JUST BREATHE.

OPTIMAL VENTILATION TECHNIQUES FOR ASTHMATICS IN RESPIRATORY FAILURE

Christine B. Davis
Emergency Medicine
Henry Ford Hospital
6 March 2014
GOALS

- Analyze current research in order to learn the best methods to ventilate asthmatic patients presenting in respiratory failure with a focus on ventilator settings

- Details on pharmacological management and prevention of future episodes of severe asthma are beyond the scope of this presentation

- Details of the types and mechanics of various ventilators are beyond the scope of this presentation
ACKNOWLEDGEMENTS

Thank you to Doctors:

- Gregory Hays
- Emmanuel Rivers
- Seth Krupp
- Michael Mendez
- Daniel Ouellete

for their mentorship of this lecture
- Asthma affects **300 million people** globally
- **2 million emergency department visits** for acute asthma per year
- 12 million people reporting having had asthma “attacks” in the past year

- Accounts for **1 in every 250 deaths** worldwide
  - *many of which are preventable*
ASTHMATIC IN RESPIRATORY FAILURE

- Inability to maintain respiratory effort due to fatigue
- Declining mental status; Agitation
- Cyanosis; Profound diaphoresis
- Accessory muscle use; chest wall retractions
- Brief, fragmented speech (1-2 words)
- Inability to lie supine
- Peak expiratory flow or FEV1 < 35 - 50% of predicted
- Arterial O2 sat < 91%
- Paradoxical pulse exceeding 25 mmHG
- Rapid, shallow breathing (respiratory rate >30 breaths/minute)
- Failure of medical management (i.e. O2, bronchodilators, corticosteroids, Mg, anticholinergics, heliox, ketamine, leukotriene receptor agonists.)
ASTHMA PATHOPHYSIOLOGY

- airflow obstruction; mucus plugging
- bronchial hyper-responsiveness; bronchoconstriction
- underlying inflammation; airway edema
- Reduces work of breathing
- Decreases airway resistance
- Relieves the feeling of dyspnea
- Re-expands collapsed alveoli
- Provides rest for the muscles of respiration
NONINVASIVE POSITIVE PRESSURE VENTILATION SETTINGS

BiPap
- **Bilevel positive airway pressure**
  - **IPAP**: pressure applied during patient triggered breaths
  - **EPAP**: pressure applied in between patient triggered breaths
  - **FiO2**: fraction of O2 percentage that is added to the delivered air
  - **Vf**: respiratory rate set as a guarantee for intermittent bursts of IPAP

CPAP
- **Continuous positive airway pressure**
  - unchanged during inspiration and expiration

PSV
- **Pressure support ventilation**
  - provides a small amount of pressure during inspiration to assist the patient as they draw in a spontaneous breath
Continuous positive airway pressure (CPAP):

- bronchodilatory effect in asthma
- unload fatigued inspiratory muscles
- improve gas exchange
- prevent methacholine- and histamine-induced asthma.
- increases tidal volume

Bilevel positive airway pressure (BiPAP):

- All that a CPAP does with the added advantage of adding external positive end-expiratory pressure (PEEP) to offset the intrinsic PEEP that builds up during an asthmatic attack.
CONTRAINDICATIONS TO NIPPV

**Absolute contraindication**
- need for urgent intubation (e.g. cardiac or respiratory arrest)

**Relative contraindications**
- facial trauma or surgery
- upper airway deformity
- inability of patient to cooperate or to maintain cooperation
- copious secretions; risk for aspiration
- recent esophageal anastomosis
ADVERSE EFFECTS OF NONINVASIVE POSITIVE PRESSURE VENTILATION

° local skin trauma secondary to mask  ° eye irritation  ° gastric distension
ALTHOUGH THERE ARE NO ROBUST RANDOM CONTROL TRIALS FOR NIPPV IN ASTHMA SHOWING MORTALITY BENEFIT AS THERE ARE FOR PULMONARY EDEMA, COPD, AND IMMUNOCOMPROMISED PATIENTS; I WILL REVIEW SOME PROMISING DATA THAT SUGGEST THAT NIPPV CAN BE USEFUL ADJUNCT TO TREATMENT IN THE ED
A PILOT PROSPECTIVE, RANDOMIZED, PLACEBO-CONTROLLED TRIAL OF BILEVEL POSITIVE AIRWAY PRESSURE IN ACUTE ASTHMATIC ATTACK

