Ventilator

- Positive pressure
- Negative pressure

- The first iron lung was used on october 12 at children hospital boston
- used in a child unconscious from respiratory failure

Iron lung ward filled with Polio patients,

Rancho Los Amigos Hospital, ca. 1953

Sessions

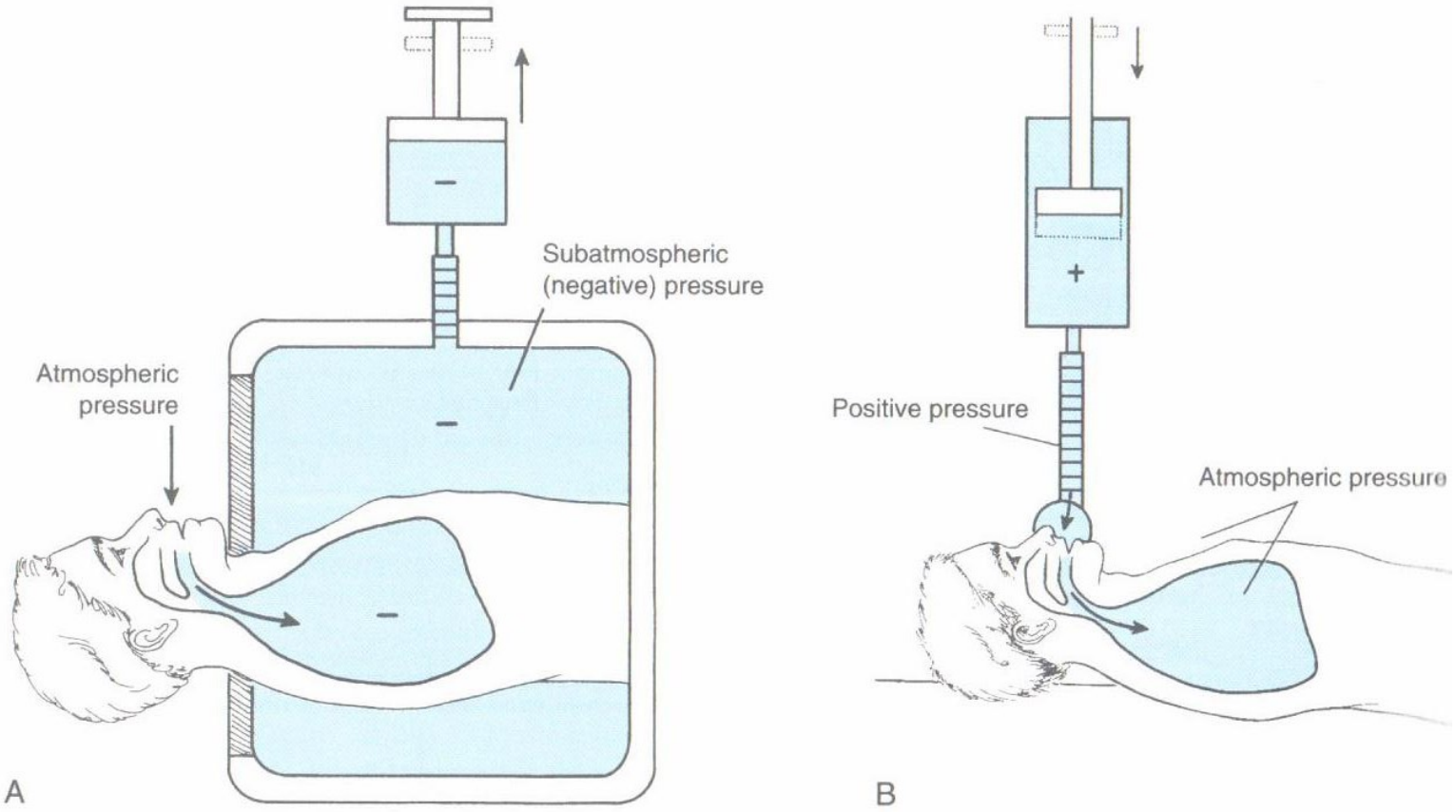


Fig. 2-3 **A,** When subatmospheric pressure is applied around the chest wall, pressure drops in the alveoli and air flows into the lungs. **B,** Application of positive pressure at the airway provides a pressure gradient between the mouth and the alveoli; as a result, gas flows into the lungs. (From Cairo JM, Pilbeam SP: *Mosby's respiratory care equipment*, ed 8, St Louis, 2010, Mosby.)

- Mechanical ventilators used increasingly in
- Anesthesia and intensive care
- To treat polio patients and
- The increasing use of muscle relaxants during anesthesia

Indication for intubation

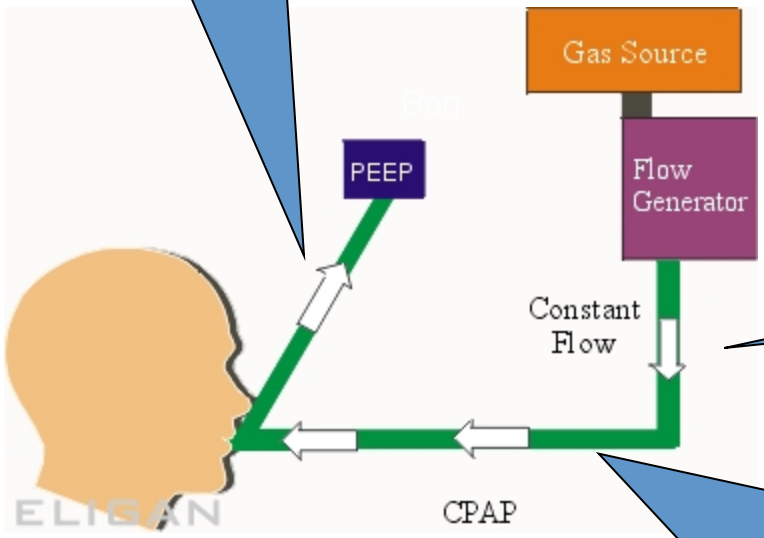
- Protect airway
- Maintain airway
- Mechanical ventilation
- Bronchial toileting

Indication for mechanical ventilation

- Ventilation Failure
- Oxygenation Failure

Mechanical ventilator

expiration is passive



gas flows along a pressure gradient between the upper airway and the alveoli

Flow is either volume targeted and pressure variable, or pressure limited and volume variable.

The pattern of flow may be either sinusoidal (which is normal), decelerating or constant. Flow is controlled by an array of sensors and microprocessors.

