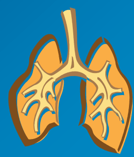
Basics Of Mechanical Ventilation:



Fred Mann
Strategic Account Manager,
Philips Respironics

innovation + you

Basics of Mechanical Ventilation

- History [Wikipedia]

- The Greek physician Galen may have been the first to describe mechanical ventilation: "If you take a dead animal and blow air through its larynx [through a reed], you will fill its bronchi and watch its lungs attain the greatest distention."[20] Vesalius too describes ventilation by inserting a reed or cane into the trachea of animals.[21] In 1908 George Poe demonstrated his mechanical respirator by asphyxiating dogs and seemingly bringing them back to life.[22]

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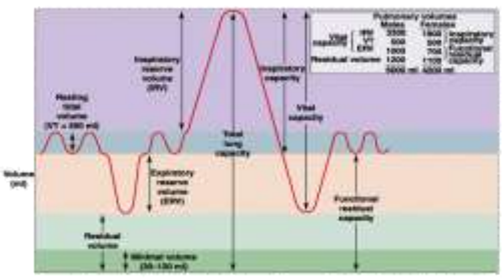
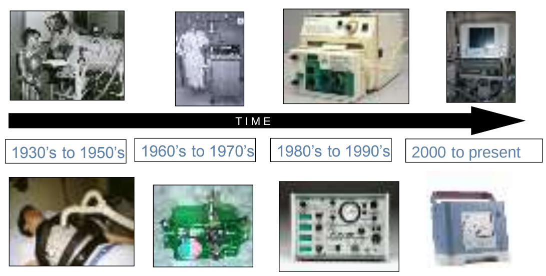
Lung Volumes and Capacities



PHILIPS

Evolution of Mechanical Ventilation



Branson, et. al. Respiratory Care Equipment 2nd ed. 1999

Goals of Mechanical Ventilation

- Relieve symptoms
- Reduce work of breathing
- Improve or stabilize gas exchange
- Improve duration and quality of sleep
- Enhance the quality of life
- Prolong survival
- Provide cost effective care
- Improve or sustain physical and psychological function

1 Nicholas Hill, *Noninvasive Positive Pressure Ventilation: Principles and Applications*
2 AARC Clinical Practice Guideline: Long-Term Invasive Mechanical Ventilation in the Home Respiratory Care 2007;52(1):1056-1062

Definitions

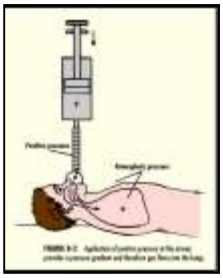
Non-Invasive Ventilation (NIV)

Non-invasive ventilation refers to the delivery of mechanical ventilation to the lungs using techniques that do not require an artificial airway

Invasive Ventilation (IV)

Invasive ventilation refers to a life support system designed to replace or support normal ventilatory function utilizing an artificial airway

Positive Pressure Ventilation



- Creates a positive intra pleural pressure in presence of atmospheric extra thoracic pressure
- Mouth (atmospheric), Lungs (atmospheric) = Inspiration
- Problems - Barotrauma

7

Mechanical Ventilation

Positive Pressure Ventilators

- Volume ventilators
- Pressure ventilators
- Mixed mode ventilators

8

Positive Pressure Ventilation

Volume-Targeted Ventilation

- Preset volume is delivered to patient
- Inspiration ends once volume is delivered
- Volume constant, pressure variable
- Ensures proper amount of air is delivered to lungs regardless of lung condition
- May generate undesirable(high) airway pressures

9

Positive Pressure Ventilation

Pressure-Targeted Ventilation

- Preset inspiratory pressure is delivered to patient
- Pressure constant, volume variable
- Clinician determines ventilating pressures
- Volumes may increase or decrease in response to changing lung conditions

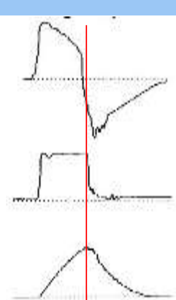
10

Waveforms

Flow

Pressure

Volume



Inspiration Expiration

11

A Breathing Cycle

A breathing cycle consists of:

