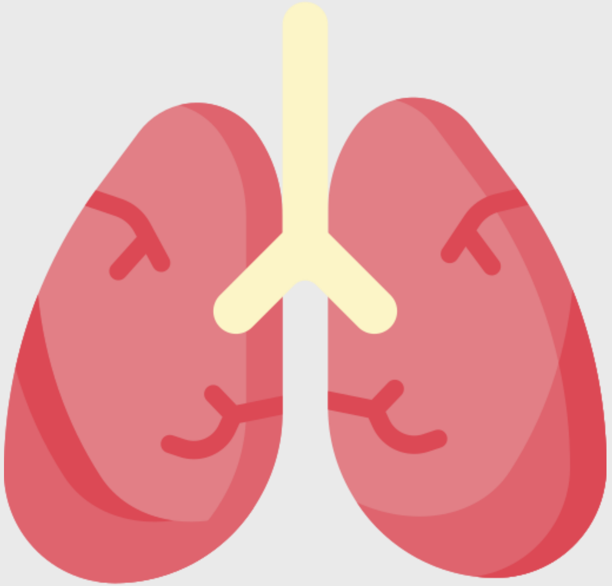
Acute Respiratory Failure



JM Tayona, Sushmita Tare and Trisha Thadhani
UPCM Class 2021 – Block 10A

The respiratory system has two main functions:

oxygenation

CO_2 elimination

Acute Respiratory Failure or **ARF** happens when the respiratory system fails in one or both of these two gas exchange functions.

What is Acute Respiratory Failure or ARF?

It is defined as having $pO_2 < 60$ mmHg or $pCO_2 > 45$ mmHg at rest, on room air and temperature and may be acute or chronic.

Note: it is acceptable to have lower pO_2 at higher altitudes!

ACUTE

life-threatening derangements in arterial blood gases and acid-base status (**minutes to hours**)

CHRONIC

manifestations are less dramatic and may not be readily apparent (**several days or longer**)

Is ARF the same thing as ARDS?

NO. They may have similar symptoms and are used interchangeably, but they are different!

ARDS

Acute Respiratory Distress Syndrome

Widespread injury to lung parenchyma due to inflammation.

Caused by direct insult to the lungs that eventually leads to respiratory failure.

Onset is acute (≤ 1 week)

ARF

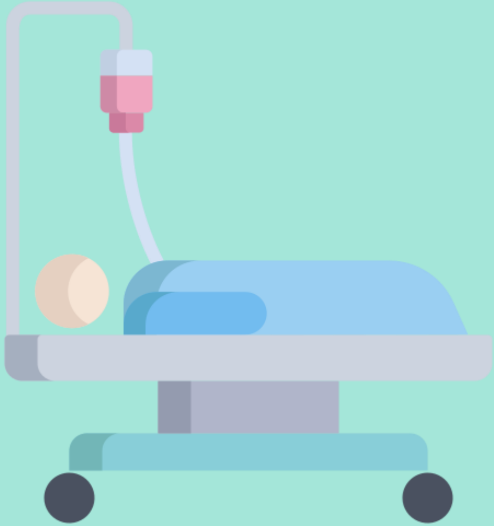
Acute Respiratory Failure

Impairment of the respiratory system resulting in inadequate gas exchange.

More general term; can be due to lung injury, or central causes like neuromuscular impairment.

May be acute or chronic.

ARF is a **syndrome** rather than a single disease process.



It is the most common form of organ failure and reason for admission in the ICU, with up to **75%** or more patients requiring mechanical ventilation during their stay.

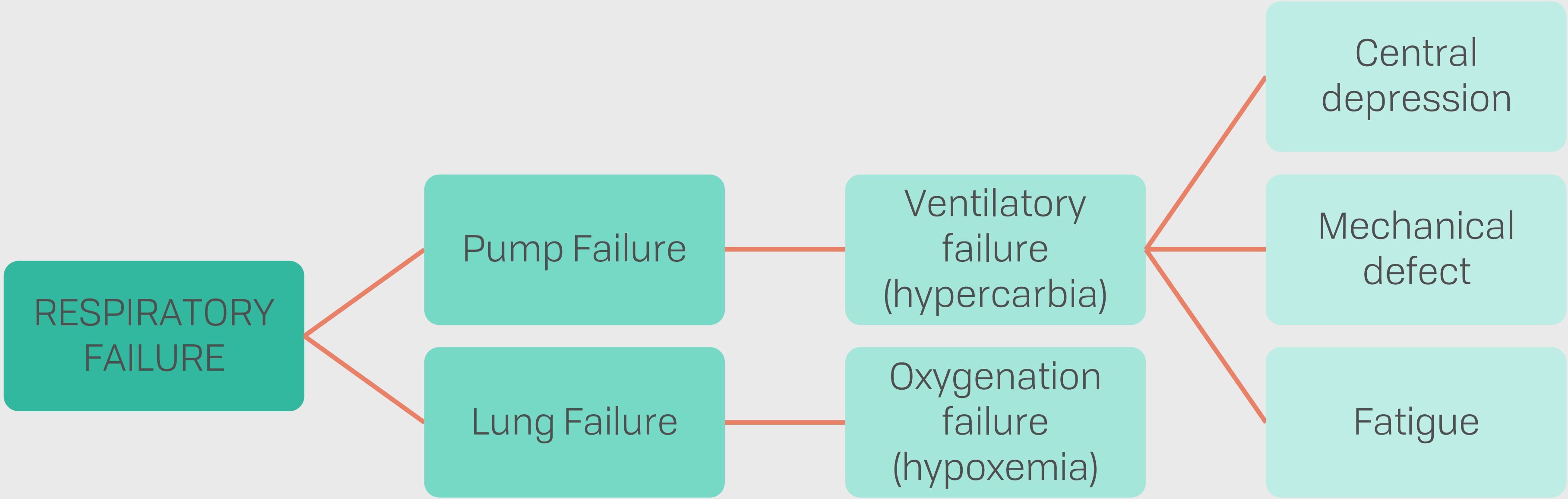
Mortality rates among **men** are higher than for women and are highest in patients older than **85 years**.

In patients younger than 45 years the most frequent causes of ARF are

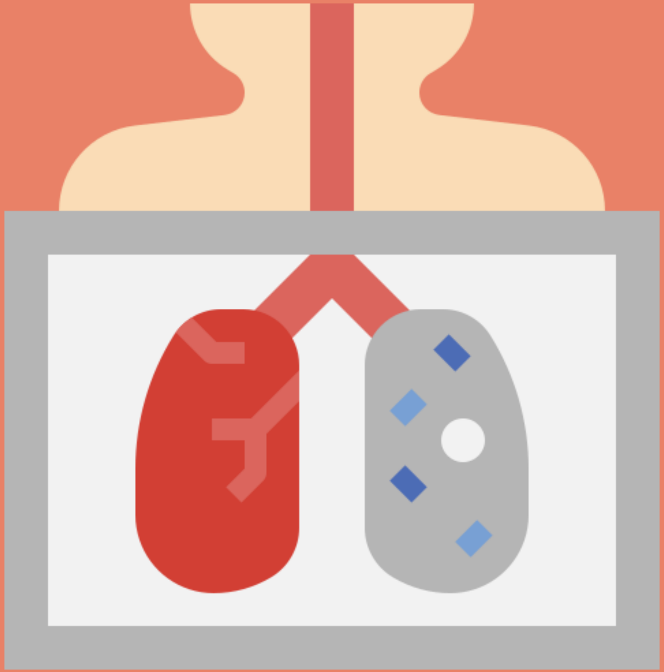
- pneumonia
- ARDS
- sepsis
- asthma
- drug ingestion
- trauma

The most common etiologies of ARF for patients over 65 years are:

- pneumonia
- ARDS
- sepsis
- CHF
- COPD



Types of Respiratory Failure



CLINICAL PRESENTATION OF RESPIRATORY FAILURE

HYPOXEMIC RESPIRATORY FAILURE

Failure of Oxygenation

Typical clinical manifestations include:

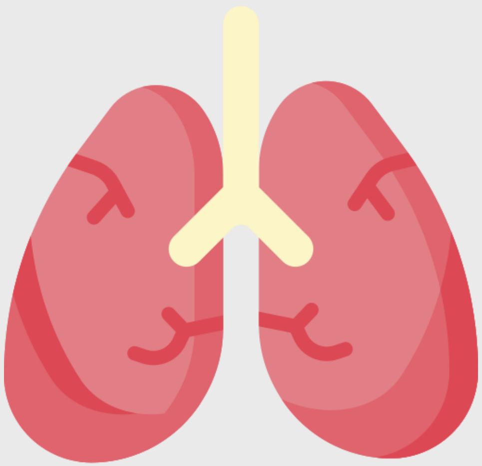
dyspnea and tachypnea
restlessness, anxiety, confusion, delirium
fluid overload
heart failure
tachycardia, elevated blood pressure
neck vein distension
cardiac arrhythmia
cyanosis

These patients always have abnormal lung findings, such as **rales** or **crackles** on auscultation.

HYPERCAPNIC RESPIRATORY FAILURE

Failure of Ventilation

Initially, these patients have rapid, shallow breathing, followed by bradypnea due to the increased CO_2.



