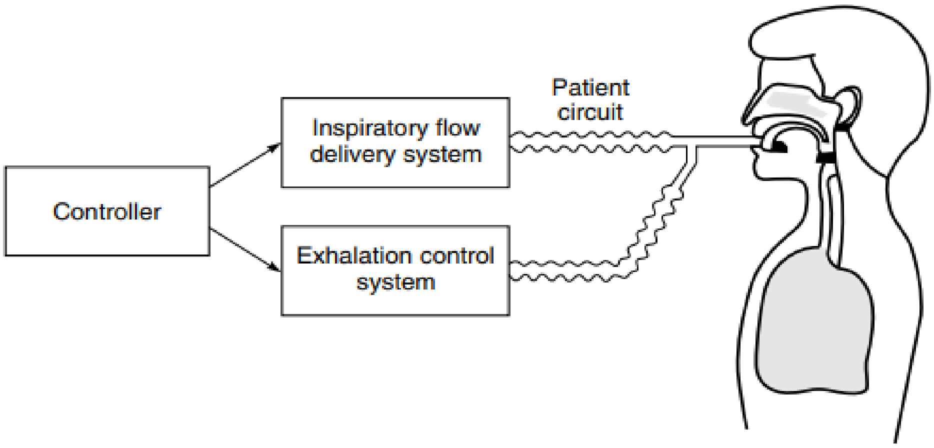
4.6 Types of Ventilators – Pressure, Volume, and Time controlled. Flow, Patient Cycle Ventilators

- ventilators are devices that connect to the patient's airway and are designed to augment or replace the patient's ventilation automatically.
- They are employed with a mask, endotracheal tube (within the trachea), or tracheostomy tube (through an artificial opening in the trachea via the throat).
- These ventilators consist of a
  - ✓ controller, which operates independently of the patient's inspiratory effort,
  - ✓ an assistor, which augments or assists inspiration of the spontaneously breathing patient, and
  - ✓ an assist-controller, which assists and/or controls.
- **Controller-type ventilators** regulate a specific variable—**pressure**, **volume**, or **flow**—to assist or control a patient's breathing. These devices use feedback systems to maintain desired respiratory parameters and are essential in critical care and anesthesia.
- **Assister-type ventilators** provide breathing assistance to patients who can initiate their own respiratory effort. These ventilators respond to the patient's inspiratory efforts by delivering supportive breaths, helping to reduce the work of breathing. Below is an overview of assister-type ventilators and their key features:

4.6.1 Types of Ventilators:

1. Pressure-Controlled Ventilators (PCV)
2. Volume-Controlled Ventilators (VCV)
3. Time-Controlled Ventilators (TCV)
4. Flow-Controlled Ventilators (FCV)
5. Patient-Controlled Ventilators

4.6.2 Components of Ventilators:



The diagram depicting the components of a **ventilator system**.

Central Component:

- **Controller:** This is the brain of the ventilator, responsible for managing all aspects of the breathing cycle. It determines factors like the rate, volume, and pressure of breaths, as well as adjusting these settings based on patient needs and feedback from sensors.

Key Components:

- **Inspiratory Flow Delivery System:** This system delivers air or oxygen-rich gas mixture into the patient's lungs during inhalation. It includes components like flow sensors, valves, and tubing.
- **Patient Circuit:** This is the pathway through which the gas travels from the ventilator to the patient and back. It typically includes a breathing tube (endotracheal tube or tracheostomy tube) and a humidifier to add moisture to the gas.
- **Exhalation Control System:** This system manages the exhalation phase of the breathing cycle. It may include valves or other mechanisms to control the flow of exhaled air and prevent rebreathing.

Overall Function:

The controller sends signals to the inspiratory flow delivery system to initiate inhalation. The gas mixture flows through the patient circuit and into the patient's lungs. During exhalation, the exhalation control system manages the outflow of air. The controller continuously monitors various parameters (like lung pressure, flow rates, etc.) and adjusts settings as needed to maintain optimal ventilation.

