"MAKING WAVES" IMPORTANCE OF EXPIRATORY FLOW BIAS IN SECRETION CLEARANCE

Steve Deatrick B.A., RRT

Objectives

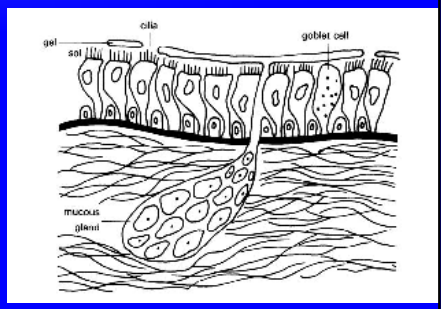
- 1. Review normal mechanisms of mucociliary transport
- 2. Discuss some of the common methods for using expiratory airflow to enhance secretion removal
- 3. Discuss the importance of ensuring an expiratory bias flow to enhance secretion clearance during OPEP therapy

Objectives

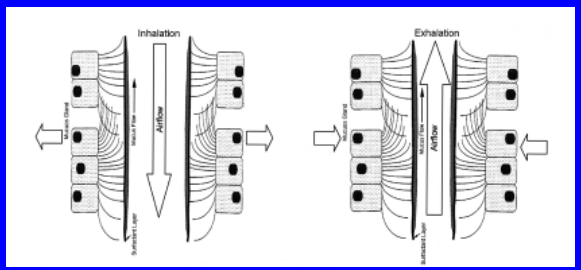
- 4. Describe three mechanisms by which OPEP devices aid in clearance of secretions
- 5. State the effects of increasing resistance on an OPEP device
- 6. Name one simple thing the RCP can do to enhance expiratory flow bias

NORMAL MECHANISMS OF MUCUS CLEARANCE

- Mucus produced by goblet and submucosal glands – 100 ml per day
- Two layers of mucus – sol and gel
  - Sol – thin, watery (serous cells)
  - Gel – thick, superficial layer
- Cilia beat at 11-13 cycles per second to propel mucus layer cephalad at about 4-5 mm per minute (about an inch a minute)



- A healthy muco-ciliary escalator moves respiratory secretions toward the oropharynx where final clearance achieved by swallowing
- Increase in air velocity during exhalation also contributes to mucus movement
- As diameter of airway decreases during exhalation, velocity increases



Fink, J. Forced Expiratory Technique, Directed Cough, and Autogenic Drainage; Respiratory Care, September 2007, Vol 52, No 9

Difference between flow and velocity

- Flow is volume divided by time
- Velocity is flow divided by cross-sectional area

What is flow bias?

- Preponderance of flow direction based on inspiratory and expiratory flowrates
- A higher peak inspiratory flow (PIF) than peak expiratory flow (PEF) generates a flow bias toward the lungs. This is referred to as **inspiratory flow bias**
- A higher peak expiratory flow (PEF) than peak inspiratory flow (PEF) generates a flow bias toward the mouth. This is referred to as **expiratory flow bias**

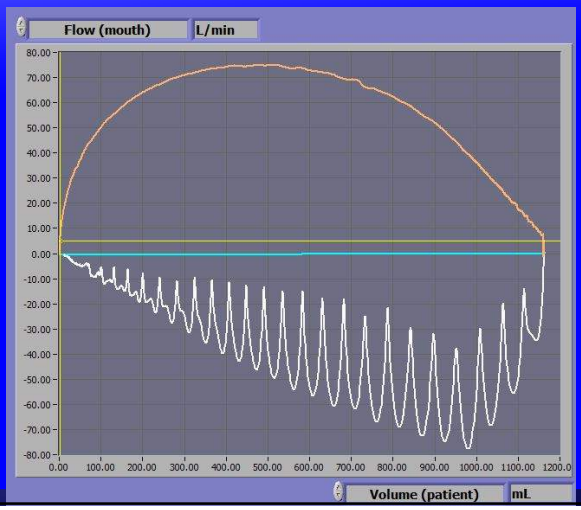
- Expiratory flow bias is important in secretion clearance
- In order to move secretions cephalad toward the oropharynx, the PEF/PIF ratio needs to be greater than 1.1 (McIlwaine et al, ERR, 2017) or PEF/PIF difference of +17 l/m (Volpe et al, 2008)

THE SLOWER THE INSPIRATION, THE GREATER THE EXPIRATORY FLOW BIAS.

