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Lawrence, V. et. al. Strategies To Reduce Postoperative Pulmonary Complications after Noncardiothoracic Surgery: Systematic Review for the American College of Physicians  
 Annals of Internal Medicine Clinical Guidelines April 2006. <https://doi.org/10.7326/0003-4819-144-8-200604180-00011>

**a. Method:**

- systematic literature review of randomized controlled trials (RCT), systematic reviews or meta-analyses that met predefined inclusion criteria using MEDLINE from January 1980 to June 2005.

**b. N = 20**

- RCTs and 11 systematic reviews were included

**c. Results:**

- Good evidence (2 systematic reviews, 5 additional RCTs) indicates that lung expansion interventions reduce pulmonary risk after abdominal surgery.

**d. Conclusion:**

- For patients having abdominal surgery, the evidence suggests that any type of lung expansion intervention is better than no prophylaxis. No modality seems superior, and combined modalities do not seem to provide additional risk reduction. Incentive spirometry may be the least labor-intensive, while continuous positive airway pressure may be particularly beneficial for patients who cannot participate in incentive spirometry or deep breathing exercises.

**Table 4. Strength of the Evidence for Specific Interventions To Reduce the Risk for Postoperative Pulmonary Complications**

Risk Reduction Strategy	Strength of Evidence*	Type of Complication Studied
Postoperative lung expansion modalities	A	Atelectasis, pneumonia, bronchitis, severe hypoxemia
Selective postoperative nasogastric decompression	B	Atelectasis, pneumonia, aspiration
Short-acting neuromuscular blockade	B	Atelectasis, pneumonia
Laparoscopic (vs. open) operation	C	Spirometry, atelectasis, pneumonia, overall respiratory complications
Smoking cessation	I	Postoperative ventilator support
Intraoperative neuraxial blockade	I	Pneumonia, postoperative hypoxia, respiratory failure
Postoperative epidural analgesia	I	Atelectasis, pneumonia, respiratory failure
Immunonutrition	I	Overall infectious complications, pneumonia, respiratory failure
Routine total parenteral or enteral nutrition†	D	Atelectasis, pneumonia, empyema, respiratory failure
Right-heart catheterization	D	Pneumonia

\* Definitions for categories of strength of evidence, modified from the U.S. Preventive Services Task Force categories (11). A = good evidence that the strategy reduces postoperative pulmonary complications and benefit outweighs harm; B = at least fair evidence that the strategy reduces postoperative pulmonary complications and benefit outweighs harm; C = at least fair evidence that the strategy may reduce postoperative pulmonary complications, but the balance between benefit and harm is too close to justify a general recommendation; D = at least fair evidence that the strategy does not reduce postoperative pulmonary complications or harm outweighs benefit; I = evidence of effectiveness of the strategy to reduce postoperative pulmonary complications is conflicting, of poor quality, lacking, or insufficient or the balance between benefit and harm cannot be determined.

† Evidence remains uncertain (strength of evidence I) on total parenteral or enteral nutrition for severely malnourished patients or when a protracted time of inadequate nutritional intake is anticipated.

**Key Takeaways:**

1. For patients who had abdominal surgery, any type of intervention to prevent or treat PPCs is better than nothing.
2. The only therapy that received an “A” in strength of evidence in the manuscripts included was postoperative lung expansion.

Restrepo, R. & Braverman, J. (2015) Current challenges in the recognition, prevention, and treatment of perioperative pulmonary atelectasis

Expert Review of Respiratory Medicine, 9:1, 97-107, DOI: 10.1586/17476348.2015.996134

**a. Method:**

- Expert review to describe the most common challenges encountered in the recognition, prevention and management of perioperative atelectasis and the role it plays as a cause of post-operative pulmonary complications.

**b. N =**

- Not applicable

**c. Results:**

- not applicable

**d. Conclusion on Lung Expansion Therapy**

- Lawrence et al. evaluated qualifying RCTs that focused upon strategies to reduce atelectasis, pneumonia, and respiratory failure after non-cardiothoracic surgery.
- Their team then synthesized outcomes data and ranked the 'strength of evidence' on a graduated scale. Among the modalities evaluated, lung expansion techniques only received 'A' level grade.
- Data did not permit preference of one technique over another and led only to the conclusion that all lung expansion therapies reduced PPCs by >50% compared with no treatment and that any treatment was superior to no treatment.
- The Lawrence reviews currently serve as the basis for the most recent practice guideline by the American College of Physicians.

