

2017 OSHA Conference
Considering pulmonary defenses and function
in dysphagia assessment

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Speaker Disclosure

- Financial
 - Employed PSU, OHSU
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 - None

Learner Outcomes

- Describe pulmonary defense mechanisms
- Interpret results of spirometry and other measures of pulmonary function
- Understand how impairments of pulmonary defense mechanisms can contribute to risk for pneumonia

Why consider pulmonary function and defenses?

An important objective in assessment of swallowing is to estimate the individuals' risk for developing aspiration pneumonia

Dysphagia 13:69-81 (1998)



Predictors of Aspiration Pneumonia: How Important Is Dysphagia?*

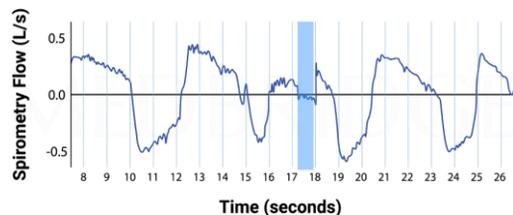
Susan E. Langmore, PhD,^{1,2} Margaret S. Terpenning, MD,^{1,2} Anthony Schook, PhD,³ Yimiao Chen, MS,⁴ Joseph T. Murray, MA,⁵ Dennis Lopatini, PhD,⁶ and Walter J. Loesche, DMD, PhD⁷
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Why consider pulmonary function and defenses?

Breathing is integral to & tightly coordinated with swallowing.

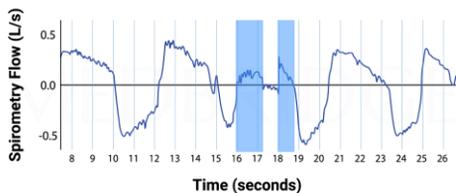
- Breathing swallowing coordination
- Subglottic pressure support for swallowing
- Changes in swallowing can impact breathing & vice versa

Coordination of Breathing & Swallowing: Swallow Apnea Duration



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**Coordination of Breathing & Swallowing:
Respiratory Phase Pattern**



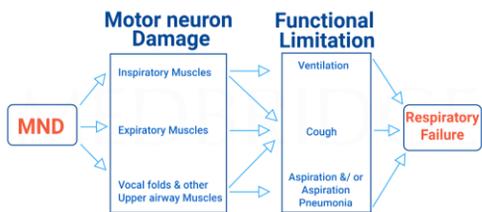
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Subglottic pressure support for swallowing

Facilitates healthy swallowing

- May aid expiratory airflow following swallow apnea (Lang et al. 2002; Nishino & Honda, 1986)
- May stimulate mechanoreceptors to aid laryngeal adduction (Shin et al., 1988)
- Swallowing timing and efficiency is aided by higher lung volume (Gross, 2009)

Potential impact of neurologic disease on respiratory function



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Content from Management of Speech and Swallowing Disorders in Degenerative Diseases, Third Edition (p. 13), by K. Yorkston, R. Miller, E. Strand and D. Britton, 2013, Austin, TX: PRO-ED. Copyright 2013 by PRO-ED, Inc.

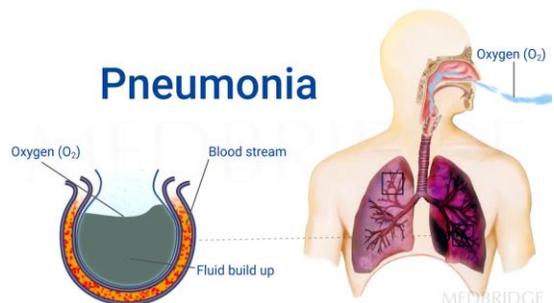
Pneumonia & other forms of pathology related to aspiration



**Pathology related to aspiration
(Prather et al., 2014)**

- Aspiration Pneumonia
 - Acute pneumonia
 - Organizing pneumonia
 - Exogenous lipid pneumonia
- Aspiration bronchiolitis
- Aspiration pneumonitis
- Foreign-body airway obstruction
- Interstitial fibrosis
- Abscess formation

What is pneumonia?