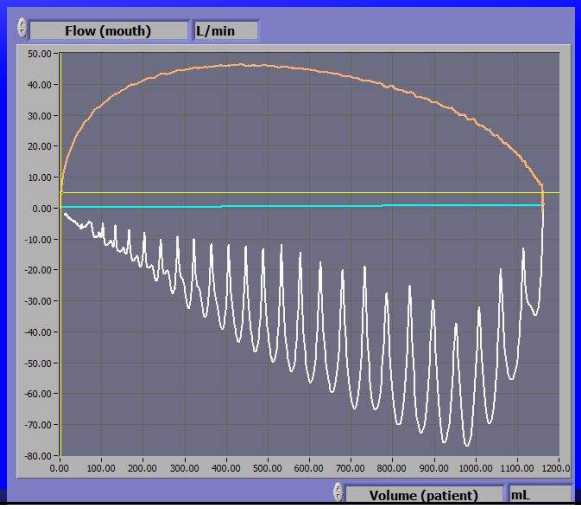
CONSIDER THE FOLLOWING FOUR EXAMPLES… NOTICE THAT THE LONGER THE INSPIRATORY TIME, THE GREATER THE EXPIRATORY FLOW BIAS

0.5 second IT (IFB of 27 l/m)

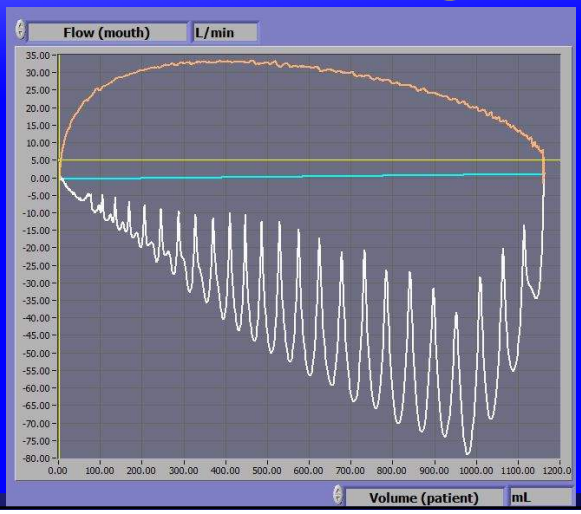
1 second IT (EFB of 5 l/m)



2 second IT (EFB of 22 l/m)



3 second IT (EFB of 45 l/m)



COMMON METHODS OF SECRETION CLEARANCE

Two basic principles for secretion clearance

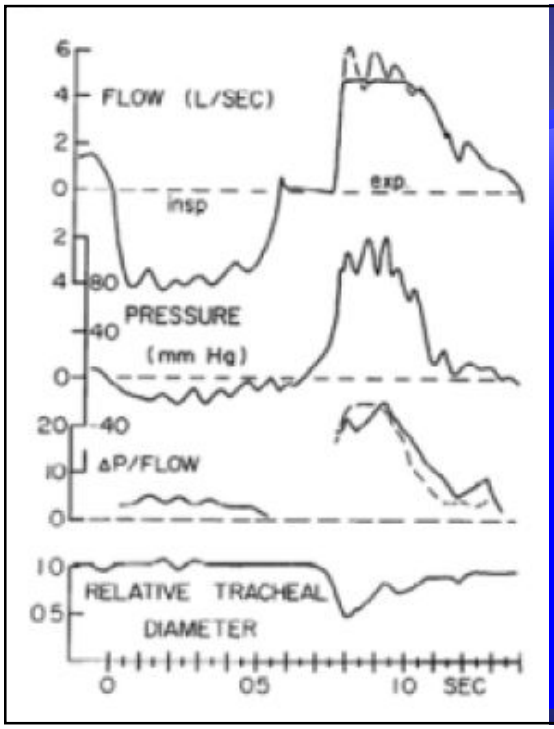
- Move air behind obstructions and ventilate regions distally
- Modulate expiratory airflow to move secretions toward the oropharynx

