



The Usage of Intrapulmonary Percussive Ventilation

Douglas Li, MD, and the CTS Pediatric Committee*

Mechanism of action

Intrapulmonary percussive ventilation (IPV) is a form of high frequency oscillatory ventilation that can be used via mouthpiece, mask interface, or inline with artificial airway or mechanical ventilation. IPV was designed to improve mucus clearance and recruit obstructed bronchi and alveoli using a lung protective strategy; it avoids barotrauma caused by over-inflation of preferential airways. By improving mucus clearance, hyperinflation is reduced, and lung mechanics and gas exchange are improved (1). The principles of IPV are applied to high-frequency percussive ventilation (HFPV), which delivers subtidal (less than dead space) volumes at high rates of 300-1200/min superimposed on a pressure-limited time-cycled conventional respiratory rate of 10-15/min.

IPV is a pneumatic device that utilizes high frequency oscillatory ventilation. It consists of a physiologic interface, called a phasitron, which delivers a series of high frequency pulsatile bursts of subtidal volumes of gas at high flows into the airways followed by passive exhalation. The phasitron is a spring-controlled, sliding venturi that acts as both inhalation and exhalation valve (see image A, reference 1). The venturi slide moves back and forth in a percussive manner at high frequencies (100-300 oscillations/minute), and provides laminar air flow at lower peak airway pressure due to the Venturi effect (a reduction in pressure and increase in velocity when gas flows through a narrowed section of a tube). IPV uses an asymmetric flow pattern, where expiratory flow exceeds inspiratory flow, thereby propelling secretions centrally. During inspiration, the high frequency pulses progressively increase lung volumes. Continuous intrapulmonary wedge pressure is maintained to stabilize the airways, and high velocity percussive laminar flow opens airways thus allowing air to move behind endobronchial secretions. This high velocity flow creates a countercurrent flow that allows mobilization of secretions from peripheral airways to conducting airways during the expiratory phase. Secretions are moved centrally to larger airways where they can be expectorated or suctioned (see image B, reference 1). Simultaneously, mean airway pressures oscillate between 5-35 cm H₂O and the airway walls vibrate in synchrony with these oscillations (1-4).

IPV also provides therapeutic lung recruitment while maintaining a lung protective strategy by using subtidal volumes. It improves the efficiency and distribution of ventilation, provides an alternative system to deliver aerosolized treatments, and an alternative method for delivery of positive pressure to the lungs (5,6).

Research Supporting Utility

Small physiologic studies have shown that IPV may improve timing and quantity of mucous clearance, respiratory and ventilatory parameters such as PaO₂/FiO₂ ratio and gas exchange, peak inspiratory pressure, compliance, degree of dyspnea, and radiographic evidence of atelectasis, including obese patients, burn patients and patients needing mechanical ventilation or extracorporeal support (ECMO).

Acute Illness with Atelectasis

Limited studies suggest that IPV may be safe and effective at decreasing atelectasis in both children and adults. In pediatric studies, IPV showed statistical significance in improvement of atelectasis score when compared to standard CPT and postural drainage in intubated, mechanically ventilated children. Deakins et al (2002, n=46) compared IPV to conventional chest PT in intubated and mechanically ventilated

patients. Atelectasis scores were similar prior to the initiation of treatment, and improved only with IPV usage, with average duration 6.2 days. Thus, IPV may benefit children with atelectasis.

In obese adults with acute respiratory failure due to compression atelectasis and unresponsive to conventional ventilation, IPV superimposed on conventional ventilation significantly decreased atelectasis and improved dynamic compliance and oxygenation (7). All 10 patients in this study were successfully weaned off the ventilator and survived; however, this study did not have a control group

Cystic Fibrosis

The majority of studies of IPV in cystic fibrosis (CF) are comparison studies between IPV and other modalities of airways clearance.

Natale (1994) showed that in 9 outpatients with CF, IPV therapy was well tolerated, but not superior to standard aerosol treatments. These findings were based on analysis of lung function [forced vital capacity, forced expiratory volume (1 second), forced expiratory flow (25-75%)] as well as the quality and quantity of expectorated sputum. These results were supported by Homnick et al (1995), with a prospective comparison study of 16 patients followed for 6 months in 2 groups, standard CPT and IPV. No significant differences in spirometric measures, numbers of hospitalizations, use of oral or IV antibiotics, or anthropometric measurements were detected between the groups.