Decreased sensorium, headache, and/or delirium follow, give the patient a **sleepy appearance**.

These patients have wheezing, poor air entry, or even normal auscultatory findings. If you don't hear wheezing, it may sometimes mean *worse* prognosis because the airways might be too tight!

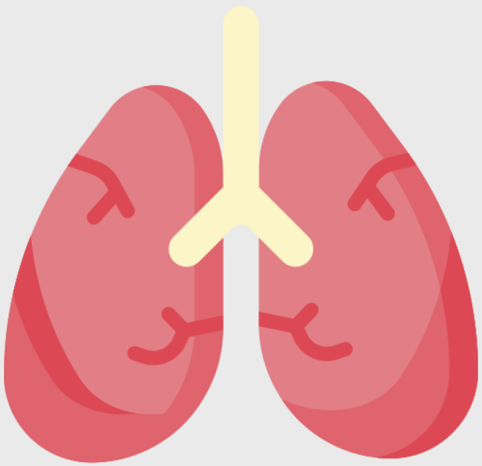
HYPERCAPNIC RESPIRATORY FAILURE

Failure of Ventilation

Their skin may be flushed, with associated tachycardia and elevated blood pressure. Muscle twitches may occur.

Initially, the O_2 saturation is normal, but may become lower as CO_2 increases (level of CO_2 at 70-80).

The end tidal CO_2 monitor measure the amount of CO_2 exhaled.



PATHOPHYSIOLOGY OF RESPIRATORY FAILURE

Respiratory failure can arise from an abnormality in any of the components of the respiratory system, including the airways, alveoli, central nervous system (CNS), peripheral nervous system, respiratory muscles, and chest wall.

It may result from either a
reduction in ventilatory capacity, an
increase in ventilatory demand,
or both.

In hypoxemic respiratory failure, the pathophysiologic mechanisms that account for the hypoxemia observed in a wide variety of diseases are V/Q mismatch and shunt.

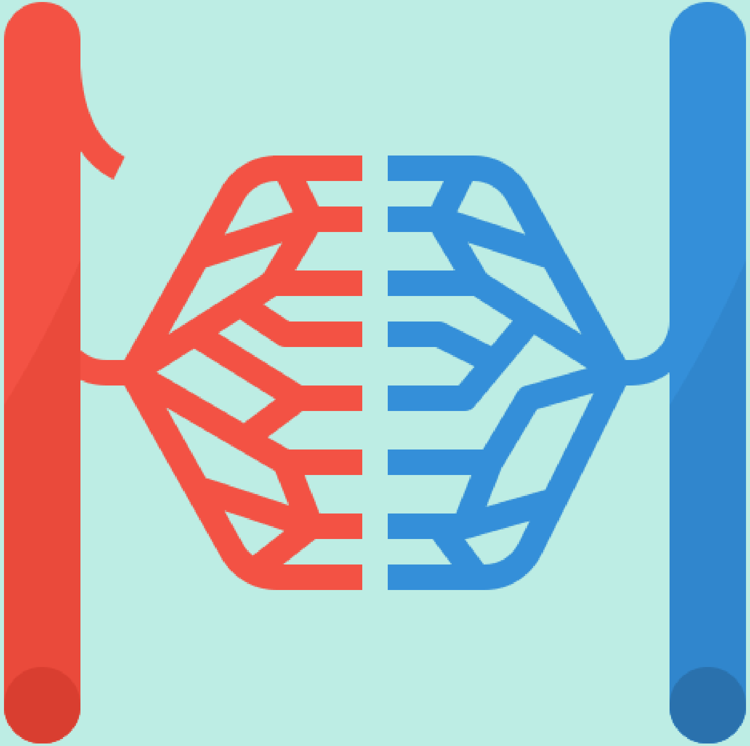
The optimally ventilated alveoli that are **not perfused** well have a large ventilation-to-perfusion ratio (V/Q) and are called high-V/Q units (which act like **dead space**).

Alveoli that are optimally perfused but **not adequately ventilated** are called low-V/Q units (which act like a **shunt**).

V/Q Mismatch

Most common cause of hypoxemia.

The low-V/Q units contribute to hypoxemia and hypercapnia, whereas the high-V/Q units waste ventilation but do not affect gas exchange unless the abnormality is quite severe.

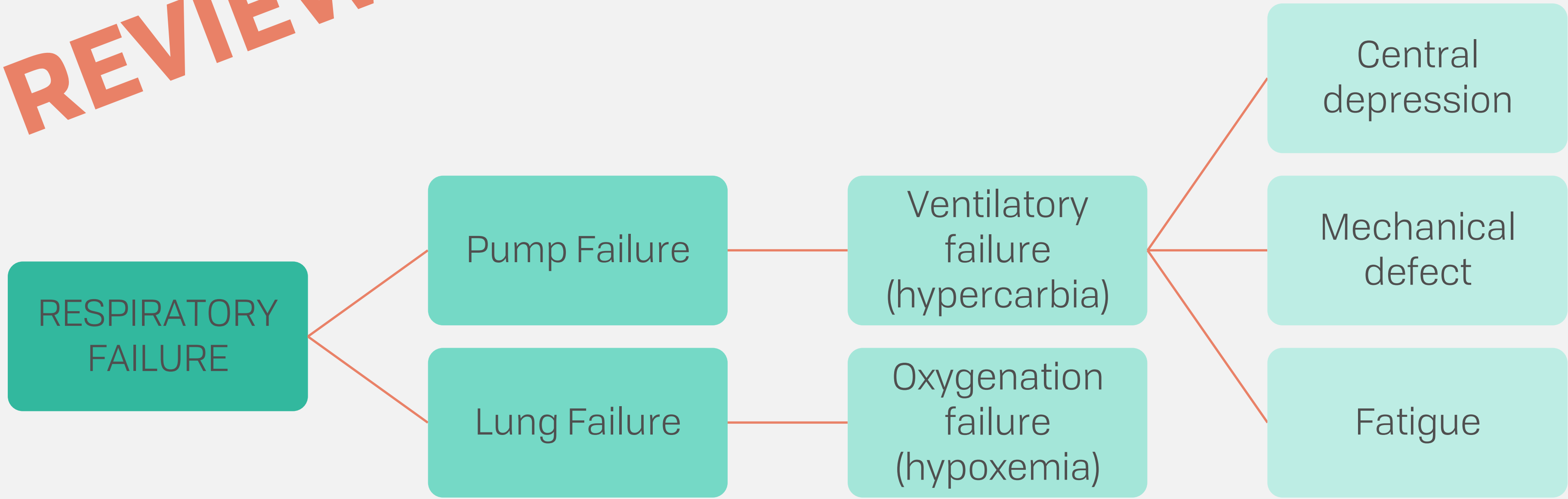


Shunt

Persistence of hypoxemia despite 100% oxygen inhalation.

The deoxygenated blood (mixed venous blood) bypasses the ventilated alveoli and mixes with oxygenated blood that has flowed through the ventilated alveoli, consequently leading to a reduction in arterial blood content.

REVIEW!



Types of Respiratory Failure

Type I Respiratory Failure

Also known as **acute hypoxemic respiratory failure** is characterized by an arterial oxygen tension of $PaO_2 < 60$ mmHg with a low or normal $PaCO_2$, usually from alveolar flooding with intrapulmonary shunting.

Alveolar flooding may be a consequence of:

- Pulmonary edema (cardiogenic or non cardiogenic)
- Pneumonia
- Pulmonary (alveolar) hemorrhage
- ARDS

Type II Respiratory Failure

Also known as hypercarbic respiratory failure (with a $pCO_2 > 45$ mmHg).

Result of alveolar hypoventilation and leads to the inability to eliminate CO_2 effectively, and caused by many mechanisms such as:

Diminished breathing effort of the central nervous system (CNS)

drug overdose, brainstem injury, sleep-disordered breathing, hypothyroidism

Reduced strength of neuromuscular function, impaired neuromuscular transmission

Myasthenia gravis, Guillain-Barre syndrome, Amyotrophic lateral sclerosis, Phrenic nerve injury

Type II Respiratory Failure

Reduced strength of neuromuscular junction resulting in respiratory muscle weakness
Myopathy, electrolyte derangements, fatigue

Increased overall load on the respiratory system

increased resistive loads
bronchospasm
COPD, asthma, suffocation

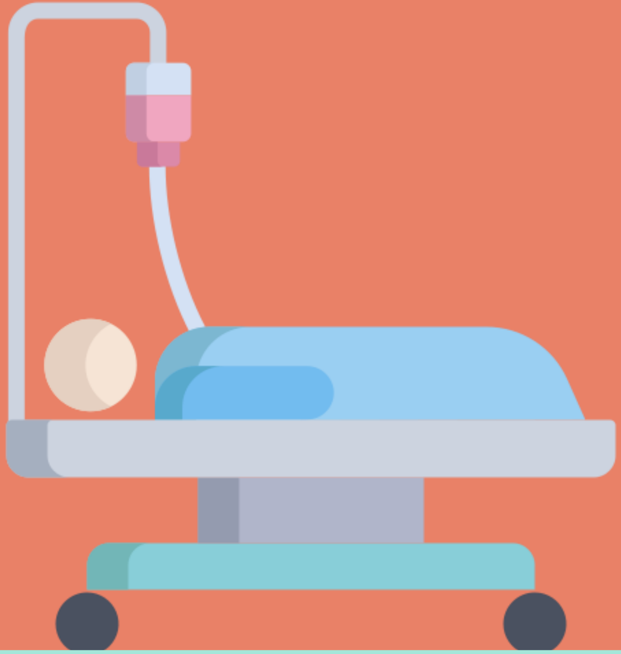
loads due to reduced lung compliance
alveolar edema, atelectasis, intrinsic PEEP

loads due to reduced chest wall compliance
pneumothorax, pleural effusion, abdominal distension

loads due to increased minute ventilation requirements
pulmonary embolism, sepsis