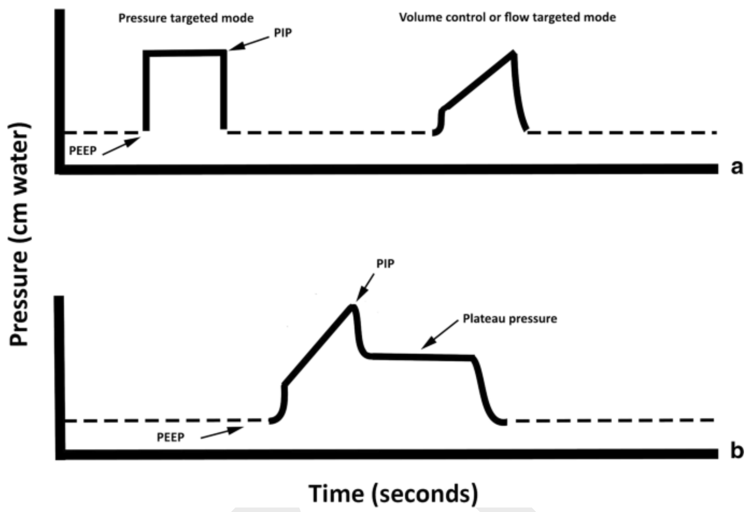
4.6.3 Pressure-Controlled Ventilators (PCV):

- **Pressure-Controlled Ventilators (PCV)** are a mode of mechanical ventilation where the ventilator delivers a preset pressure to the patient's airways during inspiration. The key characteristic of pressure-controlled ventilation is that the airway pressure is controlled, while the delivered volume depends on factors such as lung compliance and airway resistance.

Features of Pressure-Controlled Ventilation:

1. **Preset Inspiratory Pressure:**
    - The clinician sets the maximum inspiratory pressure (target pressure) that the ventilator will deliver during each breath.
2. **Variable Tidal Volume:**
    - The tidal volume (amount of air delivered per breath) is not fixed but depends on:
        - **Lung compliance** (stiffness or elasticity of the lungs).
        - **Airway resistance** (any blockages or narrowing in the airways).
3. **Inspiratory Time:**
    - The duration for which the pressure is maintained during inspiration is set (inspiratory time).
    - This determines the ratio of inspiration to expiration (I:E ratio).
4. **Control Parameters:**
    - The clinician sets the inspiratory pressure, respiratory rate, inspiratory time, and positive end-expiratory pressure (PEEP).
5. **Flow Dynamics:**

- ❖ The flow of gas into the lungs decelerates as the pressure reaches the preset level, creating a characteristic waveform for flow and pressure.



This diagram illustrates the pressure waveforms in two different modes of mechanical ventilation:

Top Graph (a):

1. **Pressure-Targeted Mode (Pressure-Controlled Ventilation):**
   - ❖ The pressure quickly rises to the preset **Peak Inspiratory Pressure (PIP)** and is maintained throughout the inspiratory phase.
   - ❖ This represents the controlled pressure delivery in pressure-controlled modes.
2. **Volume-Controlled or Flow-Targeted Mode:**
   - ❖ The pressure increases gradually during inspiration, corresponding to the volume being delivered to the patient.
   - ❖ The shape reflects the airway resistance and lung compliance.

Bottom Graph (b):

1. **Pressure-Time Relationship in Volume-Controlled Ventilation:**
   - ❖ The pressure increases to a peak during inspiration (**PIP**) and then plateaus if inspiratory hold is applied (**Plateau Pressure**).
   - ❖ **PEEP (Positive End-Expiratory Pressure):** Maintains a baseline airway pressure to prevent alveolar collapse during exhalation.

2. **Key Pressures Identified:**
   - **PIP:** The maximum pressure during inspiration.
   - **Plateau Pressure:** The pressure when airflow is paused (indicates compliance).
   - **PEEP:** The baseline pressure between breaths.

4.6.4 Volume - Controlled Ventilators (VCV):

- **Volume-Controlled Ventilators (VCV)** are a mode of mechanical ventilation where the ventilator delivers a pre-set tidal volume (VT) with each breath. Unlike pressure-controlled modes, here the ventilator ensures a fixed volume regardless of changes in lung compliance or airway resistance, but the airway pressure may vary.