Techniques

- Cough
- Huff coughing
- Active cycle of breathing
- Autogenic drainage

Cough

- Normal defense mechanism to clear secretions
- Can exceed 500 l/m at the moment the glottis is opened in normal adults
- Dynamic compression of the airways
  - Increase in velocity producing a sheer force detaching mucus from the airway wall
- Key to an effective cough is a deep breath



Anatomy of a cough

- Volume 2.5 L
- I.T 0.65 s
- glottal closure 0.2 s
- E.T. 0.5 s
- Expiratory pressure 120 mmHg
- Inspiratory flow 4 l/s
- Expiratory flow 6 l/s
- Expiratory flow bias +2 l/s

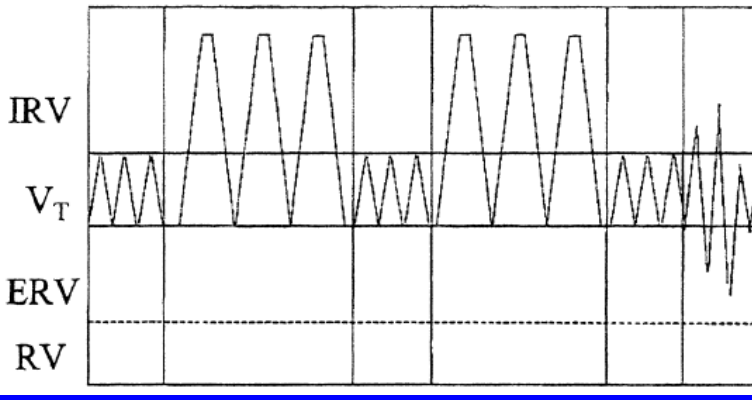
Huff coughing

- Forced expiratory maneuver with an open glottis
- As dynamic compression occurs and airways narrow, velocity increases propelling secretions cephalad

Active Cycle of Breathing

- Several minutes of relaxed diaphragmatic breathing
- 3–4 active deep inspirations with passive relaxed exhalation
- Back to relaxed diaphragmatic breathing
- 3–4 active deep inspirations with passive relaxed exhalation
- 2–3 huff coughs at low volume, followed by 2–3 huff coughs at higher volume

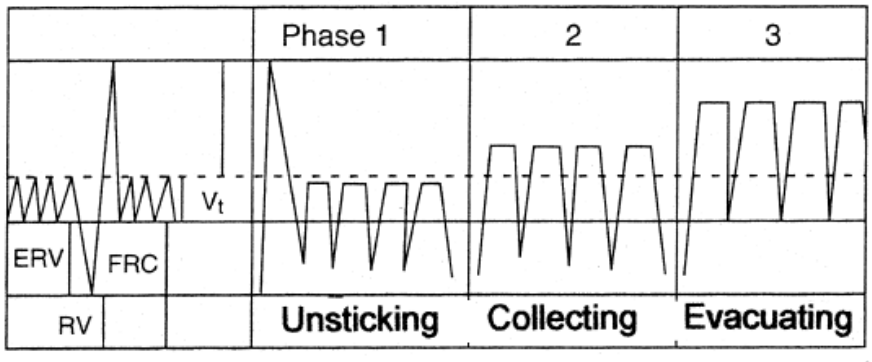
Active cycle of breathing



Autogenic drainage

- Start with low-volume breaths, from expiratory reserve volume
- Repeat for 10–20 breaths, until secretions are felt gathering in the airways
- Suppress the urge to cough and take 10–20 larger breaths
- Take a series of even larger breaths (near vital capacity)
- Take several huff coughs