Key Takeaways:

3. Lung expansion therapy reduced PPCs by > 50% compared to no treatment.

4. These data are the basis of the most recent practice guidelines by the American College of Physicians.

**a. Method: retrospective analysis and prospective comparison**

- In stage I, CPT and ICD codes were queried for patients (n = 210) undergoing thoracic, upper abdominal, or aortic open procedures at 3 institutions from December 2014 to April 2016. Patients were selected randomly. Age, comorbidities, American Society of Anesthesiologists physical status classification scores, and PPC rates were determined.
- In stage II, 209 subjects were enrolled prospectively from October 2016 to July 2017 using the same criteria. Stage II subjects received OLE treatment and standard respiratory care. The PPCs rate (prolonged ventilation, high-level respiratory support, pneumonia, ICU readmission) were compared. We also compared ICU length of stay (LOS), hospital LOS, and mortality.

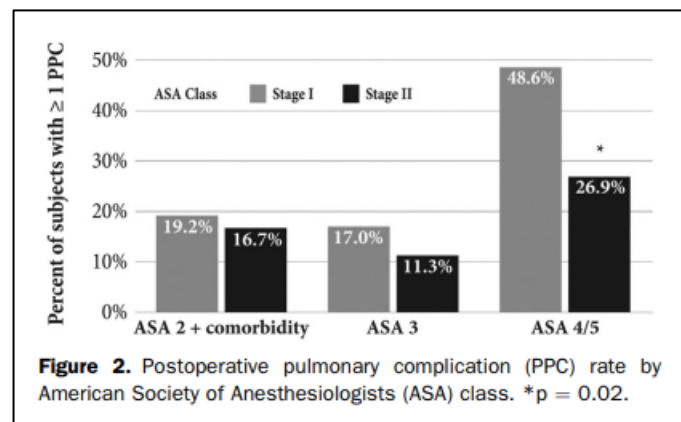
**b. N = 419**

**c. Results:**

- Treatment with OLE decreased PPCs from 22.9% to 15.8% (p < 0.01 adjusted for age, American Society of Anesthesiologists score, and operation time).
- Similarly, OLE treatment reduced ventilator time (23.7 +/- 107.5 hours to 8.5 +/-27.5 hours; p < 0.05) and hospital LOS (8.4 +/- 7.9 days to 6.8 +/- 5.0 days; p < 0.05).
- No differences in ICU LOS, pneumonia, or mortality were observed.

**d. Conclusion:**

- Aggressive treatment with OLE reduces PPCs and resource use in high-risk surgical patients.



Key Takeaways:

5. Treatment with OLE reduced relative risk of PPCs by 31%.
6. Treatment with OLE reduced ventilator time by 64%.
7. Treatment with OLE reduced hospital LOS by 19%.

Nyland, B., et al. A Preventative Respiratory Protocol to Identify Trauma Subjects at Risk for Respiratory Compromise on a General In-Patient Ward.

*Respiratory Care* 61.12 (2016): 1580-1587. <http://rc.rcjournal.com/content/61/12/1580>

**a. Method: prospective**

- Trauma patients received a respiratory therapy evaluation at the time of admission to a general in-patient ward at a Level 1 trauma center. If subjects met protocol inclusion criteria, they received prophylactic respiratory treatments, primarily MetaNeb therapy, Vest therapy, or EzPAP. Multiple phases were included to evaluate the effectiveness of the protocol, with 50 subjects in each phase: a pre-protocol phase before adoption of the protocol; phase 1, which was found to have low physician adherence and overly broad inclusion criteria; and phase 2, with improved adherence and narrower inclusion criteria.

**b. N = 150**

**c. Results:**

- The respiratory protocol was associated with the elimination of unplanned admissions to the ICU.
- After controlling for injury severity and other important clinical factors, receiving the protocol significantly decreased hospital stay by approximately 1.5 days.
- More subjects were admitted from the emergency department directly to the ward, avoiding the ICU.
- Bronchodilator use also decreased, although the result did not reach statistical significance.

