forced Oscillatory Resistance



Paediatric Respiratory Reviews
Volume 18, March 2016, Pages 46-51



Clinical usefulness

The Forced Oscillation Technique in Paediatric Respiratory Practice

Eleni Skylogianni [1] ✉, Konstantinos Douros [2] ✉, Michael B. Anthracopoulos [1] ✉, Sotirios Fouzas [1] ✉

Equation of motion

Newton's Law (third law of motion)
For every action there is an equal and opposite reaction.

$$F_{app} = F_{opp}$$

$$F_{opp} = F_{el} + F_{res} + F_{in}$$

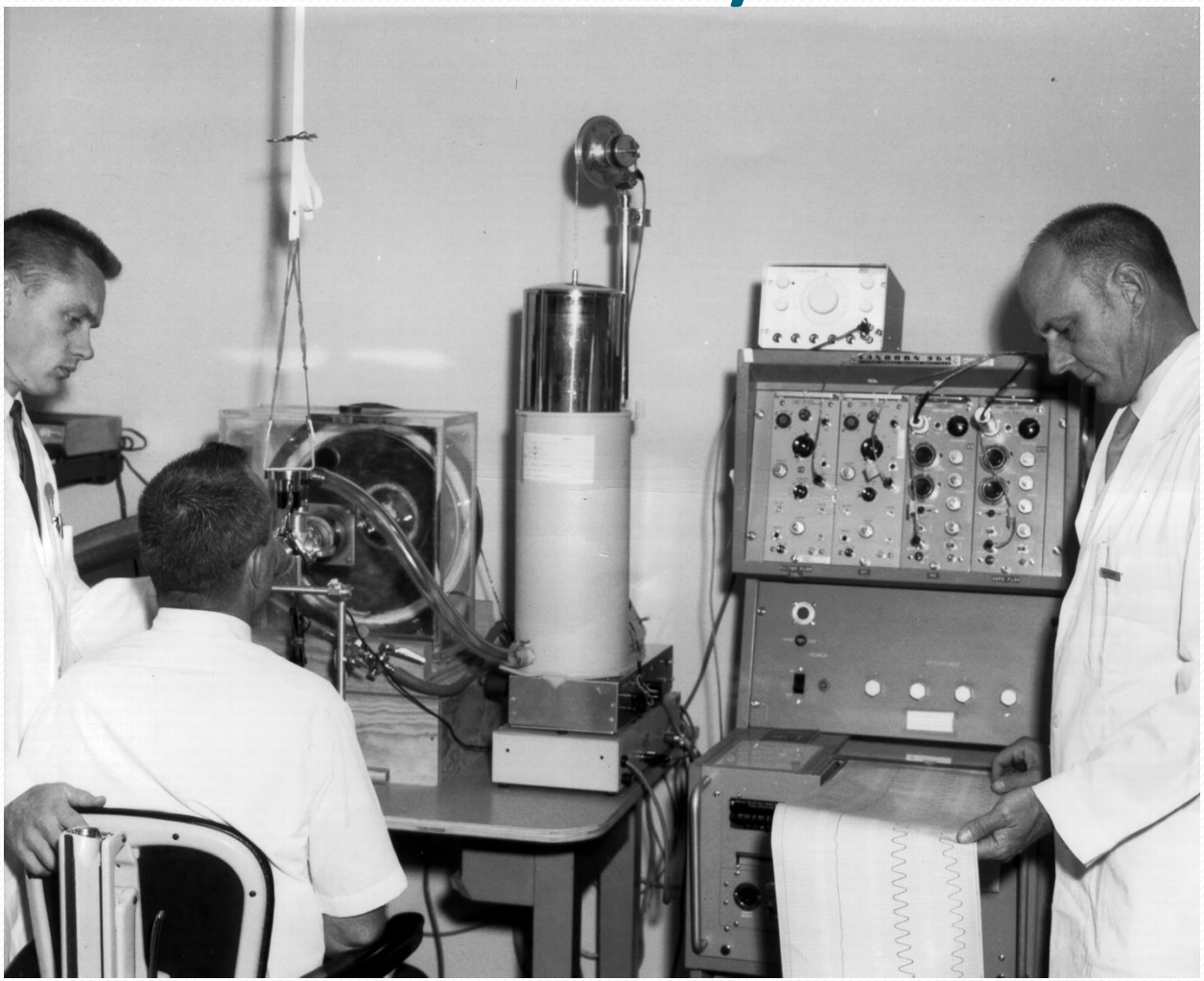
Elastance (E)
Resistance (R)
Inertance (I)