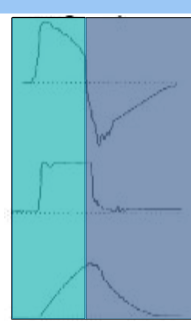
Inspiratory Phase

+

Expiratory Phase

=

One Breathing Cycle



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A Spontaneous Breath

A breath that has been initiated by the patient:

The ventilator has detected that the patient wants to breath in and delivers the breath

A Controlled Breath

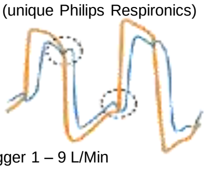
A breath that has been initiated by the ventilator:

The ventilator start the breathing cycle

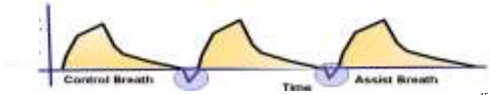
Trigger

= the mechanism that detects breathing effort of the patient and initiates the breathing cycle

1. Digital AutoTrak (unique Philips Respironics)



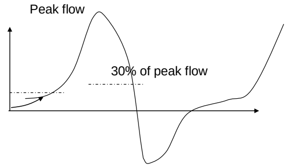
2. Patient Flow Trigger 1 – 9 L/Min



Cycle (Cycling)

= the mechanism that terminates the inspiratory phase and initiates the expiratory phase (cycles from Inspiration to Expiration).

1. Digital AutoTrak
2. Flow Cycle 10 - 90% of the peak flow



Ventilator Parameters

Tidal Volume (Vt)

"Is the volume of air during one breath"

Vti (= Inspiratory Tidal Volume)
Is the amount of air moved during the inspiration.
When used on ventilators: the amount of air that is delivered by the ventilator to the patient during the inspiration.

Vte (= Expiratory Tidal Volume)
Is the amount of air breathed out by the patient.

Vti – Vte = Leak

Respiratory Rate (RR)

The Respiratory Rate the number of respirations during 1 minute.
Most of the time expressed in BPM (= Breaths Per Minute)

In the monitoring screen:
The number of respiration measured during 1 minute (spontaneous and controlled)

In the setting screen of the ventilator:
(depending on the mode of ventilation)
- Minimal frequency that has to be maintained. When this value is reached the ventilator will start delivering controlled breaths (spontaneous modes).

- Mandatory frequency maintained by the ventilator (controlled modes).

Minute Ventilation (Mv or Vmin)

Is the amount of air that has moved in and out of the patient in one minute.

It is expressed in Liter/Minute (l/min)

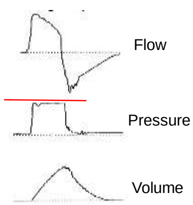
$$Vmin = RR \times Vte$$

RR = 10 BPM
Vte = 500ml

Vmin = 10 BPM x 500ml = 5000 ml/minute → 5l/min

Peak Inspiratory Pressure (PIP)

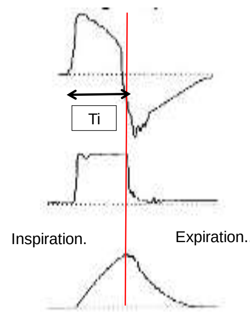
PIP is the highest pressure measured during the inspiratory phase.



Inspiratory Time (Ti)

Is the time expressed in seconds of the inspiratory phase.

i.e.: Ti = 1,2s



Ratio I/E *or* Ti/Ttot

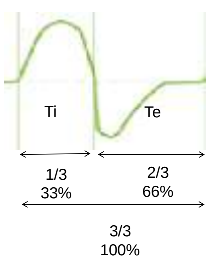
Reflects the duration of the <u>inspiration</u> compared to the whole breathing cycle

There are two ways of expressing this:
I/E or Ti/Ttot

In this example:

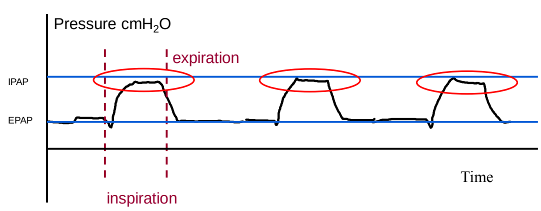
I/E = 1/2 (parts)