For children hospitalized with CF, IPV, HFCC vest, and Percussion/postural drainage were found to yield dry weight sputum amounts that were not significantly different. (Varekojis 2003, n=24)

Overall, these data do not support a significant benefit to IPV usage over other airways clearance modalities. However, IPV was not inferior to the other modalities and may have a role in selected patients with cystic fibrosis, especially those who have failed conventional airway clearance techniques.

Neuromuscular Weakness with Cognition

In a comparison study with incentive spirometry, IPV was shown to have a significant effect on antibiotic usage and hospitalization days (8). This study randomized 18 adolescents with neuromuscular disease to use IPV versus incentive spirometry. Antibiotic usage was 24/1000 patient days in the IS vs. 0/1000 in IPV group. Hospitalization days were 4.4/1000 patient days in IS vs. 0/1000 in IPV group. This suggests that IPV is superior to IS in the measures studied.

Device Specifics

Set up: Assemble phasitron and nebulizer cup. Connect color-coded hose to matching attachments on IPV unit. The nebulizer cup should be filled with saline or nebulized medication solution. Connect the unit to a 50psi air or oxygen source. There are 3 knobs on the unit: 1) operational pressure, which sets mean airway pressure (MAP), 2) percussion, which sets frequency, and 3) main power switch. The MAP and frequency knobs each have corresponding manometers (see image C, reference 9).

Administering to patient: Patient should be sitting upright, in a comfortable position during IPV therapy with the head of bed elevated at least 45 degrees. If feasible, any food or fluid intake should be held at least 45 minutes prior to therapy to avoid risk of aspiration. Patients report that frequency is easiest to tolerate when turned counterclockwise and more difficult to tolerate when turned clockwise. Consider starting with easiest setting and rotate to hardest as patient acclimates to the treatment. During the treatment, some advocate that the frequency should alternate between easy and hard settings, for 5 minutes each, in order to reach alveolar units with different time constants. Assess the patient's chest

excursion and breath sounds and adjust the pressure to a level where effective chest wiggle/chest wall motion is visible. Maximum airway pressure (MAP) is based on the patient's lung compliance; low MAPs mean the respiratory system has less compliance, while high MAPs indicate the respiratory system has high compliance. Each treatment should last about 15-20 minutes (10).

Device Time Cost

The cost in time is approximately 20 minutes per treatment plus time to setup. Each inhaled medication may add additional 15 minutes to this therapy time, since many medications cannot be mixed (i.e. dornase alpha with other medications).

Summary

IPV appears to be safe and well tolerated. It is as effective as (but not shown to be superior to) standard chest physiotherapy and postural drainage as a means of mucous clearance in hypersecretory patients. It may have a role in the treatment of atelectasis, neuromuscular weakness, and other restrictive lung diseases. Further comparison studies are needed to clarify the role of IPV.

Indications

- Hypersecretory conditions / conditions with inability to clear mucous (i.e. cystic fibrosis, bronchiectasis, neuromuscular disorders with cognition)
- Mechanically ventilated patients with atelectasis

Contraindications

-Pneumothorax*

* IPV has contributed to resolving long-term localized pneumothoraces after subtotal lobectomies in 4 patients (11).

-Radiologic evidence of blebs or bullae

-Hemoptysis or active pulmonary hemorrhage

-Unstable chest wall, ie. fractures**

** Safety and efficacy of IPV discussed in a case report of an infant with Osteogenesis Imperfecta type III/IV who had resolution of recurrent atelectasis and respiratory failure after initiation of IPV during an acute illness (12).

-Increased intracranial pressure***

***Multiple studies have shown decreased intracranial pressures (ICP) with use of HFPV in adult patients with traumatic brain injuries (13, 14)

Future research needs

-Studies on pediatric population of neuromuscular weakness and static encephalopathies

-Further comparison studies with high frequency chest compression therapy in various conditions

-Suggested outcomes include hospitalization rates, length of hospitalizations, rates of ER visits, rate of decline in FEV1 over 1 year, antibiotic usage, number of respiratory infections, quality of life measures, and school days missed due to illness.