**d. Conclusion:**

- Study results suggest that a preventive respiratory protocol had a beneficial effect on patient outcomes; receiving the protocol reduced hospital days and eliminated unplanned admission to the ICU.

Key Takeaways:

- Treatment with OLE eliminated unplanned admissions to the ICU.
- Treatment with OLE decreased hospital stay by ~1.5 days.

**a. Method:**

- prospective comparison of the aerosol medication delivery efficiency on 2 different OLE technologies: BiWaze Clear and Volara
- A filter was attached between the tracheal outlet and the lung model to capture inhaled aerosol at the distal trachea and quantify the inhaled lung dose.
- A nonabsorbable radiopharmaceutical particulate, was mixed with 2.5 ml normal saline and nebulized as a radioaerosol tracer and surrogate for inhaled medication.
- The deposited aerosols were quantified on these regions of interest:
  - System components (bacterial/viral filter, breathing circuit, nebulizer, handset, mouthpiece)
  - Nasopharyngeal and tracheal airways
  - Lung (filter)
  - Plethysmograph and filter (fugitive aerosol)

**b. N = 1**

- Spontaneous breathing adult lung model

**c. Results:**

- BiWaze Clear showed a 5-fold greater lung filter deposition with PEP and a 3-fold greater lung deposition with OSC therapy compared to Volara.
- The residual nebulizer losses were high (>50%) with the Volara and low with BiWaze Clear at (<7%) for PEP and OSC therapy.
- Volara had about 1/3 of the nebulizer dose dispersed through the handset's expiratory leak valve as fugitive aerosols

**d. Conclusion:**

- Study found that BiWaze Clear's aerosol efficiency was superior to Volara.
- Study findings indicate that BiWaze Clear provides high efficiency medication delivery, which increases the total dose of inhaled pulmonary aerosols.

Key Takeaways:

- BiWaze Clear showed a 5-fold greater lung filter deposition with PEP and a 3-fold greater lung deposition with OSC therapy compared to Volara.
- The residual nebulizer losses were high (>50%) with the Volara and low with BiWaze Clear at (<7%) for PEP and OSC therapy.

**a. Method:**

- Randomized crossover study
- Patients underwent on consecutive days IPV and chest physical therapy.
- Before each session, immediately after the session, 30 min after the session, and 4 hours after the session we measured SpO<sub>2</sub>, heart rate, respiratory rate, and (with a visual analog scale) the patient's subjective sensation of phlegm encumbrance and dyspnea.
- Immediately after each treatment session we also measured (via visual analog scale) the patient's discomfort.
- We also measured the volume and wet and dry weight of collected sputum.

**b. N = 22**

**c. Results:**

- No adverse effects were so severe as to require discontinuation of treatment, and the incidence of adverse effects was similar in the groups (27%).
- Heart rate ( $P = .002$ ) and respiratory rate ( $P = .047$ ) decreased during treatment, and sensation of phlegm encumbrance improved ( $P = .03$ ) with both treatments.
- Only IPV improved ( $P = .004$ ) the sensation of dyspnea.
- The patients found IPV more comfortable than our traditional standard chest physical therapy ( $P = .03$ ).
- Both treatments caused important phlegm production, but there were no differences in sputum volume, wet weight, or dry weight.

**d. Conclusion:**

- In patients with bronchiectasis and productive cough, short-term IPV was as safe and effective as traditional chest physical therapy, with less discomfort.

