NONINVASIVE VENTILATOR TECHNIQUES

HOSPITAL MEDICINE UPDATE

OVERVIEW

- Review of Basics
- Definition
- Goals of NIV
- Types
- Advantages and Disadvantages
- Indications and Contraindications
- Interface
- Modes of NIV
- Guidelines for Initiation and Termination
- Complications
- Evidence for use
- Conclusion

REVIEW OF BASICS

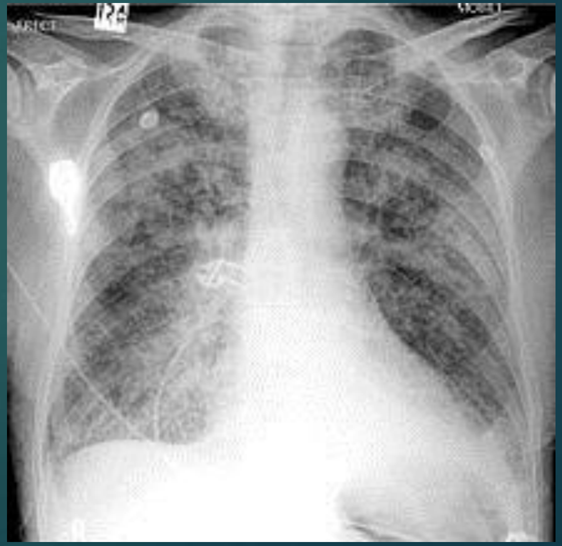
- Respiratory failure is a syndrome where the respiratory system fails in one or both of its gas exchange functions:
  - Oxygen uptake
  - Carbon dioxide elimination
- Respiratory failure may be acute, chronic, or acute on chronic
- Derangements in ABG and acid-base status
  - Acute – life threatening
  - Chronic – less dramatic
- Hypoxemia and/or hypercapnea
  - Type 1 – Hypoxemia, PaO2 <60 mmHg, normal or low PaCO2
  - Type 2 – Hypoxemia and hypercapnea

CAUSES OF RESPIRATORY FAILURE

- Alveolar filling processes
- Pulmonary vascular disease
- Diseases causing airways obstruction (central or distal)
- Hypoventilation: decreased central drive
- Hypoventilation: peripheral nervous system/respiratory muscle dysfunction
- Hypoventilation: chest wall and pleural disease
- Increased ventilatory demand

HYPOXEMIC RESPIRATORY FAILURE

- Most common form of respiratory failure
- Associated with virtually all acute diseases of the lung involving fluid filling or collapse of alveolar units
  - Pulmonary edema, pneumonia, ARDS, pulmonary embolism
- Caused by one of the four mechanisms
  - V/Q mismatch
  - Shunt
  - Diffusion Impairment
  - Hypoventilation
- V/Q mismatch is the most common and most important
  - Areas of low ventilation relative to perfusion
- Shunts – intracardiac or intrapulmonary



HYPERCAPNIC RESPIRATORY FAILURE

- Characterized by $PaCO_2$ >50 mmHg
- Hypoxemia is common
- pH depends on HCO_3 level, dependent on duration of hypercapnia
- Seen with opiate overdose, neuromuscular disease, chest wall abnormalities, and severe airway disorders (status asthmaticus, severe COPD)
- Acute failure can develop over minutes to hours, pH <7.3
- Chronic failure develops over days or longer, renal compensation, pH only slightly decreased

Hypoxemic Respiratory Failure	Hypercapnic Respiratory Failure
Known as: Type I ARF, Lung Failure, Oxygenation Failure, Respiratory Insufficiency	***Known as:*** Type II ARF, Pump Failure, Ventilatory Failure
Definition: The failure of lungs and heart to provide adequate O_2 to meet metabolic needs	***Definition:*** The failure of the lungs to eliminate adequate CO_2
Criteria: $PaO_2 < 60$ mmHg on $F_IO_2 \geq .50$ or $PaO_2 < 40$ mmHg on any F_IO_2 $SaO_2 < 90$	***Criteria:*** Acute ↑ in $PaCO_2 > 50$ mmHg or Acutely above normal baseline in COPD with concurrent ↓ in pH < 7.30
Basic Causes: R-L shunt V/Q mismatch Alveolar hypoventilation Diffusion defect Inadequate FIO_2	***Basic Causes:*** Pump failure (drive, muscles, WOB) ↑ CO_2 production R-L shunt ↑ Deadspace

causes of hypoxemic

- Pneumonia
- Cardiogenic pulmonary edema
- Noncardiogenic pulmonary edema
- Pulmonary fibrosis
- COPD
- Asthma
- Pulmonary embolism
- Pulmonary arterial hypertension
- Hypersensitivity pneumonitis
- Pneumoconiosis
- Bronchiectasis
- Congenital heart disease
- Shunts
- Massive pleural effusion
- Pneumothorax
- Pulmonary hemorrhage

CAUSES OF HYPERCANIC

- COPD
- Status Asthmaticus
- Drug overdose
- Poisonings
- Myasthenia gravis
- Poliomyelitis
- Guillan-Barre
- Polyneuropathy
- Spinal injury/Head injury

- Primary alveolar hypoventilation
- Obesity hypoventilation syndrome
- Severe pulmonary edema
- Severe ARDS
- Myxedema
- Tetanus

DEFINITION

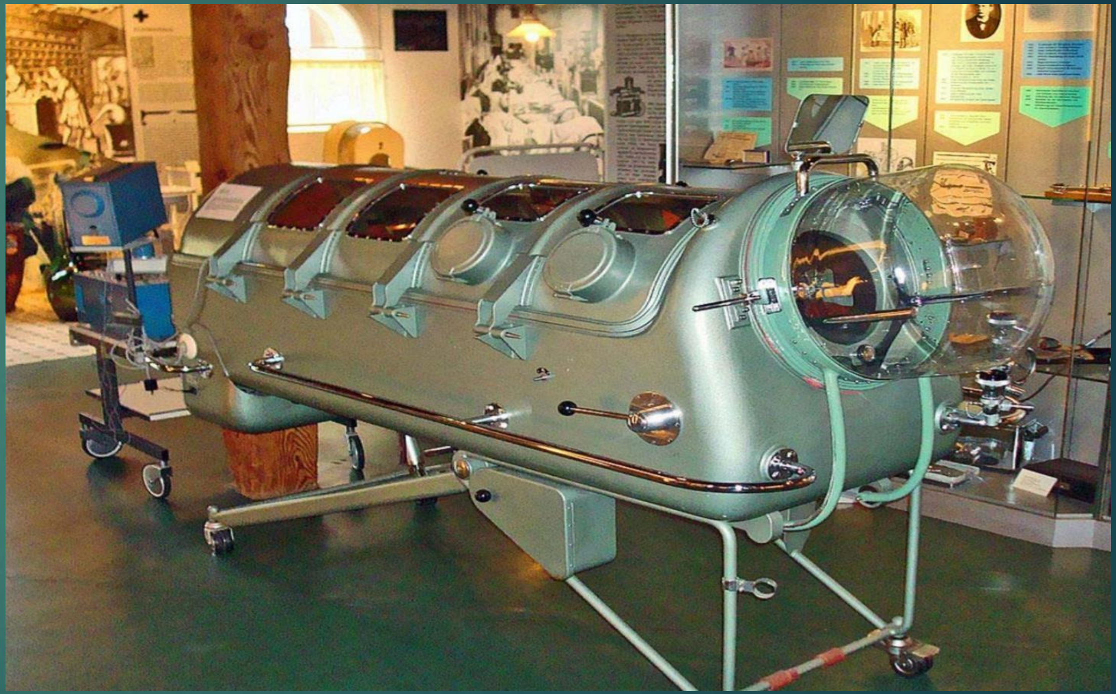
- Noninvasive ventilation (NIV) refers to the delivery of mechanical ventilation to the lungs using techniques that do not require an invasive artificial airway (endotracheal tube, tracheostomy)
- Goals:
  - Provide time for the cause of respiratory failure to resolve and improve gas exchange
  - Overcome auto-PEEP
  - Unload the respiratory muscle
  - Decrease dyspnea
  - Avoid Endotracheal Intubation
  - Avoid complications

TYPES OF NIV

- Negative Pressure NIV
  - Main means of NIV during the early 1900’s
  - Extensively used during the polio epidemics
  - Tank ventilator “iron lung”
  - Cuirass, Jacket ventilator, Hayek oscillator
- Positive Pressure NIV
  - Positive pressure delivered through mask
  - CPAP
  - BIPAP
  - AVAPS
  - ASV

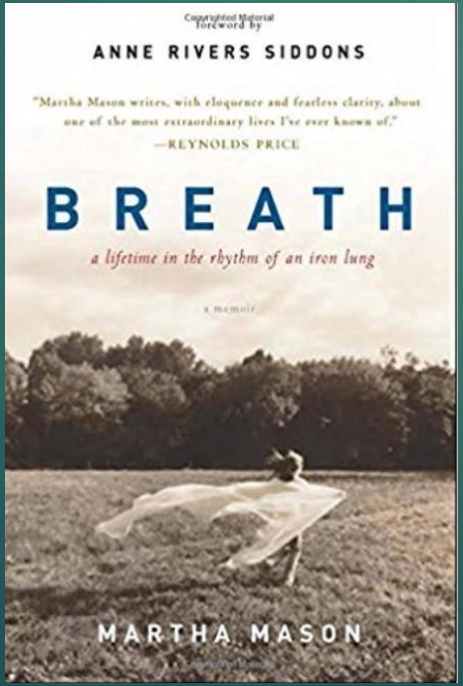
NEGATIVE PRESSURE VENTILATION

- Applies negative pressure intermittently around the patient's body or chest wall resulting in a pressure drop around the thorax
- Negative pressure is transmitted to the pleural space and alveoli creating a pressure gradient between the lungs and mouth
- As a result gas flows into the lungs
- Patient's head (upper airway) is exposed to the room



IRON LUNG

- New York Times May 2009
- “Martha Mason, who wrote a book about her decades in an iron lung, dies at age 71.”