Autogenic drainage



Devices

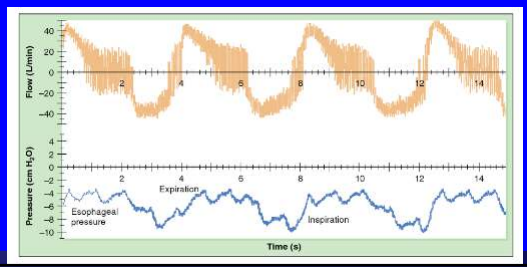
- High frequency chest wall compression
- High frequency chest wall oscillation
- Positive expiratory pressure
- Oscillating positive expiratory pressure
- Positive Airway Pressure

Criteria for airway clearance devices

- 1. Increase in peak expiratory flow (PEF) to move secretions towards the oropharynx
- 2. PEF greater than 60 l/m (Tarran et al, 2006)
- 3. Expiratory flow bias. PEF needs to be 10% greater than PIF (Kim et al, 1986) OR PEF needs to be at least 17 l/m greater that PIF (Volpe et al, 2008)

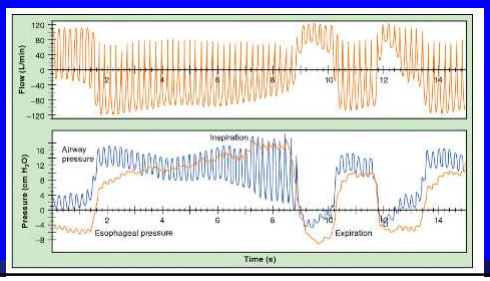
High frequency chest wall compression (vest)

- Inflatable vest used to apply high frequency pulses to the chest wall
- Creates inspiratory and expiratory flow
- Flow pulses help to mobilize secretions



HFCWO (IPV, Metaneb)

- Creates positive trans-respiratory pressure by injected short rapid inspiratory flow pulses
- Mini-bursts of air are delivered at 100-300 per minute
- Active exhalation enhances secretion removal



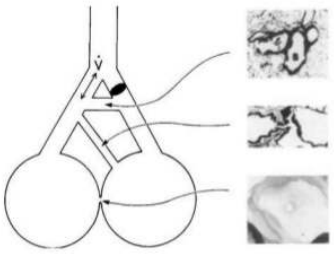
PAP

- Flow regulating technique that increases FRC moves air behind secretions by adding external oxygen flow through an attached venturi starting at 5 LPM at about 45% FIO2
- PEPs of 10-20 cmH2O are can employed

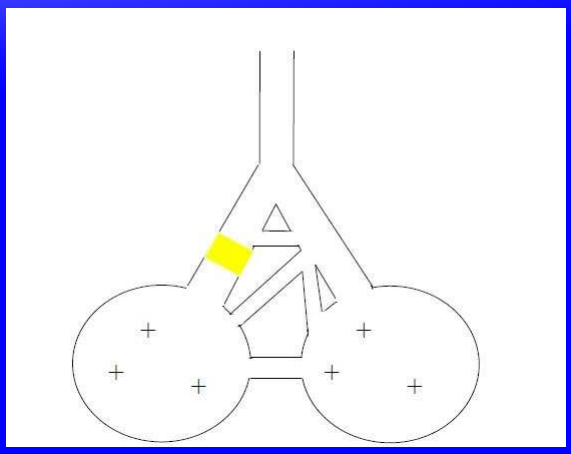
Collateral ventilation

Definition :
"the ventilation of alveolar structures through passages or channels that bypass the normal airways"

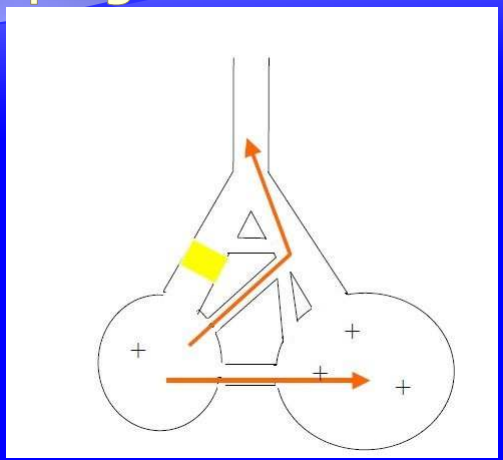
And these are :
- Inter-bronchiolar
- Inter-alveolar
- Bronchiolo-alveolar.
- Interlobar " through fissues "