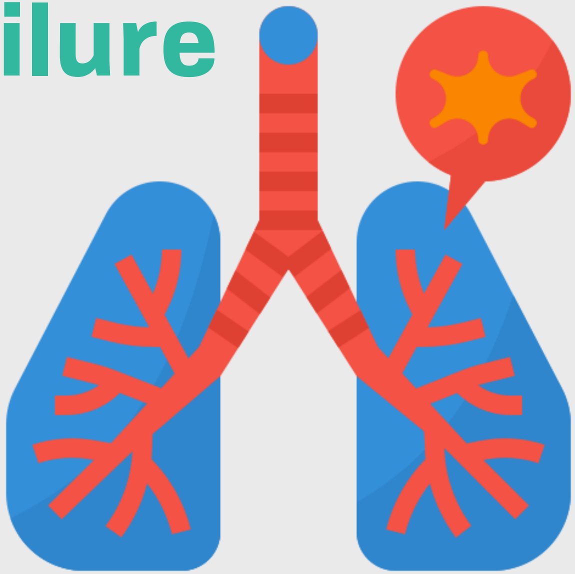
Also called perioperative respiratory failure as this is commonly found in the perioperative period (usually from pain).

Occurs as a result of lung atelectasis.



Type III Respiratory Failure

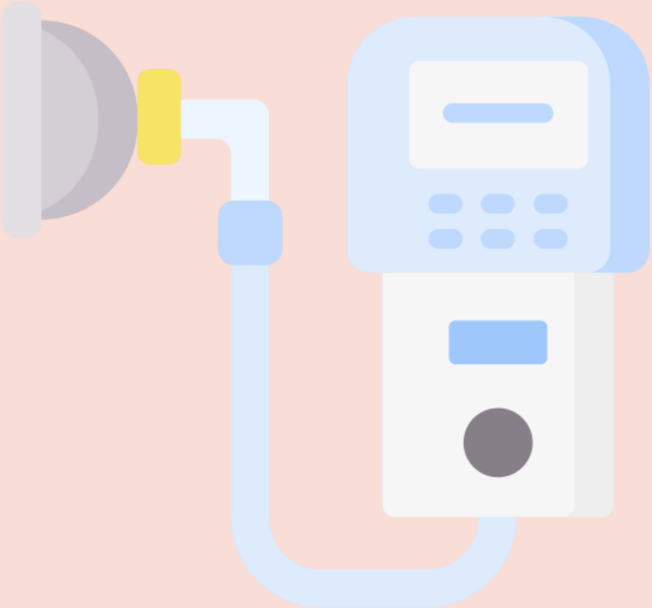
Type IV Respiratory Failure



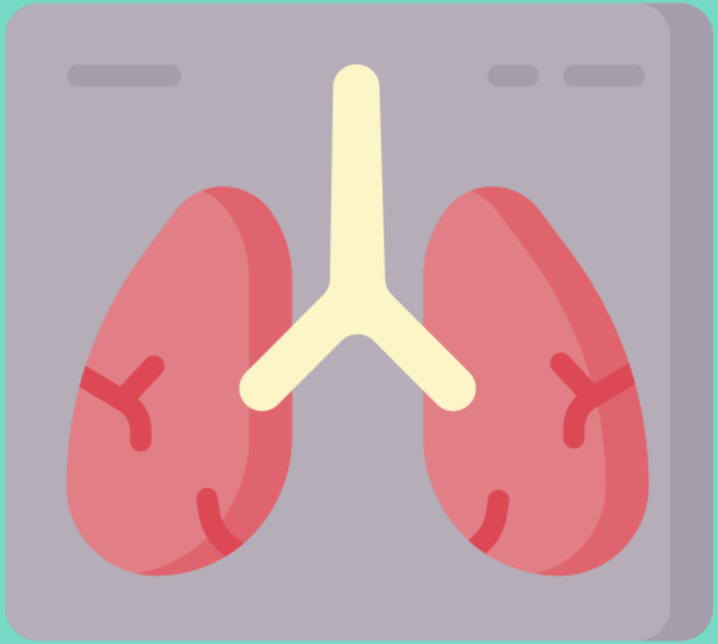
Results from **hypoperfusion** of respiratory muscles in patients in shock (respiratory muscles normally consume <5% of the total cardiac output and O_2 delivery).

Patients in shock often experience respiratory distress due to **pulmonary edema** (e.g. patients in cardiogenic shock), **lactic acidosis**, and **anemia**. In this setting, up to 40% of the cardiac output may be distributed to the respiratory muscles.

Type IV Respiratory Failure



Intubation and **mechanical ventilation** can allow redistribution of the cardiac output away from the respiratory muscles and back to vital organs while the shock is treated.



HOW IS RESPIRATORY FAILURE DIAGNOSED?

Arterial Blood Gas (ABG)	Helps assess the severity of respiratory failure and guides management.
Complete Blood Count (CBC)	May indicate anemia, which can contribute to tissue hypoxia, whereas polycythemia may indicate chronic hypoxemic respiratory failure.
Chemistry Panel	Provide clues to the etiology of respiratory failure or alert the clinician to complications associated with respiratory failure. Abnormalities in electrolytes such as potassium, magnesium, and phosphate may aggravate respiratory failure and other organ function.
Serum Creatine Kinase with fractionation and Troponin I	Helps exclude recent myocardial infarction.

Microbiologic Studies	Evaluate infection via respiratory, blood, urine, and body fluid culture and sensitivity studies.
Thyroid-Stimulating Hormone (TSH)	Evaluate the possibility of hypothyroidism, a potentially reversible cause of respiratory failure.
Chest radiography	Often reveals the cause.
2D Echocardiography	Useful test when a cardiac cause of acute respiratory failure is suspected.
Pulmonary Function Tests (PFTs)	Useful in the evaluation of chronic respiratory failure. A decrease in the FEV -to-FVC ratio (FEV/FVC) indicates airflow obstruction, whereas a reduction in both FEV and FVC and maintenance of FEV/FVC suggest restrictive lung disease. May be difficult to perform if the patient is critically ill.

MANAGEMENT OF RESPIRATORY FAILURE

Management of Respiratory Failure:

THE BASICS

Never forget your ABC's!

Ensure the airway is adequate

Provide supplemental oxygen and assisted ventilation, if warranted

Support circulation as needed

The management of respiratory failure is highly varied, and focuses on the identification and treatment of the underlying cause when possible.

Infection
Antimicrobials, source control

Airway Obstruction
Bronchodilators, glucocorticoids

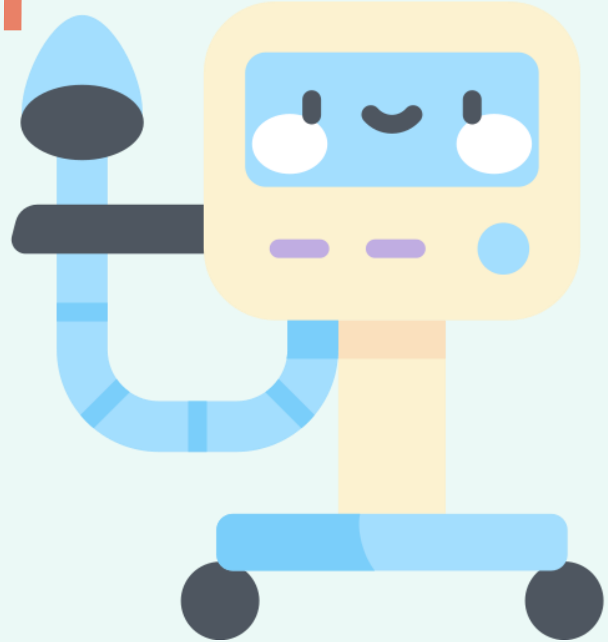
Improve cardiac function
Positive airway pressure, diuretics, vasodilators, morphine, inotropy, revascularization

Management of Respiratory Failure

Purpose of Mechanical Ventilation

MV rests the respiratory muscles and an appropriate therapy for respiratory muscle fatigue.

Virtually all mechanical ventilatory support for ARF is provided by PPV.



The primary indication for MV is respiratory failure.

