# IN THE NAME OF GOD


**Fig. 3.13** Some popular ICU ventilators based on the intermittent positive pressure ventilation (IPPV) principle.

# Mechanical Ventilation

By dr jalal saem MD

# Introduction

Mechanical ventilation is one important part of care of many critically ill patients especially in patients with respiratory failure. It is mostly provided inside the hospital, especially inside the ICU, but it is also provided at the side outside the ICU and outside the hospital

It is important to know and understand different mechanical ventilation modes in order to match breath delivery to specific clinical application and patient needs.

Modes of mechanical ventilation can be classified as totally or partially ventilator controlled.

# NEGATIVE PRESSURE VENTILATION

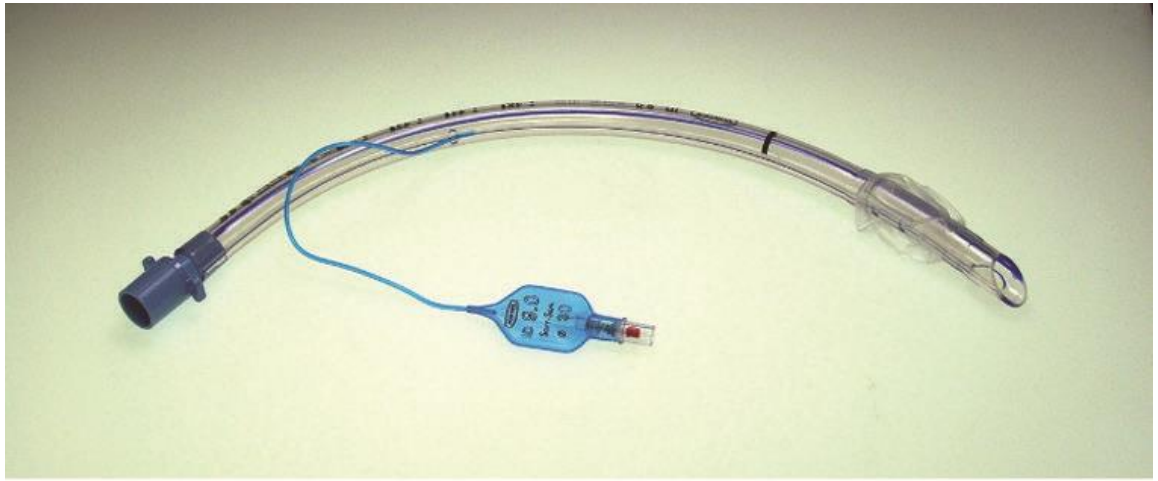
(a)

(b)

**Fig. 3.15** a) An iron lung, b) A cuirass ventilator.

(a) Poumon artificiel, Wikimedia Commons, accessed 6 October 2016, https://commons.wikimedia.org/wiki/File:Poumon_artificiel.jpg This image is in the public domain and thus free of any copyright restrictions. This media comes from the Centers for Disease Control and Prevention's Public Health Image Library.

# POSITIVE PRESSURE VENTILATION



•Although positive-pressure mechanical ventilation is usually applied through an endotracheal tube or a tracheotomy, it also may be delivered noninvasively to the patient’s mouth, nose, or through helmets.

# VENTILATORS


**Fig. 3.13** Some popular ICU ventilators based on the intermittent positive pressure ventilation (IPPV) principle.

# *Control System of Respiration*

- Brain sensors, which are near the medulla, will sense the level of CO2 by knowing the pH of the blood that flows through the brain. Sensors in the aortic arch and carotid artery will sense the level of O2 and CO2 in the blood.
- The brain decides to either increase or decrease the inspiratory rate or the depth of breathing.
- The brain stimulates the respiratory center through the nerves for the respiratory muscles (diaphragm and intercostal muscles) to move.
- The diaphragm and the intercostal muscles move to expand the lungs and the alveoli inside the lungs.