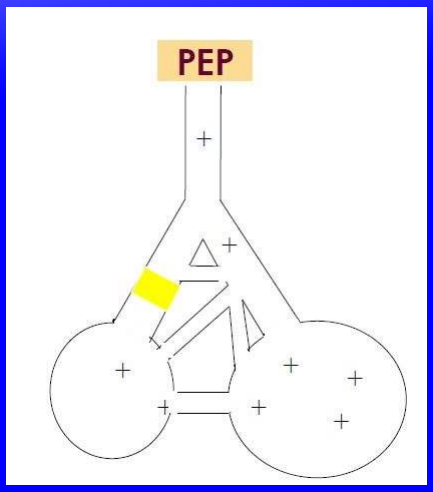
Mucus plug (yellow)



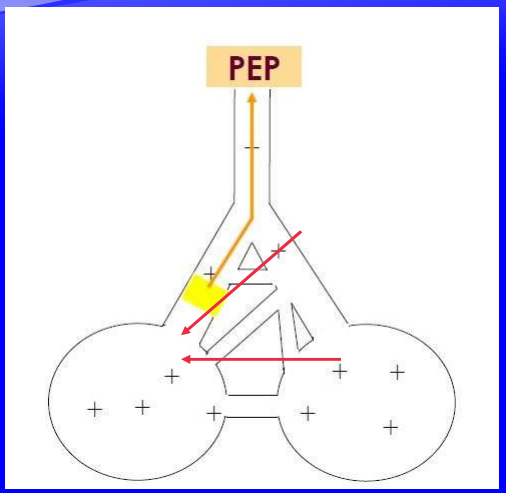
Mucus plug with normal breathing



Application of PEP therapy



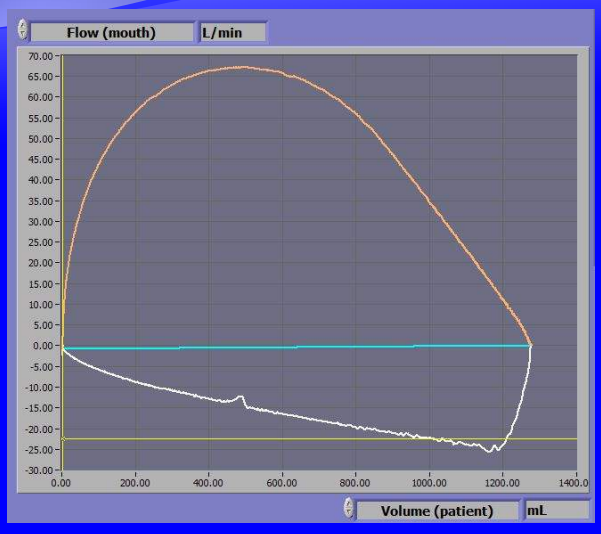
Evacuation of mucus plug through collateral ventilation channels



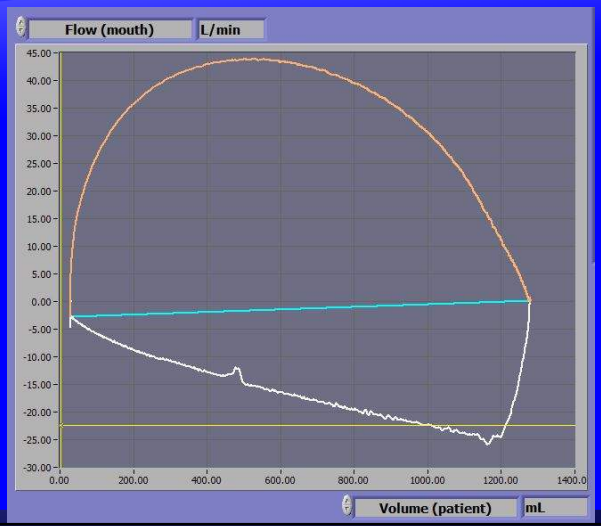
Downside to PEP

- Expiratory flow bias is difficult to achieve therefore must be combined with huff coughing
- Consider the following four examples…
- Notice the effective expiratory flow bias is never achieved, even with a 4 second inspiratory time