Indications for Mechanical Ventilation

- Cardiac or respiratory arrest
- Tachypnea or bradypnea with respiratory fatigue or impending arrest
- Acute respiratory acidosis
- Refractory hypoxemia (when the PaO_2 cannot be maintained above 60 mmHg with FiO_2 > 1.0
- Inability to protect the airway associated with depressed levels of consciousness

Indications for Mechanical Ventilation

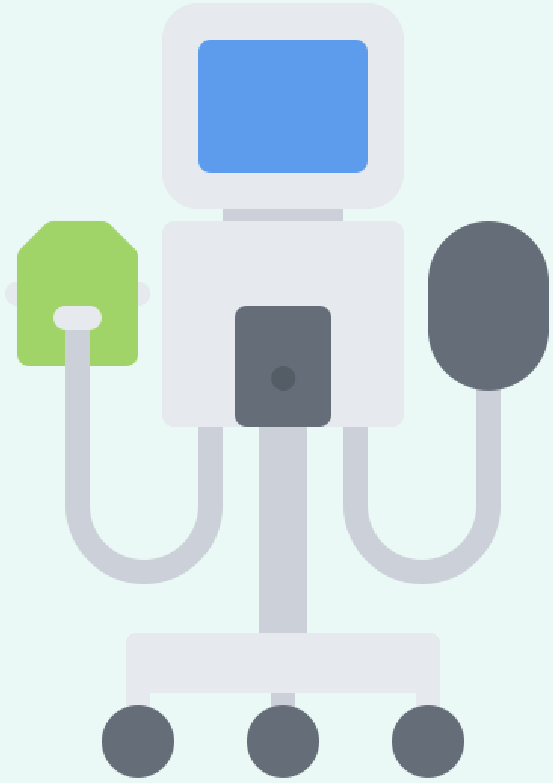
Shock associated with excessive respiratory work
Inability to clear secretions with impaired gas exchange or excessive respiratory work
Newly diagnosed neuromuscular disease with a vital capacity < 10-15 ml/kg
Short term adjunct in management of acutely increased intracranial pressure

Goals of Mechanical Ventilation

Improve ventilation by augmenting respiratory rate and tidal volume.

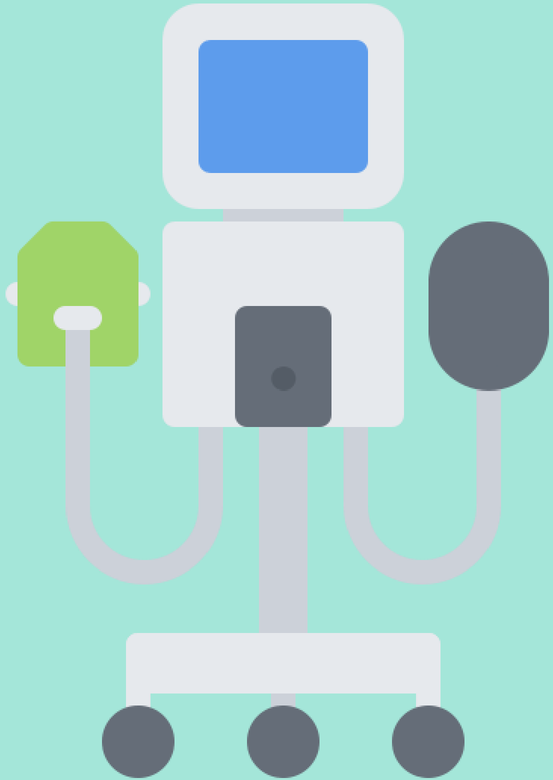
Assistance for neuromuscular dysfunction

- Sedated, comatose or paralyzed patient
- Neuropathy, myopathy or muscular dystrophy
- Intraoperative ventilation



Goals of Mechanical Ventilation

Correct hypoxemia using high FiO2 and positive end expiratory pressure (PEEP)
Correct acute respiratory acidosis, provided goals of lung protective ventilation are met
Rest ventilatory muscles
Improve cardiac function by decreasing preload, afterload and metabolic demand.



Principles of Mechanical Ventilation

Mechanical ventilation for protective ventilatory strategy

Optimization of oxygenation while avoiding ventilator-induced lung injury due to overstretch and collapse/re-recruitment

Risk of lung damage associated with large volume and high pressures to normalize pH via CO_2 elimination

Permissive hypercapnia
Condition well tolerated when care taken to avoid excess acidosis by pH buffering

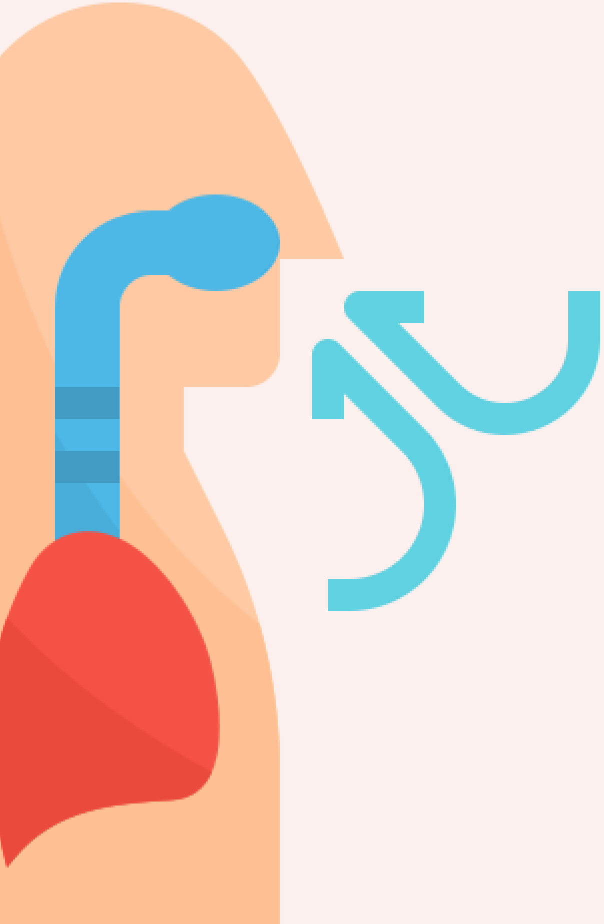
What is permissive hypercapnia?

Permissive hypercapnia is a ventilation strategy that allows $PaCO_2$ to rise by accepting a lower alveolar minute ventilation to avoid certain risks:

- Dynamic hyperinflation (“auto-PEEP”) and barotrauma in asthmatic patients
- Ventilator-associated lung injury, in patients with, or at risk of Acute Lung Injury (ALI) and Acute Respiratory Distress Syndrome (ARDS)

It is contraindicated in patients with increased intracranial pressure such as head trauma!

Correction of Hypoxemia: Goals



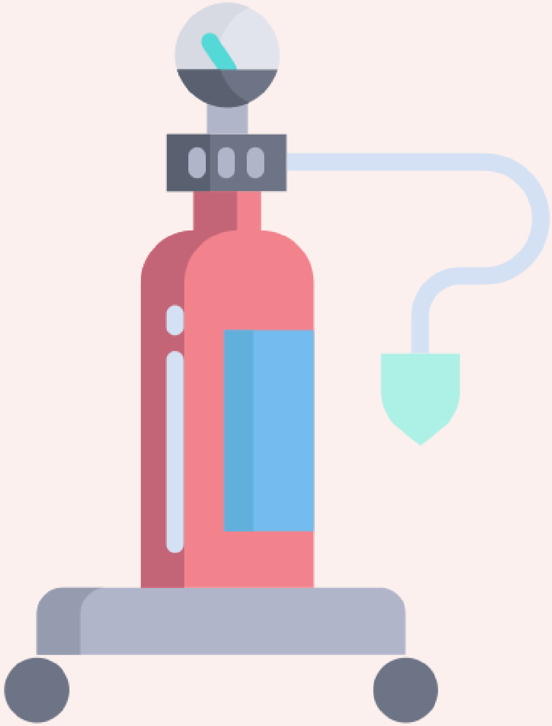
Reverse and/or prevent tissue hypoxia

- Hypercapnia without hypoxia is generally well tolerated, unless the pH < 7.2.
- Correct the coexistent hypercapnia and respiratory acidosis by treating underlying cause.
- Patient may be admitted to a respiratory care unit or ICU.
- **Extracorporeal membrane oxygenation (ECMO)** may be more effective than conventional management in refractory cases.

Correction of Hypoxemia: Goals

Maintain adequate tissue oxygenation

- Generally PaO_2 of 60 mmHg or SaO_2 >90%.
- Give supplemental oxygen via nasal cannula, face mask, or high flow nasal cannula.
- Consider intubation and mechanical ventilation in severe hypoxemia.