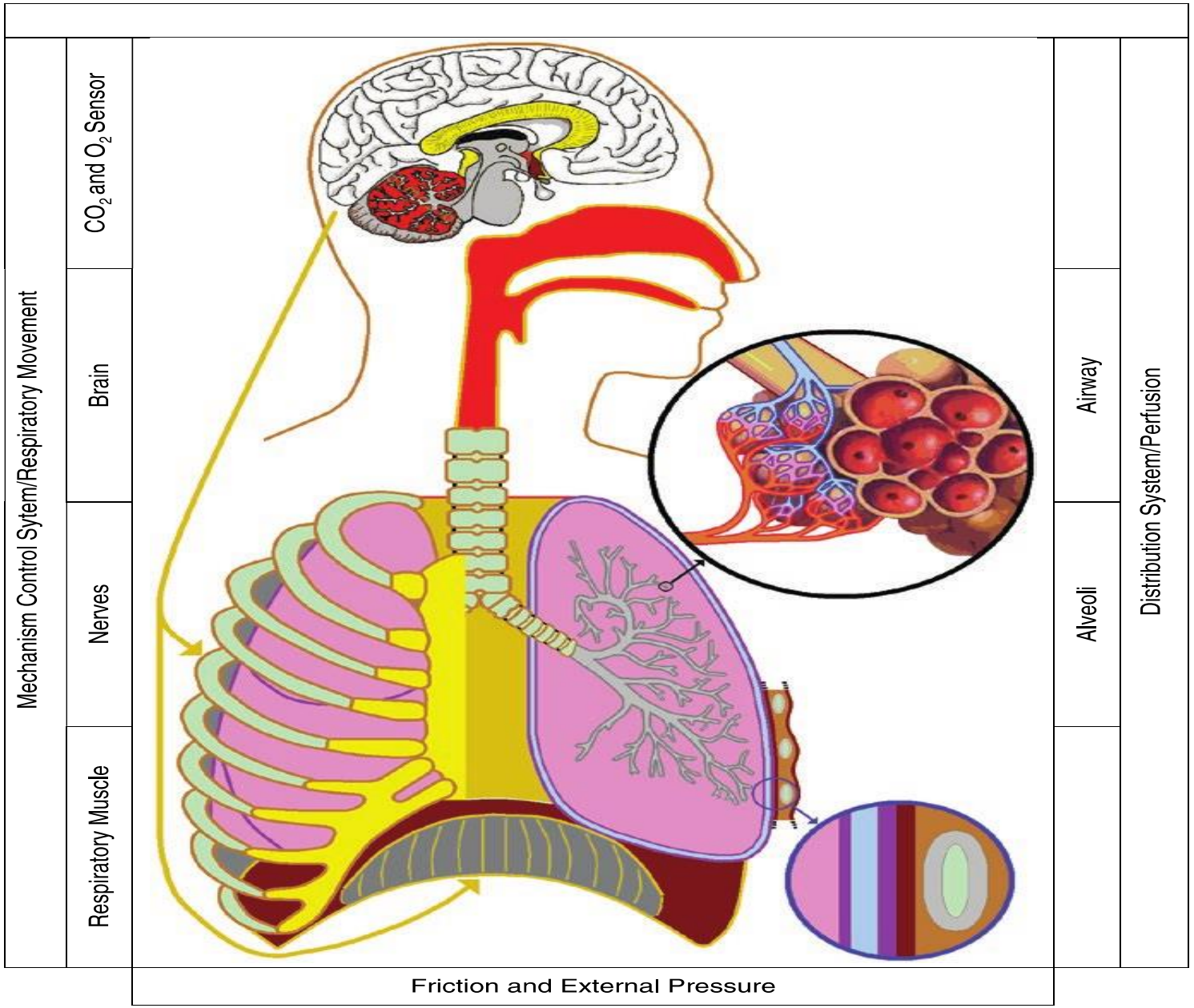



**Fig. 2.3** Control system and respiratory anatomy

# *Distribution System/Perfusion*

- On inspiration, fresh air goes into the upper airway then into the lower airway.
- Fresh air goes into the alveoli, so gas exchange with the blood occurs.
- Gas exchange occurs when O2 goes into the blood cell and CO2 from the blood
- goes into the alveoli.
- On expiration, used air goes out of the alveoli.
- Used air goes out through the lower airway and the upper airway.