Arie Soroksky; David Stav; Isaac Shpirer

- 30 patients (18 to 50 years old) with a severe asthma exacerbation, defined as:
  - respiratory rate >30 breaths per minute
  - FEV1 <60 percent of predicted when measured 30 minutes after inhaled bronchodilator therapy
- Also, with a history of asthma of at least 1 year and duration of current asthma attack of < 7 days.
- Randomly assigned to receive nasal BPAP or sham (subtherapeutic BPAP) for 3 hours in the emergency department.
BIPAP SETTINGS

- Inspiratory pressure was set at 8 cm H$_2$O then increased gradually by 2 cm H$_2$O every 15 min
  - to a maximum of 15 cm H$_2$O
  - or until a respiratory rate of < 25 breaths/min was reached
- Expiratory pressure was set at 3 cm H$_2$O then increased gradually by 1 cm H$_2$O every 15 min
  - to a maximum of 5 cm H$_2$O

- Rationale for these settings:
  - Gradual increase in both the inspiratory and expiratory pressures was aimed at increasing patient comfort and patient compliance
  - Values were set in a rather arbitrary manner, designed to provide what would be considered by most as a mild PEEP and mild-to-moderate inspiratory pressure support
RESULTS

Primary endpoint:
- BiPAP increased the likelihood of a significant improvement in FEV1
  - 80% vs. 20% (p < 0.004)

Secondary endpoint:
- BiPAP reduced the rate of hospitalization
  - 18% vs. 63% (p = 0.0134)
  - Hospitalization was required for:
    - 3 of 17 patients (17.6%) in the BPV group
    - 10 of 16 patients (62.5%) in the control group

Conclusion:

In selected patients with a severe asthma attack, the addition of BiPAP to conventional treatment can improve lung function, alleviate the attack faster, and significantly reduce the need for hospitalization.
In 21 patients with acute asthma, the effects were studied of nasal continuous positive airway pressure (CPAP) on:

- expiratory flow
- arterial blood gas tensions
- cardiovascular status
- dyspnea
CPAP SETTINGS

- CPAP sequence:
  - 30 minutes at 5 cm H2O
  - 20 minutes at 0 cm H2O
  - 30 minutes at 7.5 cm H2O
  - 20 minutes at 0 cm H2O
  - Six control patients were fitted with a CPAP mask but given no positive-pressure therapy
RESULTS

- Significant reductions in respiratory rate occurred from a baseline of 22.0 +/- 1.0:
  - 19.8 +/- 3.8 breaths/min at CPAP 5 cm H2O
  - 19.4 +/- 4.3 breaths/min at CPAP 7.5 cm H2O (P < .05)
- No significant change occurred in FEV1, heart rate, MAP, or ABG tension with either level of CPAP.
- Dyspnea, as assessed by a breathlessness score, improved during CPAP therapy (P < .05)
  - In comparison, the control group showed no change in heart rate, respiratory rate, or breathlessness score during the study period.

Conclusion:

These data show that application of CPAP in acute asthma reduces respiratory rate and dyspnea.
Seven-year period retrospective observational study. 58 patients were included in the study.

25 patients (43%) were not eligible for NIMV:
- 11 patients (19%) because of respiratory arrest on their arrival at the Emergency Room
- 14 patients (24%) because of improvement with medical management.