Ti/Ttot = 33%



IPAP (Inspiratory Positive Airway Pressure)

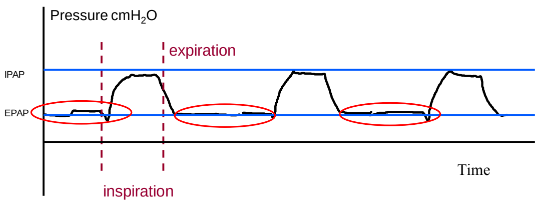
Is the pressure applied during the inspiratory phase



EPAP (Expiratory Positive Airway Pressure)

Also referred to as : PEEP (Positive End Expiration Pressure)

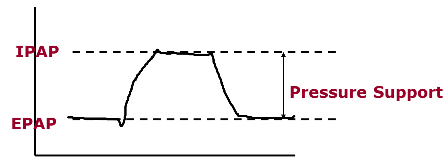
Is the pressure maintained during the expiratory phase



Pressure Support (PS)

PS = IPAP – EPAP

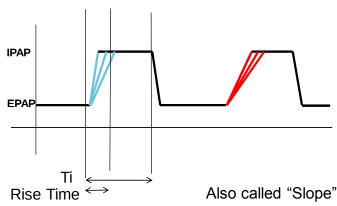
Pressure support is the amount of pressure applied above the EPAP during inspiration. This creates the “ventilation”.



IPAP = 25 cm H_2O EPAP = 5 cm H_20 → **PS = 20 cm H_2O**

Rise Time

Is the time used by the machine to build up the pressure from EPAP to IPAP. It is expressed in milliseconds (ms).
Usually from 100ms (fast) to 600ms (slow).
The Rise Time is a part of the Ti (inspiratory time).

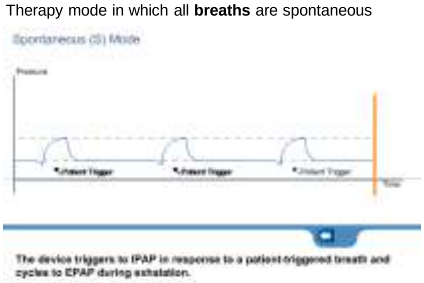


Also called “Slope”

Modes of Ventilation

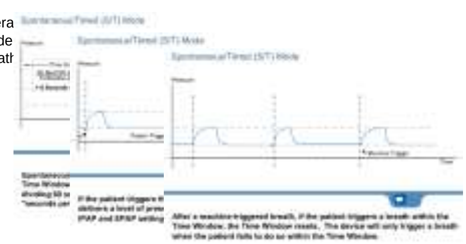
Spontaneous Mode (S)

Therapy mode in which all **breaths** are spontaneous



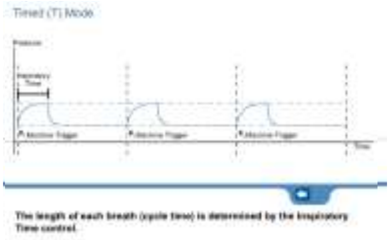
Spontaneous/Timed Mode (S/T)

- Thera
mode
breath



Timed Mode (T)

Times pressure support therapy mode with all mandatory delivered breaths.



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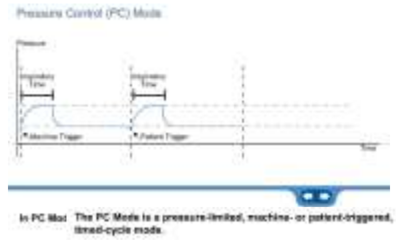
Pressure Control Mode (PC)

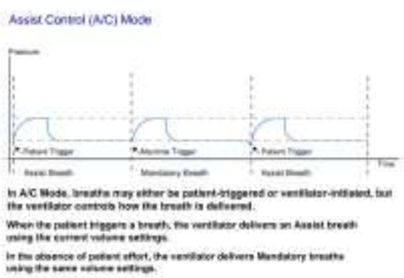
Delivers assisted and mandatory breaths at a user-defined pressure.