Options for Oxygen Delivery

OXYGEN SUPPLY	Appropriate Maximum Delivered FiO_2
Room Air	0.21
Nasal Cannula	0.50
Venturi Mask	0.50
Open Face Tent	0.60
Simple Face Mask	0.60
Partial Rebreather	0.70
Non-Rebreather	0.80 – 0.80
Mechanical Ventilation	> 0.90

Issues and Considerations:

Initiating Mechanical Ventilation

Do **NOT** wait for frank respiratory acidosis especially with evidence of:

- Inability to protect airway
- Persistent or worsening tachypnea (respiratory rate > 35 cpm)
- Respiratory muscle fatigue

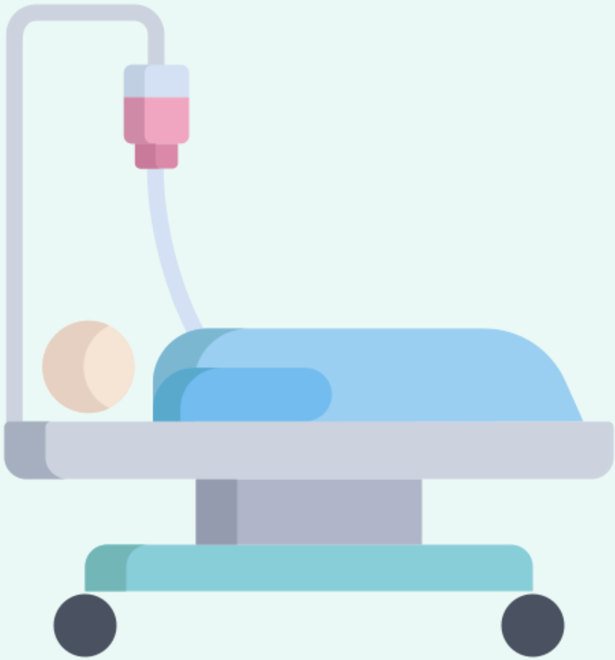
ALWAYS *consider risks and benefits of initiation and continuation of mechanical ventilation.*

Issues and Considerations:

Intubated and Ventilated Patients

Unless contraindicated, elevate the head of the bed >30 degrees, and use ulcer and DVT prophylaxis.

Modify the settings of the ventilator primarily to achieve patient-ventilator synchrony. If this fails, use the least amount of sedation required to achieve comfort and avoid unnecessary neuromuscular blockade.

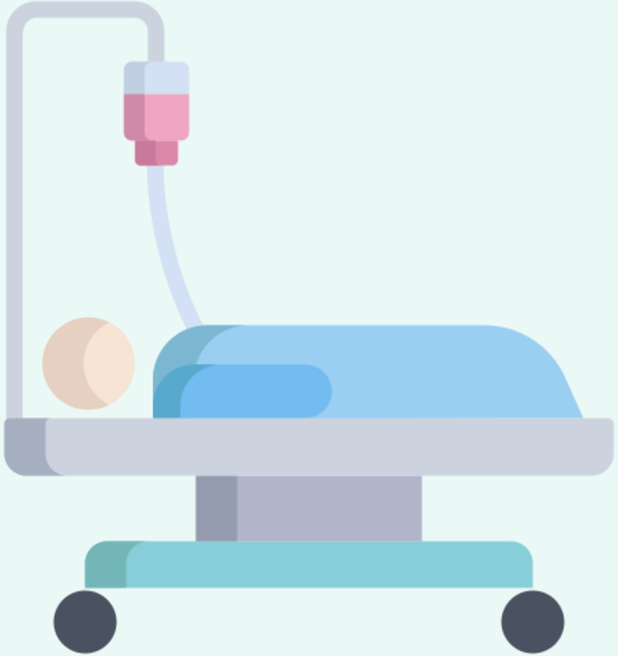


Issues and Considerations:

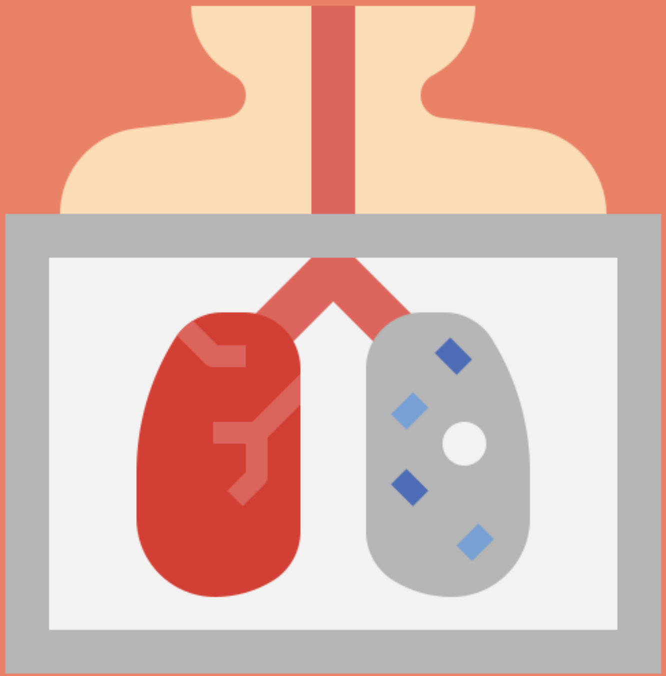
Intubated and Ventilated Patients

Monitor patient comfort, gas exchange, mechanics, and ventilator waveforms daily, or more frequently as needed.

When minimal settings are required for oxygenation, and patient is hemodynamically stable, perform a spontaneous breathing trial daily.

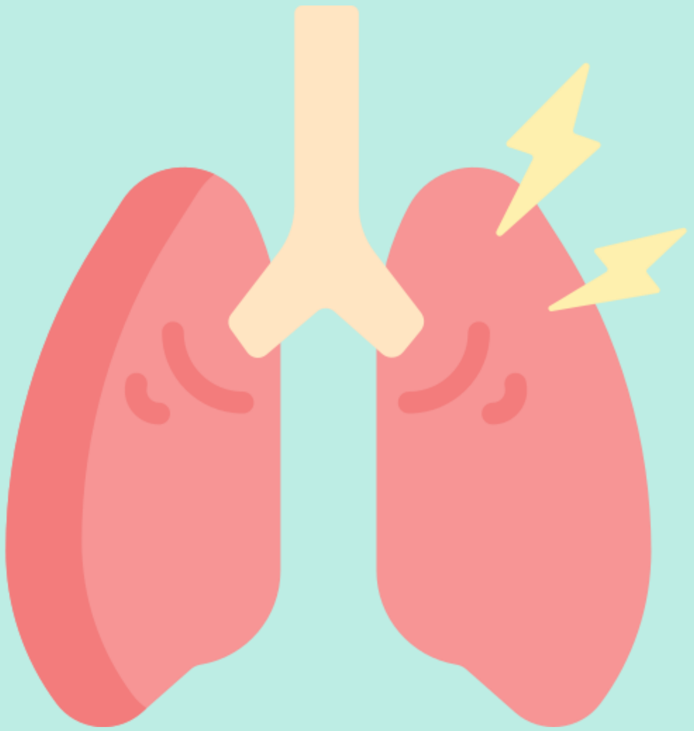


Barotrauma
Nosocomial pneumonia
Oxygen toxicity
Tracheal stenosis
Deconditioning of respiratory muscles
Ventilator dependence



Complications of Mechanical Ventilation

COMPLICATIONS OF RESPIRATORY FAILURE



Complications of Respiratory Failure

LUNG

Pulmonary embolism
Irreversible scarring
Pneumothorax

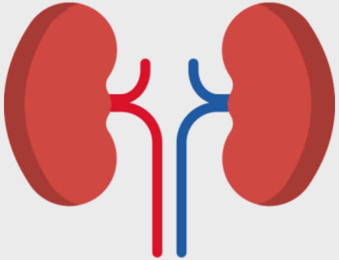
HEART

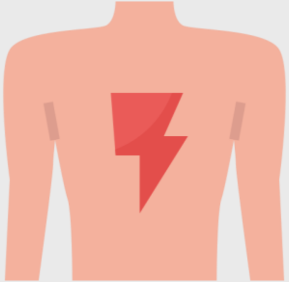
Heart Failure
Arrhythmia
Acute Myocardial Infarction

BRAIN
(from prolonged hypoxia)

Irreversible brain damage
Brain death

Complications of Respiratory Failure





KIDNEYS

Acute renal failure (from hypoperfusion and/or nephrotoxic drugs)

GI

Stress ulcer
Ileus
Hemorrhage

NUTRITION

Malnutrition
Diarrhea
Hypoglycemia
Electrolyte imbalance

BONUS!

If you want more information on...

ARF and COVID-19

CLICK HERE!

MECHANICAL VENTILATION TYPES AND MODES

CLICK HERE!

BONUS!

QUIZ!

Acute respiratory failure is defined as:

Having a $pO_2 < 60$ mmHg or $pCO_2 > 45$ mmHg at rest, on room air and temperature

Having a $pO_2 < 45$ mmHg or $pCO_2 < 60$ mmHg at rest, on room air and temperature

Having a pO_2 equal to pCO_2 at rest, on room air and temperature

None of the above

Which of the following patients have higher mortality rates from acute respiratory failure?

Women over 85 years old	Women below 85 years old
Men over 85 years old	Men below 85 years old

This is a type of ARF characterized by arterial oxygen tension $PaO_2 < 60$ mmHg with a low normal $PaCO_2$.

Type I	Type II
Type III	Type IV

This is type of ARF occurs as a result of atelectasis.

Type I

Type II

Type III

Type IV

This is type of ARF results from hypoperfusion of respiratory muscles.

Type I

Type II

Type III

Type IV

What is the main goal of ARF management?