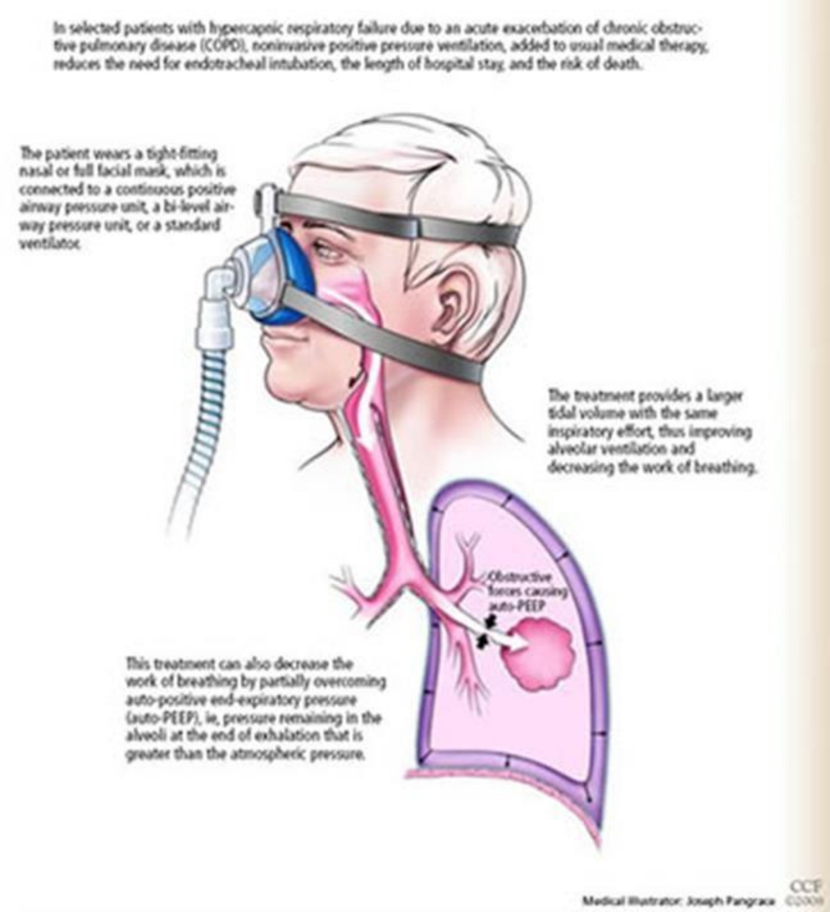


HOW DOES NIV WORK?

- Reduction in inspiratory muscle work and avoidance of respiratory muscle fatigue
- Augments tidal volume
- Improves compliance by reversing microatelectasis
- Overcome intrinsic PEEP
- Enhanced cardiovascular function (afterload reduction)
- Stent the airway
- Reduce CO2 production

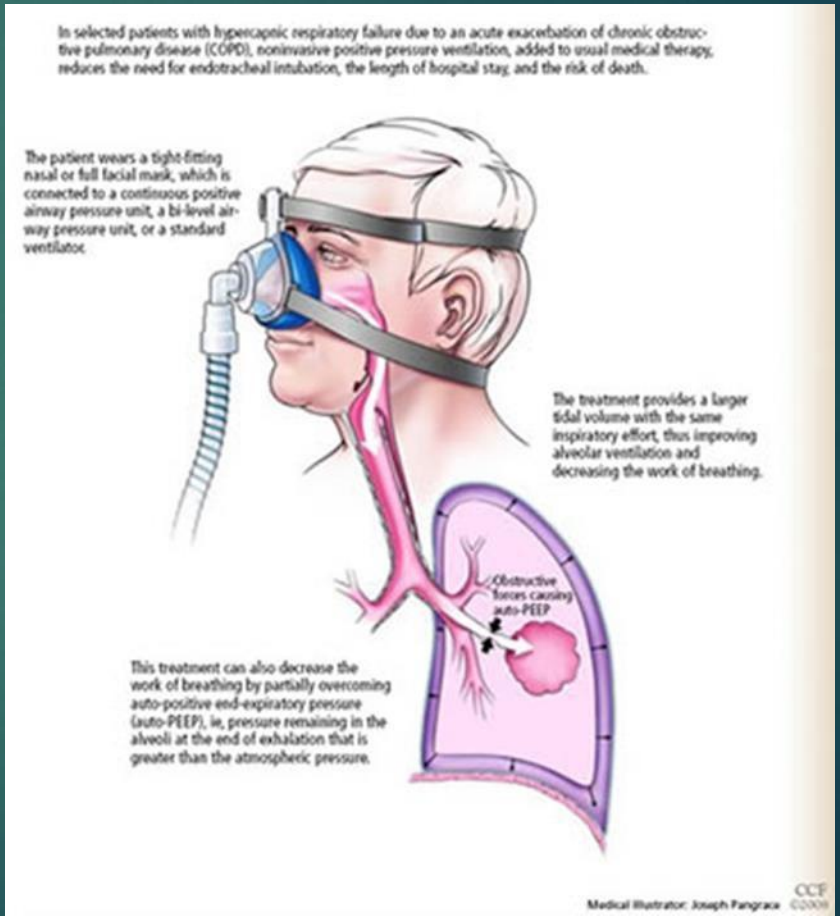
NIV FOR HYPOXEMIC RESPIRATORY FAILURE

- Increased FIO2
- PEEP
  - Alveolar recruitment
  - Increased V/Q
  - Decreased Shunt
  - Increased FRC
  - Decreased RR and WOB



NIV FOR HYPERCAPNIC RESPIRATORY FA

- Offsets auto-PEEP
- Reduce airway resistance
- Improve VT, VE, PaCO2



ADVANTAGES

- Noninvasive
- Correction of gas exchange
- Improve lung mechanics
- Reduce resistive work imposed by invasive ventilation
- Ventilates effectively with lower pressures
- Flexibility in initiation/termination
- Intermittent application
- Patient comfort
- Correct mental status
- Preserves speech/swallowing/expectoration
- Reduces need for nasogastric tubes
- Reduce need for sedation
  - Avoids complications of ETT
    - Trauma/injury, aspiration
- Avoids complications of invasive ventilation
  - Infection-pneumonia, sepsis, sinusitis
  - GI bleed
  - DVT
- Less cost
- Decrease mortality associated with respiratory failure
- Assist in end of life care

DISADVANTAGES

- System
  - Slower correction of gas exchange abnormalities
  - Time commitment/attention
  - Gastric distention
- Interface
  - Leaks
  - Skin necrosis/rash
  - Eye/ear irritation
  - Sinus pressure
- Airway
  - Aspiration
  - Limited secretion clearance

CONTRAINDICATIONS

- Cardiopulmonary arrest
- Hemodynamic instability
- Nonrespiratory multiorgan failure
- Mental status change
  - Uncooperative
  - Encephalopathy (GCS <10)
  - Seizure
- Inability to protect airway
  - Secretions
- Recent Trauma
  - Facial/angioedema
  - Upper airway surgery

- Facial deformities
- +/- edentulous
- GI Bleed/surgery
- Intractable emesis
- Tumors:
  - Head/neck
  - Extrinsic compression of airway
- Airway obstruction
- Recent neurosurgery
- Burns
- Untreated pneumothorax

INTUBATE EARLY!

Respiratory abnormalities suggestive of the need for mechanical ventilation

Parameter	Value
Clinical assessment	
Apnea	
Stridor	
Severely depressed mental status	
Flail chest	
Inability to clear respiratory secretions (eg, excessive secretions, loss of protective reflexes, neuromuscular failure)	
Trauma to mandible, larynx, trachea	
Loss of ventilatory reserve	
Respiratory rate	>35 breaths/min
Tidal volume	<5 mL/kg
Vital capacity	<10 mL/kg
Negative inspiratory force	Weaker than –25 cm H_2O (2.44 kPa)
Minute ventilation	<10 L/min
Rise in $PaCO_2$	>10 mmHg (1.33 kPa)
Refractory hypoxemia	
Alveolar-arterial gradient (FiO_2 = 1)	>450
PaO_2/PAO_2	<0.15
PaO_2 with supplemental O_2	<55 mmHg (7.32 kPa)

$PaCO_2$: arterial tension of carbon dioxide; FiO_2: fraction of inspired oxygen; PaO_2: arterial tension of oxygen; PAO_2: alveolar tension of oxygen.

CANDIDATES FOR NIV

- Clinical judgement supersedes
- Cooperative patient
- Dyspnea/increased WOB
- Hypoxemia and/or hypercapnia
- Respiratory acidosis
- Clinical Conditions
  - COPD
    - stable
    - acute exacerbation
  - Cardiogenic Pulmonary edema
  - Immunosuppressed
  - DNR/DNI

- Selected patients:
  - COPD + Pneumonia
  - Facilitate weaning
  - Asthma
  - OSA/OHS
  - Cor pulmonale
  - ARDS
  - Neuromuscular disease
  - Restrictive thoracic disorders
  - Cystic Fibrosis
  - Post extubation
  - Post op respiratory failure
  - Bronchoscopy

Evidence-based Utilization of Noninvasive Ventilation and Patient Outcomes

Anuj B. Mehta[1,2,3], Ivor S. Douglas[2,3], and Allan J. Walkey[4,5]

Abstract

Rationale: Strong evidence supports use of noninvasive ventilation (NIV) for patients with respiratory distress from chronic obstructive pulmonary disease and heart failure (strong evidence conditions [SECs]). Despite unclear benefits of NIV for other causes of acute respiratory failure, utilization for conditions with weaker evidence is increasing, despite evidence demonstrating higher mortality for patients who suffer NIV failure (progression from NIV to invasive mechanical ventilation [IMV])) compared with being treated initially with IMV.

Results: Among 22,706 hospitalizations with NIV as the initial ventilatory strategy, 6,820 (30.0%) had SECs. Patients with SECs had lower risk of NIV failure than patients with weak evidence conditions (8.1 vs. 18.2%, $P < 0.0001$). Regardless of underlying diagnosis, patients admitted to hospitals with greater use of NIV for SECs had lower risk of NIV failure (Quartile 4 vs. Quartile 1 adjusted odds ratio = 0.62; 95% CI = 0.49–0.80). Even patients without an SEC benefited from admission to hospitals that used NIV more often for patients with SECs (Quartile 4 vs. Quartile 1 adjusted odds ratio for NIV failure = 0.68; 95% CI = 0.52–0.88).

Conclusions: Most patients who received NIV did not have conditions with strong supporting evidence for its use with wide institutional variation in patient selection for NIV. Surprisingly, we found that all patients, even those without an SEC, benefited from admission to hospitals with greater evidence-based utilization of NIV, suggesting a “hospital effect” that is synergistic with patient selection.