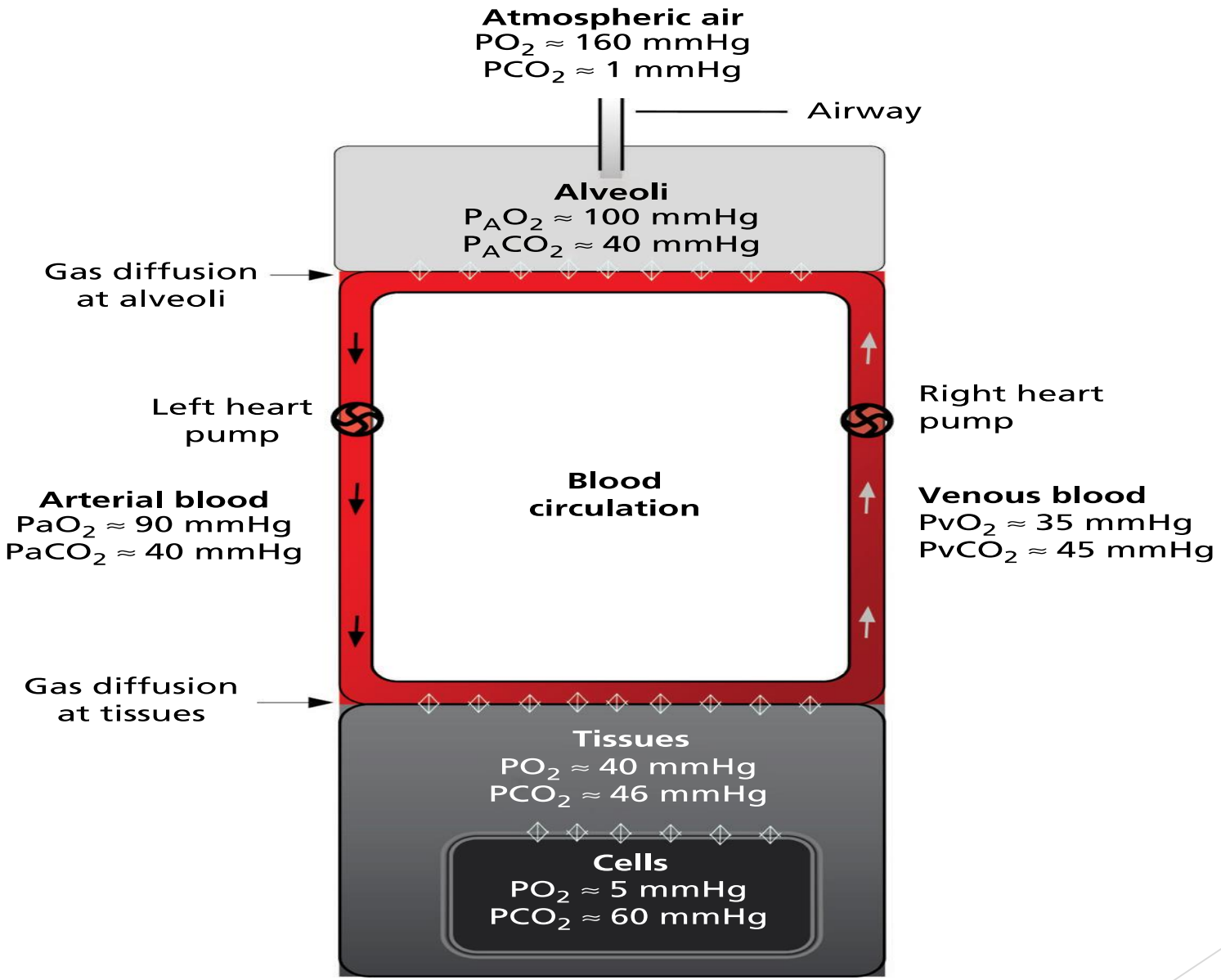



**Fig. 3.6** Diagram of the entire respiration process.

# ventilatory support

- (1) impairs the capacity of the respiratory muscles to generate sufficient Pmus, (Pmus = Pres + Pel )
- (2) increases the ventilatory requirements above the muscle capacity,
- 
- (3) increases the workload associated with the act of breathing.

# Clinical conditions often requiring mechanical ventilation

- **Acute pulmonary parenchymal disease**
  - Pneumonia - infectious, aspiration, inhalation injury
  - Acute respiratory distress syndrome
- **Cardiogenic pulmonary edema**
  - Acute myocardial infarction
  - Cardiomyopathy
  - Intravascular volume overload of any cause
- **Airways disease**
  - Exacerbation of chronic obstructive pulmonary disease
  - Acute, severe asthma
- **Primary ventilatory failure**
  - Guillain-Barre syndrome
  - Myasthenia gravis
  - Drug overdose
  - Chest wall disease
- **Systemic illness**
  - Shock
  - Sepsis
- **Miscellaneous**
  - Intraoperative (general anesthesia)
  - Chest trauma

# Abnormalities suggestive of the need for mechanical ventilation

**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 cmH20
- Minute ventilation<10 L/min
- Rise in PCO2>10 mmHg

**Refractory hypoxemia**

- Alveolar-arterial gradient (FiO2 = 1.0)>450
- PaO2/PAO2<0.15
- PaO2 with supplemental O2<55 mmHg

# A Breath Sequence

- Breath Initiation (Trigger Variable)
- Breath Delivery Target (Limit)
- Cycling to Expiration (Cycle Variable)
- Expiration (Baseline Variable)
- (1) the trigger variable (what initiates the breath), (2) the limit variable (the algorithm that governs positive pressure delivery), and (3) the cycle variable (what terminates the inspiratory phase).

# Various Types of Breath Delivery Based on Flow Control Target

- **Volume-Controlled Breath Delivery**