Reverse lung damage

Correct hypoxemia

Ensure adequate perfusion

Improve lung compliance

What is the most common indication for mechanical ventilation?

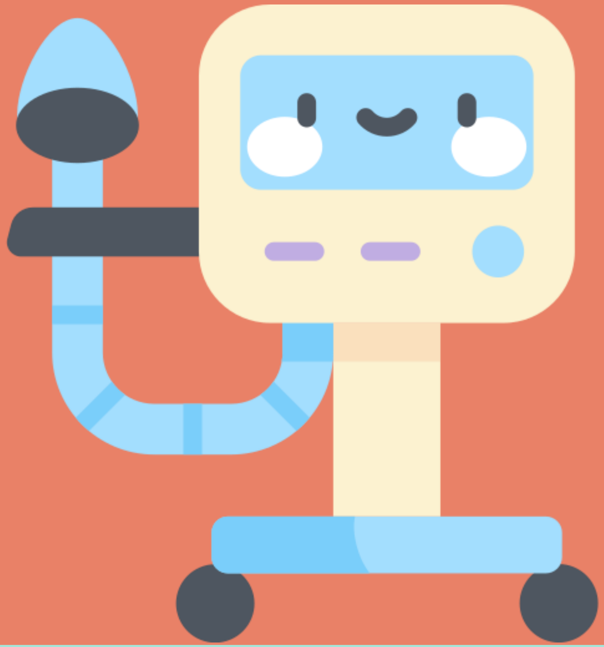
Congestive heart failure

ARF from sepsis

ARF secondary to ARDS

Severe pneumonia

THANK YOU!



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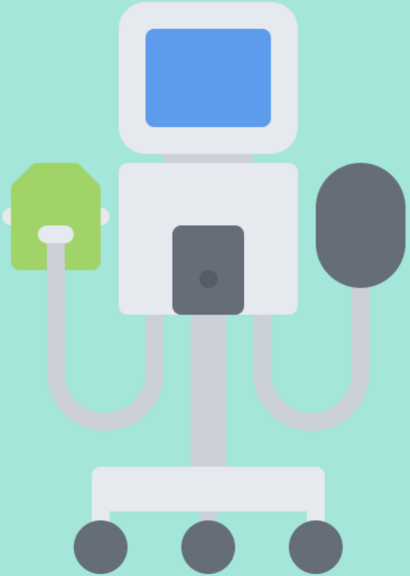
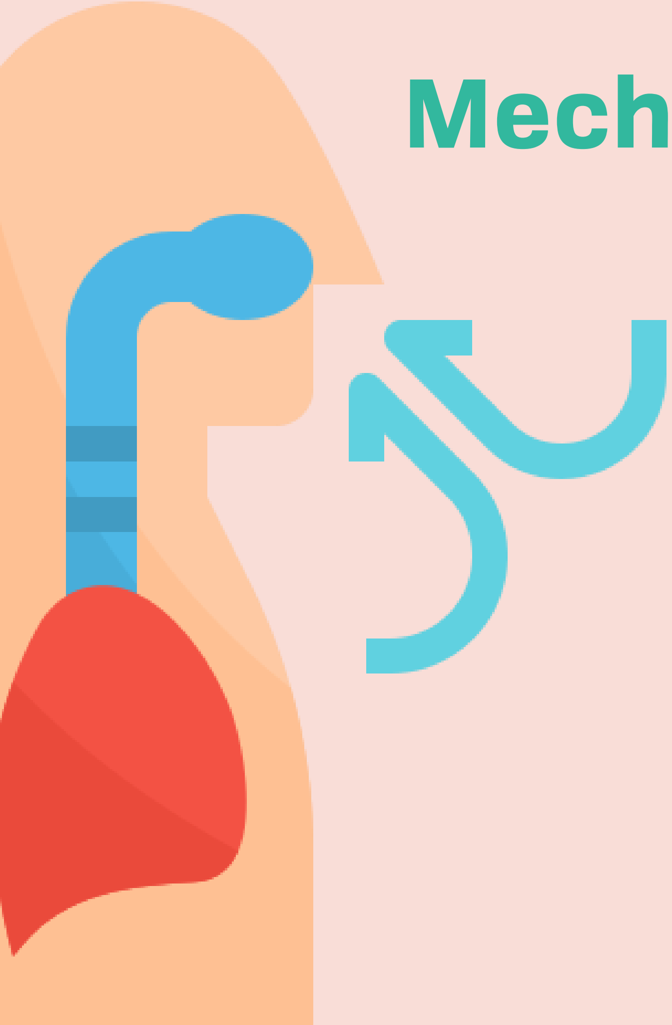


MECHANICAL VENTILATION TYPES & MODES

Mechanical Ventilation Types



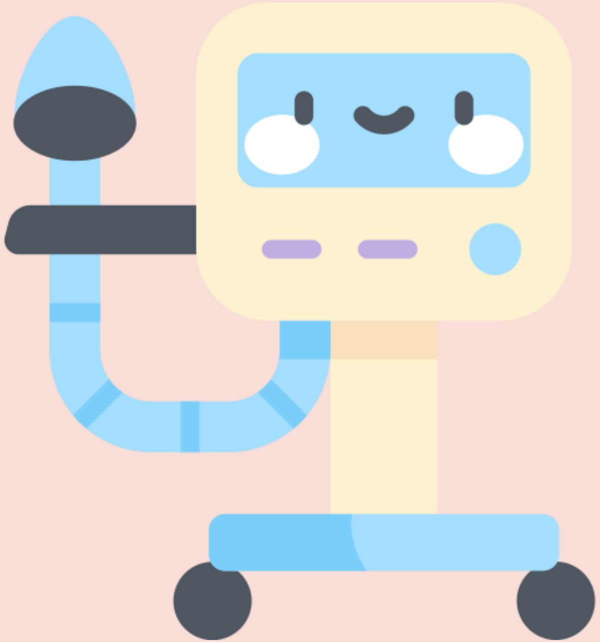
Noninvasive ventilation (NIV)

- Fewer complications (pneumonia and tracheolaryngeal trauma)
- Highly effective in ARF from COPD exacerbations and respiratory acidosis
- Most frequently implemented as bilevel positive airway pressure (BiPAP) ventilation or pressure-support ventilation (PSV)
    - Apply a preset positive pressure during inspiration and a lower pressure expiration

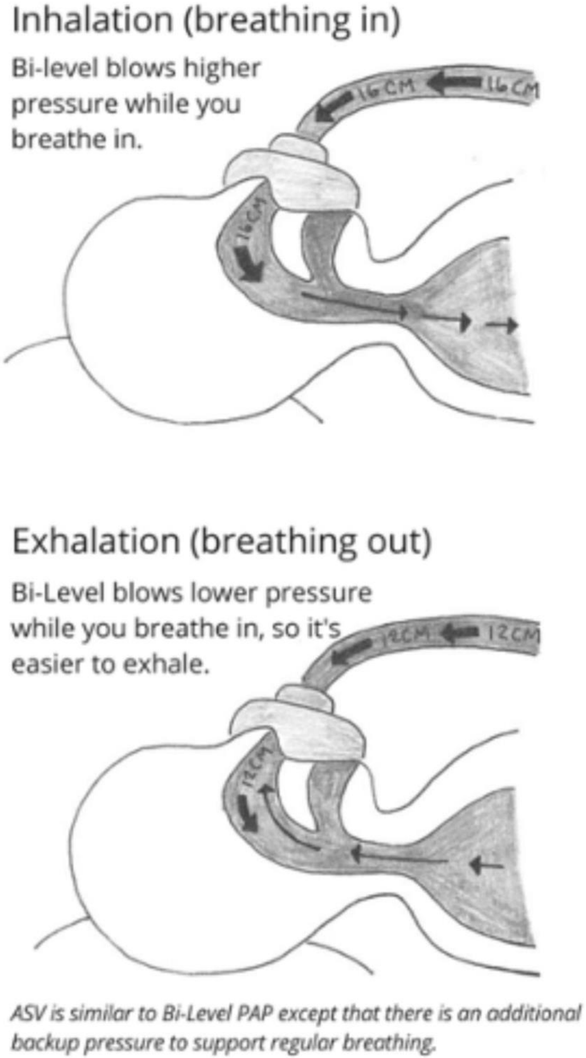
Mechanical Ventilation Types

Noninvasive ventilation (NIV)

- Well tolerated by a conscious patient
- Optimizes patient-ventilator synchrony
- Major limitations
    - Patient intolerance: NIV interface can cause both physical and psychological discomfort
    - Limited success in acute hypoxemic respiratory failure