Annals ATS November 2017

OUTCOMES OF NONINVASIVE VENTILATION FOR ACUTE EXACERBATIONS OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE UNITED STATES 1998-2008

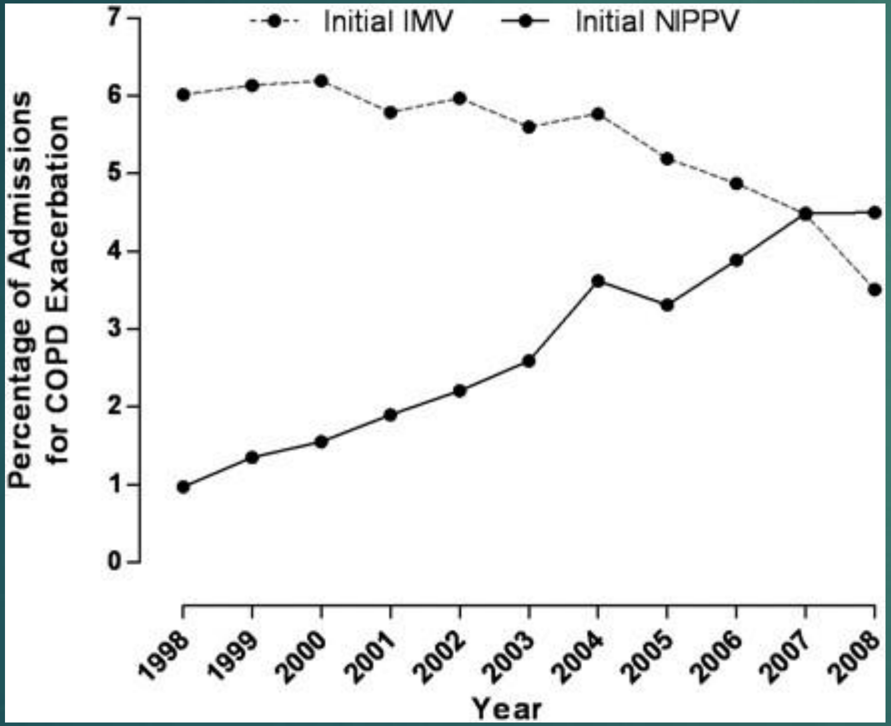
An estimated 7,511,267 admissions for acute exacerbations occurred from 1998 to 2008.

We used data from the **Nationwide Inpatient Sample of the Healthcare Cost and Utilization Project (HCUP-NIS)** from 1998 to 2008.

Since 1988, HCUP-NIS has collected patient-level clinical and resource use data included in the discharge abstract on about 5 to 8 million inpatient hospital stays from close to a 1,000 hospitals. ***This represents an approximately 20% stratified probability sample of all United States acute-care, nongovernmental hospitals each year.***

Chandra et al. Am. J. Respir. Crit. Care Med. 2012; 185: 152

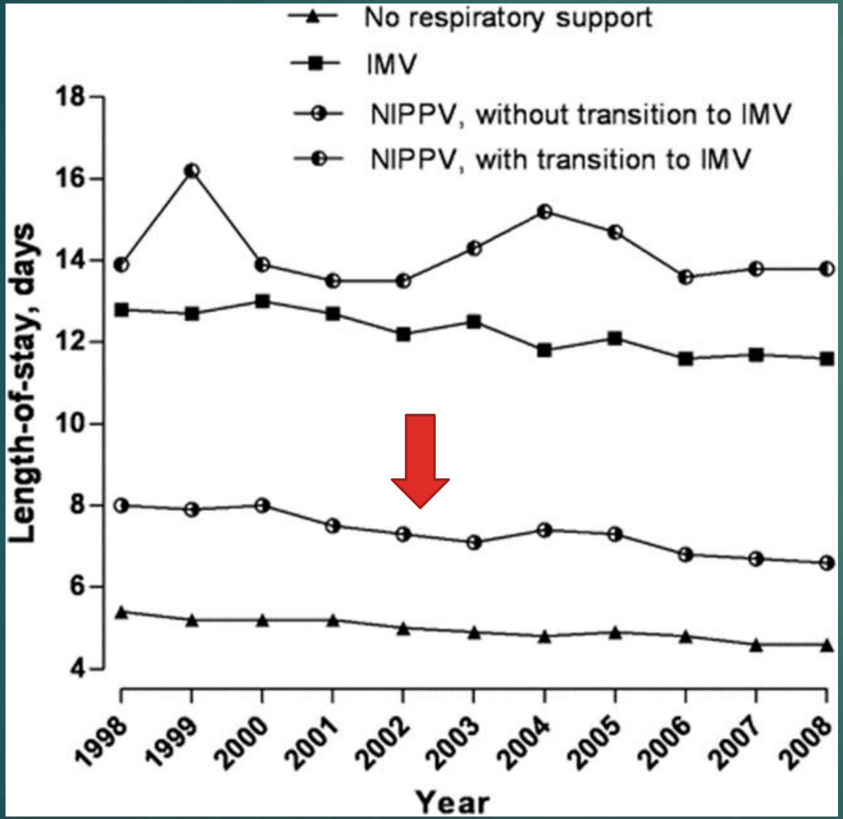
OUTCOMES OF NONINVASIVE VENTILATION FOR ACUTE EXACERBATIONS OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE UNITED STATES 1998-2008



Temporal trends in the use of noninvasive positive pressure ventilation (NIPPV) and invasive mechanical ventilation (IMV) as the initial form of respiratory support in patients hospitalized with acute exacerbations of chronic obstructive pulmonary disease (COPD) in the United States, 1998–2008.

Chandra et al. Am. J. Respir. Crit. Care Med. 2012; 185: 152

OUTCOMES OF NONINVASIVE VENTILATION FOR ACUTE EXACERBATIONS OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE UNITED STATES 1998-2008



Length-of-stay in days for patients admitted with acute exacerbations of chronic obstructive pulmonary disease grouped by type or respiratory support used during the hospitalization, 1998–2008.

IMV = invasive mechanical ventilation; NIPPV = noninvasive positive pressure ventilation.

Chandra et al. Am. J. Respir. Crit. Care Med. 2012; 185: 152

NONINVASIVE POSITIVE PRESSURE VENTILATION FOR TREATMENT OF RESPIRATORY DUE TO EXACERBATIONS OF COPD (REVIEW)

- Data from quality RCTs show benefit of NIV as FIRST line intervention in addition to usual medical care to ARF secondary to acute exacerbation of COPD in all suitable patients
- Use EARLY in the course of respiratory failure as a means of reducing the likelihood of endotracheal intubation, treatment failure, and mortality

Ram, et al. Cochrane Database Syst Review 2004; 3: CD004104

NIV IN COPD EXACERBATION

- Multiple RCTs support a success rate of 80-85%
- Shown to improve respiratory acidosis
- Decrease work of breathing, dyspnea, and complications including VAP, LOS hospital
- Reduce mortality and intubation rates

NIV IN AECOPD

- Large observational study 25,628 patients admitted with AECOPD
- Early NIV use confirmed significant reduction in:
  - Hospital mortality
  - Hospital acquired pneumonia
  - Duration of mechanical ventilation

Lindenauer, et al. JAMA Internal Med 2014; 174: 1982-93

NIV AND STABLE COPD

- NIV is increasingly used in stable very severe COPD
- NIV and oxygen therapy in selected patients with pronounced daytime hypercapnia
- COPD/OSA overlap
- Clear benefits in both survival and risk of hospital admission

GOLD Guidelines

NONINVASIVE POSITIVE PRESSURE VENTILATION AS A WEANING STRATEGY FOR INTUBATED ADULTS WITH RESPIRATORY FAILURE (REVIEW)

- 12 trials of moderate to good quality
- Compared to IPPV strategy, NPPV significantly reduced:
  - Mortality (RR 0.55)
  - VAP (RR 0.29)
  - ICU LOS (WMD -6.27 days) and hospital LOS (WMD -7.19 days)
  - Total duration of ventilation (WMD -5.64 days)
  - Duration of endotracheal mechanical ventilation (WMD -7.81 days)
    - WMD = weighted mean difference
- Compared to IPPV, noninvasive weaning had no effect on weaning failures or the duration of ventilation related to weaning
- Concluded: consistent, positive effect on mortality and VAP

Burns, et al. Cochrane Database Syst Rev 2010; 8: CD004127

The Role of Noninvasive Ventilation in the Ventilator Discontinuation Process

Dean R Hess PhD RRT FAARC

Introduction
NIV to Shorten the Length of Invasive Ventilation
NIV to Prevent Extubation Failure
NIV to Rescue Failed Extubation
When to Stop
Equipment and Resources
Summary and Recommendations

In recent years, there has been increasing interest in the use of noninvasive ventilation (NIV) in the post-extubation period to shorten the length of invasive ventilation, to prevent extubation failure, and to rescue a failed extubation. The purpose of this review is to summarize the evidence related to the use of NIV in these settings. NIV can be used to allow earlier extubation in selected patients who do not successfully complete a spontaneous breathing trial (SBT). Its use in this setting should be restricted to patients who are intubated during an exacerbation of COPD or patients with neuromuscular disease. This category of patients should be good candidates for NIV and should be extubated directly to NIV. In patients who successfully complete an SBT, but are at risk for extubation failure, NIV can be used to prevent extubation failure. These patients should also be good candidates for NIV and should be extubated directly to NIV. NIV should be used cautiously in patients who successfully complete an SBT, but develop respiratory failure within 48 hours post-extubation. In this setting, NIV is indicated only in patients with hypercapnic respiratory failure. Reintubation should not be delayed if NIV is not immediately successful in reversing the post-extubation respiratory failure. Evidence does not support routine use of NIV post-extubation.