The remaining 33 patients were eligible for NIMV (57%):
- 11 patients (33%) received invasive MV
- 22 patients (67%) were treated with NIMV
  - 3 NIMV patients (14%) needed ETI
Pressure support ventilation (PSV)

- Trigger sensitivity adjusted to 0.5 cm H2O
- PSV was titrated to achieve a minimum expired tidal volume of 400 mL
- Then increased by steps of 3 cm H2O to improve patient’s breathing pattern or ABG
- Positive end expiratory pressure (PEEP) applied until a substantial improvement in the effort required to trigger the ventilator was noted

Continuous positive airway pressure (CPAP)

- Oxygen levels adjusted to maintain O2 >90%
- Fixed CPAP values of:
  - 5 cmH2O; or
  - 7.5 cmH2O
RESULTS

- Significant differences were observed in arterial blood gases on admission to the Emergency Room between MV and NIMV:
  - $\text{PaCO}_2$ (89±29 mmHg vs 53±13 mmHg, $p<0.05$),
  - pH (7.05±0.21 vs 7.28±0.008, $p<0.05$)
  - $\text{HCO}_3^-$ level (22±5 mmol/l vs 26±6 mmol/l, $p<0.05$).
- No differences were found in the median length of ICU stay (4.5 vs 3 days), median hospital stay (15 vs 12 days) and mortality (0 vs 4%).

**Conclusion:**

*Face mask NIMV appears to be a suitable method for improving alveolar ventilation and can reduce the need for intubation in a selected group of patients with SA.*
17 episodes of asthma and ARF over a 3-year period in the ICU.

Mean age was 35.4±11.3 years; 10 patients were female.

**Initiation of NIPPV:**
- pH was 7.25±0.01
- PaCO$_2$ was 65±2
- PaO$_2$ fraction of inspired oxygen was 315±41
- Respiratory rate was 29.1±1

**less than 2 hours:**
- pH was 7.32±0.02 (p=0.0012)
- PaCO$_2$ was 45±3 (p<0.0001)
- PaO$_2$ 403±47
- Respiratory rate was 22±1 (p<0.0001)

**2 to 6 hours:**
- pH was 7.36±0.02 (p<0.0001)
- PaCO$_2$ 52±3 (p=0.002)
- PaO$_2$ 367±47
- Respiratory rate was 20±1

**12 to 24 hours:**
- pH was 7.38±0.02
- PaCO$_2$ 45±4
- PaO$_2$ 472±67 (p=0.06)
- Respiratory rate was 7±1
Initial ventilatory settings included CPAP at 4 +/- 2 cm H2O to offset intrinsic positive end-expiratory pressure.

Pressure support ventilation (PSV) at 14 +/- 5 cm H2O aiming at a respiratory rate less than 25 breaths/min and an exhaled tidal volume of 7 mL/kg or more.

PSV was then adjusted following arterial blood gas results.

The mean (+/- SD) peak inspiratory pressure to ventilate in the NIPPV-treated patients was 18 +/- 5 cm H2O and always less than 25 cm H2O.
CONCLUSION

In asthmatic patients with ARF, NIPPV via a face mask appears highly effective in correcting gas exchange abnormalities using a low inspiratory pressure (<25 cm H2O).
A prospective, randomized, crossover study.

20 children admitted to the PICU with acute lower airway obstruction (increased work of breathing, wheezing, dyspnea)

Randomized to receive either:

- 2 hrs of BiPAP followed by crossover to 2 hrs of standard therapy; or
- 2 hrs of standard therapy followed by 2 hrs of BiPAP
- spontaneous mode without a backup rate
- Oxygen supplementation to keep O2 >90%
- inspiratory positive airway pressure (IPAP) of 10 cm H2O
- expiratory positive airway pressure (EPAP) of 5 cm H2O
  - settings remained unchanged throughout the course of the study period
RESULTS

Primary end points:

- change in respiratory rate
- Clinical Asthma Score (CAS) – work of breathing, wheezing, dyspnea
- assessment of gas exchange

- BiPAP was associated with a decrease in respiratory rate (49.5 ± 13.9 vs. 32.0 ± 6.2 breaths/min, p < .0001) for all patients after 2 hrs compared with baseline