Control

- Either Volume Controlled (volume limited, volume targeted) and Pressure Variable or
- Pressure Controlled (pressure limited, pressure targeted) and Volume Variable or
- Dual Controlled (volume targeted (guaranteed) pressure limited)

Cycling

- Time cycled - such as in pressure controlled ventilation
- Flow cycled - such as in pressure support
- Volume cycled - the ventilator cycles to expiration once a set tidal volume has been delivered: this occurs in volume controlled ventilation

Triggering

- what causes the ventilator to cycle to inspiration?
- Ventilators may be time triggered,
- pressure triggered or
- flow triggered.
- Time: the ventilator cycles at a set frequency as determined by the controlled rate.
- Pressure: the ventilator senses the patient's inspiratory effort by way of a decrease in the baseline pressure.

Flow trigger

- modern ventilators deliver a constant flow around the circuit throughout the respiratory cycle (flow-by).
- A deflection in this flow by patient inspiration, is monitored by the ventilator and it delivers a breath
- This mechanism requires less work by the patient than pressure triggering.
-

Breath are either

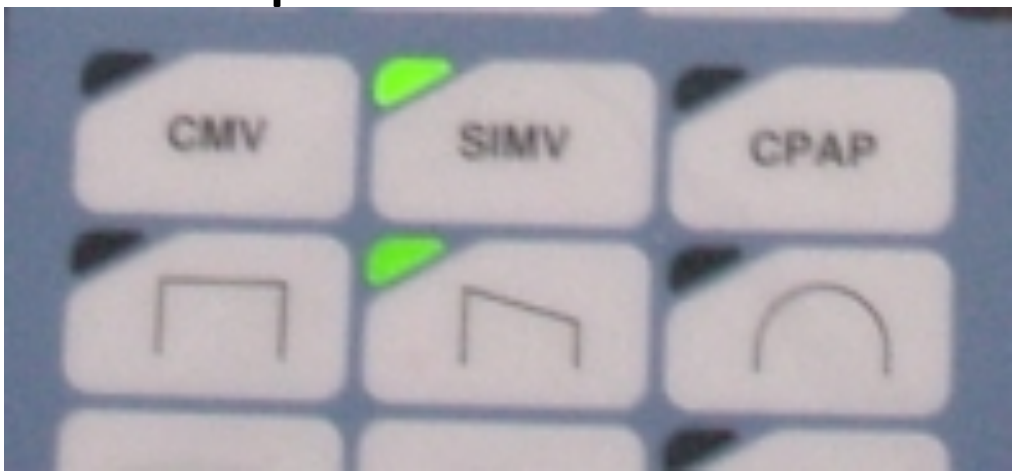
- Mandatory (controlled) - which is determined by the respiratory rate.
- Assisted - (as in assist control, synchronized intermittent mandatory ventilation, pressure support)
- Spontaneous- (no additional assistance in inspiration, as in CPAP)

Flow pattern

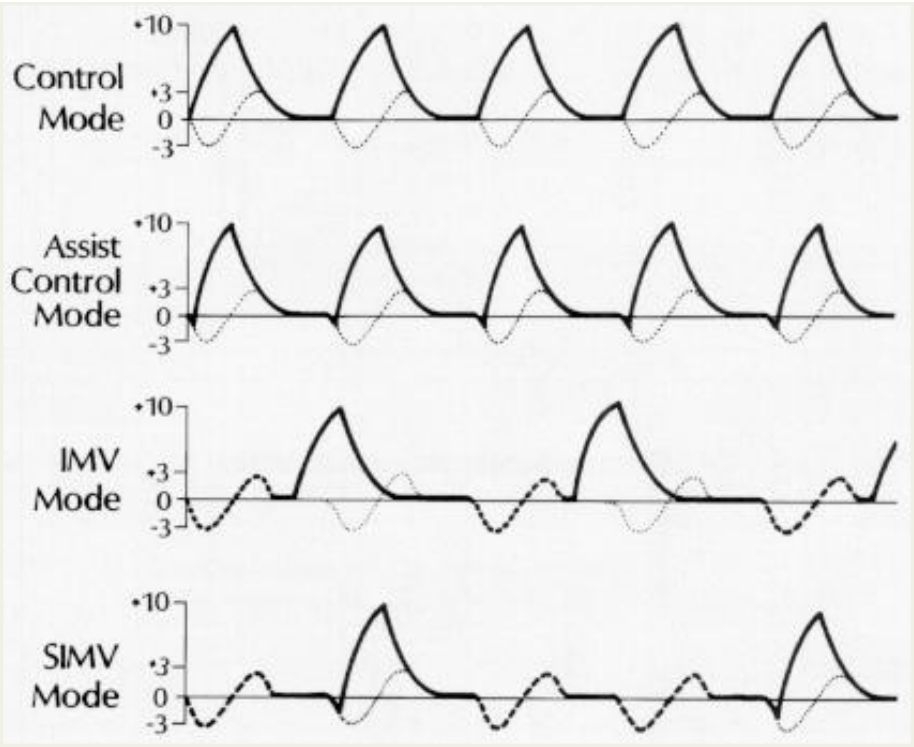
- Sinusoidal = this is the flow pattern seen in spontaneous breathing and CPAP
- Decelerating = the flow pattern seen in pressure targeted ventilation
- inspiration slows down as alveolar pressure increases (there is a high initial flow).

Flow pattern

- Constant - flow continues at a constant rate until the set tidal volume is delivered
- Accelerating - flow increases progressively as the breath is delivered. This should not be used in clinical practice.