- **Tidal Volume Setting:** The clinician sets the desired tidal volume, which is the amount of air delivered with each breath.
- **Inspiratory Time:** The clinician also sets the inspiratory time, which is the duration of the inhalation phase of each breath.
- **Respiratory Rate:** The clinician sets the desired respiratory rate, which determines how often the ventilator delivers breaths.
- **Consistent Tidal Volume:** Ensures that the patient receives a predetermined amount of air with each breath.

4.6.5 Practical differences between pressure and volume-controlled ventilation:

	PCV	VCV
Acute Respiratory Distress Syndrome (ARDS):	Preferred (protects lungs, improves oxygenation).	Can be risky due to high pressures.
Neuromuscular Disorders:	Can be used, but tidal volumes need monitoring.	Preferred (ensures consistent minute ventilation).
Post-Surgical Patients:	Less common unless lung compliance is low.	Common for stable lungs and controlled settings.
Spontaneously Breathing Patients:	Better synchrony due to variable flow.	May cause dyssynchrony with fixed flow.

4.6.6 Time-Controlled Ventilator:

- **Time-Controlled Ventilators (TCVs)** are a subset of mechanical ventilation modes where the inspiratory and expiratory phases are determined and fixed by preset time intervals, irrespective of patient effort or other variables. These ventilators prioritize control over the breathing cycle's timing.

- **Fixed Inspiratory and Expiratory Times (I:E Ratio):**

  - The ventilator operates on a predefined respiratory cycle with a set inspiratory time (TI) and expiratory time (TE).
  - Example: If the respiratory rate (RR) is 20 breaths per minute (bpm), the total cycle time is 3 seconds, and the ratio (e.g., 1:2) determines the split between TI (1 second) and TE (2 seconds).

- **Constant Flow Rate:** A steady flow of gas is delivered throughout the respiratory cycle.
- **Limited Patient Triggering:** The patient has limited control over the timing and initiation of breaths.

4.6.7 Flow-Controlled Ventilators (FCV):

- **Flow-Controlled Ventilators** are a type of mechanical ventilation where the flow of gas into the patient's lungs during the inspiratory phase is regulated to achieve a desired tidal volume or pressure. These ventilators maintain control over the rate of airflow, which impacts the distribution of gas in the lungs.
- **Control Parameter:**

  - ✓ Inspiratory flow is the primary controlled variable.
  - ✓ The flow rate (measured in liters per minute, L/min) is set by the clinician.

- **Dependent Variables:**

In flow-controlled ventilation, either the pressure or volume is the outcome, depending on the mode.

- ✓ **Volume-Controlled Mode:** Flow and tidal volume are fixed; pressure varies with lung compliance and airway resistance.
- ✓ **Pressure-Controlled Mode:** Flow delivers the set pressure; tidal volume depends on compliance and resistance.

4.6.8 Patient-Controlled Ventilation:

- ❒ **Patient-Controlled Ventilation (PCV)** refers to ventilation modes where the patient's spontaneous respiratory efforts primarily drive the ventilator. These modes allow the patient to control certain aspects of their breathing while the ventilator provides assistance to ensure adequate ventilation. PCV is designed to enhance patient comfort and synchrony while reducing the work of breathing.

- ❒ **Patient-Initiated Breaths:**
  - ❖ The ventilator detects the patient's inspiratory effort (trigger) and delivers assistance in response.
  - ❖ Triggers can be pressure-based or flow-based.
- ❒ **Supportive Assistance:**
  - ❖ The ventilator supplements the patient's efforts by delivering a preset level of pressure or volume.
  - ❖ Commonly used modes include **Pressure Support Ventilation (PSV)** and **Proportional Assist Ventilation (PAV).**

- ❒ **Flexible Inspiratory Flow:**
  - ❖ Inspiratory flow adapts to the patient's demand, improving comfort and synchrony.
- ❒ **Adjustable Back-Up Ventilation:**
  - ❖ If the patient's efforts are insufficient, the ventilator can provide mandatory breaths (e.g., in **Spontaneous/Timed (S/T)** modes).

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