32

Volume Assist Control Mode (AC)

Delivers assisted and mandatory breaths at a user-defined volume.



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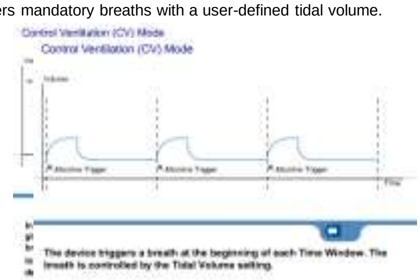
Volume Control (CV)

Delivers mandatory breaths with a user-defined tidal volume.



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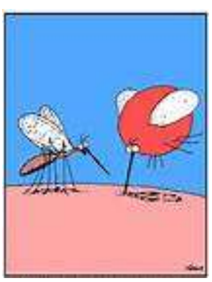


“Pull out Betty! Pull out…You’ve hit an artery”

Possible Complications of Mechanical Ventilation

Non-invasive Ventilation	Invasive Ventilation
Aspiration	Barotrauma
Gastric insufflation	Mucosal injury
Mask issues (pressure sores, air leaks, discomfort, rash)	Decreased venous return
Nasal congestion/dryness	Hyper/hypoventilation
Eye irritation	Decreased urinary output

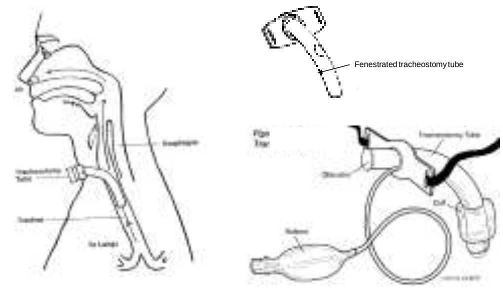
Long-term invasive mechanical ventilation in the home

Patients may have shown

- An inability to be completely weaned from invasive ventilatory support
- A progression of disease etiology that requires increasing ventilatory support
- Conditions may include
  - Ventilatory muscle disorders
  - Obstructive lung diseases
  - Restrictive lung diseases

AARC Clinical Practice Guideline: Long-Term Invasive Mechanical Ventilation in the Home Respiratory Care 2007;52(1):1056-1062

Tracheostomy Tube



All About Home NIV

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Advantages of Home Noninvasive Ventilation

- Ease of use
- Reduced need for skilled caregivers
- Elimination of tracheostomy-related complications
- Improved patient comfort
- Allows speech, improved communication
- Lower overall cost of care

Indications for NIV

Symptoms of chronic hypoventilation may include

- Worsening of dyspnea or orthopnea
- Morning headaches
- Daytime hypersomnolence

Physiological criteria may include

- Worsening acid/base balance
- Sustained oxygen desaturation
- Vital capacity below 50%
- Maximal inspiratory force less than 60 cm H_2O

Cairo, JM and Pilbeam, SP. Mechanical Ventilation: Physiological and Clinical Applications 4th ed 2006

Goals of Noninvasive Ventilation

- Relieve symptoms
- Reduce work of breathing
- Improve or stabilize gas exchange
- Improve duration and Quality of Sleep
- Maximize Quality of Life
- Prolong survival

Nicholas Hill, *Noninvasive Positive Pressure Ventilation: Principles and Applications*

Which pathologies would benefits from Home NIV?

The Use of NIV in Chronic Respiratory Insufficiency

What is CRF?

- **Chronic respiratory failure (CRF)** may result from different pathologies, which make the body inept to bring oxygen and/or wash out its CO_2.
- As a result there is a decrease of the PaO_2 (hypoxemia) and/or an increase of the Pa CO_2 (hypercapnia) noticed during blood gases analysis

Chronic Respiratory Failure
Patients Management

« The management strategy is based on an individualized assessment of disease severity and response to various therapies. »

Source: Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease
GOLD scientific committee - NHLBI/WHO workshop summary - AJRCCM 2001

Therapy depends upon the patient's pathology type and severity

COPD and Ventilation

Cost of COPD

Chapman et al. Eur Respir J 2006; 27: 188–207

COPD

Pink puffer
emphysema prédominant

Blue bloater
bronchitis prédominante

COPD Patient
Some definitions

COPD
Chronic Obstructive Pulmonary Disease is the name given to the progressive narrowing of the airways