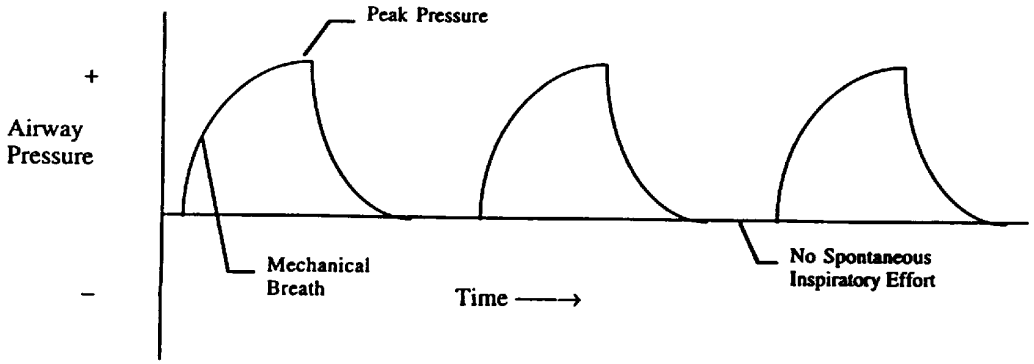
Various modes of mechanical ventilation



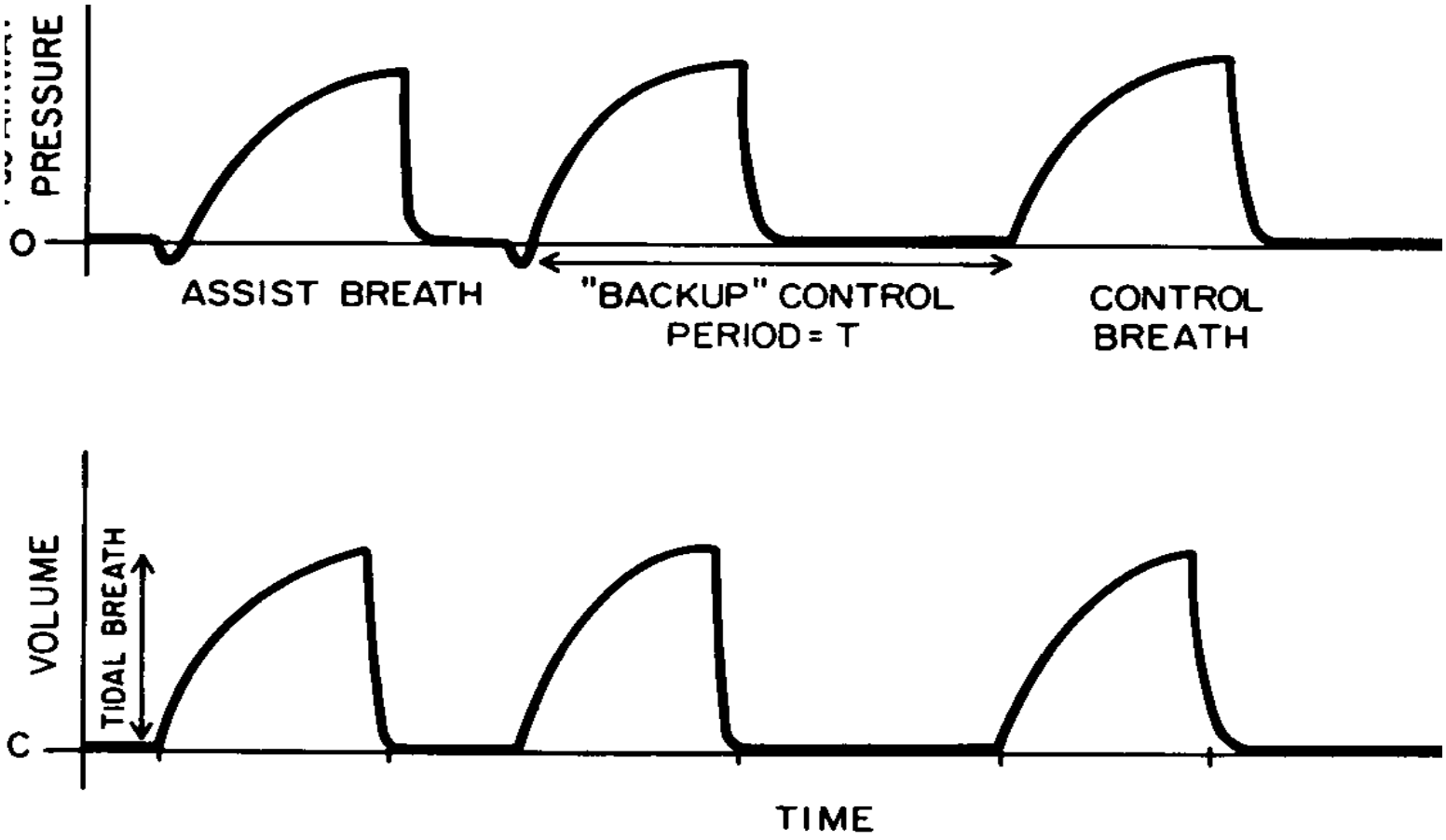
Control Modes

- every breath is fully supported by the ventilator
- in classic control modes, patients were unable to breathe except at the controlled set rate
- in newer control modes, machines may act in assist-control, with a minimum set rate and all triggered breaths above that rate also fully supported.

CMV


Peak Pressure
+
Airway
Pressure
–
Mechanical
Breath
Time ⟶
No Spontaneous
Inspiratory Effort

Assist-control



Ingento EP & Drazen J: Mechanical Ventilators, in Hall JB, Scmidt GA, & Wood LDH(eds.): *Principles of Critical Care*