References:

1. Percussionaire® Corporation educational documents on IPV 2005.
2. Kallet RH. Adjunct therapies during mechanical ventilation: airway clearance techniques, therapeutic aerosols, and gasses. *Respir Care* 2013;58(6):1053-1071.
3. Salim A, Martin M. High-frequency percussive ventilation. *Crit Care Med* 2005;33(3):S241-S245.
4. Vargas F, Dellamonica J. Intra-pulmonary percussive ventilation – brief review of clinical and physiological studies. *Euro Resp Dis* 2007.
5. Hristara-Papadopoulou A, Tsanakas J, Diomou G, Papadopoulou O. Current devices of respiratory physiotherapy. *Hippokratia* 2008;12(4):211-220.
6. National Institute of Health Critical Care Therapy and Respiratory Care Section. Intrapulmonary percussive ventilation. *Bronchial hygiene. Policy #3.* 2000.
7. Tsuruta R, Kasaoka S, Okabayashi K, Maekawa T. Efficacy and safety of intrapulmonary percussive ventilation superimposed on conventional ventilation in obese patients with compression atelectasis. *J Crit Care* 2006;21:328-332.
8. Reardon C, MD; Christiansen D; Barnett E; Cabral H. Intrapulmonary Percussive Ventilation vs Incentive Spirometry for Children With Neuromuscular Disease. *Arch Pediatr Adolesc Med.* 2005;159:526-531
9. Clini EM, Antoni FD, Vitacca M, Crisafulli E, Paneroni M, Shezzi-Silva S, Maurizio M, Trianni L, Fabbri L. Intrapulmonary percussive ventilation in tracheostomized patients: a randomized controlled trial. *Intensive Care Med* 2006;32:1994-2001.
10. Natale JE, Pfeifle J, Homnick DN. Comparison of intrapulmonary percussive ventilation and chest physiotherapy. A pilot study in patients with cystic fibrosis. *Chest* 1994; 105:1789-93.
11. Nates JL, Cravens J, Hudgens C, et al. Effects of volumetric diffusive respiration with normal or inverse I:E ratio on intracranial pressure. *Crit Care Med* 1999;27:A73.
12. Nino G, McNally P, Miske LJ, Hickey E, Panitch HB. Use of intrapulmonary percussive ventilation (IPV) in the management of pulmonary complications of an infant with osteogenesis imperfecta. *Pediatr Pulmonol* 2009;44(11):1151-1154.
13. Hurst JM, Branson RD, Davis K. High-frequency percussive ventilation in the management of elevated intracranial pressure. *J Trauma* 1988;28:1363-1367.
14. Salim A, Miller K, Dangleben D, et al. High-frequency percussive ventilation : an alternative mode of ventilation for head injured patients with adult respiratory distress syndrome. *J Trauma* 2004;57:542-546.

15. Barrette RR, Hurst JM, Branson RD, et al. A comparison of conventional mechanical hyperventilation with two forms of high-frequency ventilation for the control of intracranial pressure in closed head injury. *Respir Care* 1987;32:733-740.
16. Deakin K, Chatburn RL. A comparison of intrapulmonary percussive ventilation and conventional chest physiotherapy for the treatment of atelectasis in the pediatric patient. *Respir Care* 2002;47(10):1162-1167.
17. Homnick DN, White F, de Castro C. Comparison of effects of an intrapulmonary percussive ventilator to standard aerosol and chest physiotherapy in treatment of cystic fibrosis. *Pediatr Pulmonol* 1995;20(1):50-55.
18. Medical Specialties, Inc. Intrapulmonary percussive ventilation application guide. www.medspecialties.com.
19. Reper P, van Looy K. Chest physiotherapy using intrapulmonary percussive ventilation to treat persistent atelectasis in hypoxic patients after smoke inhalation. *Burns* 2013;39:187-193.
20. Toussaint M, De Win H, Steens M, Soudon P. Effect of intrapulmonary percussive ventilation on mucus clearance in Duchene muscular dystrophy patients: A preliminary report. *Respir Care* 2003;48(10):940-947.
21. Varekojis SM, Douce H, Flucke RL, Filbrun DA, Tice JS, McCoy KS, Gastile RG. A comparison of the therapeutic effectiveness of and preference for postural drainage and percussion, intrapulmonary percussive ventilation, and high-frequency chest wall compression in hospitalized cystic fibrosis patients. *Respir Care* 2003;48(1):24-28.
22. Wada N, Murayama K, Kaneko T, Kitazumi E. Effect of intrapulmonary percussive ventilation in a severely disabled patient with persistent pulmonary consolidation. *No To Hattatsu* 2005;37(4):332-336.
23. Yen Ha TK, Bui TD, Tran AT, Badin P, Toussaint M, Nguyen AT. Atelectatic children treated with intrapulmonary percussive ventilation via a face mask: clinical trial and literature overview. *Pediatr Int.* 2007;49(4):502-507.

*The CTS warmly acknowledges the Children's Hospital Oakland Airway Clearance Multidisciplinary CQI team for creation of initial document through an IRB approved project.