Analysis of Tidal Volume and Expiratory Pressure during Oscillatory PEP Therapy in Healthy Subjects

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Introduction

Airway clearance techniques have changed dramatically since the author's entry into the field of respiratory care in the early 1970's. Back then "bronchial hygiene therapy" consisted primarily of IPPB with a bronchodilator, ultrasonic nebulization with half-normal saline, and chest physical therapy. The axiom was "open 'em up, wet 'em down, beat it out." These therapies were performed separately or as a triad on COPD patients although any patient with accumulated secretions may have received any or all of these forms of therapy.

Blow bottles were also prescribed for patients recovering from post-operative abdominal and chest surgery. This device consisted of two, approximately one liter plastic containers — one empty and one filled with dye-colored water — connected together with Tygon tubing. The idea was for the patient to take a deep breath and transfer water, as much they could, from one container into the other. The goal was to prevent atelectasis by producing positive pressure on exhalation. The therapy ended up causing the opposite effect and produced more complications than benefits ultimately resulting in its demise — most likely due the effects of excessive transpulmonary pressure. On the positive side, it did provide much entertainment and competition for many respiratory therapists with the goal of seeing who could transfer the most fluid on a single breath!

Today, positive expiratory pressure therapy or PEP therapy can be looked at as a kinder, gentler, and safer version of the positive pressure expiratory techniques of the 1970's. Oscillating PEP or OPEP therapy adds airway vibrations with positive pressure on exhalation. Common instructions for OPEP therapy include: 1) starting at resting expiration (FRC), have the patient take a deeper breath than normal, 2) perform a short breath hold of approximately two seconds, and 3) exhale through the device for approximately four seconds. The process is repeated 10-20 times with huff coughing between sessions over a 15-20 minute treatment time. The oscillations produce wide swings in expiratory air flow and pressure as the patient exhales, which hypothetically assists in mobilizing secretions. Resistance can be adjusted to help patients maintain a four second expiratory time.

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It has been noted in at least one publication that tidal volume during OPEP therapy lands somewhere between 10 ml/kg and forced vital capacity.[1] We agree with this reasoning but wondered objectively, "what exactly constitutes a deeper than normal breath" and how consistent is this volume across a population when corrected for age, height, and gender. We were also curious about the average positive expiratory pressures achieved in this population when using a resistance setting commonly seen in the clinical setting. Therefore the objective of this study is to determine the tidal volume and percentage of predicted inspiratory capacity subjects achieved as they took a "deeper than normal" breath and to measure the pressure midway through a sustained expiratory maneuver.

Method

Forty-two students and faculty without history of lung disease were recruited from the Allied Health Department at Ozarks Technical Community College in Springfield, MO. There were 15 males and 27 females. The range of age was 19-65 (mean 29). After obtaining approval from the college's institutional review board — each subject was educated about the procedure and each signed a consent form agreeing to participate in the study. Information about the subject's age, height, and gender was stored in the database. A predicted inspiratory capacity was also calculated for each subject.[2]

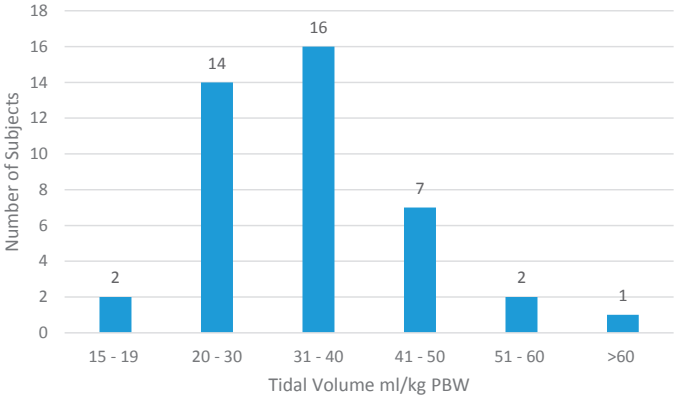
A Fluke VT Plus HF gas flow analyzer with VT for Windows software (Fluke Corporation, Everett, WA) was used in the data acquisition and analysis. A not-previously-used Acapella (green) OPEP device (DHD Healthcare, Wampsville, NY) set at adjustment level 3 (mid-resistance setting) was then connected to the high flow exhaust of the instrument using a 22 mm ID straight rubber adaptor. Each subject had their own bacteria filter which attached to the opposite side on the instrument's high flow inlet. Participants were seated in an upright position and instructed to take a "deeper than normal" breath, hold their breath for two seconds, and exhale through the device for at least four seconds. This procedure was repeated multiple times and the following data was collected: tidal volume (ml/kg PBW), mid-expiratory pressure (cmH2O), and percent of predicted inspiratory capacity each subject achieved as they took a deeper than normal breath. Values are expressed as an average of ten breaths.

