Clinical Foundations

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Oscillating Positive Expiratory Pressure (OPEP)

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"To know even one life has breathed easier because you have lived. This is to have succeeded."
– Ralph Waldo Emerson

Oscillating positive expiratory pressure (OPEP) is a therapeutic method which facilitates airway clearance through the combination of positive expiratory pressure and airflow oscillations during an active exhalation.[1,2,3] OPEP devices have been described in the literature since the late 1990s as cost-effective secretion-clearance alternatives to the labor and time consuming interventions such as: postural drainage, percussion, and vibration.[3]

There are several types of OPEP devices on the market. The quality of the airflow oscillations and pressure thresholds are dependent on the device design and the ability of the patient to generate flow during an active exhaled maneuver, or maneuver that engages the muscles to assist with the flow of gas from the lungs. Thus, the device and the patient work together to produce the therapeutic effect of airway clearance.[3,4,5]

The Mechanisms of Mucociliary Clearance.

Prior to our discussion of the theory and clinical application of OPEP therapy, it is essential that we briefly review the normal mechanisms of mucociliary clearance. This brief review will focus on the endogenous mechanisms of secretion clearance beginning with an examination of airway architecture, mucous composition, ciliary function and finally, the role of the cough.

The conducting airways have been described as a "tree of irregular dichotomies," fashioned in a pattern of morphogenic dichotomous branching.[6] The conducting airway architecture is fractal, or has the same airway distribution pattern up to the 24th generation.[7] This airway geometry not only supports ventilation, or the movement of gases in and out of the lungs, but assists with the transport of airways secretions, to minimize the propensity for bronchial obstruction.

Airway surface liquid is an essential component of native lung defense and is approximately 10 μm deep with two distinct layers; the periciliary sol, (thin layer), beneath the upper layer of mucus gel, (thick, sticky).[8] The sol layer has a low-viscosity, watery, property and surrounds the cilia, while the gel layer is glutinous, dense, sticky, and rides the tips of the cilia.[8]

The "sea grass" of cilia is so very thick that the gel layer cannot penetrate it. The gel layer rides along the top of the beating cilia, which move in a rhythmic wavelike manner at a rate of 3 to 4 mm/min.[9] This metachronal movement propels airway debris cephalad toward the large airways. The centripetal movement of the mucociliary escalator clears secretions to minimize or alleviate airway obstruction.[10]

Airways secretions are produced daily, which range from 1 to 100 mL in healthy individuals.[11] However, there are many factors which make it difficult for individuals to mobilize and evacuate secretions. Aging, tobacco use, environmental exposures, and pulmonary disorders such as bronchiectasis, COPD, and cystic fibrosis impair the efficiency of the mucociliary escalator.[12-14] Neurodegenerative conditions weaken muscles which reduce the ability to actively exhale and cough effectively.[15,16]

The Function of the Cough

The cough is a fundamental biological defense mechanism and a significant protective mechanism of the respiratory system. The cough's primary function is ejecting secretions, foreign bodies, and vaporous vexations from the respiratory tract. This complex maneuver is predominantly involuntarily. A cough begins with the irritation or stimulation of airway mechanoreceptors disseminated throughout conducting airways. These receptors are abundant at the carina with specialized irritant chemoreceptors scattered in the distal airway bifurcations where deleterious vapor particles will have a greater probability of depositing.[17]

There are three phases of a cough. Initially, there is an amplified inspiration through an abducted glottis where inhaled volume is transiently larger than tidal volume. Next, the compressive phase occurs, which is initiated by the rapid adduction of the glottis and expiratory muscle contraction. Although the compression phase lasts only hundredths of a second, it may increase intrathoracic pressure to approximately 300 cm H_2O.[17,18]

The final phase, of the normal cough, is the expiration phase. The glottic release of amplified intrathoracic pressure produces a subatmospheric drop in central airway pressures and creates a striking pressure gradient and a rapid and dynamic compression of the airways. The combined muscle pressure, intrathoracic pressure, and glottic release intensify an already substantial airflow velocity creating a shearing force across the surface of the mucociliary stairway discharging a massive expulsion of mucous and airway debris.[17,18] There are conditions in which the intrathoracic pressure and glottic release causes small airway collapse, trapping secretions and contributing to bronchial obstruction. A huff cough technique, or forced expiratory technique is an alternative method for expelling secretions and airway debris. Rather than exhaling forcefully against a closed glottis, the huff cough, also known as forced expiratory technique, is a forced exhalation with an open glottis. The word "huff" was coined from the sound the individual makes during the expiration with an open glottis.