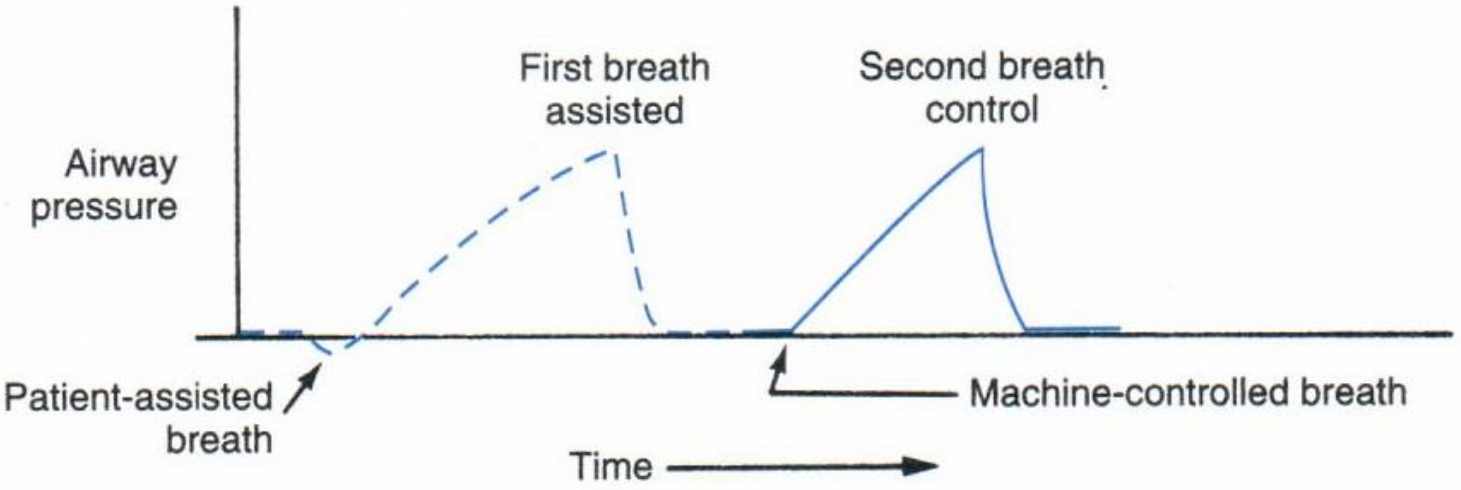
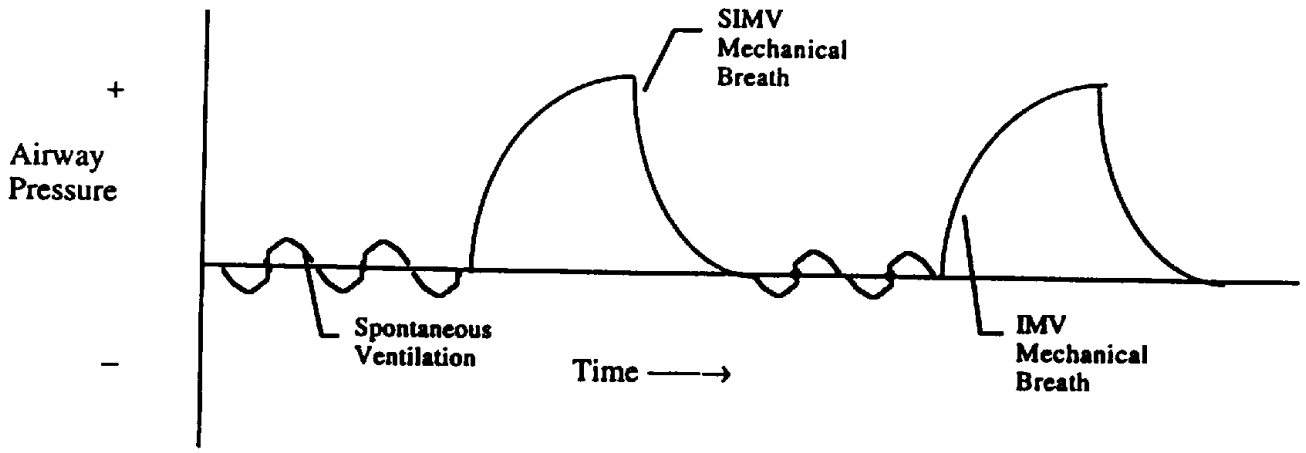
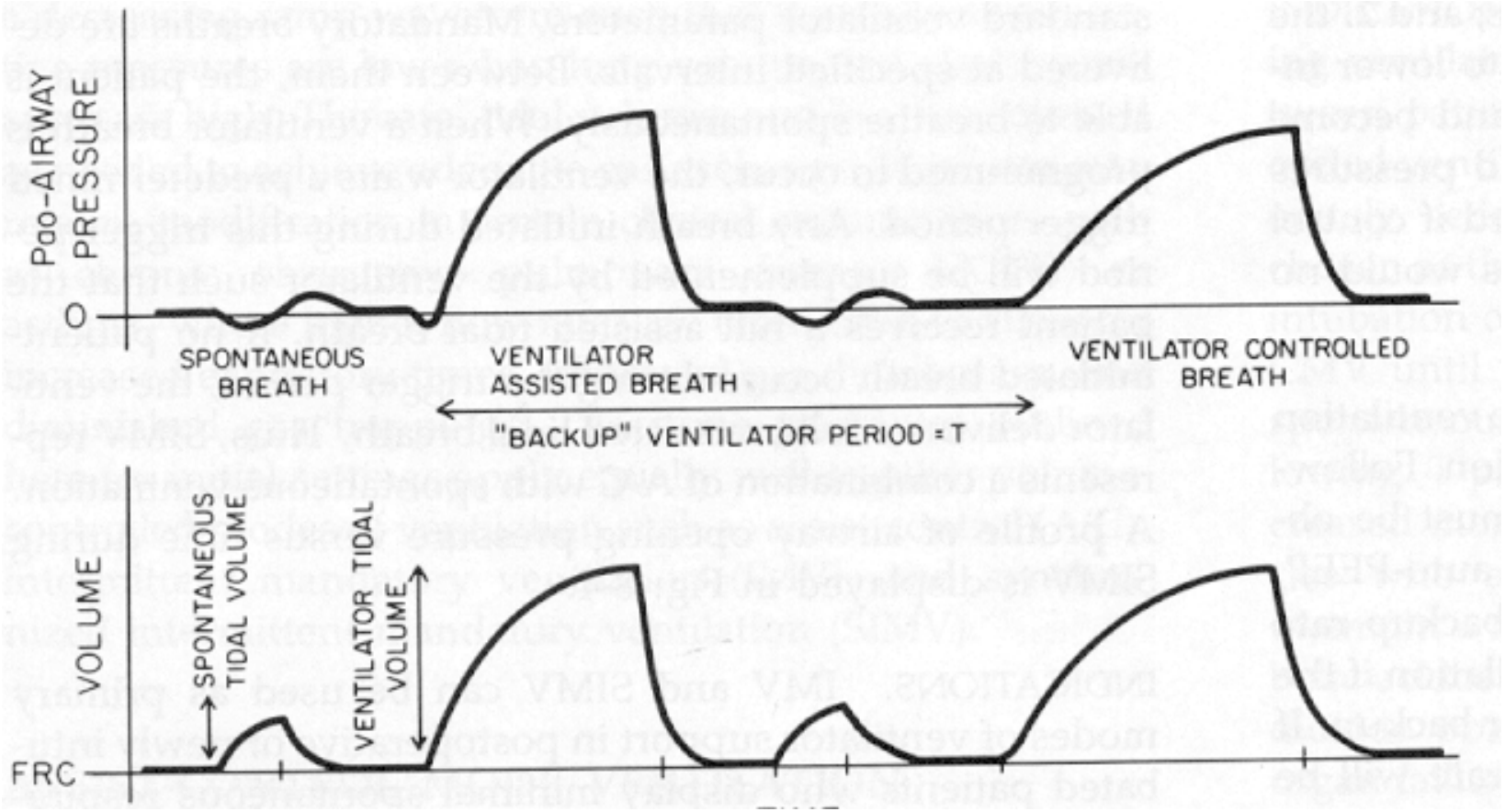


Fig. 3-8 Assist/control pressure curve. A patient-triggered (assisted) breath shows negative deflection of pressure before inspiration, whereas a controlled (time-triggered) breath does not.

SIMV


+
Airway
Pressure
–
SIMV
Mechanical
Breath
Spontaneous
Ventilation
Time ⟶
IMV
Mechanical
Breath

SIMV



Ingento EP & Drazen J: Mechanical Ventilators, in Hall JB, Scmidt GA, & Wood LDH(eds.): *Principles of Critical Care*