- **Pressure-Controlled Breath Delivery**
- **Pressure Support Breath Delivery**
- CPAP

# Volume-Controlled Breath Delivery

**Table 3.1** Advantages and disadvantages of volume-controlled ventilation

| Advantages | Disadvantages |
|---|---|
| – Tidal volume of the lungs is more constant and safer from the risk of volutrauma<br>– Minute volume (MV) is constant with the same respiratory rate to stabilize the removal of $CO_2$ | – Peak pressure is not always stable, which depends on the changes of airway resistance and needs to be stabilized by the pressure alarm<br>– Peak pressure is not always stable, which depends also on the lung compliance and that has the possibility of having risk of barotrauma. Because of this, this needs to be stabilized by the pressure alarm<br>– Inspiratory flow demand has already been set with the tidal volume setting and inspiratory time (and plateau time) |

# Respond to pt trigger

**Table 3.11** Respond from ventilator in patient trigger based on ventilation modes

| | Breath variety | Ventilation mode | Respond to patient trigger |
|---|---|---|---|
| PEEP | Volume-controlled breath | (Full) volume controlled | Patient trigger is ignored |
| | | (Assist) volume controlled | Volume-controlled breath is given |
| | | Volume SIMV | Volume-controlled breath is given in assist period |
| | Pressure support breath | | Pressure support is given in spontaneous period |
| | | Pressure support ventilation | Pressure support breath is given |
| | | Pressure SIMV | Pressure support is given in spontaneous period |
| | Pressure-controlled breath | | Pressure-controlled breath is given in assist period |
| | | (Assist) pressure controlled | Pressure-controlled breath is given |
| | | (Full) pressure controlled | Patient trigger is ignored |