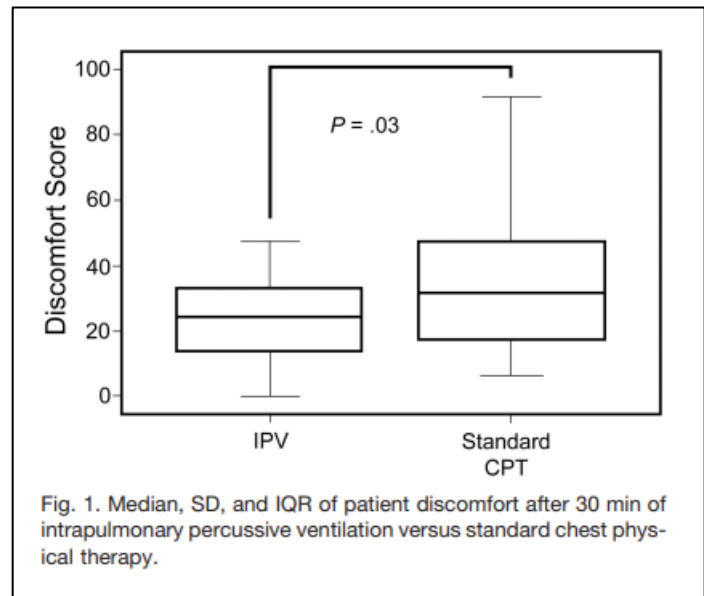


Fig. 1. Median, SD, and IQR of patient discomfort after 30 min of intrapulmonary percussive ventilation versus standard chest physical therapy.

**Key Takeaways:**

- Comparing IPV with chest physical therapy, only treatment with IPV improved symptoms of dyspnea.
- Patients found IPV more comfortable than chest physical therapy.

Toussaint M, De Win H, Steens M, Soudon P. Effect of intrapulmonary percussive ventilation on mucus clearance in Duchenne Muscular Dystrophy patients: a preliminary report.

*Respir Care*. 2003 Oct; 48(10):940-7.

**a. Method:**

- Crossover study with each patient serving as his or her own control
- Duchenne Muscular Dystrophy patients who had advanced stage illness and required mechanical ventilation.
- All patients had cuffless tracheotomy tubes that allowed suctioning
- The study aimed to compare two different assisted-mucus clearance techniques (AMCT) and nebulizer-saline treatment sequences: one with and one without IPV during nebulization.
- Patients received 15 treatments alternating with and without IPV, the first treatment type was chosen at random.
- Suction was conducted and secretions were weighed

**b. N = 8**

**c. Results:**

- All patients reported no adverse events and tolerated the therapies well
- 5 subjects were hypersecretive and 3 were non-hypersecretive
- Among the hypersecretive patients there was a significant difference between IPV+ and IPV-.
- The mean and SD weight of collected secretions was 6.53 +/- 4.77 g with IPV+ vs. 4.57 +/- 3.50 g with IPV- (p = 0.01)

- Among the nonhypersecretive patients there was no significant difference between IPV+ and IPV-

**d. Conclusion:**

- Study suggests that IPV is a safe mode of treatment for tracheotomized Duchenne muscular dystrophy patients.
- IPV seems to improve the efficacy of an aerosol therapy combined with ACMT, by enhancing mucus transport from the peripheral respiratory tract

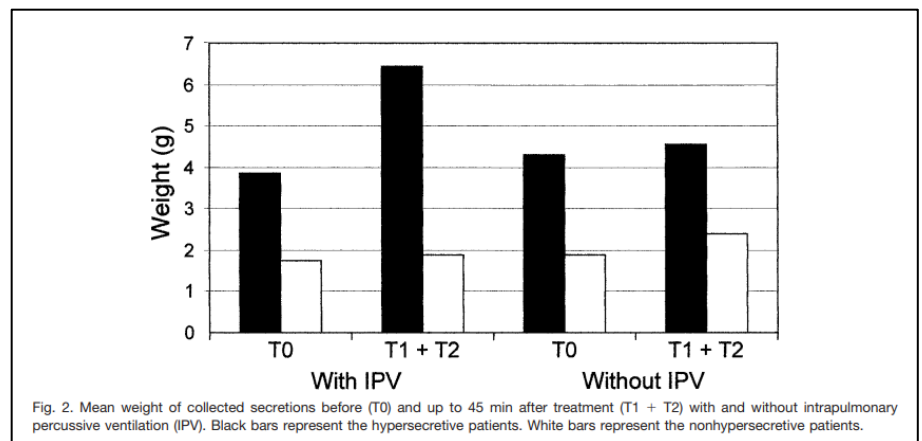


Fig. 2. Mean weight of collected secretions before (T0) and up to 45 min after treatment (T1 + T2) with and without intrapulmonary percussive ventilation (IPV). Black bars represent the hypersecretive patients. White bars represent the nonhypersecretive patients.