Respiratory Care 2012 Oct; 57(10): 1619-25

NONINVASIVE POSITIVE PRESSURE VENTILATION (CPAP OR BILEVEL NIPPV) FOR CARDIOGENIC PULMONARY EDEMA (REVIEW)

- Included 32 studies
- NIV is a safe and effective intervention for the treatment of adult patients with acute cardiogenic pulmonary edema
    - Evidence to date on the potential benefit of NIV in reducing mortality is entirely derived from small trials and further large scale trials are needed

Vital, et al. Cochrane Database Syst Rev 2013; 5: CD005351

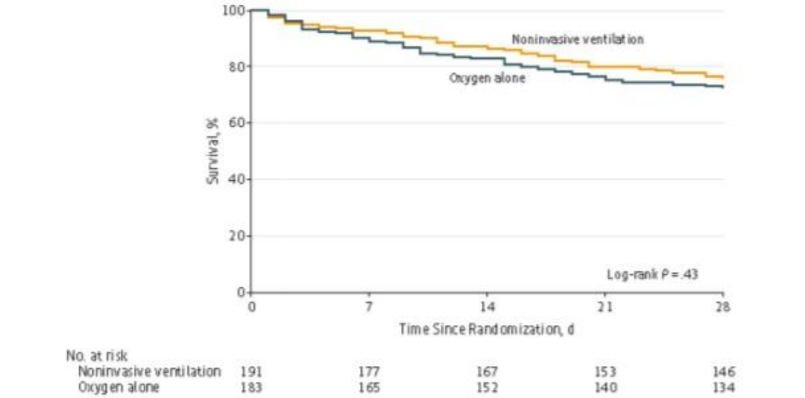
NIV IMMUNOCOMPROMISED PATIENT

- Immunocompromised patients are particularly exposed to increased infectious risk related to invasive mechanical ventilation
- Multiple RCTs support, whenever possible, NIV should be tried first
- Antonelli et al JAMA 2000
  - 40 subjects with solid organ transplantation who developed hypoxemic respiratory failure
  - NIV v oxygen support
  - NIV had lower rates of intubation and mortality
- Hilbert et al NEJM 2001
  - 52 patients with hypoxemia
  - NIV v oxygen support
  - NIV had lower rates of intubation and mortality

IMMUNOCOMPROMISED PATIENT

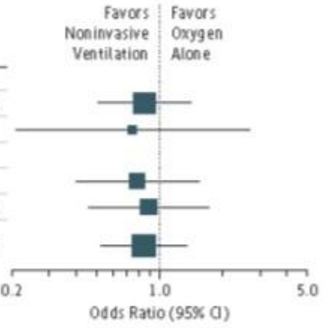
- Trends toward better survival
- Trends towards decreased need for intubation and invasive ventilation
- No significant clinical advantage
  - Mortality, infection, intubation, LOS
- 374 patients (50/50 split)

Figure 2. Probability of Survival at Day 28



Probability of survival and subgroup analyses of the risk of day-28 mortality Kaplan-Meier estimates of the probability of day-28 mortality in immunocompromised patients with acute respiratory failure receiving either early noninvasive ventilation or oxygen only. Statistical test used the log-rank test.

Figure 3. Odds Ratio for 28-Day Mortality in the Early Noninvasive Ventilation Group, Compared With the Oxygen Group, Overall and in Predefined Subgroups



Source	No. of Deaths/Total No. Oxygen Alone	Noninvasive Ventilation	Odds Ratio (95% CI)	P Value for Interaction[a]
Underlying Conditions				
Solid tumors or hematologic malignancies	43/150	41/161	0.85 (0.51-1.40)	.66
Immunosuppressive treatment or organ transplant	7/33	5/30	0.74 (0.2-2.63)	
Oxygen flow at randomization[b]				
>9 L/min	26/77	24/84	0.78 (0.4-1.53)	.64
≤9 L/min	24/106	22/107	0.88 (0.46-1.70)	
All patients	50/183	46/191	0.84 (0.53-1.34)	

Lemiale V et al. JAMA 2015

Noninvasive Ventilation for Patients With Acute Lung Injury or Acute Respiratory Distress Syndrome

Stefano Nava MD, Ania Schreiber MD, and Guido Domenighetti MD

Introduction
Physiological Rationale
Meta-analyses and Systematic Reviews
NIV to Prevent Endotracheal Intubation in ALI/ARDS Patients
NIV as an Alternative to Endotracheal Intubation in ALI/ARDS Patients
Summary

Few studies have been performed on noninvasive ventilation (NIV) to treat hypoxic acute respiratory failure in patients with acute lung injury (ALI) or acute respiratory distress syndrome (ARDS). The outcomes of these patients, for whom endotracheal intubation is not mandatory, depend on the degree of hypoxia, the presence of comorbidities and complications, and their illness severity. The use of NIV as an alternative to invasive ventilation in severely hypoxemic patients with ARDS (ie, P_{aO_2}/F_{IO_2} < 200) is not generally advisable and should be limited to hemodynamically stable patients who can be closely monitored in an intensive care unit by highly skilled staff. Early NIV application may be extremely helpful in immunocompromised patients with pulmonary infiltrates, in whom intubation dramatically increases the risk of infection, pneumonia, and death. The use of NIV in patients with severe acute respiratory syndrome and other airborne diseases has generated debate, despite encouraging clinical results, mainly because of safety issues. Overall, the high rate of NIV failure suggests a cautious approach to NIV use in patients with ALI/ARDS, including early initiation, intensive monitoring, and prompt intubation if signs of NIV failure emerge. *Key words:*

Respiratory Care 2011 Oct 1; 56(10): 1583-8

CHEST

Original Research

CRITICAL CARE MEDICINE

Extubation of Patients With Neuromuscular Weakness

A New Management Paradigm

John Robert Bach, MD; Miguel R. Gonçalves, PT; Irram Hamdani, MD; and Joao Carlos Winck, MD, PhD

Background: Successful extubation conventionally necessitates the passing of spontaneous breathing trials (SBTs) and ventilator weaning parameters. We report successful extubation of patients with neuromuscular disease (NMD) and weakness who could not pass them.

Methods: NMD-specific extubation criteria and a new extubation protocol were developed. Data were collected on 157 consecutive "unweanable" patients, including 83 transferred from other hospitals who refused tracheostomies. They could not pass the SBTs before or after extubation. Once the pulse oxyhemoglobin saturation (SpO_2) was maintained at ≥95% in ambient air, patients were extubated to full noninvasive mechanical ventilation (NIV) support and aggressive mechanically assisted coughing (MAC). Rather than oxygen, NIV and MAC were used to maintain or return the SpO_2 to ≥95%. Extubation success was defined as not requiring reintubation during the hospitalization and was considered as a function of diagnosis, preintubation NIV experience, and vital capacity and assisted cough peak flows (CPF) at extubation.

Results: Before hospitalization 96 (61%) patients had no experience with NIV, 41 (26%) used it < 24 h per day, and 20 (13%) were continuously NIV dependent. The first-attempt protocol extubation success rate was 95% (149 patients). All 98 extubation attempts on patients with assisted CPF ≥ 160 L/m were successful. The dependence on continuous NIV and the duration of dependence prior to intubation correlated with extubation success ($P < .005$). Six of eight patients who initially failed extubation succeeded on subsequent attempts, so only two with no measurable assisted CPF underwent tracheotomy.

Conclusions: Continuous volume-cycled NIV via oral interfaces and masks and MAC with oximetry feedback in ambient air can permit safe extubation of unweanable patients with NMD.

CHEST 2010; 137(5):1033–1039

CHEST

Original Research

CRITICAL CARE MEDICINE

Noninvasive Ventilation Reduces Intubation in Chest Trauma-Related Hypoxemia

A Randomized Clinical Trial

Gonzalo Hernandez, MD, PhD; Rafael Fernandez, MD, PhD; Pilar Lopez-Reina, MD; Rafael Cuena, MD; Ana Pedrosa, MD; Ramon Ortiz, MD; and Paloma Hiradier, MD

Background: **Guidelines for noninvasive mechanical ventilation (NIMV) recommend continuous positive airway pressure in patients with thoracic trauma who remain hypoxic despite regional anesthesia. This recommendation is rated only by level C evidence because randomized controlled trials in this specific population are lacking. Our aim was to determine whether NIMV reduces intubation in severe trauma-related hypoxemia.**

Methods: **This was a single-center randomized clinical trial in a nine-bed ICU of a level I trauma hospital. Inclusion criteria were patients with $Pa_{O_2}/F_{IO_2} < 200$ for > 8 h while receiving oxygen by high-flow mask within the first 48 h after thoracic trauma. Patients were randomized to remain on high-flow oxygen mask or to receive NIMV. The interface was selected based on the associated injuries. Thoracic anesthesia was universally supplied unless contraindicated. The primary end point was intubation; secondary end points included length of hospital stay and survival. Statistical analysis was based on multivariate analysis.**

Results: **After 25 patients were enrolled in each group, the trial was prematurely stopped for efficacy because the intubation rate was much higher in controls than in NIMV patients (10 [40%] vs 3 [12%], *P* = .02). Multivariate analysis adjusted for age, gender, chronic heart failure, and Acute Physiology and Chronic Health Evaluation II at admission revealed NIMV as the only variable independently related to intubation (odds ratio, 0.12; 95% CI, 0.02-0.61; *P* = .01). Length of hospital stay was shorter in NIMV patients (14 vs 21 days *P* = .001), but no differences were observed in survival or other secondary end points.**

Conclusion: **NIMV reduced intubation compared with oxygen therapy in severe thoracic trauma-related hypoxemia.**

Trial registration: **clinicaltrials.gov; identifier: NCT 00557752.** ***CHEST 2010; 137(1):74–80***

Noninvasive Ventilation of Patients with Acute Respiratory Distress Syndrome

Insights from the LUNG SAFE Study

Abstract

Rationale: Noninvasive ventilation (NIV) is increasingly used in patients with acute respiratory distress syndrome (ARDS). The evidence supporting NIV use in patients with ARDS remains relatively sparse.

Objectives: To determine whether, during NIV, the categorization of ARDS severity based on the Pa_{O_2}/FI_{O_2} Berlin criteria is useful.

Methods: The LUNG SAFE (Large Observational Study to Understand the Global Impact of Severe Acute Respiratory Failure) study described the management of patients with ARDS. This substudy examines the current practice of NIV use in ARDS, the utility of the Pa_{O_2}/FI_{O_2} ratio in classifying patients receiving NIV, and the impact of NIV on outcome.

Measurements and Main Results: Of 2,813 patients with ARDS, 436 (15.5%) were managed with NIV on Days 1 and 2 following fulfillment of diagnostic criteria. Classification of ARDS severity based on Pa_{O_2}/FI_{O_2} ratio was associated with an increase in intensity of ventilatory support, NIV failure, and intensive care unit (ICU) mortality. NIV failure occurred in 22.2% of mild, 42.3% of moderate, and 47.1% of patients with severe ARDS. Hospital mortality in patients with NIV success and failure was 16.1% and 45.4%, respectively. NIV use was independently associated with increased ICU (hazard ratio, 1.446 [95% confidence interval, 1.159–1.805]), but not hospital, mortality. In a propensity matched analysis, ICU mortality was higher in NIV than invasively ventilated patients with a Pa_{O_2}/FI_{O_2} lower than 150 mm Hg.