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General risk factors for pneumonia
Examples: no particular order

- Being hospitalized
- Smoking
- Use of proton pump inhibitors (PPIs)
- Pulmonary conditions, e.g., COPD
- Age– e.g., 65 & older or under age 2
- Impaired immune system – many causes
 - E.g., malnutrition
 - E.g., chemotherapy
- Excessive Alcohol or IV drug use
- Neurological injury

Pneumonia causing pathogens



A primary source of bacteria is contained in oral secretions



Pathogenic organisms can invade & infect the lung via 4 routes:

- Aspiration
 - Oral
 - Gastric
- Inhalation
- Hematogenous spread
- Contiguous site of infection

What is Aspiration Pneumonia?



<http://www.radiologyassistant.nl/en/440bc82f1b77>



<http://www.medscape.com/viewarticle/408725>

- Aspiration ≠ pneumonia
- Aspiration pneumonia is a lung infection caused by aspiration colonized by pathogenic bacteria

Factors associated with aspiration pneumonia

- Many articles mentioning risk for aspiration pneumonia actually discuss risk for aspiration
- Possible factors associated with development of aspiration pneumonia
 - Pulmonary defenses
 - Volume and/or viscosity of aspirate
 - pH of aspirate
 - Bacteria load &/or pathogens aspirated

Aspiration pneumonitis?

Aka, “Mendelson syndrome”

Chemical injury to lung tissues that occurs due to inhalation of large amounts of sterile gastric contents (Marik, 2001; Prather et al., 2014)

- Tends to occur during reduced LOC
- Results in acute lung injury &/or chemical burns to lung parenchyma
- Respiratory distress typically occurs within 2-5 hours following the aspiration event

Foreign body aspiration

- E.g., aspiration of whole seeds, nuts, vegetables, meat, and/or “Lentil aspiration”
- May lead to
 - Obstruction (e.g., Café coronary syndrome)
 - Local inflammation
 - Abscess
 - Necrosis

Other possible aspiration related sequelae (Prather et al., 2014)

- Exogenous lipid pneumonia: due to aspiration of oily foods or materials.
- Diffuse aspiration bronchiolitis (DAB): inflammation of bronchioles due to aspiration – rare!

Chronic Aspiration &/or Micro-Aspiration

- Saliva, food, or reflux
- According to Prather et al., 2014...May lead to...
 - “Pulmonary fibrosis”
 - “Organizing pneumonia” (OP), &/or
 - “Diffuse pulmonary ossification” (DPO),

Pulmonary Defenses

Pulmonary defenses

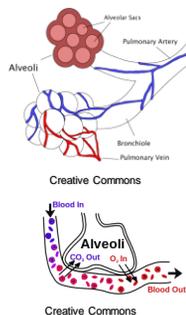
Pulmonary defenses guard the lungs from infections. Pulmonary defenses include protective.....

- Anatomic features
- Mucociliary clearance
- Reflexes, including cough
- Volitional cough
- Cellular defenses

Certain conditions and interventions can impair pulmonary defenses

Pulmonary defenses

The gas exchange surface of the lung is the largest surface area in the body that is exposed to the outside environment.



Anatomic Airway Defenses

- Nose
- Nasopharynx
- Branching Tracheobronchial Tree

- Swallowing - related
 - Laryngeal closure
 - Valleculae & pyriform sinuses
 - Epiglottic inversion
 - Laryngeal closure
 - UES contraction / closure – e.g., to prevent reflux

The Nose is a Filter

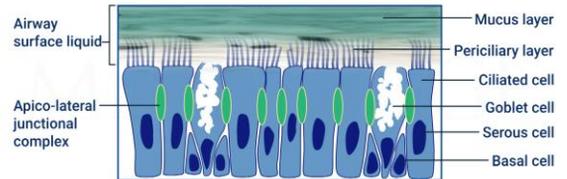


Narrow twisting passages, nasopharyngeal angle and high air velocity promote particle impaction

Loss of Anatomic Airway Defenses

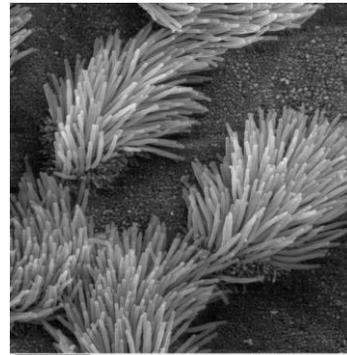
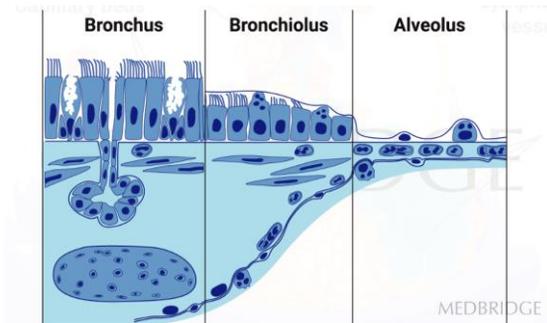
- Mouth Breathing (Exercise)
- Trauma or Obstruction
- Intubation or Tracheostomy