Key Takeaways:

- IPV was safe and well tolerated by patients with tracheotomized Duchenne muscular dystrophy
- IPV improved efficacy of nebulizer combined with assisted mucus clearing treatment

Morgan, S., et al. Continuous High-Frequency Oscillation Therapy in Invasively Ventilated Pediatric Subjects in the Critical Care Setting.

*Respiratory Care* 61.11 (2016): 1451-1455. DOI: [10.4187/respcare.04368](https://doi.org/10.4187/respcare.04368)

**a. Method:**

- Retrospective chart review of mechanically ventilated patients treated with continuous high frequency oscillation (CHFO) from July 1, 2007 to August 31, 2012.
- We evaluated changes in ventilator settings in subjects with ventilator data documented within 6 h pre- and post-treatment.
- We evaluated arterial blood gas (ABG) results for individual treatments, comparing ABG results within 8 h pre-therapy to ABG results within 3 h post-treatment.
- Oxygen index and  $P_{aO_2}/F_{IO_2}$  were calculated.
- Demographic data, blood pressure, heart rate, and development of new air leak while being treated with CHFO were recorded.
- Pre- and post-CHFO measurements were compared using Wilcoxon signed-rank testing.

**b. N = 59**

**c. Results:**

- We evaluated data on 528 total treatments (range per subject 1–39 treatments).
- Peak inspiratory pressure significantly decreased with CHFO, whereas other parameters, including  $PaCO_2$  and breathing frequency, remained stable.
- There was no significant change in systolic blood pressure, diastolic blood pressure, or heart rate following treatment with CHFO.
- One subject (2%) developed a clinically insignificant pneumothorax during CHFO.

**d. Conclusion:**

- CHFO is feasible and seems safe in our cohort of mechanically ventilated pediatric subjects. The rate of pneumothorax was consistent with that seen in similar pediatric ICU populations. These preliminary results suggest that CHFO may be beneficial by improving lung compliance in pediatric subjects with secretion-induced atelectasis. Prospective clinical studies are needed to further evaluate the clinical efficacy and safety of CHFO in children receiving invasive mechanical ventilation.

Key Takeaways:

- CHFO is feasible and seems safe in our cohort of mechanically ventilated pediatric subjects. The rate of pneumothorax was consistent with that seen in similar pediatric ICU populations.
- Results suggest that CHFO may be beneficial by improving lung compliance in pediatric subjects with secretion-induced atelectasis.

Deakins K., et al. A comparison of intrapulmonary percussive ventilation and conventional chest physiotherapy for the treatment of atelectasis in the pediatric patient.

Respiratory Care. 2002 Oct;47(10):1162-1167. [PMID: 12354335](#).

**a. Method:**

- First, a retrospective analysis of patients who received intrapulmonary percussive ventilation (IPV) therapy.
- Medicated aerosol therapy with albuterol 2.5 mg in 6 mL normal saline solution was delivered with each IPV treatment.
- Baseline and subsequent chest radiographs were evaluated by a pediatric radiologist.
- Then, we conducted a prospective, randomized, controlled study of intubated and mechanically ventilated patients to compare changes in atelectasis and static compliance.
- Baseline and daily chest radiographs were evaluated using the same scoring system as in the retrospective pilot evaluation.
- Patients were randomized to chest physical therapy (CPT) clapping and vibration or IPV with 6 mL of normal saline solution via medicated aerosol.
- Both treatments were given every 4 h and lasted 10-15 min.
- Static compliance measurements were calculated from exhaled tidal volumes and plateau pressures.

**b. N = 46**

**c. Results:**

- In the retrospective study, the median duration of IPV was 6.2 days. A change in atelectasis score from 3 to 1 ( $p < 0.001$ ) was seen.
- In the randomized, controlled trial the atelectasis scores before treatment were comparable between the CPT and IPV groups.
- Atelectasis scores after treatment were unchanged in the CPT group but improved in the IPV group. Treatment lasted an average of 6.2 days in the CPT group and 2.1 days in the IPV group ( $p = 0.018$ ). Neither group showed any change in static compliance following treatment.

**d. Conclusion:**

- In the retrospective study a clinically important improvement in atelectasis was seen in patients who received IPV therapy. In the controlled, clinical trial the IPV group showed more clinically important improvement in atelectasis than the CPT group. IPV is a safe and effective method of alternative airway clearance and can be used on patients with artificial airways.