Conclusions: NIV was used in 15% of patients with ARDS, irrespective of severity category. NIV seems to be associated with higher ICU mortality in patients with a Pa_{O_2}/FI_{O_2} lower than 150 mm Hg.

Clinical trial registered with www.clinicaltrials.gov (NCT 02010073).

Keywords: noninvasive ventilation; acute respiratory distress syndrome

Bellani, G et al Amer J Resp and Crit Care Med Vol 195 No 1Jan 2017

NIV IN ASTHMA

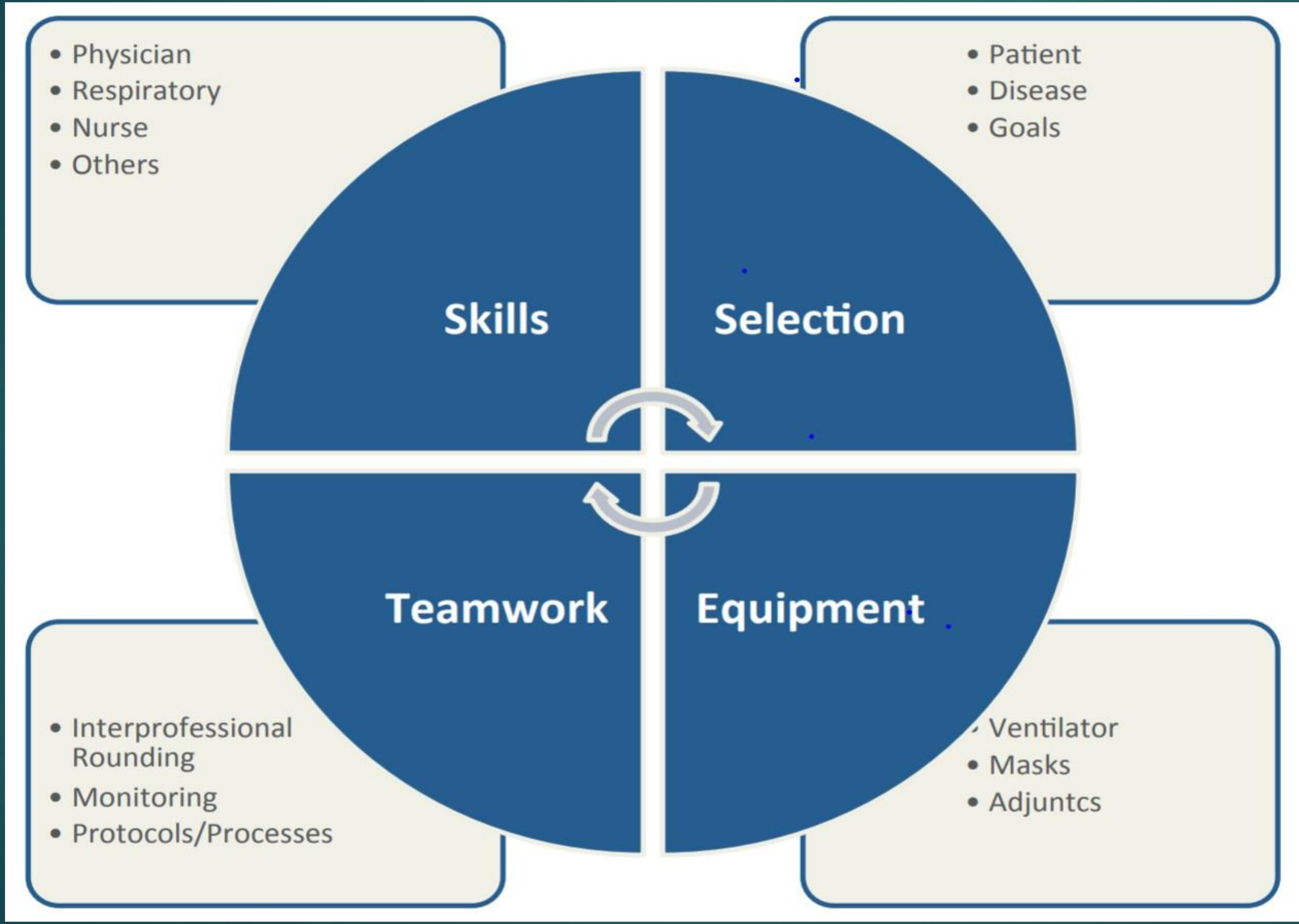
- Role for NIV in asthma not well defined
- Alternative to invasive mechanical ventilation in patients who have failed standard treatment
- Prevent need for invasive mechanical ventilation in patients who do not have substantial impairment in gas exchange

Noninvasive Ventilation in Severe Acute Asthma

Jhaymie L Cappiello MSc RRT-ACCS and Michael B Hocker MD MHS

RESPIRATORY CARE • OCTOBER 2014 VOL 59 NO 10

MULTIDISCIPLINARY APPROACH



Singh, www.chestnet.org

PATIENT SELECTION

- Step 1
  - Is the etiology of respiratory failure likely to respond favorably to NIV?
- Step 2
  - Clinical presentation
  - ABG analysis
  - Monitored location
    - Pre-hospital
    - ED/Floor/Stepdown Unit
    - ICU
- Step 3
  - Exclude situations where NIV would be unsafe

SUCCESSFUL APPLICATION OF NIV

- Choose Ventilator
- Choose Interface
- Choose Settings
- Work with Patient, Reassess and Adjust
- Assess for Success/Failure/Weaning

Singh, www.chestnet.org

MODES OF NIV

- CPAP
- NIV with PSV (BIPAP)
- Average Volume Assured Pressure Support (AVAPS)
- Adaptive Servo Ventilation (ASV) or AutoSV
- High Flow nasal cannula

- Deliver with oxygen to maintain adequate oxygen saturatio
- Humidification

MODES OF NIV

MODES OF NIV

Pressure Modes

- Better tolerated than volume-cycled mode
- Constant positive airway pressure (CPAP)
- Bilevel or biphasic positive airway pressure (BiPAP)
- Pressure support ventilation (PSV)

Volume Modes

- Initial TV range 10-15 ml/kg
- Control
- Assist control

INTERFACE

Nasal

Full Face

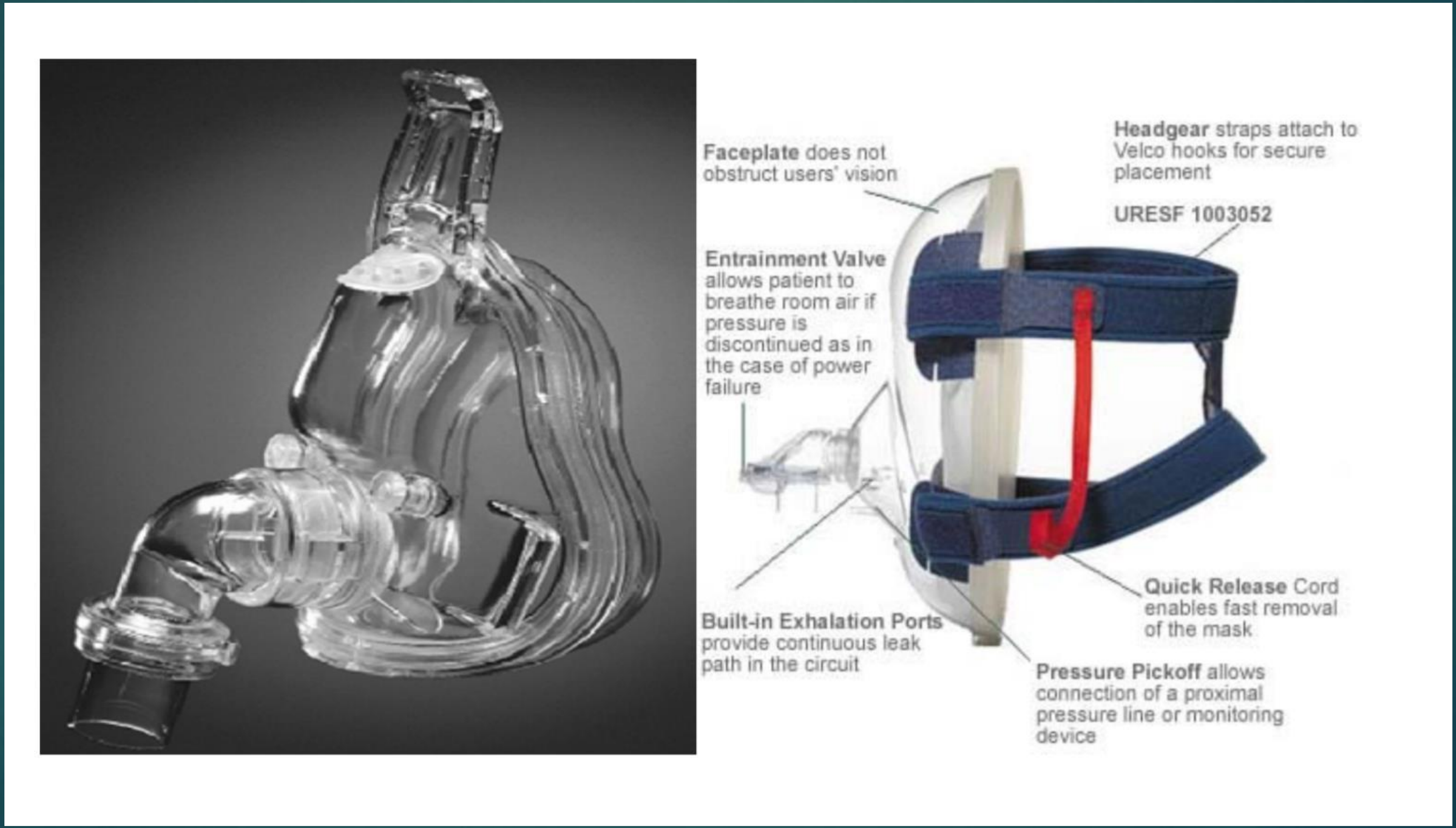
Nasal Pillows

Hybrid

Oral

Total Face

ORONASAL MASK



HELMET INTERFACE

- Equally tolerated
- Effective in ameliorating gas exchange
- Decreased inspiratory effort but less efficient
- Limited patient-ventilator interaction