Mucociliary clearance, the "Mucociliary Escalator"



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Bronchial-to-Aveolar Epithelial Changes



Creative commons

Failure of Mucociliary Escalator Function

– Examples (e.g., Tilley et al., 2014)

- Genetic disorders
 - Primary Ciliary Dyskinesia
 - Cystic Fibrosis
- Acquired
 - Smoking
 - Other environmental factors, air pollution, allergens
 - Infection (e.g. Influenza virus)
 - Obstruction (e.g. endotracheal tube, trach, tumor)
 - Dehydration

Airway Defense Reflexes

Examples:

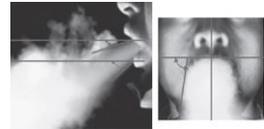
- Sneeze
- Swallow
- Gag
- Laryngeal closure
- Huff
- Cough

Cough

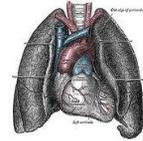
Rapid mass movement of secretions and foreign material out of the conducting airways



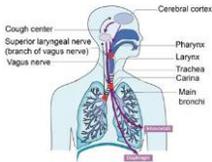
"The cough reflex is the watchdog of the lungs" (C. Jackson)



Gupta et al, 2009



Cough receptors

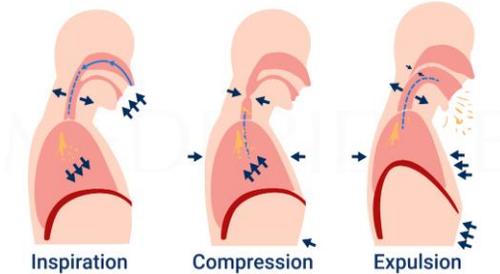


Cough receptors

- Mechanosensitive – located primarily in larynx and trachea
- Chemosensitive – located primarily in distal airways

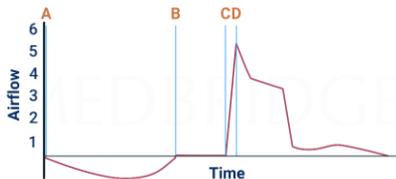
- Cough may be volitional or reflexive (Lasserson et al., 2006; Stephens et al., 2003; Widdicombe & Fontana, 2006)
- Normally function - Can exert volitional control over cough – even when reflexive (e.g., Hegland et al., 2011, 2012)

Phases of normal cough



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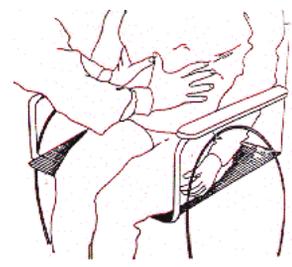
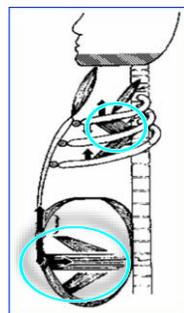
Measurement of cough effectiveness



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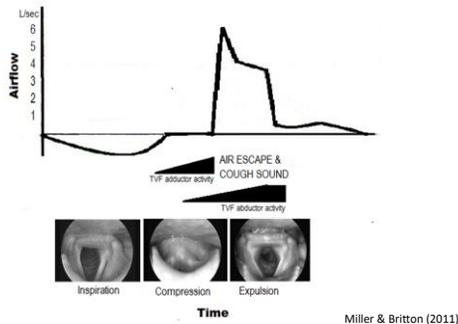
- Inspiration: A to B
- Compression phase: B to C
- Expulsion phase rise time (EPRT): C to D
- Peak expiratory cough flow (PECF): D
- "Volume acceleration" (VA): PECF / EPRT