This narrowing may result from an obstruction of the airways in patients with Chronic Bronchitis (scarring of the airways and sputum secretion) or emphysema

Emphysema
Emphysema is brought about by cigarette smoking which results in chemical changes that destroy lung tissue:
- Loss of lung tissue: reduction of elasticity
- Airways tend to close

COPD patients who may benefit from NIV

- Severe, stable COPD & persistent symptoms despite medical therapy
- Substantial daytime CO_2 retention: $PaCO_2$ > 55 mm Hg **or**
- $PaCO_2$ of 50-54 mmHg and hospitalization related to recurrent episodes of hypercapnic respiratory insufficiency (> 2 episodes in 1 year)
- Nocturnal oxygen desaturation: SaO_2 < 88% for > 5 consecutive minutes sustained while receiving oxygen therapy
- Motivated patient

Before intubation a trial of NIV should be attempted

1 Consensus Conference, Chest 1999

2 Kacmarek, et. al. The Essentials of Respiratory Care 4th ed. 2005

COPD Patient

<70% **FEV1/FVC** **<30%**

Mild stage	Moderate stage	Severe stage
Mild airflow limitation	Worsening airflow limitation	Severe airflow limitation

Drugs and Pulmonary Rehabilitation

Long Term Oxygen Therapy

Noninvasive Ventilation

As the disease progresses, hypoxemia occurs and hypercapnia is seen in advanced disease.

Global Strategy for the Diagnosis, Management, and Preventation of Chronic Obstructive Pulmonary Disease
Gold Scientific Committee, NHLBI/WHO workshop summary, AJRCCM 2001

COPD Patient Oxygen Therapy

- **LTOT** (12-17hrs/day) has been shown to
  - Increase survival
  - Decrease hospitalization rate

- **Adverse effects:**
  - Hypoventilation and CO_2 retention
  - Increased $PaCO_2$ at night may contribute to arousals
  - Sudden High $PaCO_2$ deteriorate the gas balance and may lead to acidosis (exacerbation risks)

COPD Patients Home NIV Therapy

- Conflicting results of studies
- COPD population likely to benefit from NIPPV:
  - Substantial daytime CO_2 retention
  - Severe airway obstruction
  - Nocturnal oxygen desaturation
- **Benefits**:
  - Reduce nocturnal hypoventilation: allows respiratory centre to reset, improves daytime hypercapnia.
  - Improve sleep quality by reduced episodes of hypoventilation and desaturations
  - Resting chronically fatigued respiratory muscles, allowing recovery of inspiratory muscle function
  - Decrease Decompensation episodes risks/severity

Benefits: improve patient quality of life

Source: Consensus conference : « Clinical indications for noninvasive positive pressure ventilation in chronic respiratory failure due to restrictive lung disease, COPD and Nocturnal hypoventilation » Chest 1999

Evidence Statements from NICE
(National Institute for Clinical Excellence)

- Addition of NIV to LTOT improved daytime $PaCO_2$ during oxygen breathing
- Resting dyspnoea improved in NIV+LTOT group, and was significantly better at month 24
- After 2 years QOL was significantly improved
- Overall hospital admissions decreased by 45% in the NIV+LTOT group compared with increase of 27% in LTOT (follow back period of 12 months)

http://thorax.bmjjournals.com/content/vol59/suppl_1/

NICE Recommendation

Adequately treated patients with Chronic hypercapnic respiratory failure who have required assisted ventilation (whether invasive or non-invasive) during an exacerbation or who are hypercapnic or acidotic on LTOT should be referred to a specialist centre for consideration of long-term NIV.