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It is important for the clinician to understand the mechanisms that can impair mucus clearance and evaluate the patient to determine what factors or clinical conditions exist which can impede the acceleration of mucous out of the airway or prevent the patient from using the OPEP device as intended.[19-22]

Oscillating Positive Expiratory Pressure (OPEP) Therapy

Oscillating positive expiratory pressure, (OPEP) therapy is a mechanical means to manipulate air flow, to mobilize secretions cephalad, and to facilitate evacuation. The clinical intentions of this therapy are the augmentation and/or intensification of native airway defense mechanisms, to mobilize mucous and airway debris, present or relieve airways obstruction, and re-establish a normal FRC.[1-4,22]

The OPEP devices interrupt expiratory flow through a resistive apparatus which generates flow oscillations and positive pressure during an active exhalation of exaggerated slightly larger than tidal volume breath. The airflow oscillation has four components; (1) a peak pressure (Ppeak), (2) baseline positive expiratory pressure (PEP), (3) pressure amplitude (AMP) or the difference between Ppeak and PEP, which is a measure of the burst of flow the device creates, and (4) frequency or the number of airflow oscillations occurring in a one - minute time period. There are several different types of commercially available OPEP devices on the market. Virtually every device uses unique mechanisms to produce the oscillations in airflow and attendant positive pressure, Table 1.

The current evidence maintains that the physical mechanisms for providing the expiratory pressure and oscillations are device-dependent but share a common character in that the airflow oscillations have a peak pressure and baseline positive expiratory pressure. The pressure amplitude (AMP) is the gradient between Ppeak and PEP and is reflective of flow velocity, sustained pressure, and airway mechanics while frequency is the number of oscillations occurring in a minute.[3,4,23]

Device	Mechanism of Action	Special Considerations
Aerobika®	Expiratory flow passes through a valve that "chatters," creating oscillatory PEP.	Can be used with nebulizer.
Acapella®	A counterweight and magnet create oscillatory flow velocities during exhalation.	Oscillatory performance is not gravity-dependent. Device comes in different models: green for patients with expiratory flow > 15 L/min; blue model is for patients with expiratory flows < 15 L/min; a dial for expiratory resisitance.
RC-Cornet®	A semi-circular tube encompassing an inner malleable tube. Expiratory flow causes the tube to undulate creating oscillating positive pressure.	Cannot be used in-line with nebulizer. Can adjust frequency, amplitude, and MAP.
Flutter®	A stainless steel ball sits in a "pipe-like" housing and the weight of this ball is displaced with the expiratory maneuver. Exhalation into the Flutter valve causes the steel ball-bearing to oscillate causing oscillation of the airways with intermittent positive expiratory pressure.	Gravity-dependent; best used in the sitting or supine lying position; Flutter ball chamber must be pointed upwards in order to create optimal oscillations. Tilting the Flutter device will change the oscillatory frequency.
Quake®	Manually operated spinning knob creates oscillations; oscillation frequency-dependent upon speed of knob rotation. Slow rotation creates low-frequency oscillation with higher expiratory pressure. Fast rotation delivers rapid oscillations with lower expiratory pressure	Very patient-dependent. Must coordinate spinning of the reel with expiratory flow.

Compiled from references 3,4 & 20.

Clinically, the differences in expiratory pressure, oscillation depth, amplitude, and flow velocity are a real challenge for the clinician and underline the inherent operational differences of the devices under similar patient conditions. This calls both for greater investigation into the individual devices and greater clinician familiarity with individual device parameters.

The device should match patient need, ability, and therapeutic intention.[3,4,22-25] The mindful clinician will understand that functional capabilities may vary significantly across the range of resistance settings and there may be a significant interaction effect with maneuver time as has been reported by Volsko, et al.[3,4,23]

The use of these devices with the huff cough can generate a synergy that enhances the efficacy of both device and maneuver. The huff cough is typically performed between a set of exhalations through the OPEP device. The huff

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cough evacuates airway secretions that are mobilized toward the central-airways, through a series of slow mindful inspirations, and is followed by a three-second breath hold and mindful forced exhalations with mini-coughs through an open glottis, where they can be expelled. The combined effect of the huff maneuver with OPEP expiratory flow, pressure, oscillation and amplitude gives one greater flexibility in the clinical toolbox. The OPEP devices have been demonstrated effective in patient scenarios as diverse as cystic fibrosis, neurogenic compromise, bronchiectasis, and the post-operative retention of secretions.[24-27] The OPEP device is an effective appliance in the context of pulmonary rehabilitation and disease management for the patient with COPD.[28] The most commonly used OPEP devices are Flutter®, RC-Cornet®, and Acapella®.[29] In the greater context of pulmonary rehab and disease management OPEP devices may have a role in the prevention of hospital readmission for the patient with COPD. However, further investigation into outpatient outcomes of the OPEP devices is necessary.[30]