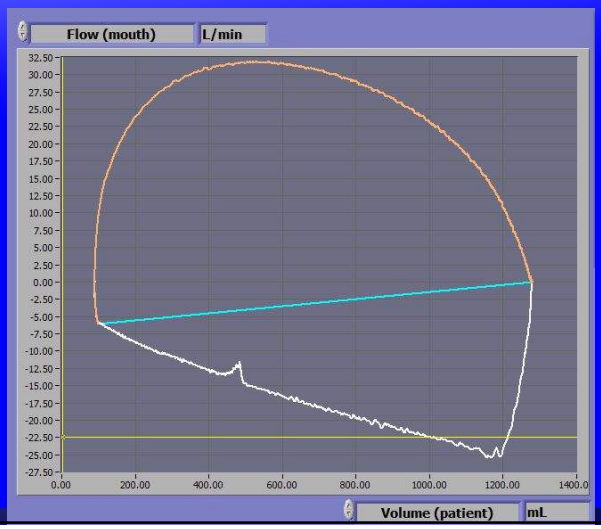
PEP therapy 1 second inspiration (IFB of 42 l/m)



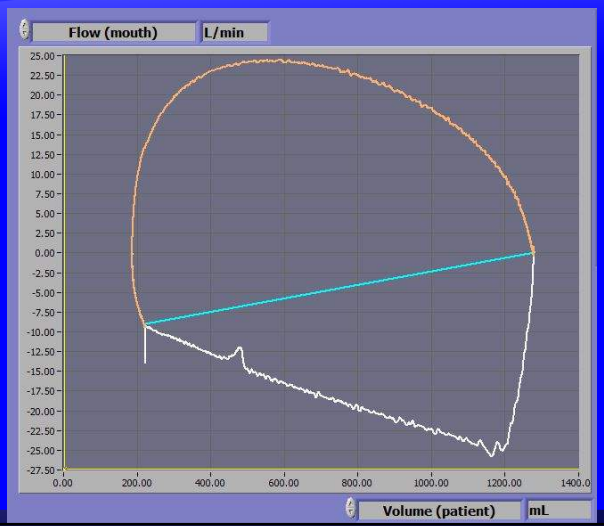
PEP therapy 2 second inspiration (IFB of 19 l/m)



PEP therapy 3 second inspiration (IFB of 7 l/m)



PEP therapy 4 second inspiration (EFB of 2 l/m)



Oscillating PEP

- Uses a mechanical means to interrupt expiratory flow and produce flow oscillations
- Oscillations reportedly decrease the viscoelastic properties of the mucus

OPEP Mechanisms

- 1. Similar to a cough, expiratory flow bias (PEF > PIF) helps drive secretions cephalad
- 2. High frequency oscillations (mini-coughs) help thin the mucus or chop it up by creating short bursts of increased expiratory airflow
- 3. Positive expiratory pressure increases FRC and also helps get air behind the secretions from collateral ventilation channels

Critical OPEP components

- Deeper than normal breath but not all the way to TLC
  - Allows achievement of increased peak expiratory flow
- 2-3 second breath hold
  - Increases distribution of ventilation
  - Alters time constants and allows air to move behind obstructions though collateral channels
- Active exhalation to produce expiratory flow bias and flow oscillations

Tale of two patients

- Ms. Smith and Mr. Jones are two patients who are performing OPEP therapy. The resistance is set on the lowest setting for both patients.
- For purposes of this discussion, both are exhaling 1.5 liters of air and have a peak expiratory flowrate of 60 l/m.
- Both patients have been instructed to breathe in slowly to a volume slightly larger than normal, hold their breath for a couple of seconds, and perform a steady exhalation for 3-4 seconds

Tale of two patients (continued)