NASAL VS ORONASAL MASK

Variables	Nasal	Oronasal
Comfort	+++	++
Claustrophobia	+	++
Rebreathing	+	++
Lowers CO2	+	++
Permits expectoration	++	+
Permits speech	++	+
Permits eating	+	-
Function if nose obstructed	-	+

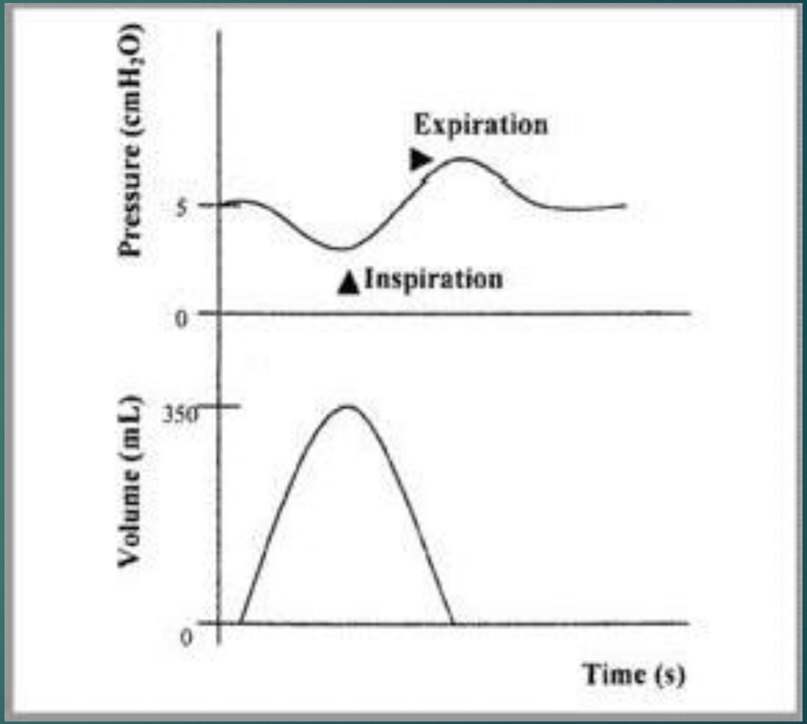
Interface	Advantages	Disadvantages
Nasal Mask	Comfort, less dead space, less aspiration	Mouth leak, nasal resistance, irritation
Nasal Pillows	Comfort (e.g. glasses),fit, headgear	Mouth leak, nasal resistance, irritation
Oronasal Mask	Better leak control, Mouth breathers	Aspiration risk, dead space, speaking/eating
Mouthpiece	Little dead space, no headgear	
Total Face mask	Easier to fit, maybe more comfortable for some	Greater dead space, dry eyes, aerosolized meds
Helmet	One size fits all, less skin breakdown, comfort?	Rebreathing, synchrony, meds, less respiratory unloading

MASK TIPS

- Full face (oronasal) is most commonly used in ARF
- Explain the modality and provide reassurance
- Hold the mask in place until patient is:
  - Comfortable
  - In synchrony with the ventilator
- Secure the mask avoiding a tight fit
- Passage of two fingers beneath head straps
- Allow small air leaks if exhaled VT is adequate
- Skin patch to minimize abrasion and necrosis nasal bridge and skin
- Head of bed elevated to avoid aerophagia
- Bronchodilator administration (preferably off NIV, or delivered through the circuit)
- Avoid nasogastric tubes

HOW DO WE SUPPLY NIPPV TO THE PATIENT? CPAP

- CPAP - applies a single pressure throughout the entire respiratory cycle
  - Creates "pneumatic splint" for upper airway
  - It does not augment TV but it does increase FRC
    - Improve lung compliance
    - Open collapsed alveoli
    - Improve oxygenation
    - Decrease work of breathing
  - Decrease LV transmural pressure, decrease afterload and increase CO
  - Start at 5 cmH20
  - Use higher pressure with obese patients and/or OSA

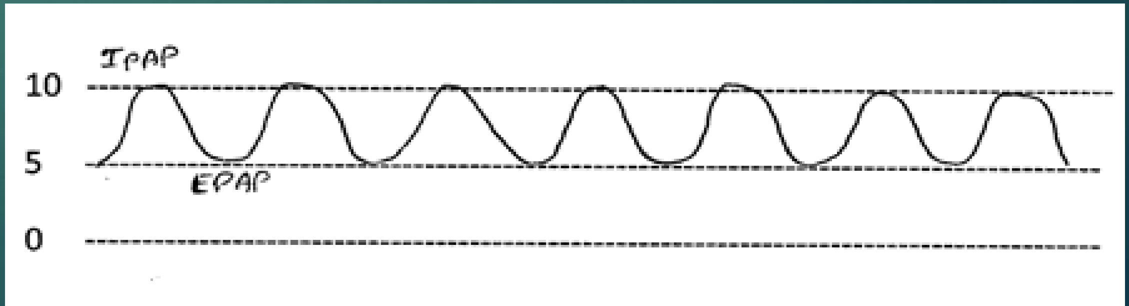


Springer Images

HOW DO WE SUPPLY NIPPV TO THE PATIENT? BIPAP

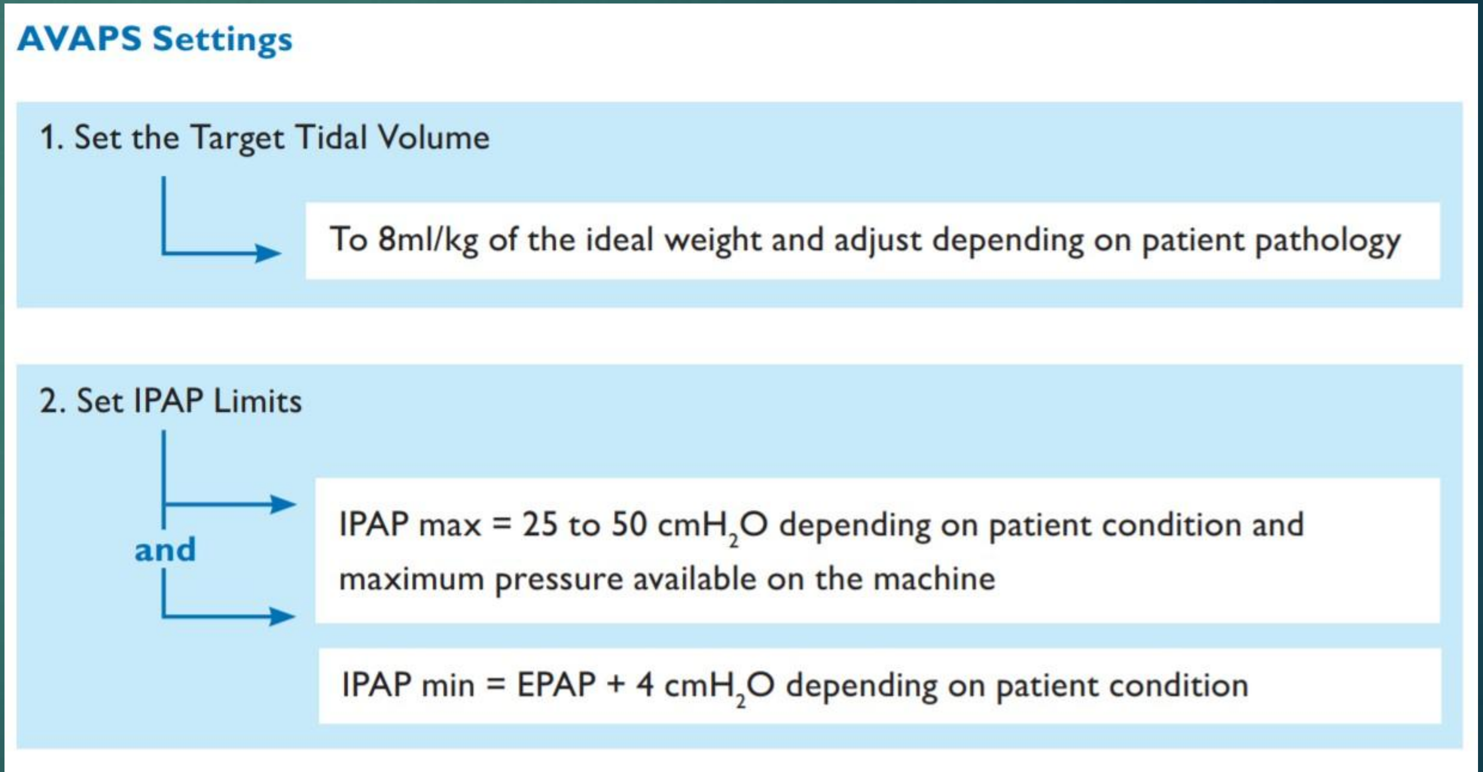
- NIV with PSV (BiPAP)
  - A specific pressure is applied to the airway for the duration of inspiration (IPAP)
  - A second pressure applied during expiration (EPAP)
  - IPAP - ventilation
  - EPAP – oxygenation
- IPAP – EPAP = PSV

- Minimum difference between I and E no less than 5 cm H20
- S mode, S/T mode
- TV varies
  - Determined by degree of IPAP
  - Patient effort
  - Lung compliance



AVERAGE VOLUME ASSURED PRESSURE SUPPORT - AVAPS

- Settings
  - Target TV
  - IPAP range (PSV varies)
  - EPAP
  - S, S/T, PC, T, auto
- Pressure and Volume limited
- Sensation of breathlessness
  - Increase minimum IPAP
- Example
  - Set TV
  - IPAP varies with effort
    - Wake v Sleep