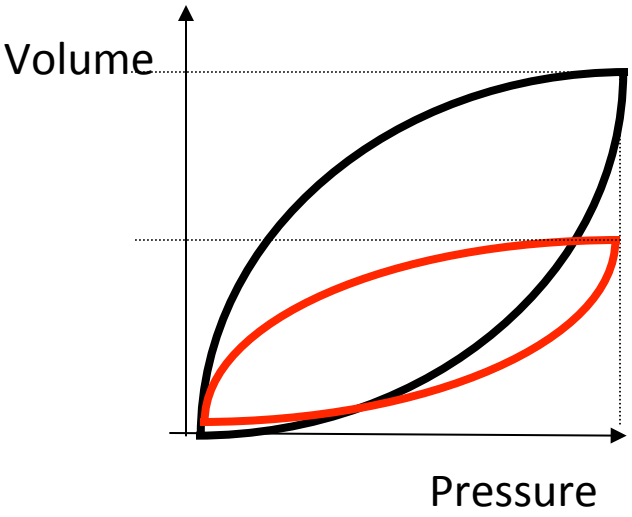
Volume Ventilation

<u>Tidal volume</u>, is not affected by the rapidly changing pulmonary mechanics

Compliance ↓

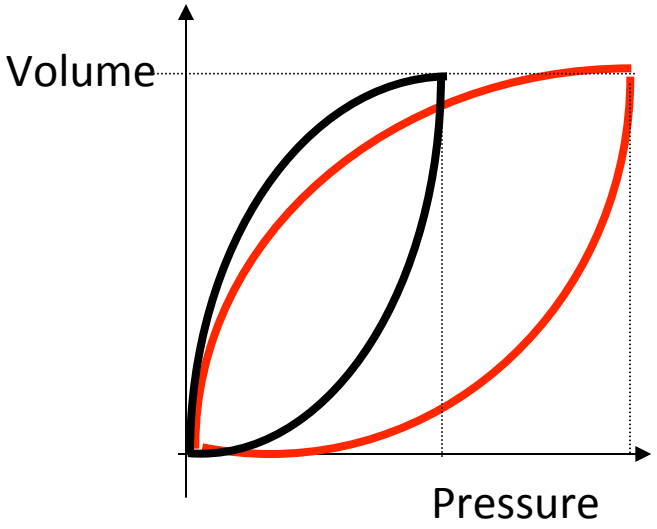
Pressure Ventilation:

Decreased Tidal Volume



Volume Ventilation:

Increased Pressure



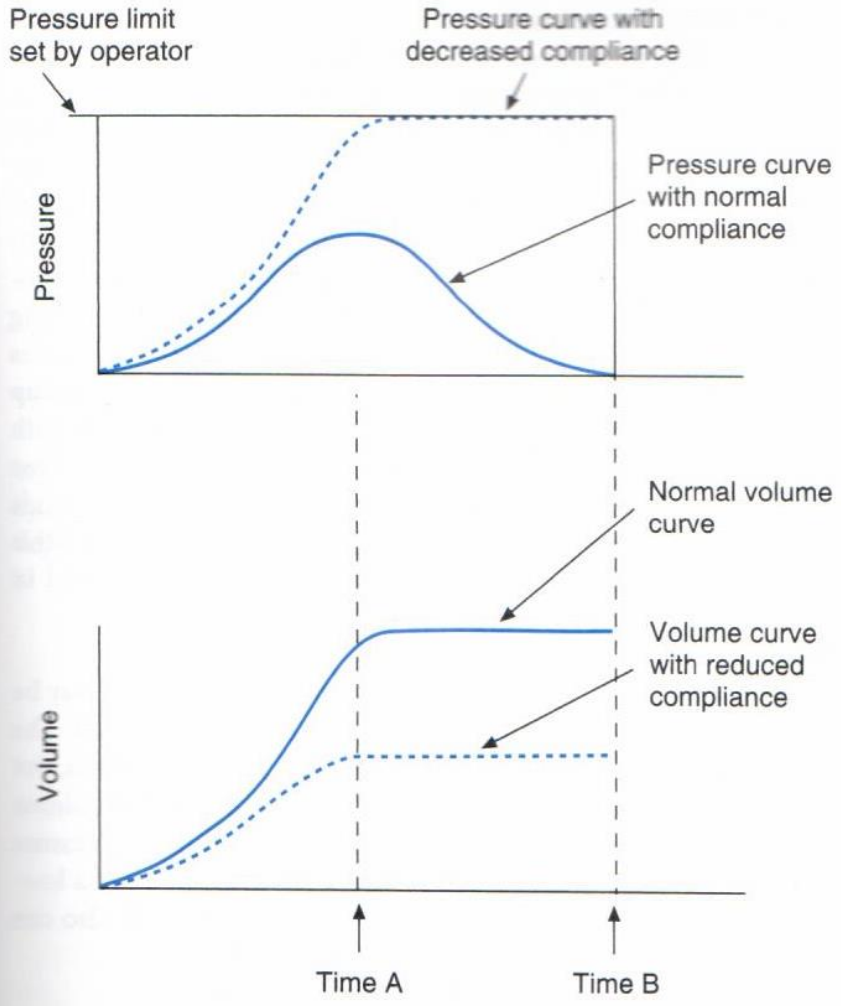


Fig. 3-10 Waveforms from a volume ventilator that delivers a sine wave pressure curve. The pressure and volume waveforms for normal compliance show pressure peaking at *Time A* and the normal volume delivered by *Time A*. Inspiration ends at *Time B*. With reduced compliance, the pressure rises higher during inspiration. Because excess pressure is vented, the pressure reaches a limit and goes no higher. No more flow enters the patient's lungs. Volume delivery has reached its maximum at *Time A*, when the pressure starts venting. Inspiration is time cycled at *Time B*. Note that volume delivery is lower when the lungs are stiffer and the pressure is limited. Some of the volume was vented to the air.