Dystussia



<http://calder.med.miami.edu/pointis/images/wchp.gif>

Active Vocal Fold Movements During Cough



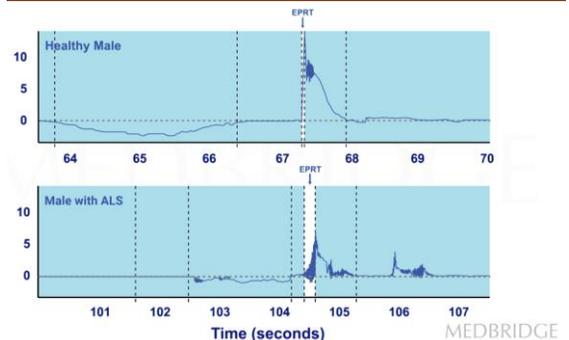
Dystussia – contributing factors

- Respiratory muscle weakness
 - Aging, e.g., (Freitas et al., 2010)
 - Neurological disease, e.g., MS (Aiello et al., 2008), SCI & Neuromuscular disease (Kang & Bach, 2000; Park et al., 2010)
- Laryngeal impairments, e.g., (Britton et al., 2014; Mahajan et al., 1994)
- Reduced cough reflex sensitivity:
 - Aging: e.g., (Newnham & Hamilton, 1997)
 - Smokers: e.g., (Dicpinigaitis, 2003)

Failure of cough & other upper airway reflexes may occur due to.....

- Any form of sedation
- Anesthesia
- Neurological injury or disease
- Structural disease
- Impaired glottic control
- Reduced expiratory function
 - Force
 - Flow

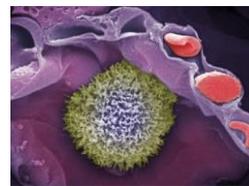
Examples: Cough Airflow



Dystussia – Additional Clinical Implications

- Increased risk for...
 - Aspiration
 - Objective measures of volitional cough
 - Stroke: (Smith-Hammond et al., 2009)
 - Parkinson's Disease (Pitts et al., 2008 & 2010)
 - Cough reflex testing with citric acid (Miles et al., 2013)
 - Aspiration pneumonia (Addington et al., 1999; Yamanda et al., 2008)
 - Respiratory distress &/or Respiratory failure (Hoesch et al., 2012; Su et al., 2010; Bianchi et al., 2012)

Defenses at the Alveolar Level



The alveolar macrophage!

http://www.sflorg.com/sciencenews/scn041906_01.html

Additional defenses at the alveolar / cellular level

- Surfactant
- Anti-bacterial substances
- Neutrophils
- Lymphocytes

Lowered resistance

- Immunodeficiency
- Virulent infections
- Chronic diseases: diabetes, alcoholism
- Malnourishment
- Leukopenia
- Immunosuppression

Pulmonary Defense Risk Factors for Pneumonia

- **Oral Hygiene**
- **Loss of anatomical defenses (e.g., nose, larynx)**
 - E.g., trach, endotracheal intubation
- **Blunted airway defense reflexes, e.g., swallowing, cough, laryngeal closure**
 - E.g., stroke, brain injury, seizure, alcohol &/or drug intoxication, anesthesia, neuromuscular disease
- **Weak or absent ability to cough**
 - E.g., tetraplegia, neuromuscular disease, COPD
- **Impaired mucociliary clearance**
 - E.g., smoking, viral infection, COPD, bronchiectasis, inherited ciliary disorders, airway obstruction, dehydration
- **Weakened immunologic/cellular defenses**
 - E.g., HIV, transplant, immunosuppressive therapy, alcoholism, malnutrition, diabetes, immunoglobulin deficiency

Table modified from Miller & Britton (2011); Happel et al., 2004

Pulmonary Function

Medical Assessment of Pulmonary Function

- Clinical exam
 - Underlying disease processes
 - Signs / symptoms of hypoventilation and/or hypercapnia
- **Arterial blood gas (ABG)**
- O₂ saturation
- Radiological tools, e.g., chest x-ray
- Pulmonary function tests (PFTs)

Symptoms & Signs of respiratory compromise

- Dyspnea
- Dyspnea on exertion or talking
- Disturbed sleep
- Morning headaches
- Excessive daytime sleepiness
- Fatigue
- Difficulty clearing secretions
- Reduced appetite
- Depression
- Poor concentration/memory
- Tachypnea
- Paradoxical breathing pattern
- Reduced chest expansion
- Weak cough
- Sweating
- Tachycardia
- Weight loss
- Hallucinations
- Dizziness or syncope

Respiratory Failure

- Type I – “Hypoxemic”
 - Low oxygen
- Type II – “Hypercapnic”
 - High carbon dioxide

ABG (Arterial blood gas)



After a pulse is found, a blood sample is taken from the artery

ADAM.