Key Takeaways:

- A clinically important improvement in atelectasis was seen in patients who received IPV therapy.
- The IPV group showed more clinically important improvement in atelectasis than the CPT group.
- IPV is a safe and effective method of alternative airway clearance and can be used on patients with artificial airways.

## Case Studies

Loving, TM, Sweet M. Case Study: The use of continuous high frequency oscillation to reverse atelectasis post-abdominal aortic aneurysm repair surgery.

Resp Therapy 2016, 11(4): 70.

- 75 year old male underwent abdominal aortic aneurysm surgery and developed lung complications 2 days post-op
- Comorbidities include Type 2 diabetes, obstructive sleep apnea, chronic kidney disease, hypertension, and previous AAA repair
- On Post-op Day 2, developed acute renal failure and on Day 6 worsening respiratory status with nocturnal desaturation
- Day 6 Chest X-ray (CXR) at 2030 revealed a large collapse of the left lung with volume loss and leftward mediastinal shift, consistent with atelectasis and likely secondary to mucous plugging.
- Treated with MetaNeb Therapy via in-line ventilator circuit using 0.9% normal saline for 10 minutes x 3 treatments at 2100, 2200, and 2300.
- Day 6 CXR at 2345 showed markedly improved aeration of the left lung and complete resolution of the collapse, only 3 hours after the initiation of MetaNeb Therapy.
- By Day 7, ventilator settings were weaned to pressure support mode; Patient was saturating well and hemodynamic ally stable on Levophed



Figure 1. Post-Op Day 6 CXR at 2030, Pre-MetaNeb Therapy.



Figure 2. Post-Op Day 6 CXR at 2345, Post-MetaNeb Therapy (3 treatments).

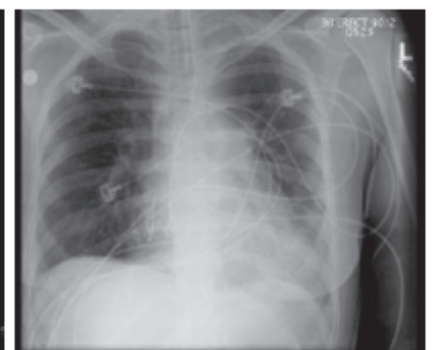
Grooms D, Swedish S, Price S. Case Series: Use of continuous high frequency oscillation (CHFO) in respiratory failure and post-operative patients.

[Resp Therapy 2017; 12\(2\): 14-16.](#)

- Case 1: 21-year-old female patient admitted in acute Respiratory Failure requiring mechanical ventilation
- Mechanical ventilation settings had been maximized and assessment was that atelectasis resultant from mucus plugging was causing physiologic deadspace
- OLE treatment was initiated to mobilize secretions



Pre-MetaNeb Treatment



18 Hours Post-MetaNeb Treatment

- Chest x-ray showed improvement along with improved gas exchange and breath sounds, so OLE was continued until the patient was extubated and later discharged
- Radiologic improvement demonstrated with OLE when other therapies had failed

- Case 2: 57-year old male presented to ER with cardiac arrest and respiratory failure requiring mechanical ventilation.
- Chest x-ray showed subsegmental atelectasis in right middle lobe, so MetaNeb therapy was initiated in line with mechanical ventilation to facilitate airway clearance of suspected retained secretions.
- 5 treatments with bronchodilators were administered and another chest x-ray was taken. This showed resolution of the right middle lobe atelectasis.



**Pre-MetaNeb Day 1 at 0352**



**Post-MetaNeb Day 2 at 0259 (5 treatments)**

- Conclusion is that in this case introducing MetaNeb in line with mechanical ventilation was the variable that produced positive results in the pulmonary system with an increase in P/F ratio, decrease in FiO2, improvement in CXR and atelectasis resolution in right middle lobe.