Volume targeted

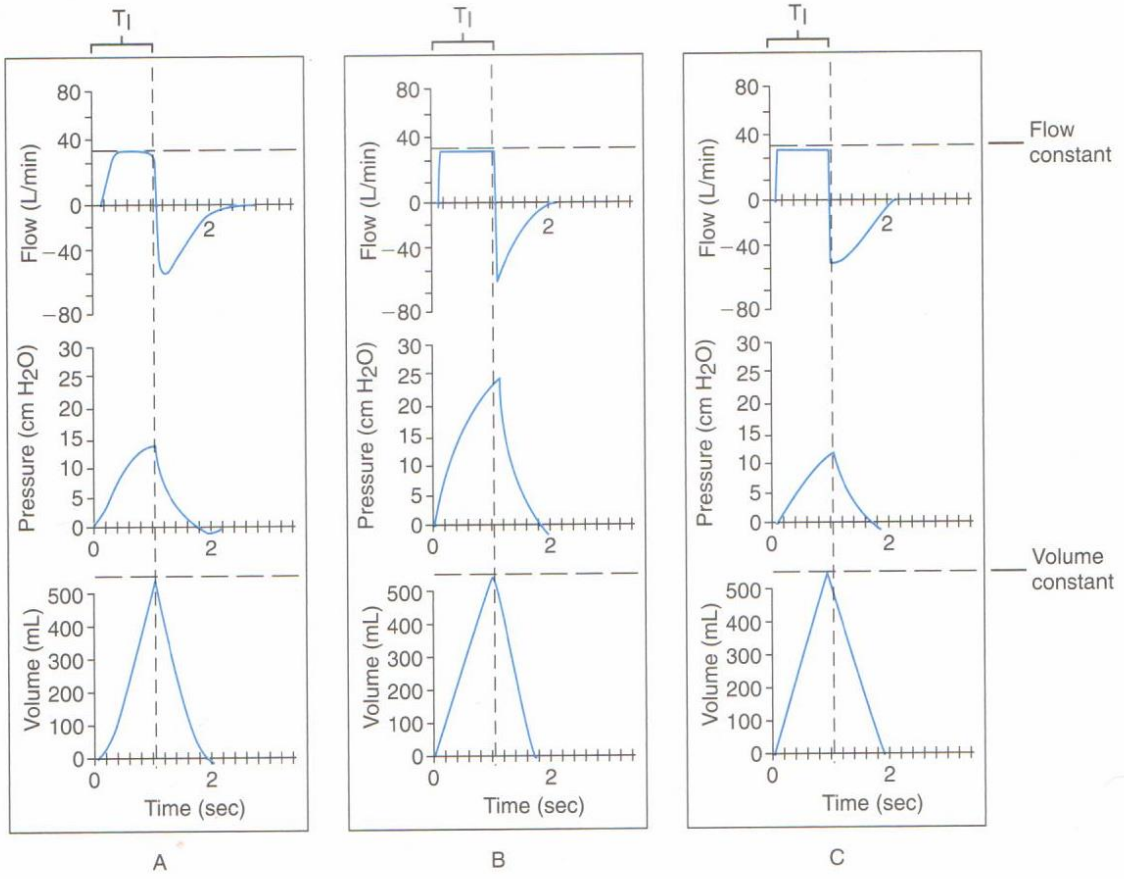


Fig. 5-1 Graphs for constant-flow, volume-targeted ventilation (constant volume) with normal compliance **(A)**, reduced compliance **(B)**, and increased compliance **(C)**. Note that inspiratory flow is above the *x* axis and expiratory flow is below the *x* axis. (See text for more information.)

Pressure Control vs. Pressure Support

Constant insp. pressure

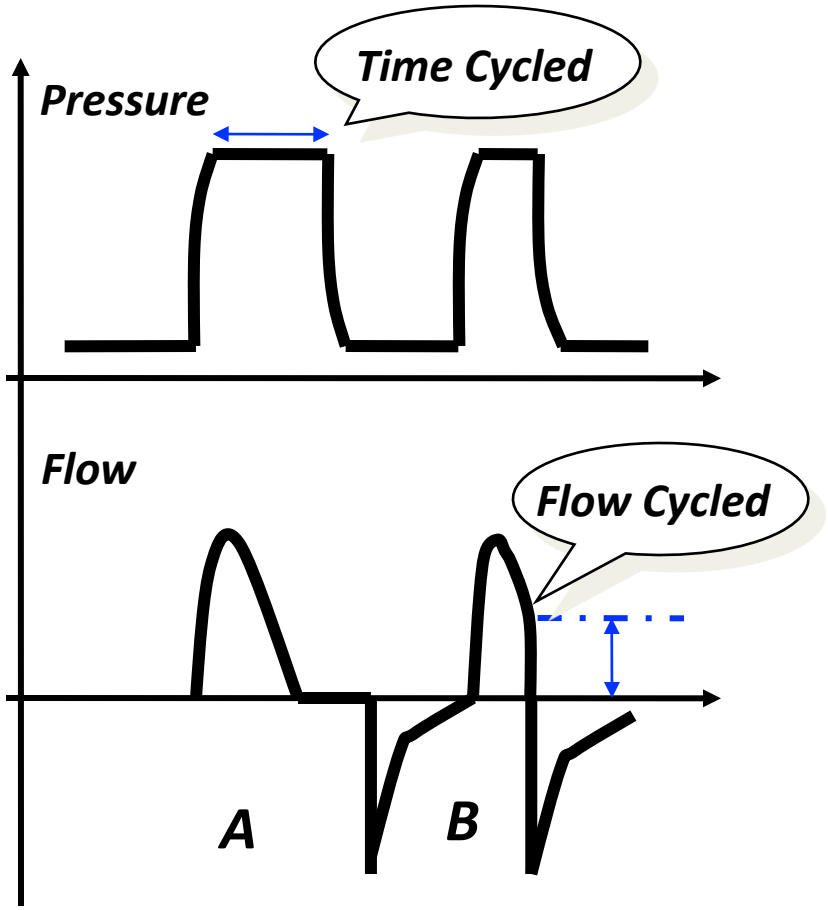
Decelerating, variable inspiratory flow rate

Time cycled: (A)

- Pressure Control

Flow cycled: (B)