Results

The mean exhaled tidal volume in our group of 42 healthy subjects was 33.5 ml/kg PWB. The range of tidal volume was

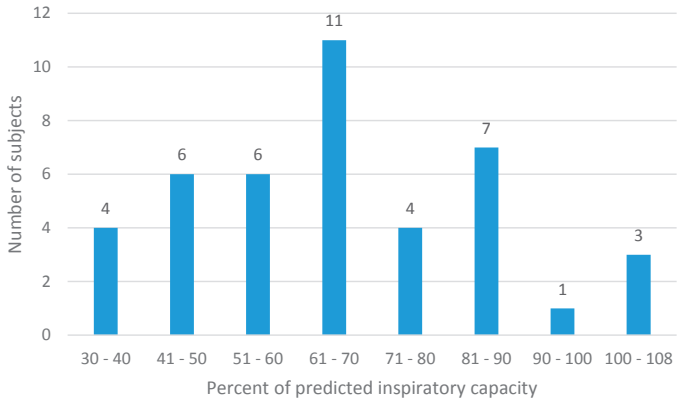
15.4-60.7 ml/kg PWB. SD was 10.6. Chart 1 shows the number of subjects that fell into each incremental range.

Chart 1. Tidal volume distribution (ml/kg PBW)



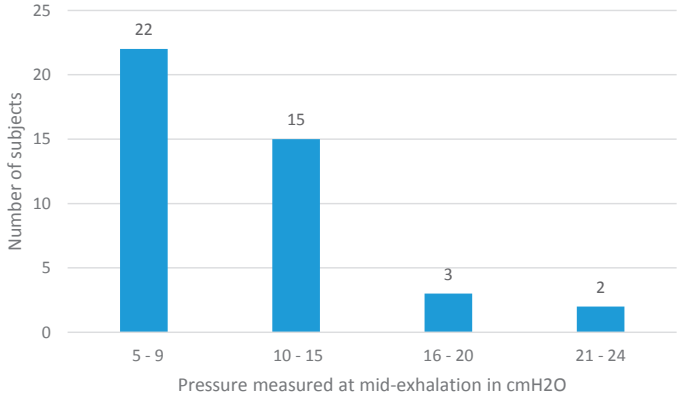
The mean percent of predicted inspiratory capacity achieved during OPEP therapy was 65.4% with a range of 31.4-107.6%. SD = 19.85. Chart 2 shows the number of subjects falling in each incremental range.

Chart 2. Distribution of % predicted inspiratory capacity



The mean pressure midway through a sustained expiration was 10.6 cmH2O with a range of 5.9-24.0 cmH2O. SD was 4.16. Chart 3 shows the number of subjects that fell in each incremental range.

Chart 3. Mid-expiratory pressure distribution (cmH2O)



Discussion

Our study found there was wide variation in the percentage of predicted inspiratory capacity achieved when subjects were asked to take a deeper breath than normal during OPEP therapy. Taking a "deeper than normal" breath did not have the same meaning to all of our subjects. Some achieved only one-third of their predicted inspiratory capacity while a few exceeded it. Most fell between 40-80% of their predicted inspiratory capacity.