The N-of-1 Trial

Unquestionably, the OPEP device is an essential component of the clinician's armamentarium yet the device must be used by the patient.[31] Patient compliance is one of the essential factors in the therapeutic relevance of any device but more decidedly so with OPEP therapy. Indeed, these devices can have a significant therapeutic impact when used often and in an appropriate fashion.

The clinical application and subsequent patient compliance with OPEP therapy is a definitive illustration of the concept of the patient-specific "n-of-1" trial.[32] The prudent clinician will work with the patient in the context of their disease to achieve an assessment-driven examination of any and all therapeutic options and their clinical effect.[33]

The n-of-1 trial is a means of structuring treatment decisions with and for the patient, in a highly individualized fashion, and monitoring the patient's responses to each treatment.[28]

Regardless of our current practice, we must explore with intellectual rigor innovations in thought, technology, and clinical practice. We must meet the patient in the context of their illness and therapeutic goals while considering their learning and physical abilities. The education of the patient and their caregiver may be the greatest single aspect necessary for the success of this therapy.

What we do at the bedside matters, consequently we must remain fully engaged and intellectually curious in order to have the greatest impact in the lives of our patients. Therefore, it is essential that we as a profession expand and cultivate the utilization of an assessment-based, evidence-grounded practice model in every clinical setting and patient contact. We have both a moral imperative and an ethical duty to treat every patient in an assessment-driven, evidence-based fashion. OPEP therapy serves as a therapeutic option best employed in this fashion and the mindful clinician will match the best device to individual patient contextual needs.

The essential message for the bedside caregiver is that these devices work and they require an informed clinical guide for the patient to use them in a way that is therapeutically beneficial. I trust the discussion that follows will feed your intellectual curiosity and support your bedside practice.

The n-of-1 trial is a means of structuring treatment decisions with and for the patient, in a highly individualized fashion, and monitoring the patient's responses to each treatment.

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Mr. Wheeler is responsible for creating the evidence-based clinical compass for the respiratory therapy arm of cardiothoracic anesthesia critical care at the Cleveland Clinic, a group that cares for over 6,000 heart and lung cases annually. He is a tireless educator having created over 35 continuing education activities for both RTs and nurses in his facility. David has also developed lung transplant mechanical ventilation protocols that have been used with more than 300 patients per year. His extensive writing background includes advanced orientation manuals, numerous pages of content for respiratory critical care issues for the facility's website, and peer-reviewed papers. A highly regarded speaker, David has lectured at international, state, and local meetings.