Arterial Blood Gas (ABG)

pH	WNL = 7.4 ± 0.03 units Higher = alkalotic Lower = acidotic
PCO₂ (Carbon Dioxide)	WNL = 40 ± 3 mmHg >45 = respiratory acidosis = hypoventilation <35 = respiratory alkalosis = hyperventilation
HCO₃ (Bicarbonate)	WNL = 24 ± 2 mEq/L Higher = metabolic alkalosis Lower = Metabolic acidosis

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Pulse Oximetry



Non-invasive measure of O₂ saturation, i.e., O₂ bound to hemoglobin

Can O₂ sats indicate risk for aspiration?

- Britton et al, Pending publication
- Systematic review
- Study findings mixed – sensitivity ranging from 10% to 87%
- Confounding variables in all studies:
 - Definition of “desaturation”
 - Mixed viscosities/textures observed
 - Mixed populations
 - Lack of comparison group

Respiratory Rate (RR)

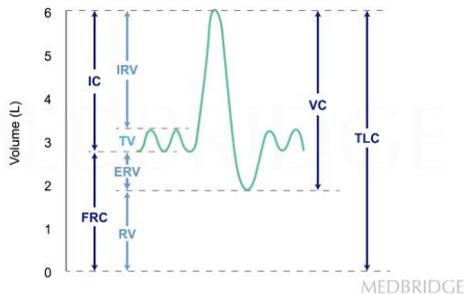
- Normal = 12-20 bpm (breaths per minute)
- Increased RR may impact coordination of breathing and swallowing
- Example: >25 bpm associated with increased risk for aspiration in COPD (Cvejic et al., 2011)

Pulmonary function tests (PFTs)

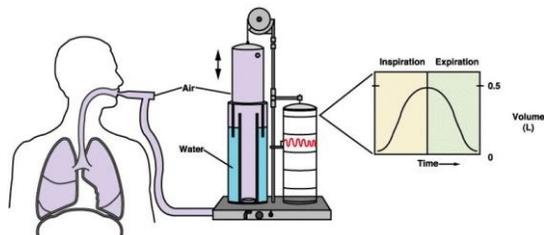
4 General Categories of Information

- Lung Volumes
- Flow rates: maximal flow out of (& sometimes into) the lung
- Maximal inspiratory and expiratory pressures
- Diffusing capacity (DLCO): measures the transfer of gas from the alveolar space into the capillary blood system

Lung volumes & capacities



Spirometry - Measurement of Lung Volumes and Flow Rates



http://3.bp.blogspot.com/-ZSj4wHFotl/Td_QEjDh2pl/AAAAAAAAACw/Uq5VTr02bzo/s1600/spirometer.jpg

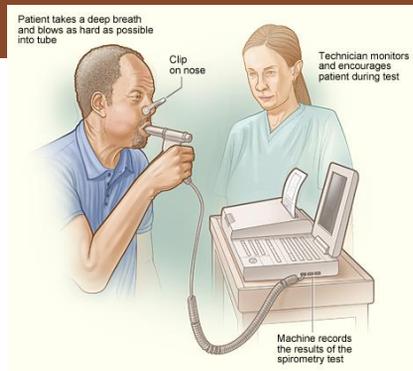
We've come a long way...



<http://www.seamed.com/zoom/product/Product.do?ca mpid=275&prubid=9207>



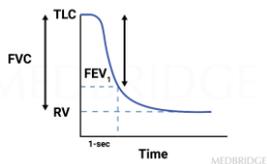
<http://www.nagelnetwork.com/pcspir.html>



Creative commons

Basic spirometry measures

- FEV₁ - volume exhaled in the first second of a forced exhalation
- FVC - forced vital capacity or the total volume exhaled during forced exhalation after a maximal inhalation
- FEV₁/FVC is a measure of airflow obstruction



Spirometry Interpretation

Interpretation	FVC	FEV1	FEV1/FVC
Normal	Normal	Normal	normal
Obstruction	Low or normal	Low	Low
Restriction	Low	Low	Normal
Combination	Low	Low	low