In addition, even though 40 of 42 subjects (95%) achieved expiratory pressures in the prescribed range of 5-20 cmH2O for PEP therapy,[3] slightly over one-half (22/42) fell in the lower part of that range. Patients with lung disease and/or airway obstruction may follow this pattern as well. The efficacy of OPEP therapy not only depends on the patient being able to achieve an adequate mean expiratory pressure but it also depends on the device being able to create an oscillatory frequency similar to the frequency of the mucociliary escalator (13 hz).[4] Both of these traits are dependent upon adequate flow through the device.

In this study, we had the advantage of observing graphical analysis of subjects' efforts as they performed OPEP therapy. Figures 1 and 2 show good instructional compliance in a healthy subject that achieved an adequate tidal volume over a four second expiratory time (mid-resistance setting). This in turn produced an adequate expiratory flow, which resulted in a mean expiratory pressure of approximately 12 cmH2O, a mean oscillatory frequency of 15 hertz, and a mean oscillatory amplitude of 6 cmH2O in this subject.

Figure 1. Flow, pressure, and volume scalars of a healthy subject performing OPEP therapy.

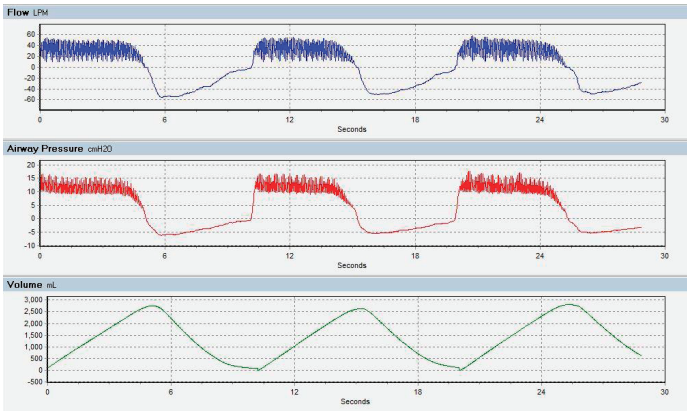
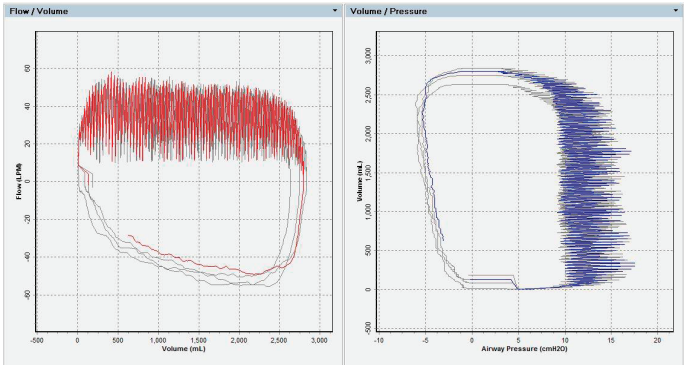


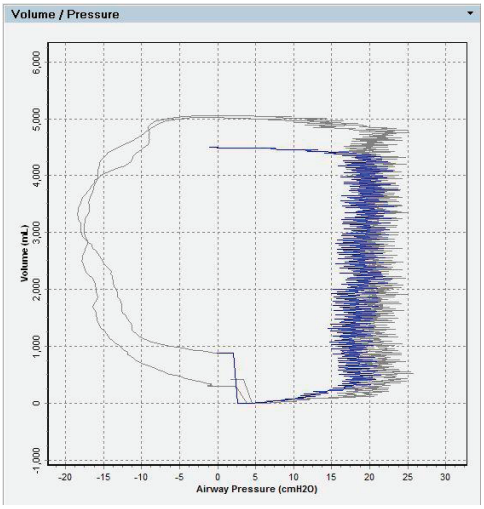
Figure 2. Flow-volume and pressure-volume loops showing a healthy subject performing OPEP therapy.