- BiPAP was associated with a lower total CAS (5.4 ± 1.2 vs. 2.1 ± 1.0, p < .0001) and lower scores for each individual component (accessory muscle use, wheeze, and dyspnea; all p < .01)
discontinuation of BiPAP in **Group 1** at the 2-hr crossover time point was associated with an increase in both respiratory rate and total CAS by the 4-hr data collection time point

**Group 2** did not improve after 2 hrs of standard therapy but showed improvement in respiratory rate and total CAS after 2 hrs of BiPAP
BiPAP in children with acute lower airway obstruction can be well tolerated and may be effective in improving clinical measures of respiratory distress.
KEY POINTS

- Asthmatic patients with acute respiratory failure who require mechanical ventilation may benefit from the administration of noninvasive positive pressure ventilation.

- Five randomized controlled trials in asthmatic adults and one in children have been identified to evaluate the efficacy of noninvasive positive pressure ventilation in acute respiratory failure, suggesting overall that treatment is well tolerated with few adverse events.

- There is limited evidence to support the efficacy of noninvasive positive pressure ventilation over other treatments in asthmatic patients, highlighting the need for methodologically rigorous clinical evaluations and research in this area.
Andreas Vesalius (31 December 1514 – 15 October 1564)
- first person to describe mechanical ventilation
- De humani corporis fabrica (On the fabric of the human body)
MECHANICAL VENTILATION

- Associated with significant morbidity and mortality
  - increased airway resistance, airway injury, barotrauma, hemodynamic instability, nosocomial pneumonia, increased length of hospital stay (which can lead to DVT, PE, myopathies, malnutrition and infections)

- Last resort –
  - when medical management has failed; and noninvasive ventilation is contraindicated or has failed
  - mortality rate of only 8%
    - but 27% to 45% of patients requiring mechanical ventilatory support experience serious complications
INDICATIONS FOR INTUBATION

- Cardiac arrest
- Respiratory arrest
- Altered mental status
- Progressive exhaustion
- Silent chest
- Severe hypoxia with maximal oxygen delivery
- Failure to reverse severe respiratory acidosis despite intensive therapy
- pH < 7.2
- PCO2 increasing by more than 5 mm Hg/h or greater than 55 to 70 mm Hg
- PO2 of less than 60 mm Hg
MECHANICAL VENTILATION

Assist Control Ventilation (AC)
- When patient triggers spontaneous breath, it will force in either the pressure or volume set, will stack breaths

Synchronized Intermittent Mandatory Ventilation (SIMV)
- When patient triggers spontaneous breath, the pressure or volume will be determined by the patient, it will not stack breaths
**Volume control**

When the ventilator detects the set volume having been applied, the ventilator cycles to exhalation.

- Airway pressure increases in response to reduced compliance, increased resistance, or active exhalation and may increase the risk of ventilator-induced lung injury

**Pressure Control**

Limits the maximum airway pressure delivered to the lung

- May be difficult to attain adequate tidal volumes against high airway resistance
Air Trapping

Flow (L/min)

Inspiration

Expiration

Time (sec)

Air Trapping Auto-PEEP

Normal

Patient
TROUBLESHOOTING

- Check plateau pressures by allowing for an inspiratory pause
- If peak pressures are high and plateau pressures are low then you have an **obstruction**
- If both peak pressures and plateau pressures are high then you have a **lung compliance issue**

<table>
<thead>
<tr>
<th>High Peak Pressures</th>
<th>Low Plateau Pressures</th>
<th>High Peak Pressures</th>
<th>High Plateau Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mucus Plug</td>
<td>ARDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronchospasm</td>
<td>Pulmonary Edema</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET tube blockage</td>
<td>Pneumothorax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biting</td>
<td>ET tube migration to a single bronchus</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effusion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Poor oxygenation in asthmatic patient