History

Mayo Clinic

Dr. Hyatt's lab

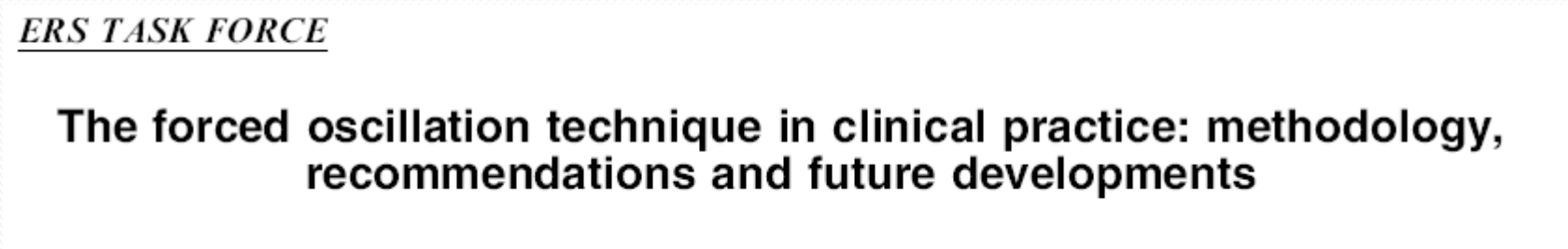
circa. 1960's



First Publication: DuBois AB, Brody AW, Lewis DH, Burgess BF. Oscillation mechanics of lungs and chest in man. J Appl Physiol 1956; 8:587–594.

Forced Oscillation Technique

- Guidelines and Statements

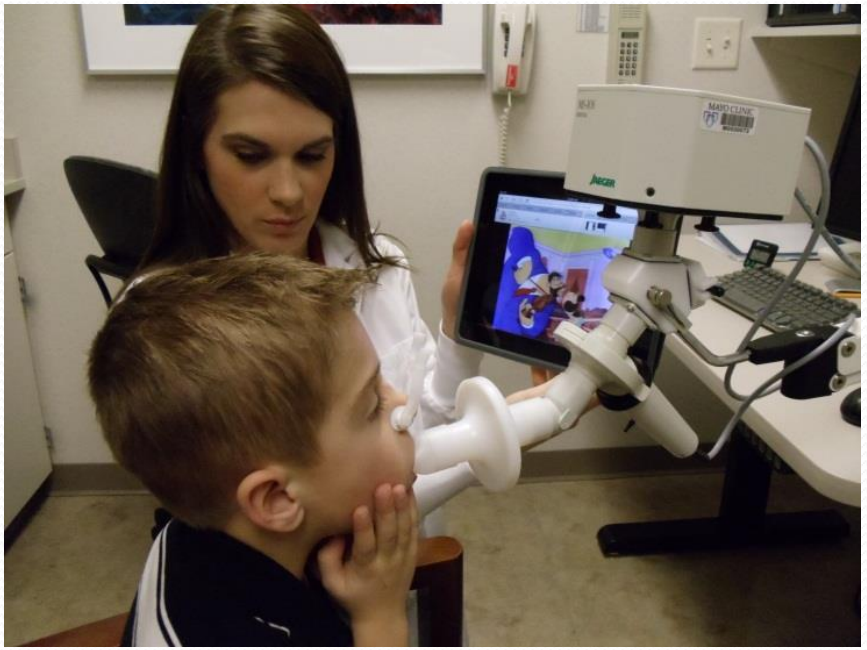


  - European Resp J. 2003 (22) 1026-1041

- ATS/ERS Working Party
  - Gaultier C, Fletcher ME, Beardsmore C, England S, Motoyama E. Respiratory function measurements in infants :measurement conditions. Eur Respir J 1995; 8: 1057–1066.