- Ms. Smith wants to get the therapy over with and is inspiring 1.5 liters in 1.5 seconds. Mr. Jones is more cooperative. He is inspiring his 1.5 liters over a three second period.
- Doing the math:
  - Ms. Smith: PEF 60 l/m, PIF 60 l/m (1.5 L ÷ 1.5 s = 1 l/s or 60 l/m)
    - PEF/PIF ratio = 1.0, PEF-PIF difference = 0 l/m
  - Mr. Jones: PEF 60 l/m, PIF 30 l/m (1.5 L ÷ 3 s = 0.5 l/s or 30 l/m)
    - PEF/PIF ratio = 2.0, PEF-PIF difference = 30 l/m
- OPEP therapy will be more effective for Mr. Jones since he has a greater expiratory flow bias

The take away…

- In order to maximize expiratory flow bias, patients should take in the slowest inspiration possible.

CMS Pay 4 Performance: Hospital Readmission Reduction Program

- Heart Attack
- Heart Failure
- Coronary Bypass Surgery
- Hip/Knee Replacement
- Pneumonia
- COPD

Hospital Readmission Reduction Program

- The financial penalty to the hospital can be up to 3% reduction in Medicare Payments

Admitting DRG

- 192 COPD w/o complications
- 195 Pneumonia w/o complications
  - Cost per day in an ICU bed
  - Cost per day for a ward bed
  - DRG Medicare payments are capitated

To Review: In OPEP therapy…

- Peak expiratory flow moves the secretions cephalad
- Oscillations reduce viscosity of the mucus
- Positive expiratory pressure helps move air behind secretions through collateral channels

WHAT ABOUT RESISTANCE?

Effects of increasing OPEP resistance

- Positive effects
  - Increases mean airway pressure, which may help with treating atelectasis
  - Increases functional residual capacity, which promotes mucus clearance by stenting the airways open – allowing air to move behind secretions through collateral channels
- Negative effects
  - Decreases peak expiratory flowrate, which may decrease expiratory flow bias and mucus clearance

- Also, in a OPEP device, frequency is directly proportional to flow. The higher the flow, the greater the frequency.
- Therefore patients with low tidal volumes may be below well below the ideal target while patients with high volumes may be well above.
- More work is needed to find the ideal range

Bottom line on PEP vs. OPEP

- Secretion movement with a PEP device works more through collateral ventilation channels and less through modulation of expiratory flow bias
- Secretions movement with an OPEP device works more through modulation of expiratory flow bias and less through collateral ventilation channels
- Combining PAP w OPEP can prove beneficial

Cystic Fibrosis

- ACTs are recommended for all patients for clearance of sputum, maintenance of lung function, and improved quality of life
- No ACT has been demonstrated to be superior to any other
- ACT should be individualized to the patient

Flume, et al; Clinical practical guidelines for pulmonary therapies committee. Cystic fibrosis pulmonary guidelines: airway clearance therapies. Respiratory Care 2009;54(4):522-537

Non-Cystic Fibrosis

- Uncomplicated pneumonia – CPT not recommended for routine treatment (AARC)
- HFCWC, PEP, and OPEP are effective alternatives to CPT (American College of Chest Physicians)
- COPD – ACTs not recommended routinely but may be considered in patients with secretion retention (AARC)

Strickland et al. AARC CPG: Effectiveness of Non-pharmacologic ACT in hospitalized patients. Respiratory Care, December 2013, Vol 58, No 12.

Cool F, Rosen M. Non-pharmacologic ACT: ACCP evidenced-based guidelines. Chest 2006;129 (1 suppl): 250s-259s.

Summary

- High frequency oscillations (mini-coughs) help decrease the viscoelastic properties of mucus
- Expiratory flow is the key component to effective secretion movement
- A PEF/PIF ratio of > 1.1 is needed to move secretions cephalad

Summary

- While increasing OPEP resistance with an inline PAP device may help with treating atelectasis
- Expiratory bias flow will be maximized when the RCP sets the resistance on the lowest setting and instructs the patient to take the slowest inspiration possible

Respiratory Therapists' are the Batman/Batgirl of healthcare. They get the signal, they show up with their gadgets, **save the day**, then they disappear and no one knows their name.


Thank You!