# Target & cycle

- Volume control : flow controlled – volume cycled
- Pressure control : pressure controlled – time cycled
- Pressure support : pressure controlled - flow cycled

# Type of Breath Based on Breath Initiation Source

- **Mandatory Breath**
- Mandatory breath is totally controlled by the ventilator which is ventilator triggering by a preset respiratory rate.
- Breath delivery target is volume controlled or pressure controlled.
- Cycle of breathing is determined by inspiratory time.
- **Assisted Breath**
- Assisted breath consists of both mandatory breath and spontaneous breathing. In assisted breath, trigger sensitivity is activated. When patient triggers the ventilator (spontaneous breathing), it will deliver breath as mandatory breath because it delivers the preset values.
- Breath delivery target is volume controlled or pressure controlled. And cycle of breathing is determined by inspiratory time
- **Spontaneous Breathing**
- Spontaneous breathing is a breath from the patient himself

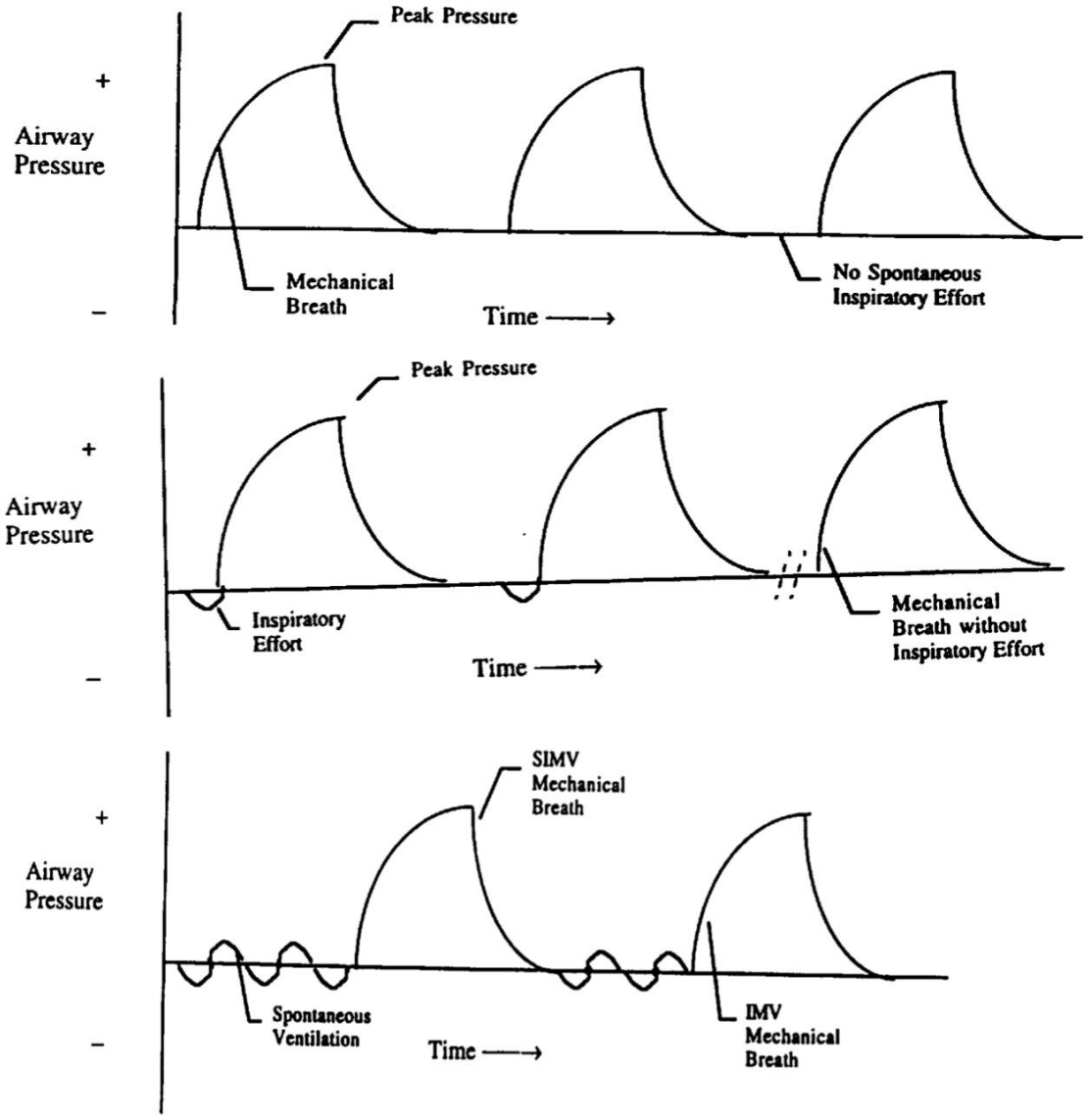
# TOTAL (FULL) VENTILATORY SUPPORT volume controlled