<table>
<thead>
<tr>
<th>Decrease respiratory rate</th>
<th>Decrease tidal volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust flow rate for quicker inspiratory rate</td>
<td>Increase sedation</td>
</tr>
<tr>
<td>Adjust I:R ratio</td>
<td>Paralysis</td>
</tr>
</tbody>
</table>
ALTHOUGH MECHANICAL VENTILATION IS USED COMMONLY FOR ASTHMATICS, THERE IS A PAUCITY OF DATA ON THE BEST SETTINGS AND MODES OF VENTILATION. THE RECOMMENDATIONS FOR SETTINGS COME FROM A FEW SMALL TRIALS AND RECOMMENDATIONS BASED ON THEORY AND CLINICAL EXPERIENCE.
Severe bronchial asthma requiring ventilation. A review of 20 cases and advice on management

- Natural history of 20 asthmatics who required mechanical ventilation
- Seven of these patients died (‘steady decline on the vent,’ 2 pneumothoraces, etc.)
- 14 were male and 6 were female; Age range was 5-64 years
VENTILATION RECOMMENDATIONS

Webb AK; et al. Postgraduate Medical Journal (March 1979) 55, 16i-170.

- “The ventilator chosen must be capable of delivering an adequate volume against a high resistance into a comparatively non-compliant thorax.”
- “A variable I:E ratio is a great advantage…The expiratory time should be sufficiently long…if the inspiratory phase begins prior (to the end of expiration), further air trapping may occur.”
- “The authors used low volumes with slow respiratory rates.”
THE EFFECTS OF VENTILATORY PATTERN ON HYPERINFLATION, AIRWAY PRESSURES, AND CIRCULATION IN MECHANICAL VENTILATION OF PATIENTS WITH SEVERE AIR-FLOW OBSTRUCTION.


- 9 patients with severe air-flow obstruction (5 asthma, 4 chronic air-flow obstruction) requiring mechanical ventilation were studied while sedated and therapeutically paralyzed.

- Pulmonary hyperinflation during steady-state ventilation was quantified by measuring total exhaled volume during 20- to 40-s apnea (end-inspiratory lung volume, VEI).
- 3 levels of minute ventilation (10, 16, and 26 L/min)
- And at each minute ventilation, 3 levels of tidal volume (VT) (0.6, 1.0, and 1.6 L)
- 3 levels of inspiratory flow (VI) (40, 70, and 100 L/min for VT = 1.0 L)
CONCLUSION

- There were progressive increases in end-expiratory lung volume:
  - when tidal volume was increased
  - or when expiratory time (TE) was decreased
    - either by an increase in rate (and hence minute ventilation) or by a decrease in inspiratory flow (at a constant minute ventilation)
- Reaching lung volumes as high as 3.6 +/- 0.4 L above functional residual capacity
PressurE-controLled venTiLAtion in chIldren with severe status asthmaticus

- Retrospective review at DMC Children’s Hospital PICU of all patients who received mechanical ventilation for status asthmaticus
- Pressure-controlled ventilation was used for 40 patients admitted for 51 episodes of severe status asthmaticus
- Pressure control
- Rate
- Inspiratory and expiratory time

- All titrated based on *blood gas values*, *flow waveform*, and *exhaled tidal volume*
RESULTS

**Before**
- Median pH: 7.21 (range, 6.65–7.39)
- Median Pco2: 65 torr (29–264 torr)

**4 hours after**
- Median pH increased to 7.31 (6.98–7.45, p < .005)
- Median Pco2 decreased to 41 torr (21–118 torr, p < .005)

- Median duration of mechanical ventilation was 29 hrs (4–107 hrs)
- ICU stay was 56 hrs (17–183 hrs)
- Total hospitalization was 5 days (2–20 days)
CONCLUSION

Pressure-controlled ventilation is an effective ventilatory strategy in severe status asthmaticus in children.
Recommended Settings

- Pressure or volume control ventilation per individual or institutional preference and patient characteristics
- Avoid air-trapping
- Inspiratory time: 0.8–1.2 s (high flow, constant rather than descending-ramp flow)
- Frequency: 10–15 breaths/min
- Tidal volume: 6–8 mL/kg
- Plateau pressure < 30 cm H2O
- PEEP: 0 cm H2O
- FIO2 adequate to provide SpO2 88–92%
INTUBATION AND MECHANICAL VENTILATION OF THE ASTHMATIC PATIENT IN RESPIRATORY FAILURE

Control of hyperinflation and auto-PEEP

- Reduction of respiratory rate
- Reduction of tidal volume
- An initial set-up of 80 L/min with a decelerating waveform configuration might be appropriate in adults.
- Shortening of inspiration with a square wave pattern and an inspiratory flow rate of 60 L/min allows greater time for exhalation in each respiratory cycle and might help control hyperinflation.
- Auto-PEEP and Plateau pressure should be followed during mechanical ventilation.