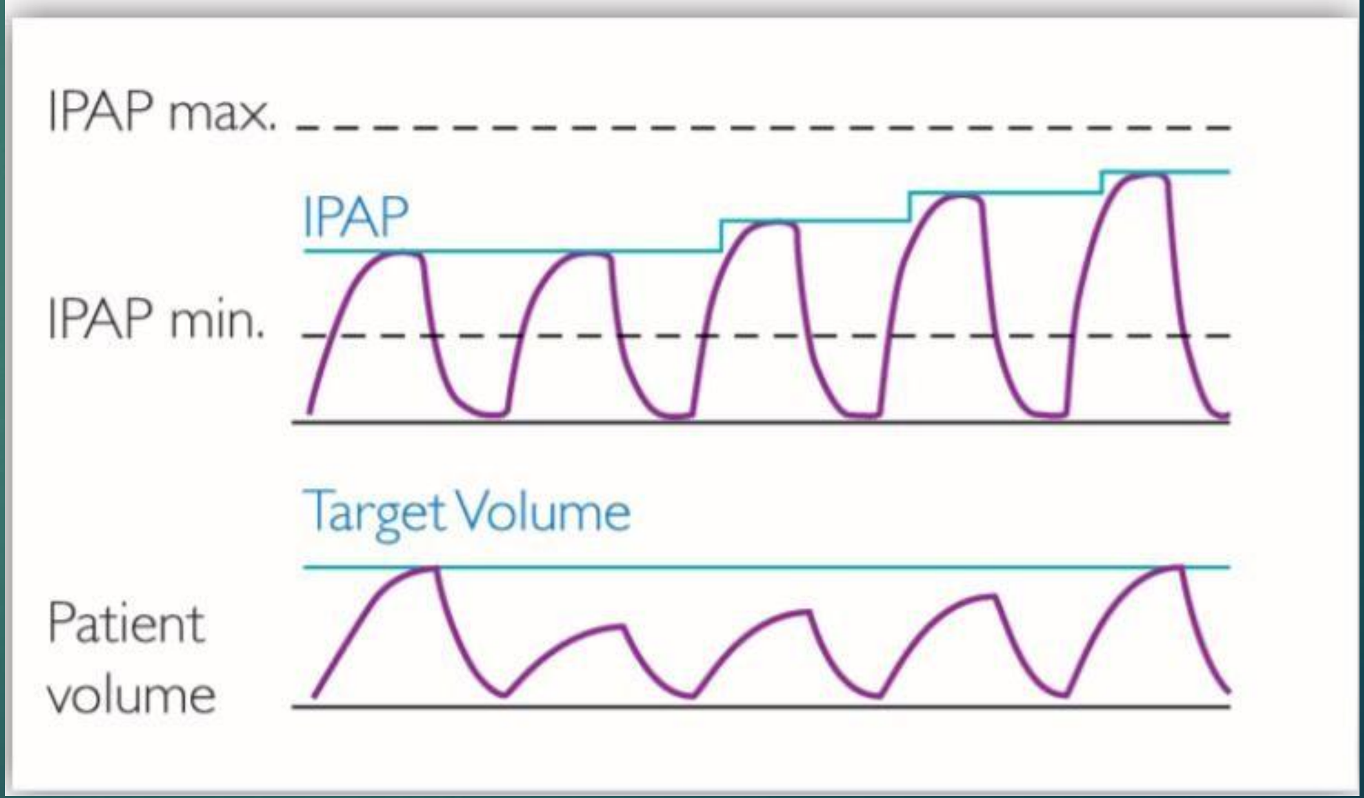


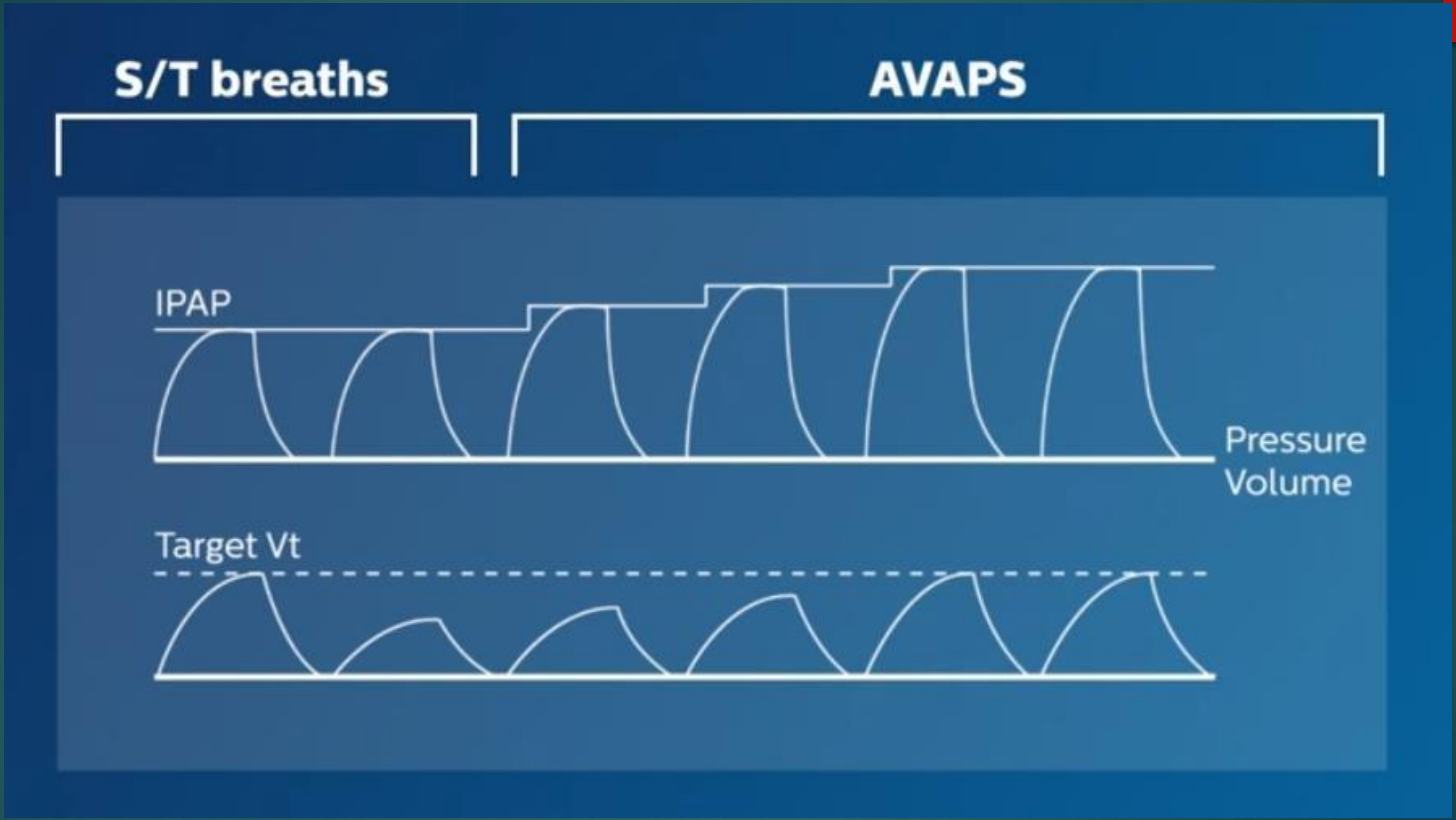
AVAPS

Informational Message
Spont
Rate
16
V_T
502
$\dot{V}_E$
8.8
PIP
17
Pt. Leak
12
Pt. Trig
95
T_I/T_{TOT}
38
100% O2
Active Mode: AVAPS
V_T
500
Rate
4
I-Time
1.00
Rise
3
EPAP
4
Min P
10
Max P
20
O2
21
AVAPS Settings
Alarm Settings
Modes
Menu
Standby

AVAPS

- COPD
- Obesity Hypoventilation
- Restrictive disease
- Neuromuscular disorders



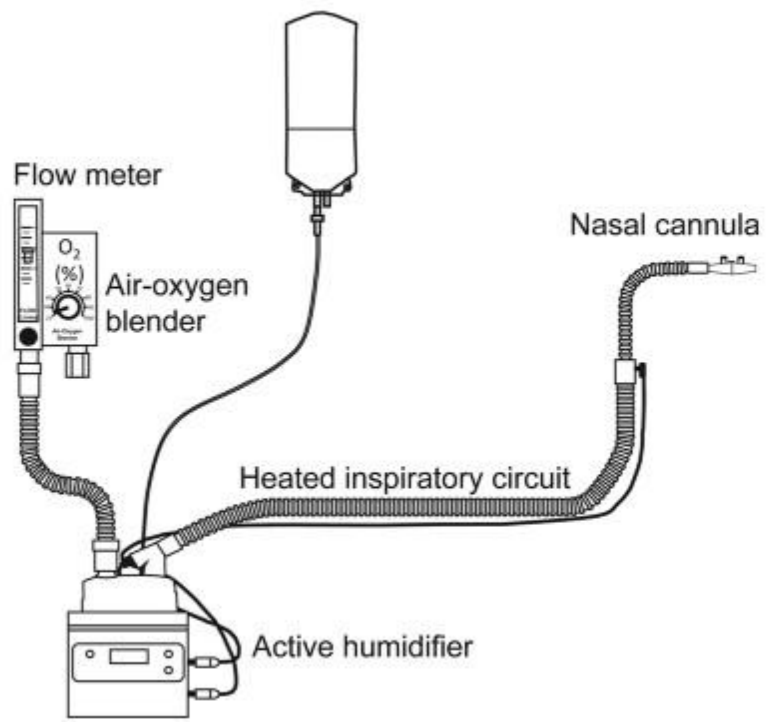

S/T breaths
AVAPS
IPAP
Pressure
Volume
Target Vt

AVAPS

- Should not be used in the acute setting where rapid IPAP changes are needed to achieve desired TV
- IPAP does not change more than 2.5 cmH_2O within one minute
- Used in patients with chronic respiratory failure in need of ventilatory support

HIGH FLOW NASAL CANNULA OXYGEN THERAPY

Basic setup for high-flow nasal cannula oxygen delivery.