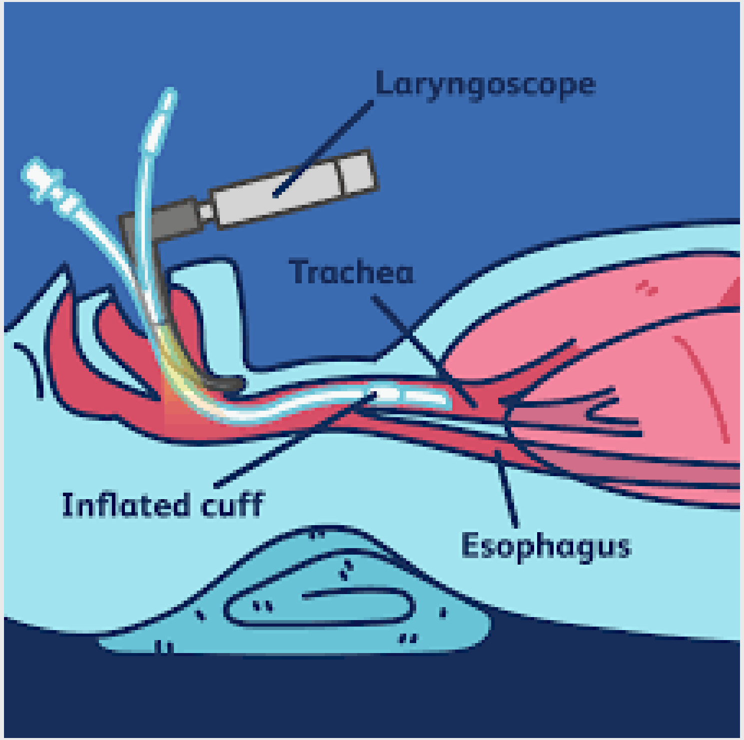
NIV: Bilevel positive airway pressure (BiPAP)



Mechanical Ventilation Types

Invasive/Conventional Mechanical Ventilation

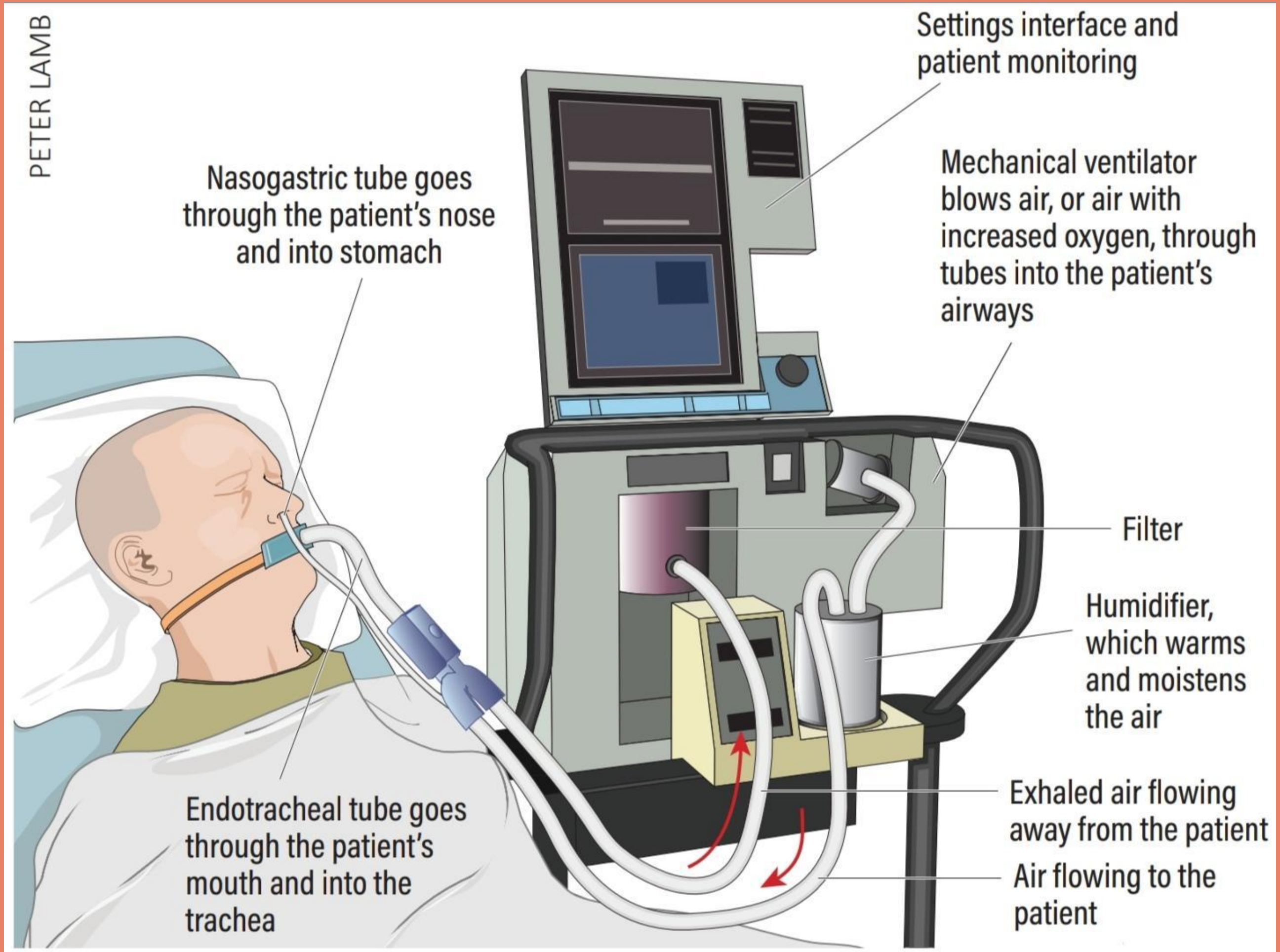
Implemented once a cuffed tube is inserted into the trachea to allow conditioned gas (warmed, oxygenated, and humidified) to be delivered to the airways and lungs at pressures above atmospheric pressure.



Mechanical Ventilation Types

- **Ventilatory assistance**
  - Controlled: ventilator delivers assistance independent of the patient's own spontaneous inspiratory efforts
  - Patient-initiated: ventilator delivers assistance in response to the patient's own inspiratory efforts

- **Pressure-targeted vs. volume-targeted ventilation in PPV**
  - Pressure-targeted: airway pressure is the independent variable set by the physician/respiratory therapist, tidal volume is the dependent variable
  - Volume-targeted: tidal volume is the independent variable, airway pressure the dependent variable



Mechanical ventilator for positive pressure ventilation

Modes of Ventilation

definition of terms

Mode

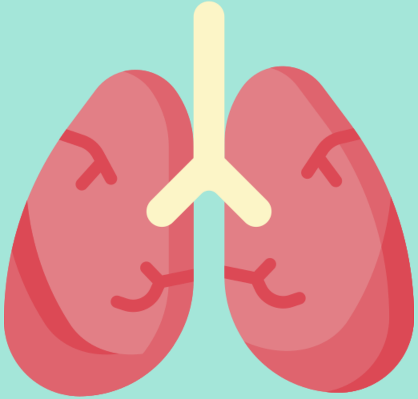
- Manner in which ventilator breaths are triggered, cycled, and limited

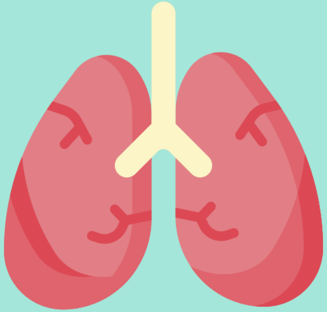
Trigger

- Defines what the ventilator senses to initiate an assisted breath
- Either an inspiratory effort or a time-based signal

Cycle

- Factors that determine the end of inspiration (e.g., when a specific tidal volume is delivered in volume-cycled ventilation)





Modes of Ventilation

definition of terms

Limiting factors

- Operator-specified values (e.g., airway pressure) monitored by transducers internal to the ventilator circuit
- If specified values exceeded, inspiratory flow is terminated, and the ventilator circuit is vented to atmospheric pressure or the specified pressure at the end of expiration

Modes of Ventilation

Assist-Control Ventilation (ACMV)

- Most widely used
- An inspiratory cycle is initiated by the patient's inspiratory effort or by a timer signal within the ventilator
- Every breath delivered consists of operator-specified tidal volume
- Ventilatory rate determined by the patient or the operator-specified backup rate, whichever is of higher frequency
- Commonly used for initiation of MV
  - Ensures backup minute ventilation in the absence of an intact respiratory drive and
  - Allows for synchronization of the ventilator cycle with the patient's inspiratory effort
- Problems can arise in patients with tachypnea due to nonrespiratory or nonmetabolic factors (anxiety, pain, airway irritation)

Modes of Ventilation

Intermittent Mandatory Ventilation (IMV)

- The operator sets the number of mandatory breaths of fixed volume tobe delivered by the ventilator; between breaths, the patient can breathe spontaneously
- Synchronized IMV (SIMV)
  - Most frequently used IMV mode
  - Mandatory breaths delivered in synchrony with patient's inspiratory efforts at a frequency determined by the operator
  - If the patient fails to initiate a breath, the ventilator delivers a fixed-tidal-volume breath and resets the internal timer for the next inspiratory cycle
  - Differs from ACMV in that only a preset number of breaths are ventilator-assisted
  - Useful for supporting and weaning intubated patients
  - Limitation: May be difficult in patients with tachypnea because they may attempt to exhale during the ventilator-programmed inspiratory cycle