- **CONTROLLED MECHANICAL VENTILATION. CMV .**
  (flow-limited controlled mechanical ventilation [CMV]) or pressure (pressure-limited controlled ventilation [PCV])
- **ASSISTED MECHANICAL VENTILATION . AMV .**
  (inspiratory time, expiratory time, duration, and ratio of inspiratory time to total breath cycle duration), and level of assistance

- **Assist/Control Mechanical Ventilation . A/C .**
  The patient is allowed to set the respiratory rate by activating the inspiratory trigger function
- Intermittent positive pressure ventilation . IPPV .

- **Intermittent Mandatory Ventilation . IMV .**
- **Synchronized Intermittent Mandatory Ventilation . SIMV .**

# Volume Control Modes



# Pressure-Controlled Breath Delivery

**Table 3.5** Advantages and disadvantages of pressure-controlled ventilation

| Advantages | Disadvantages |
|---|---|
| – Peak pressure is more constant even lung compliance is changing and so is safer from the risk of barotrauma<br>– Inspiratory flow demand is fulfilled because of regulated inspiratory flow → improve gas distribution → inflate collapsed alveoli | – Tidal volume change depends on changes of lung compliance which gives a possible risk of volutrauma that needed to be limited by volume alarm<br>– Minute volume (MV) change depends on changes of tidal volume with the same respiratory rate, which causes unstable removal of $CO_2$ |

# PRESSURE CONTRLLED VENTILATION

## BIPHASIC POSITVE AIRWAY PRESSURE (BIPAP)

## PARTIALY(ASSIST) VENTILATORY SUPPORT

- Pressure Support Ventilation
- SPONTANEOUS VENTILATION
- POSITIVE END-EXPIRATORY PRESSURE
- CONTINUOUS POSITIVE AIRWAY PRESSURE

# Pressure Support Breath Delivery

**Table 3.8** Advantages and disadvantages of pressure support breath delivery

| Advantages | Disadvantages |
|---|---|
| – Peak pressure support is more constant even respiratory drive/muscles and lung compliance changes and so safe from the risk of barotrauma<br>– Inspiratory flow demand is fulfilled because of adjusted/regulated inspiratory flow → improve gas distribution → inflate collapsed alveoli | – Tidal volume changes depend on changes of lung complianceand respiratory drive which cause possibility of having risk of volutrauma that needs to be restricted by volume alarm<br>– Minute volume (MV) changes depend on changes of tidal volume at the same respiratory rate which cause unstable removal of $CO_2$<br>– Inspiratory time (cycling) is determined by peak inspiratory flow and so with lower flow (respiratory muscles are weak), and then inspiratory time is shorter (volume decreases) |

# CPAP & PEEP

- A constant level of positive pressure applied to a spontaneous breathing cycle is termed continuous positive airway pressure (CPAP).