Obstructive vs. Restrictive Lung Disease

- Obstructive
 - Defined by reduced airflow, primarily expiratory
 - ↓ FEV1, FEV1/FVC ratio
- Restrictive
 - Defined by reduced volume (TLC)– FVC will also tend to be reduced.
 - Types of restrictive patterns
 - Internal
 - External

Obstructive vs Restrictive patterns

- Normal
 - FEV1 and FVC > 80% of normal
 - FEV1/FVC > 75%
 - TLC > 80% of normal
- Airflow obstruction
 - FEV1/FVC < 75%
- Restrictive pattern
 - TLC < 80% of normal (or Low FVC)

Handheld Respirometers



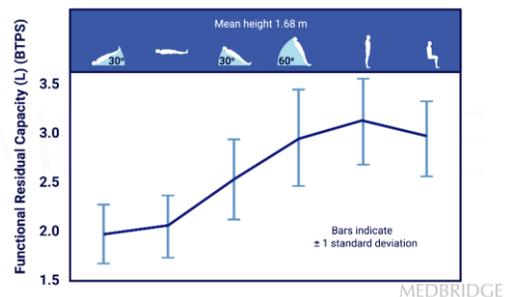
Normal values for FVC & other PFT measures

- Based on gender, height and race
- Normative equations and/or tables are available, e.g., Hankinson JL, Odencrantz JR, Fedan KB. Spirometric Reference Values from a Sample of the General U.S. Population. *Am. J. Respir. Crit. Care Med.* January 1, 1999 159(1):179-187.
- CDC Website with Tables of norms: <http://www.cdc.gov/niosh/topics/spirometry/nhanes.html>
- CDC Website – Spirometry reference calculator: <http://www.cdc.gov/niosh/topics/spirometry/referencecalculator.html>

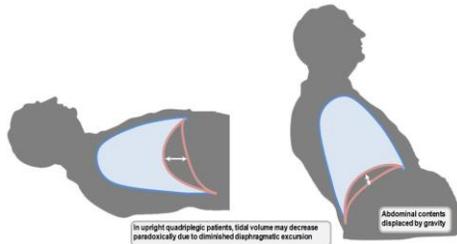
Relevance of Spirometry Measures to Dysphagia

- Consideration as a part of your medical records review; possible impact
 - Subglottic pressure support
 - Cough
 - Breathing swallowing coordination
- Possible synergic impact of respiratory impairment + bulbar impairment

Effect of position on breathing

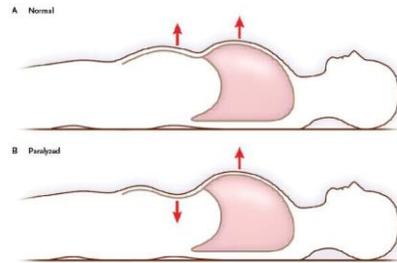


Paradoxical Breathing: Strong diaphragm, absent or weak accessory & abdominal muscles



<http://www.derangedphysiology.com/php/Neurocritical-care/Physiological-consequences-of-spinal-cord-transection.php>

Paradoxical breathing: Diaphragm paralysis



McCool & Tzelepis, 2012

Measurement of Peak Cough Flow (PCF) and Peak Expiratory Flow (PEF)



Pneumotach / Spirometry



Peak flow meter (disposable)

Peak Cough Flow

PCF Level	Clinical significance
Greater than 500 L/min	Typical threshold for healthy adults; minimal risk of airway encumbrance
Less than 270 L/min	Increased risk for airway encumbrance
160 L/min	Minimum threshold to move mucous from lungs into the upper airway

References: Bach & Saporito, 1996; Botano, 2006; Toussaint, Botano, Gathot, Steens, & Soudan, 2009; Table from: Britton, Cleary and Miller, 2013

Measures of respiratory muscle strength

- Maximum inspiratory pressure (MIP)
- Maximum expiratory pressure (MEP)



MIP / MEP Normal Values

(UpToDate: Moxham, 11/11/14)

Maximum inspiratory pressure (MIP) in cm H₂O

- Ages 18-65: men = -92 to -121, women = -68 to -79
- Ages 65-85: men = -65 to -90, women = -45 to -60

Maximum expiratory pressure (MEP) in cm H₂O

- Ages 18-65: men = 140, women = 95
- Ages 65-85: men = 140 to 190, women = 90 to 130

Thanks for your attention!