- Case 3: 46-year old male presented to ER with chest pain and shortness of breath.
- Admitted for myocardial infarction and cardiac catheterization revealed need for CABG, which was performed 3 days later.
- Patient returned from OR intubated and on a ventilator, which was removed 4 hours later. Assessment of lung capacity revealed inability to hold breath and weak cough. MetaNeb treatment was initiated to help resolve post-operative atelectasis.
- Patient returned to OR due to a leak on one of the grafts and was ventilated once again. Post extubation CXR revealed bibasilar atelectasis with low lung volumes.
- Post-extubation MetaNeb treatment was re-initiated and continued for several days, during which the need for supplemental FiO2 decreased. CXR after several days of treatment revealed improvement in atelectasis.
- Conclusion: this patient underwent extensive chest/heart surgery and developed significant atelectasis as a result of the two heart surgeries. The low lung volumes were effectively treated with CHFO.



**Post-extubation atelectasis on Day 2 at 0323**



**Post-MetaNeb Treatment Day 4 at 1418 (5 MetaNeb Treatments)**

Landon, Chris. "1941: Continuous high-frequency oscillation treatment rescue in severe cystic fibrosis. [Critical Care Medicine 44.12 \(2016\): 560.](#)

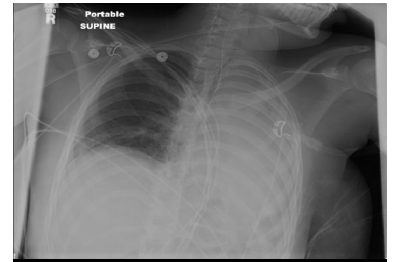
- 13-year-old patient with severe cystic fibrosis
- Increased cough and dyspnea, change in sputum, crackles on exam, >10% decrease in O2 sat
- Patient refused vest therapy and only tolerated limited CPT and EZPAP
- He tolerated OLE therapy, 7 treatments per day via mouthpiece
- ABG improved, decrease in O2 required, eventually discharged
- OLE provides an effective alternative to CPT or vest therapy when patient has serious chest discomfort

Ortiz-Pujols S, et al. Chest high-frequency oscillatory treatment for severe atelectasis in a patient with toxic epidermal necrolysis.

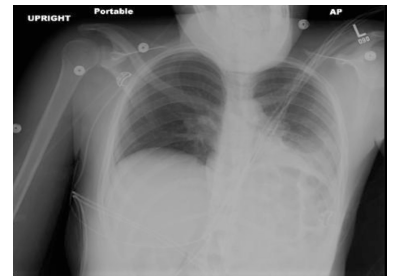
J Burn Care Res. 2013 Mar-Apr;34(2):e112-5. doi: 10.1097/BCR.0b013e318257d83e. PMID: 23377350; [PMCID: PMC3606286.](#)

- 17-year-old female patient who developed significant left-sided atelectasis after extubation
- OLE therapy initiated; 10-minute treatments every 2-3 hours
- Within 4 hours of initiating treatment, atelectasis showed improvement
- She was effectively managed with complete resolution of her atelectasis with OLE therapy
- OLE therapy prevented the need for reintubation

Before OLE:



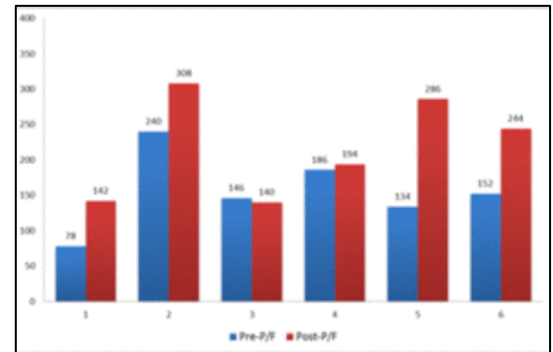
4 hrs after OLE:



Englert, W., et al. Application of High Frequency Oscillatory Therapy In-Line with Mechanical Ventilator for Secretion Removal in Burn Patients.

[American Journal of Respiratory and Critical Care Medicine](#) 2017;195:A5927

- 6 ventilator-dependent patients admitted to Burn unit with smoke inhalation injuries
- Received CHFO treatment for >48 hours in line to the ventilation circuit
- 5 of 6 patients had an increase of P/F ratio and mean P/F ratio increased from 156 to 219
- Average FiO2 requirements decreased
- All patients had a documented increase in amount of secretions after receiving therapy



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<https://abmrc.com> or call customer support: 1-877-ABMRC01 (877-226-7201)