- Positive end-expiratory pressure (PEEP) is the positive pressure applied at the end of expiration during positive- pressure mechanical ventilation

# NEW MODES

PRESSURE REGULATED VOLUME CONTROL (PRVC)
(PCVG)
volume assured pressure support (VAPSV)

ADAPTIVE SUPPORTIVE VENTILATION(ASV)

**Proportional Assisted Ventilation (PAV)**

**AIRWAY PRESSURE RELESASE VENTILATION(APRV)**

**Neurally Adjusted Ventilatory Assist**

# VENTILATOR SETUP

- MODE
- VT
- RR
- FIO2
- PEEP
- PSV
- P MAX
- FIOW
- TRIGGER
- I/E RATIO
- T. INSP

# VENTILATOR SETUP

- ABG
- PAO2
- PACO2
- PH

TV
RR
LOW MV
HIGH PR
LOW PR
FIGHT
ALARMS
sedation

# VENTILATOR SETUP

OXYGENATION GOAL:
**$PaO_2$ 55 to 80 mm Hg or $SpO_2$ 88% to 95%**
Use incremental $FiO_2$/PEEP combinations below to achieve goal:

| $FiO_2$ | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.7 |
|---|---|---|---|---|---|---|---|---|
| PEEP | 5 | 5 | 8 | 8 | 10 | 10 | 10 | 12 |
| | | | | | | | | |
| $FiO_2$ | 0.7 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 |
| PEEP | 14 | 14 | 14 | 16 | 18 | 20 | 22 | 24 |

# Objectives of mechanical ventilation

## Clinical objectives

- Reverse hypoxemia
- Reverse acute respiratory acidosis
- Relieve respiratory distress
- Prevent or reverse atelectasis
- Reverse ventilatory muscle fatigue
- Permit sedation and/or neuromuscular blockade
- Decrease systemic or myocardial oxygen consumption
- Stabilize the chest wall

# WEANING

- SIMV
- BIPAP
- PSV
- CPAP
- T-PIECE TRIAL

STABLE HEMODYNAMIC
ACCEPTABLE ABG
NO FEFVER
NO INFECTION
NO VASOPRESSORS
GCS
SECRETION
GAG ERFLEX

# ARDS

- Intermittent positive-pressure mechanical ventilation is the gold standard for assisting patients with acute respiratory failure.
- Low vt
- Low fio2
- High peep
- Permisive hypercapnia
- Sedation & mr
- other

# ARDS

- Acute respiratory distress syndrome (ARDS) is an inflammatory response of the lung with acute onset and presence of bilateral infiltrates on chest radiography. ARDS is characterized by a reduction in functional residual capacity and static compliance. The correct setting of mechanical ventilation in ARDS is of paramount importance to minimize ventilator-induced lung injury