Modes of Ventilation

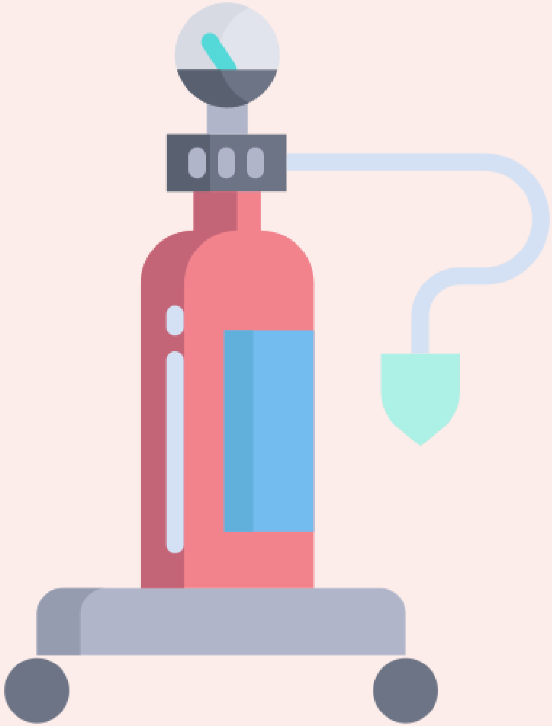
Pressure-Support Ventilation (PSV)

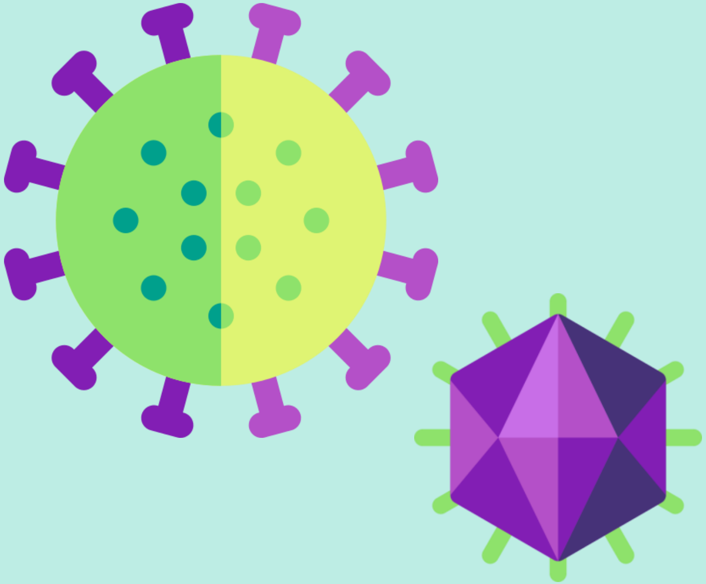
- Patient-triggered, flow-cycled, and pressure-limited
- Provides graded assistance and differs from ACMV and SIMV in that the operator sets the pressure level (rather than volume) to augment every respiratory effort
- Level of pressure adjusted by observing the patient's respiratory frequency
- Inspiration is terminated when inspiratory airflow falls below a certain level
- Patients receive ventilator assistance only when the ventilator detects an inspiratory effort
- Often used in combination with SIMV to ensure volume-cycled backup for patients with depressed respiratory drive

Modes of Ventilation

Other modes

- Pressure-Control Ventilation (PCV)
- Inverse-Ratio Ventilation (IRV)
- Continuous Positive Airway Pressure (CPAP)





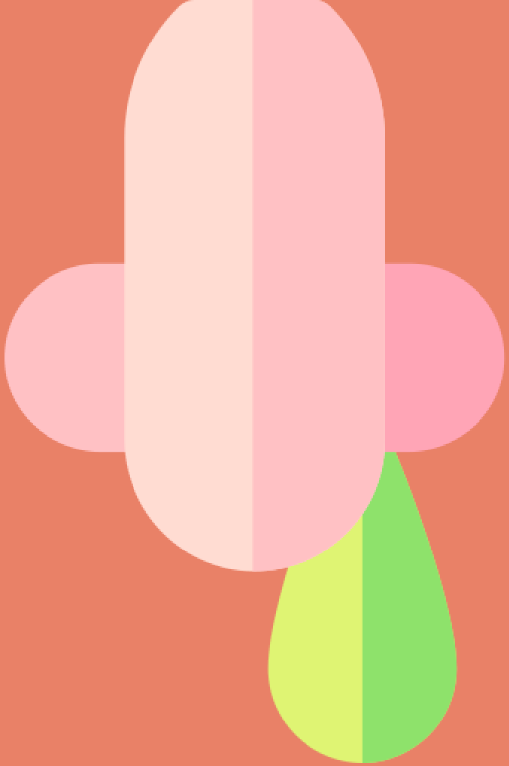
ARF AND COVID-19

COVID-19: An Overview

Newly identified infectious respiratory disease in December 2019, originating from Wuhan, China.

Caused by B-coronavirus named Severe Acute Respiratory System Coronavirus-2 **(SARS-CoV-2)**, resulting in Coronavirus Disease **(COVID-19)**.

Current evidence via genome sequencing suggest it is a zoonotic infection, with bats as natural reservoir and original host.



Mode of transmission is primarily via **respiratory droplets** generated during coughing or sneezing by an infected person. Some studies suggest fomite transmission is also implicated.

COVID-19 is a respiratory illness primarily presenting with symptoms of **fever, cough, shortness of breath**, but with documented extrapulmonary manifestations in some patients. The full extent of clinical manifestations is still currently under investigation.

ARF in COVID-19

The most concerning complication of SARS-CoV-2 infection is **acute hypoxemic respiratory failure**, resulting in patients requiring mechanical ventilation.

Numerous mechanisms have been suggested for the substantial hypoxemia seen in many COVID-19 patients, including **pulmonary edema, hemoglobinopathies, vascular occlusion and ventilation** and **perfusion mismatch**.

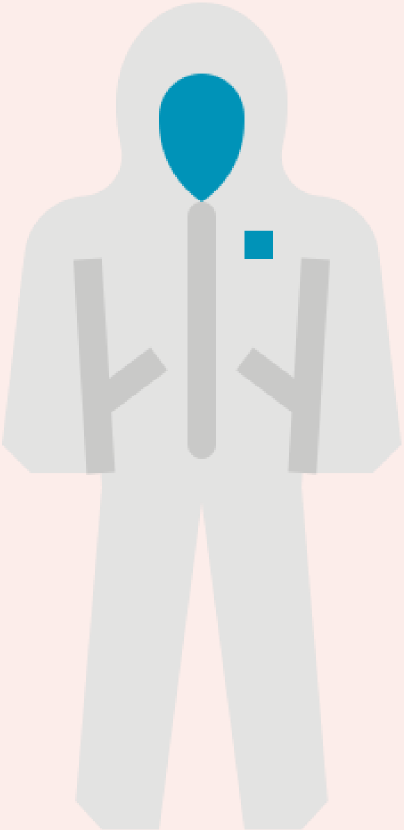
PATHOPHYSIOLOGY OF ARF IN COVID-19

The available histopathology shows diffuse alveolar damage consistent with **acute respiratory distress syndrome (ARDS)**, and variable pulmonary compliance associated with severe COVID-19 is comparable with values reported for ARDS.

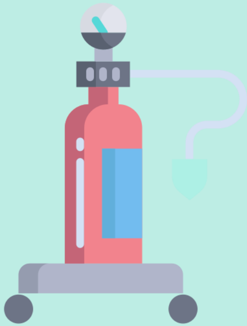
PRINCIPLES OF TREAMENT

Until a definitive cure is found, management of SARS-CoV-2 infection is primarily supportive in nature. Given the current accepted underlying mechanism of ARF in the context of COVID-19, the principles of treatment follow that of ARDS.

The principles of ventilation are to **provide ventilation to protect the lungs with low tidal volumes, low driving pressures**, and **titration of positive end expiratory pressure** to meet each patient's needs, with the overall goal of **improving lung compliance**.

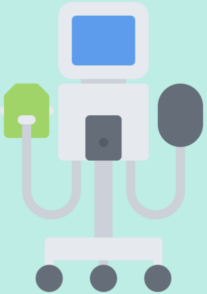


TREATMENT OF ARF IN COVID-19



O_2 THERAPY

NON-INVASIVE POSITIVE PRESSURE VENTILATION



INTUBATION

BONUS!

QUIZ!

PART 2.0

What is the most common indication for mechanical ventilation?

Congestive heart failure

ARF from sepsis

ARF secondary to ARDS

Severe pneumonia

What is the concept of optimizing oxygenation while avoiding ventilator-induced lung injury from overstretch and collapse or re-recruitment?

Extracorporeal membrane oxygenation

Protective ventilatory strategy

titration of positive end expiratory pressure

patient-ventilator synchrony

What is the most widely used mode of conventional mechanical ventilation?

BiPAP	IMV
PSV	ACMV

What type of acute respiratory failure is associated with COVID-19?

Type I

Type II

Type III

Type IV

What is the underlying pathophysiology of ARF in COVID-19?

atelectasis	ARDS
pleural effusion	pulmonary embolism

What is the overall goal in terms of treatment principles of ARF in COVID-19?

Reverse lung damage	Correct hypoxemia
Ensure adequate perfusion	Improve lung compliance

FIN.