- Pressure Support



Pressure targeted

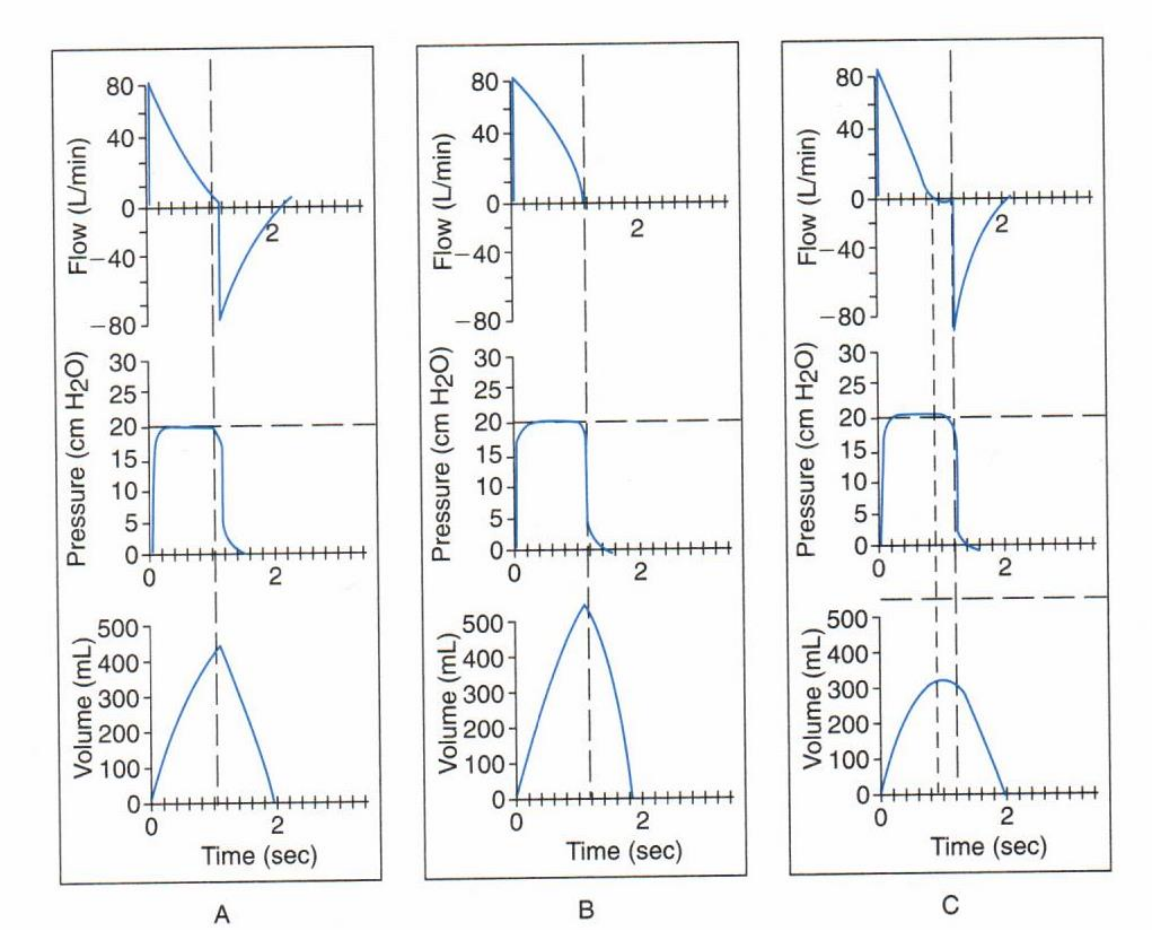


Fig. 5-2 Graphs for pressure-targeted ventilation (constant pressure) with normal compliance **(A)**, increased compliance **(B)**, and decreased compliance **(C)**. (See text for more information.)

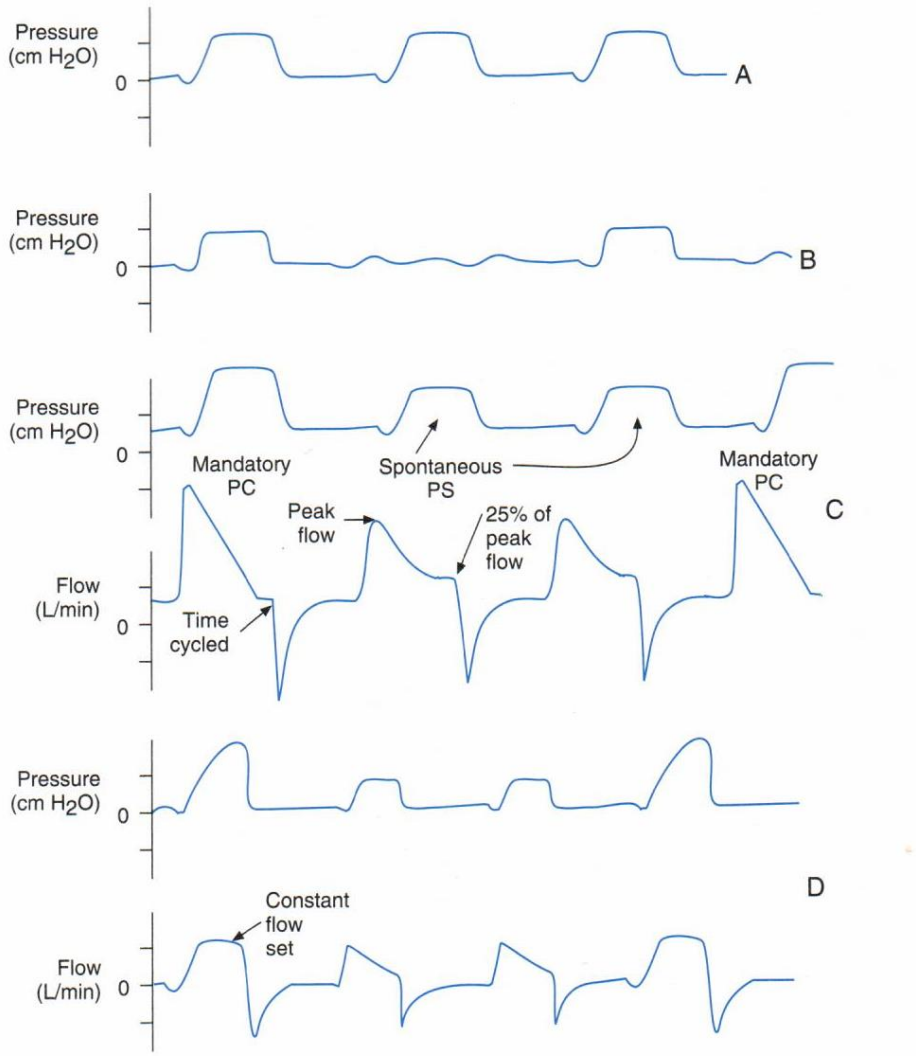


Fig. 5-5 **A,** Pressure-control continuous mandatory ventilation (PC-CMV) mode; breaths are patient triggered. **B,** Pressure-control ventilation using the spontaneous intermittent mechanical ventilation (PC-SIMV) mode with spontaneous ventilation at zero baseline. **C,** PC-SIMV mode in which pressure support (PS) has been added for spontaneous breaths. The *top curve* shows pressure, and the *lower curve* shows flow. Note that peak flow and pressure are higher for mandatory pressure-control breaths and that flow returns to zero before end-inspiration. In PS breaths, inspiration is flow cycled at 25% of peak flow. **D,** VC-SIMV mode with PS added for spontaneous breaths. Compare the upper and lower curves (pressure and flow, respectively) in **D** with those in **C**.

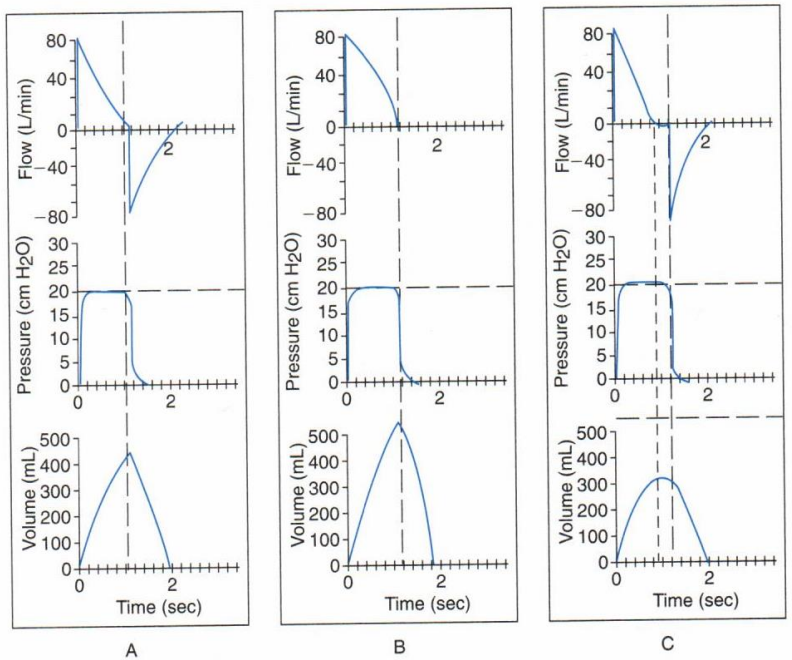


Fig. 5-2 Graphs for pressure-targeted ventilation (constant pressure) with normal compliance **(A)**, increased compliance **(B)**, and decreased compliance **(C)**. (See text for more information.)