# Non-invasive VENTILATION

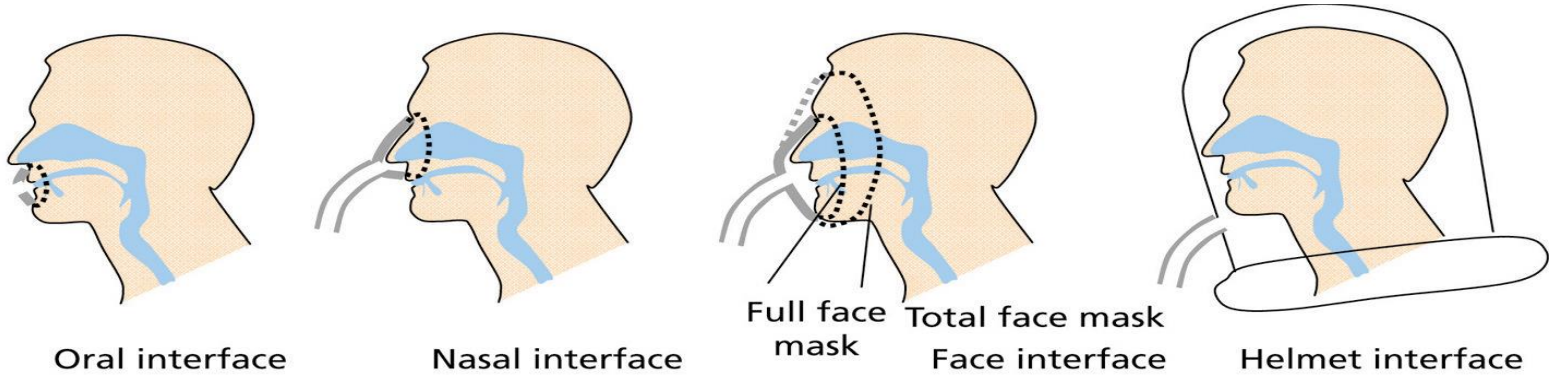



**Fig. 5.24** Four basic types of non-invasive airway interface.

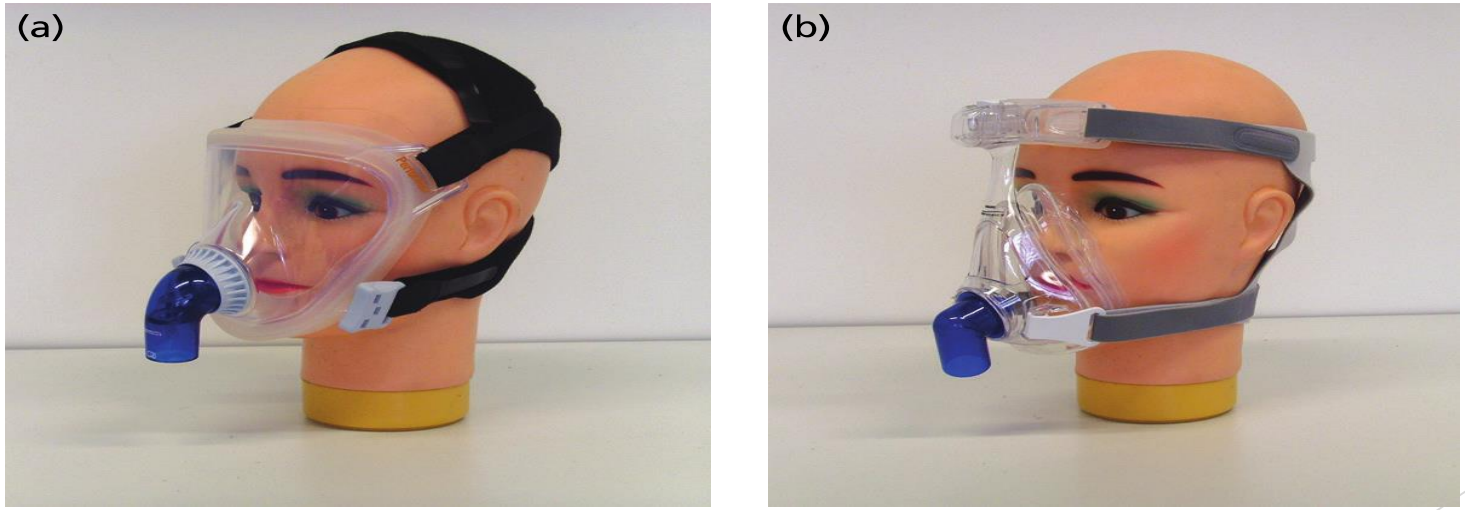



**Fig. 5.25** Total face mask (left) and full face mask (right) from Philips Respironics.

# NONINVASIVE VENTILATION

- Stable Hypercapnic Chronic Obstructive Pulmonary Disease
- Correction of Hypoventilation
- Respiratory Muscle Unloading
- Reset of the Respiratory Centers
- Cardiovascular dx
- Acute COPD Exacerbations