Chronic Obstructive Pulmonary Disease: National clinical guideline on management of chronic obstructive pulmonary disease in adults in primary and secondary care

Thorax 2004;59(suppl 1) 1-232

Rationale of chronic NIPPV in COPD

- Improved sleep
- Improved lung function
- Resting the respiratory muscles
- Less hyperinflation
- Increased respiratory drive

High Intensity NIV in Stable Hypercapnic COPD

Conclusion

"High-intensity NIV improves blood gases, lung function and hematocrit and is also associated with low exacerbation rates and a favourable long-term outcome. The current report strongly emphasises the need for randomised controlled trials evaluating the role of high-intensity NIV in stable hypercapnic COPD patients"

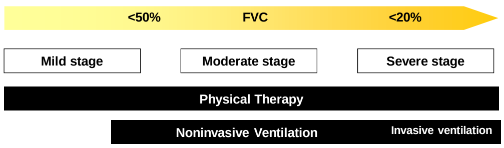
Windisch et al. Int. J. Med. Sci. 2009, 6

Restrictive Patients and NIV

Restrictive Thoracic Disorders

- **Obese Hypoventilation**
- **Chest wall deformities**
  - Kyphoscoliosis
  - Sequel of tuberculosis
- **Non progressive or slowly progressive neuromuscular disorders**
  - Central hypoventilation
  - Spinal cord injury, spinal muscular dystrophy
  - Myopathies
  - Sequel of Poliomyelitis
- **Progressive neuromuscular disorders**
  - Amyotrophic Lateral Sclerosis (ALS)
  - Duchenne muscular dystrophy

Restrictive Patients Pathology Progression



Respiratory Muscle Weakness | Cor Pulmonale

Sleep-Disordered Breathing | Oxygen desaturation during exercise

Source: "Ventilator Assistance in the Home" D Robert, B.J. Make, P Léger, A. L. Goldberg, J. Paulus, T. Willig – 1994
Source: Consensus Conference, Chest 1999

Restrictive Patients

"More recent reviews have cited the **advantages of pressure** targeted devices for **comfort** and their ability to **compensate for leaks**. Volume targeted equipment may be favorable for many patients simply because triggering mechanism are more adjustable and pressure targeted systems are **not able to guarantee a minimum minute ventilation**."

Source: Consensus Conference - Chest 1999

- 10 years ago: Invasive ventilation/volume at the late stage of the disease
- Today:
  - Start at the early stage in Pressure Support
  - Use security functions while patient becomes dependant
  - Ends up with invasive ventilation (< 5% of patients)

Restrictive Patients When shall we start NIV?

- Progressive respiratory muscle weakness and difficulties with oxygenation at night
- Substantial CO2 retention: PaCO2 > 45mmHg **or**
- Nocturnal oxygen desaturation: SaO_2 < 88% for > 5 consecutive minutes
- Maximal inspiratory pressure < 60 cmH20 and forced vital capacity < 50% predicted

Some patients may require invasive ventilation during crisis phase or long-term

1 Cairo, JM and Pilbeam, SP. Mechanical Ventilation: Physiological and Clinical Applications 4th ed 2006

2 Kacmarek, et. al. The Essentials of Respiratory Care 4th ed. 2005

Indications for NIV

Symptoms

- Worsening of dyspnea or orthopnea
- Morning headaches
- Daytime hypersomnolence

Physiological Criteria

- Vital Capacities below 50%
- Maximal Inspiratory Force less than 60 cm H_2O

Study Supporting NIV Therapy in ALS

Effect of NIV assessed on QOL and survival in ALS patients

- 92 patients assessed every 2 months and randomly assigned to NIV or standard care
- 2 different QOL outcome scales were used

Results:

- NIV improved QOL and survival in all patients and in the subgroup who had better bulbar function
- The subgroup showed improvement in several measures of QOL and a median survival benefit of 205 days
- NIV improved some QOL indices in those with poor bulbar function, but conferred no survival benefit

Bourke, SC. Et al., Lancet Neurology. 2006

Efficacy of NIV Therapy in Central Hypoventilation

• 54 patients with Obesity Hypoventilation Syndrome (OHS) treated with NIV to assess short and long-term effects
• Outcome measures were survival, clinical status and ABG results Follow-up period (50 months)

Results:

• Pa02 increased and Co2 decreased
• Improved subjective sleepiness and decrease in dyspnea in all but 4 patients
3 patients died during follow-up period

Conclusion

- NIV therapy is effective in the treatment of patients with OHS and provided a significant improvement in clinical status and gas exchange

Perez de Llano, LA et al. Chest. 2005;128:587-594

Questions?