Forced Oscillation Technique

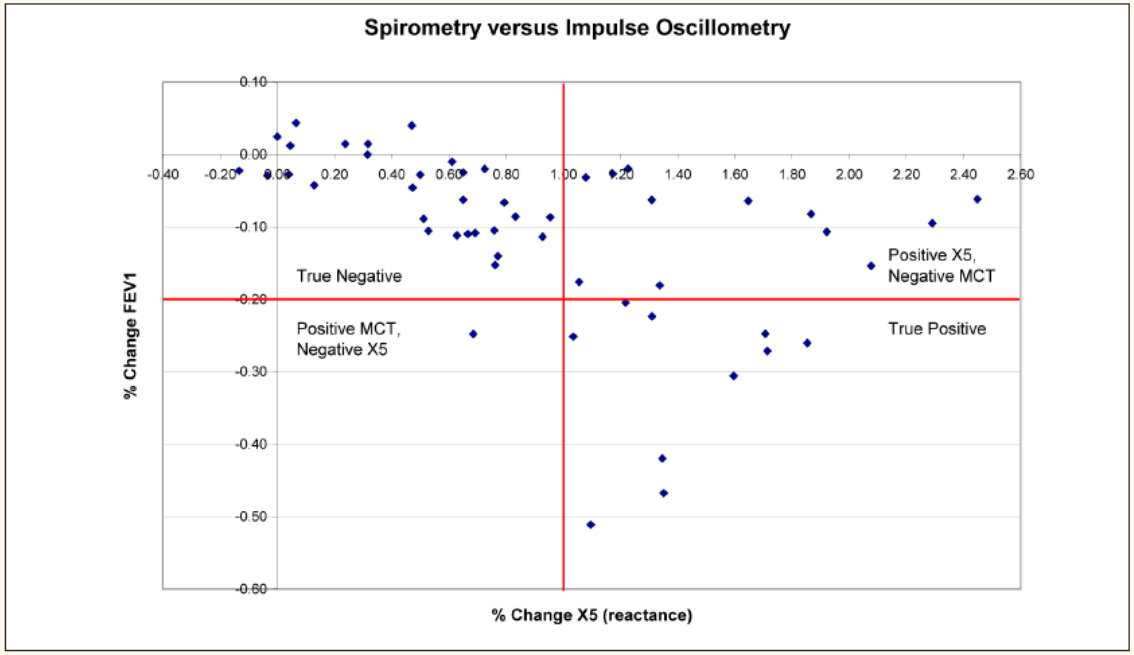
- Subject preparation
  - Performed in the sitting position
  - Head in a neutral or slightly extended position. Flexion of the head should be avoided
  - The subject (or technician) firmly supports the cheeks and the floor of the mouth using both hands
  - Noseclips are required
  - Quiet breathing for 20-30 seconds



Spirometry vs Oscillometry

- 51 subjects
  - FOT performed prior to spirometry

Figure 1



McDonald (Hynes) K, Mottram CD, Kettler B, Renner H, Johnson S, Scanlon PD. Comparison of Two Methods for Monitoring Airway Responsiveness Before and After the Administration of Methacholine. Respiratory Care Vol. 52 No. 11 pg 1617, November 2007

Forced Oscillations: Interpretation

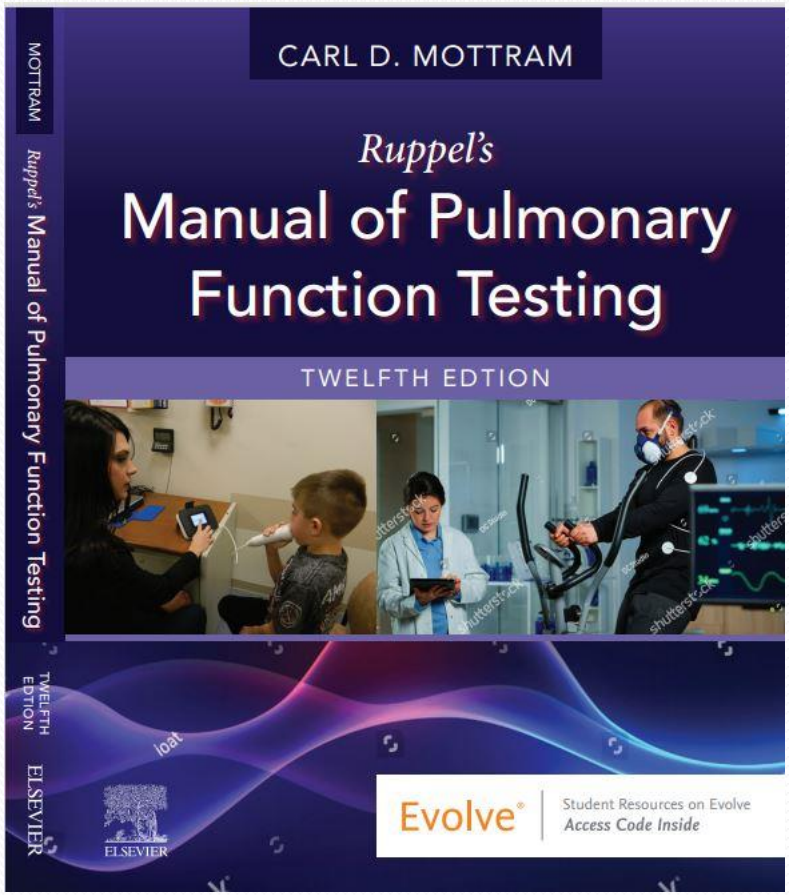
- **Resistance (R5, R20), reactance (X), impedance (Z) are not spirometry!**

$$Rrs \neq FEV_1$$

Summary

- The operator skill (training and competency), patience, and friendly demeanor are essential
- Provide a safe and kid-oriented testing environment
- Use GLI reference sets and LLN when available
- Choosing the test parameter that will address your question(s) is crucial to the outcome and know the technical standards for that test
- Children can successfully perform a variety of pulmonary function tests!!

Questions?


CARL D. MOTTRAM
Ruppel's
Manual of Pulmonary Function Testing
TWELFTH EDTION
Evolve
Student Resources on Evolve
Access Code Inside
ELSEVIER