References

1. Chatham K, Marshall C, Campbell IA, Prescott RJ. The Flutter VRP1device for post -thoracotomy patients. *Physiotherapy.* 1993;79(2):95–98.
2. Pryor JA. Physiotherapy for airway clearance in adults. *Eur Respir J.* 1999;14(6):1418-24.
3. Volsko, T. Airway clearance therapy finding the evidence. *Resp Car.* 2013;(58)10:1669-78.
4. VanFleet, H. Dunn D, McNinch N, et al. Evaluation of functional characteristics of 4 oscillatory positive pressure devices in a simulated cystic fibrosis model. *Res Care.* In Print.
5. Myers TR. Positive expiratory pressure and oscillatory positive expiratory pressure therapies. *Resp Care.* 2007;52(10):1308-1326.
6. Weibel in: Crystal, West, Weibel, Barnes. The Lung: Scientific Foundations; Lippencott; New York. 2000.
7. Ionescu, C, et al. Assessment of the airway alterations by means of a fractal ladder network model (Conference Paper) IFAC World Congress; Milano; Italy; 28 August 2011.
8. Widdicome, JH. Regulation of the depth and composition of airway surface liquid. *J.Anat.* 2002; 201; 313-318.
9. Carson JL, Collier AM, Knowles A. et al. Morphometric aspects of ciliary distribution and ciliogenesis in human nasal epithelium. *Proc Natl Acad Sci* .1981;78:6996–6999.
10. Collins Dictionary of Biology, 3rd ed. © W. G. Hale, V. A. Saunders, J. P. Margham 2005
11. Warwick WJ. Mechanisms of mucous transport. *Eur J Respir Dis* Suppl. 1983;64(Suppl 127):162-167.
12. Rubin BK. Physiology of airway mucus clearance. *Respir Care.* 2002; 47(7): 761-768.
13. Carson JL, Collier AM, Knowles MR, Boucher RC, Rose JG. Morphometric aspects of ciliary distribution and ciliogenesis in human nasal epithelium. *Proc Natl Acad Sci.* 1981;78:6996–6999.
14. Zaugg M, Lucchinetti E. Respiratory function in the elderly. *Anesthesiol Clin North America.* 2000;18(1):47-58.
15. Hernandez ML, Harris B, Lay JC, et al. Comparative airway inflammatory response of normal volunteers to ozone and lipopolysaccharide challenge. *Inhal Toxicol.* 2010; 22(8):648-656.
16. Hadjikoutis S, Wiles CM. Respiratory complications related to bulbar dysfunction in motor neuron disease. *Acta Neurol Scand.* 2001;103(4):207-213.
17. Wanner A, Salathe M, O'Riordan TG. Mucociliary clearance in the airways. *Am J Respir Crit Care Med.* 1996;154(6 Pt 1):1868–902.
18. Irwin RS, Rosen MJ, Braman SS. Cough. A comprehensive review. *Arch Intern Med.* 1977;137(9):1186-91.
19. Mello CJ, Irwin RS, Curley FJ. Predictive values of the character, timing, and complications of chronic cough in diagnosing its cause. *Arch Intern Med.* 1996;156(9):997-1003.
20. Volsko TA, DiFiore J, Chatburn RL. Performance comparison of two oscillating positive expiratory pressure devices: Acapella versus Flutter. *Resp Care.* 2003;48(2):124-130.
21. McIlwaine M. Physiotherapy and airway clearance techniques and devices. *Paediatr Respir Rev.* 2006;7(Suppl):S220–S222.
22. Oostveen E. Macleod D, Lorino R, et. al. The forced oscillation technique in clinical practice: methodology, recommendations and future developments. *Eur Respir J.* 2003;22:1026–1041.
23. Larson EB. N of 1 clinical trials a technique for improving medical therapeutics (specialty conference). *West J Med.* 1990;152:52-56.
24. Groth S, Stafanger G, Dirksen H, et al. Positive expiratory pressure (PEP-mask) physiotherapy improves ventilation and reduces volume of trapped gas in cystic fibrosis. B*ull Eur Physiopathol Respir.* 1985;21(4):339–343.
25. McCool FD, Rosen MJ. Nonpharmacologic airway clearance therapies: ACCP evidence-based clinical practice guidelines. *Chest.* 2006 Jan;129(1 Suppl):250S-259S. Review. PubMed PMID: 16428718.
26. Guyatt GH, Keller JL, Jaeschke R, Rosenbloom D, Adachi JD, Newhouse MT. The n-of-1 randomized controlled clinical trial: clinical usefulness. Out three-year experience. *Ann Intern Med.* 1990;112(4): 293-299.
27. Guyatt G, Sackett D, Adachi J, Roberts R, Chong J, Rosenbloom D, Keller J. A clinician's guide for conducting randomized trials in individual patients. *CMAJ.* 1988;139(6):497-503.
28. J Bourbeau, M Julien, F Maltais, Chronic Obstructive Pulmonary Disease axis of the Respiratory Network Fonds de la Recherche en Santé du Québec, et al. Reduction of hospital utilization in patients with chronic obstructive pulmonary disease: a disease-specific self-management intervention *Arch Intern Med.* 2003;163(5):585-91.
29. FW Ko, DL Dai, J Ngai, et al. Effect of early pulmonary rehabilitation on health care utilization and health status in patients hospitalized with acute exacerbations of COPD *Respirology.* 2011;16(4):617-24.
30. Nowobilski, R. et al. Efficacy of physical therapy methods in airway clearance in patients with chronic obstructive pulmonary disease A critical review; *Pol Arch Med Wewn.* 2010 Nov;120(11):468-77. Review.
31. Stoller JK. The effectiveness of respiratory care protocols. *Respir Care.* 2004;49(7):761-5.
32. Guyatt GH, Keller JL, Jaeschke R, Rosenbloom D, Adachi JD, Newhouse MT. The n-of-1 randomized controlled clinical trial: clinical usefulness. Out three-year experience. *Ann Intern Med.* 1990;112(4): 293-299.
33. Larson EB. N of 1 clinical trials a technique for improving medical therapeutics (specialty conference). *West J Med.* 1990;152:52-56.

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