Masaji Nishimura Respir Care 2016;61:529-541

HIGH FLOW NASAL CANNULA

- Maintains constant FiO_2
- Increased CO_2 clearance via nasopharyngeal dead space washout
- Inspiratory flow varies, TV varies
- PEEP affect, resistance against expiratory flow and increases airway pressure

HIGH FLOW NASAL CANNULA

- Recent study (Frat et al. NEJM 2015)
  - 310 ARF patients compared HFNC, oxygen support, NIV
  - No significant difference obtained in terms of intubation rates
  - Treatment with HFNC was associated with higher number ventilator free days at day 28 and a better 90 day mortality rate
- Another study (Kang et al. Intensive Care Med 2015)
  - Delayed intubation after HFNC trial is associated with adverse outcomes: poor weaning, fewer ventilator free days, and increased mortality
- Strong data are still lacking before suggesting HFNC instead of NIV/PAP as first line treatment in critically ill patients

HOW DO WE SUPPLY NIPPV TO THE PATIENT? ADAPTIVE SERVO-VENTILATION

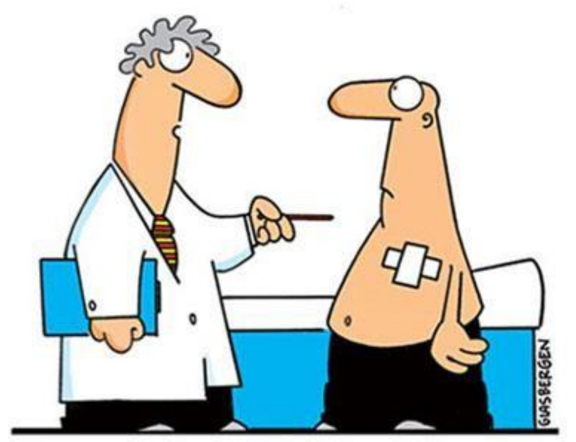
- Specifically used to treat central sleep apnea
- Designed to vary support according to a patient's individual breathing rate
- Automatically calculates a target ventilation
- Automatically adjusts pressure support to achieve target ventilation
- Not recommended for patients with systolic CHF
- Not used in acute setting

CASE PRESENTATION

- HPI: 75 yo WM with a hx of severe COPD and OSA, noncompliant with PAP therapy but wears oxygen 2 lpm hs, presents to the hospital with AECOPD. After several bronchodilator treatments he remains dyspneic, wheezing, and using accessory muscles to breathe.
- VS: T 37.2C, BP 160/95 mmHg, HR 100 bpm, RR 32 bpm, 98kg, 65 in height
- Exam AAOx3, mild respiratory distress, RRR no m/r/g, Decreased BS with expiratory wheeze bilaterally, Abdomen benign, Extremities without c/c/e
- Labs: ABG 7.25/60/65/ on 3 lpm oxygen
- CXR: hyperinflation, no infiltrates, effusion, edema

CLINICAL MONITORING

- Subjective response
  - Bedside observation
- Physiologic response
  - Improved hemodynamics (RR HR BP)
  - Patient in synchrony with NIV device
  - Decreased WOB
  - Improved TV
- Objective response
  - Improved gas exchange (ABG)
    - Check ABG 1 h after initiation and 1 h after every change in settings
    - Clinical judgement
  - Continuous EKG and pulse oximetry monitoring



"It's a pacemaker for your heart. Plus, you can download apps for your liver, kidneys, lungs, and pancreas!"

PREDICTORS OF NIV FAILURE

- Unable to reverse underlying cause/disease process
- Unable to correct acid/base derangement (within first two hours)
- Persistent hypoxemia
- Hemodynamic instability
- Altered mental status
- Edentulous
- Excessive secretions
- Inability to tolerate interface
- Older age

CAUSES OF FAILURE OF NONINVASIVE

The reported NPPV failure rate is 5–40%

With patients suffering hypercapnic respiratory failure the best NPPV success/failure predictor is the degree of acidosis/acidemia (pH and $PaCO_2$ at admission and after 1 hour on NPPV)

Whereas mental status and severity of illness are less reliable predictors.

With patients suffering hypoxic respiratory failure the likelihood of NPPV success seems to be related to the *underlying disease* rather than to the degree of hypoxia.

For example, the presence of acute respiratory distress syndrome or community-acquired pneumonia portends NPPV failure, as does lack of oxygenation improvement after an hour on NPPV.

Stefano Nava MD and Piero Ceriana MD
Respir Care 2004;49(3):295–303. © 2004

complications

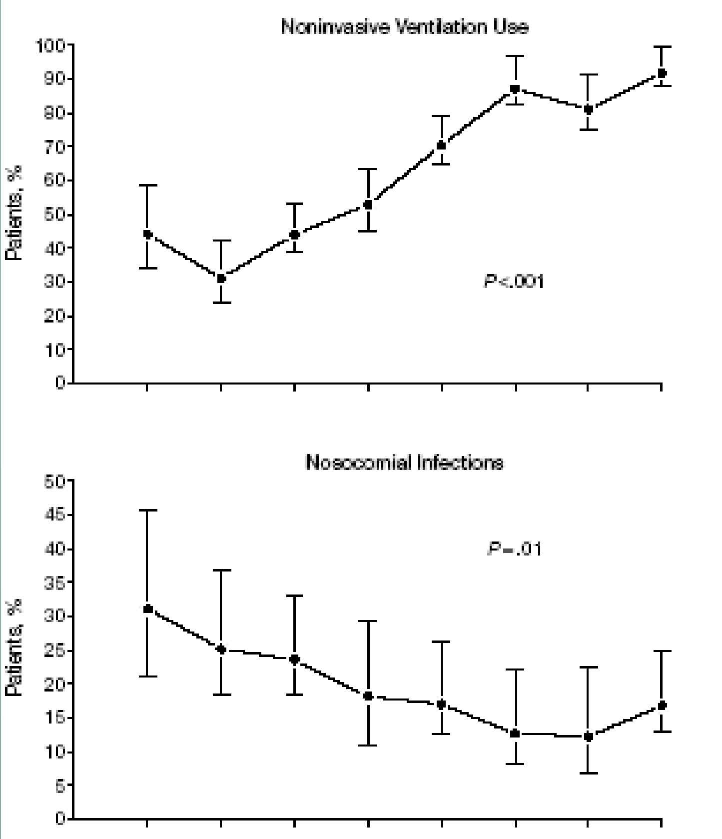
Table 1. Complications Associated with Noninvasive Ventilation and Suggested Responses.

Complication	Response
Air leak	Ensure that the mask is the correct size and has been fitted correctly. Use a mask of a different size or type. Tighten the straps. Reduce airway pressures, if possible.
Skin irritation or abrasion	Loosen the straps. Use a mask of a different size or type. Apply artificial skin or a dressing over the affected area.
Claustrophobia	Redirect the patient by having the patient watch television, talking to the patient, or having a family member talk to the patient. Use a less obtrusive mask (e.g., nasal pillows). Consider inducing light sedation in the patient.
Nasal congestion, sinus pain, or ear pain	Provide topical decongestants or antihistamines if there are no contraindications. Humidify the inspired air. Reduce airway pressures, if possible.
Mucosal dryness	Humidify the inspired air. If a nasal mask is being used, apply a chin strap to reduce air flow through the mouth.
Mucus plugging	Humidify the inspired air. Give the patient brief breaks from ventilation, if possible, and perform maneuvers that will help to clear the airway, such as chest percussion. Reduce airway pressures, if possible.
Pulmonary barotrauma or pneumothorax	Stop ventilation or, at minimum, reduce airway pressures. Insert chest tube, if appropriate.

Kelly, C et al. NEJM 2015; 372: e30

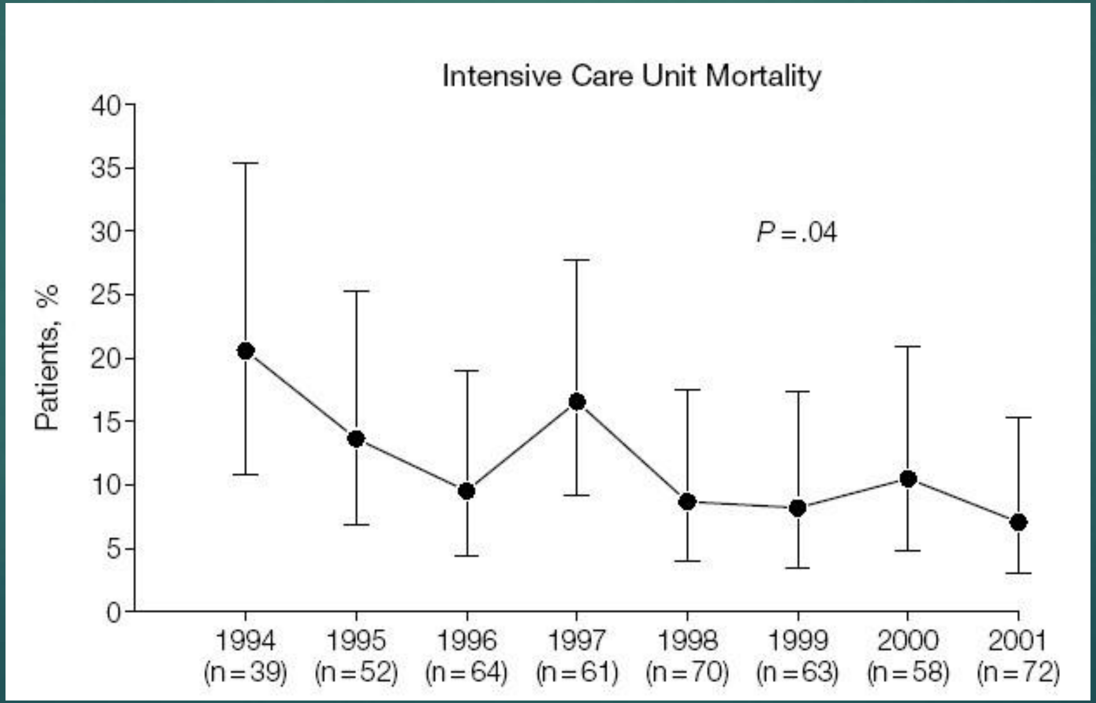
ASSOCIATION OF NIV WITH NOSOCOMIAL INFECTIONS AND SURVIVAL IN CRITICALLY ILL PATIENTS

- Retrospective, observational cohort study
- 948 patients (COPD or severe CPE)
- 1994-2001
- 521 required ventilation
- 42 excluded
- 479 included in study cohort
- 313 (65%) received NIV
- 166 (35%) received ETI



3;290:2985

ASSOCIATION OF NIV WITH NOSOCOMIAL INFECTIONS AND SURVIVAL IN CRITICALLY ILL PATIENTS



Girou et al. JAMA. 2003;290:2985

CONCLUSION

- In 1977, a former editor in chief of Respiratory Care, wrote:
  - “CPAP is no longer a new therapy, nor, alas, is the strapped positive-pressure breathing mask a new device. It is, rather, as antiquated as it is inhumane and unsafe…A patient who is sick enough to need CPAP is sick enough to need an endotracheal tube.”

Hess D. Noninvasive Ventilation For Acute Respiratory Failure
Respiratory Care 2013; 58(6): 950-69

CONCLUSION

- NIPPV has radically changed the management of ARF.
- Possible applications of NIV have increased.
- NIPPIV is no longer confined to the ICU, but has regular ward, ED and ‘out-of-hospital’, pre-hospital environment.
- Current research is focusing on improving the quality and safety of the devices and establishing new ventilatory modes in order to extend even further the indications to NIV as well as its rate of success.