Hypercapnia is preferable to hyperinflation

- Hypercapnia should **not** be used in the presence of increased intracranial pressure
- An acceptable level of hypercapnia and acidosis is a **pH as low as 7.15 and a Paco2 of up to 80 mm Hg**

CLINICAL REVIEW: MECHANICAL VENTILATION IN SEVERE ASTHMA

- Low tidal volumes and respiratory rate

- Prolong expiratory time as much as possible

- Shorten inspiratory time as much as possible

- Monitor for the development of dynamic hyperinflation (auto-PEEP, peak plateau pressure)

Goal:
- pH above 7.2
- Plateau pressure under 30 cmH2O

**Pressure control mode**
- setting the pressure to achieve a tidal volume of 6–8 ml/kg
- respiratory rate of 11–14 breaths/min
- PEEP at 0–5 cmH2O
INVASIVE MECHANICAL VENTILATION IN ADULTS WITH ACUTE EXACERBATIONS OF ASTHMA

Carlos A Camargo. UpToDate. Literature review current through: Jan 2014.

- Increasing the inspiratory flow:
  - shortens inspiratory time
  - increases expiratory time
  - allows more time to exhale

- Decreasing the tidal volume:
  - less lung inflation
  - smaller volume to exhale before the next breath

- Decreasing the respiratory rate:
  - increases the expiratory time
- **Respiratory rate** 10 to 14 breaths/min
- **Tidal volume** less than 8 mL/kg
- **Minute ventilation** less than 115 mL/kg
- **Inspiratory flow** of 80 to 100 L/min
- Extrinsic positive end-expiratory pressure (extrinsic PEEP) less than 80 percent of the intrinsic PEEP
Avoiding hyperinflation and associated complications

- Low tidal volumes
- Low respiratory rates
- Short inspiratory times
- Long expiratory times
- PEEP increases lung volumes and aggravates hyperinflation and circulatory compromise
  - Use PEEP cautiously and to ensure vigilant monitoring to determine the effect
Consensus is that invasive mechanical ventilation should be avoided if noninvasive ventilation is an option.

BiPap preferred over CPAP as it can reduce the pressure during exhalation.

Recommended initial settings:
- IPAP 8 - 10
- EPAP 3 - 5
- Titrate for correction of pH, O2 saturation, tachypnea
SUMMARY – INVASIVE MECHANICAL VENTILATION

- Last resort
- Pressure control allows for control of pressure but may not allow for adequate tidal volumes
- Recommended initial settings:
  - No PEEP
  - FiO2 for sat > 88 - 92%
  - Tidal volume 6-8 ml/kg
  - Keep plateau pressure < 30 mmHG
  - pH > 7.2; PCO2 < 80
  - Respiratory rate 10 – 14
  - Inspiratory flow rate 60 – 100 L/min
  - Minute ventilation < 115 mL/kg (volume/min)
REFERENCES


Burns SM. Ventilating patients with acute severe asthma: what do we really know? AACN Adv Crit Care. 2006 Apr-Jun;17(2):186-93


Peter Shearer, MD, Andy Jagoda, MD. Emergency airway management in acute severe asthma. UpToDate. Literature review current through: Jan 2014. | This topic last updated: Jan 30, 2014.

Carlos A Camargo, Jr, MD, DrPH. Jerry A Krishnan, MD, PhD. Invasive mechanical ventilation in adults with acute exacerbations of asthma. UpToDate. Literature review current through: Jan 2014. | This topic last updated: Oct 15, 2013.


the end.