Eleven subjects in our study had predicted inspiratory capacities of 80% or greater in spite of being told to simply take a deeper breath than normal. Three of those subjects exceeded their

predicted value. Had these subjects been patients and again having the advantage of monitoring volume, we would have instructed them to not take in such a deep breath. Figure 3 shows the volume-pressure loop of one of these patients, a 33 year old male.

Figure 3. Pressure-volume loop showing excessive volume and pressure in a 33 year old male.



Also note in in Figure 3 that as a result of the high volume, the mean airway pressure of our subject is at the upper limit of normal. Had this been a patient, we most likely would have decreased the resistance to bring the pressure down to a more acceptable level.

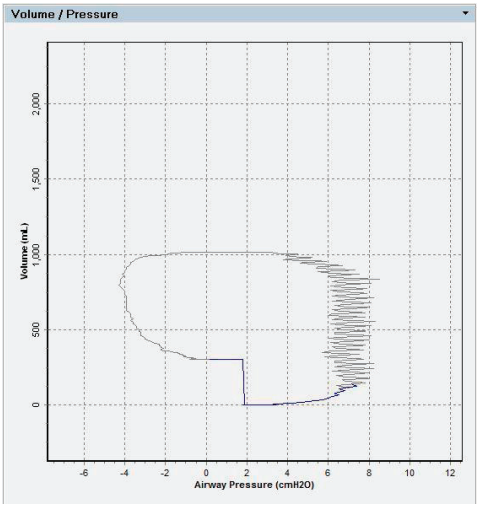
As stated earlier, twenty-two subjects in our study (52%) had mean expiratory airway pressures of between 5-9 cmH2O. This is considered the lower end of the prescribed range. In a clinical setting, assuming we were able to monitor pressures, we probably would have increased resistance to produce a more therapeutic target pressure. If the low pressures were secondary to low tidal volume, we might also have encouraged the patient take a slightly deeper breath in order to produce more expiratory flow. It is interesting to note that nine subjects in our study had what we considered to be less-than-optimal breaths at 45% or less of their predicted inspiratory capacities. These lower volumes were associated with lower expiratory pressures (6.3-8.2 cmH2O) in eight out of nine subjects. Only one subject in the lower volume group had a sustained expiratory pressure greater than 10 cmH2O.

Figure 4 shows the volume-pressure loop of a subject that demonstrated marginal tidal volume and mean expiratory pressure. Notice as a result of the low flowrate through the device, the oscillatory amplitude is only 2 cmH2O. This subject, if a patient, would benefit from an increase in resistance and/or expiratory flowrate.

Conclusions

Since the days of IPPB, ultrasonic nebulizers, and blow bottles, the field of Respiratory Care has evolved into an evidenced-based, efficacy-driven, scientific practice. Most everything we do calls for a way to measure effectiveness—except when it comes to a few procedures like OPEP therapy where for the most part we still use a blind technique in the evaluation process. Therefore, when coaching patients and changing resistance

Figure 4. Pressure-volume loop showing low expiratory pressure and amplitude in a 20 year old female.



settings during OPEP therapy, this study has demonstrated the advantage of using adjunct monitoring devices to assure adequate tidal volume and flow, to make sure patients meet therapeutic pressure thresholds, and to warn of excessive expiratory pressure that may occur if patients perform this therapy incorrectly. More studies are needed to determine if maximizing the quality of OPEP therapy relates to better outcomes.

References

1 Volsko TA, DiFiore J, Chatburn RL. Performance comparison of Two Oscillating Positive Expiratory Pressure Devices: Acapella Versus Flutter. Respiratory Care 2003; 48(2):124-130.

2 Mottram, C, Ruppel, G. Ruppel's manual of pulmonary function testing (10th). Mosby.

3 Myers, TR. Positive Expiratory Pressure and Oscillatory Positive Expiratory Pressure Therapies. Respiratory Care 2007; 52 (10): 1308-1327.

4 Silva, C.E.A., Santos, J.G., Jansen, J.M., de Melo, P.L. (2009). Laboratory evaluation of the Acapella device: pressure characteristics under different conditions, and a software tool to optimize its practical use. Respiratory Care, 54(11), 1480-1487.