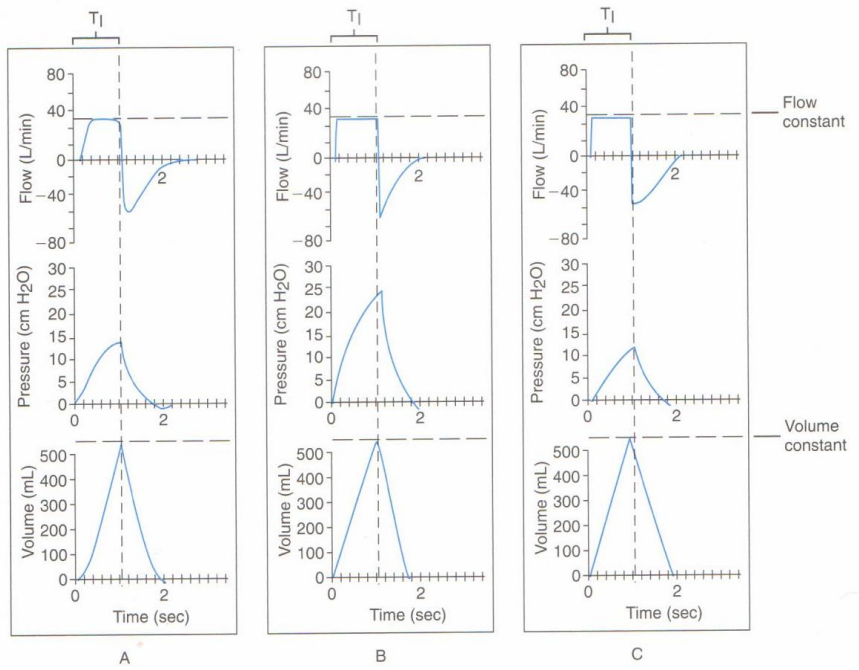
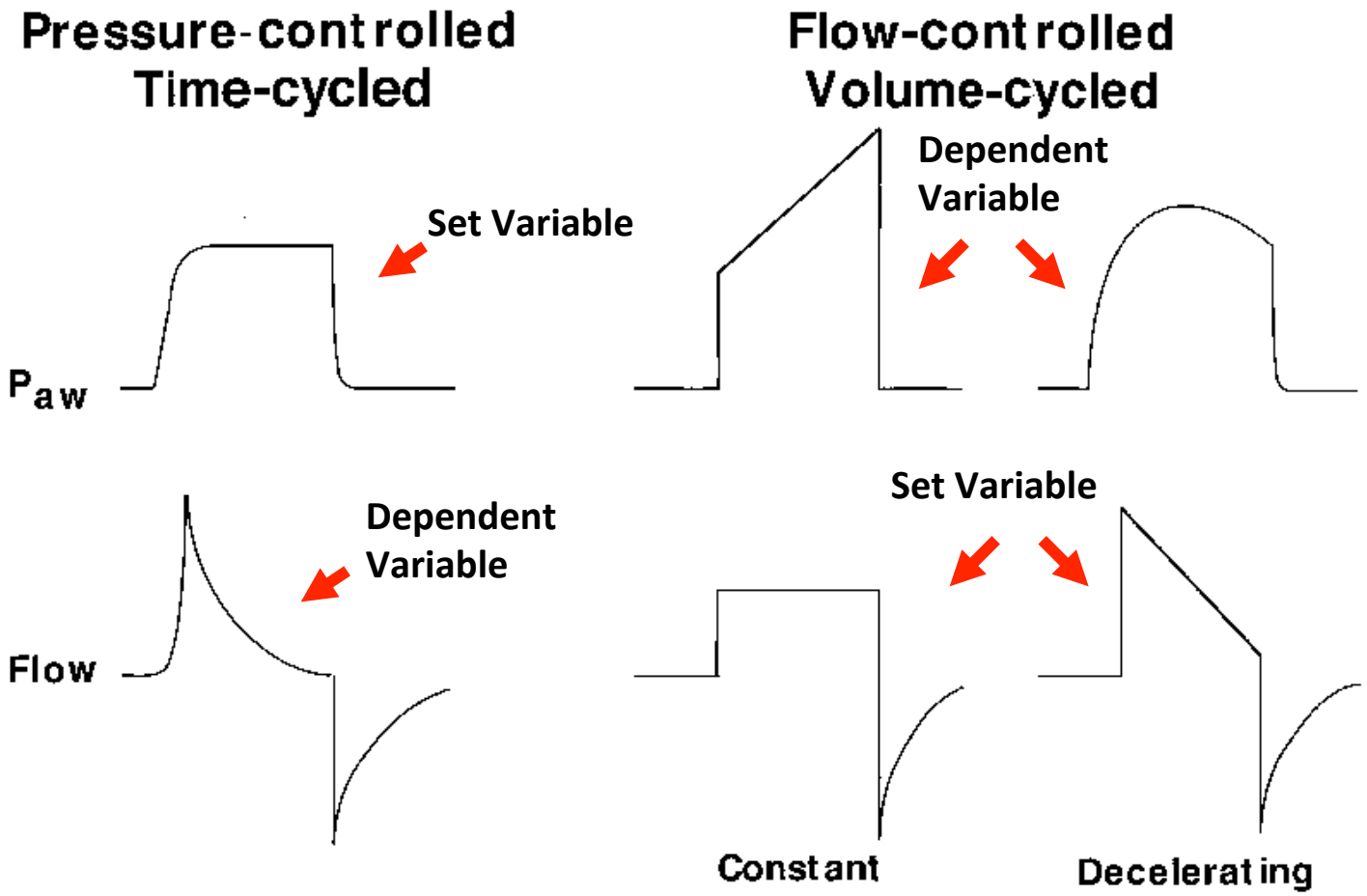


Fig. 5-1 Graphs for constant-flow, volume-targeted ventilation (constant volume) with normal compliance **(A)**, reduced compliance **(B)**, and increased compliance **(C)**. Note that inspiratory flow is above the *x* axis and expiratory flow is below the *x* axis. (See text for more information.)

Positive Airway Pressure Can Be Either Pressure or Flow Controlled—But Not Both Simultaneously



Rise time

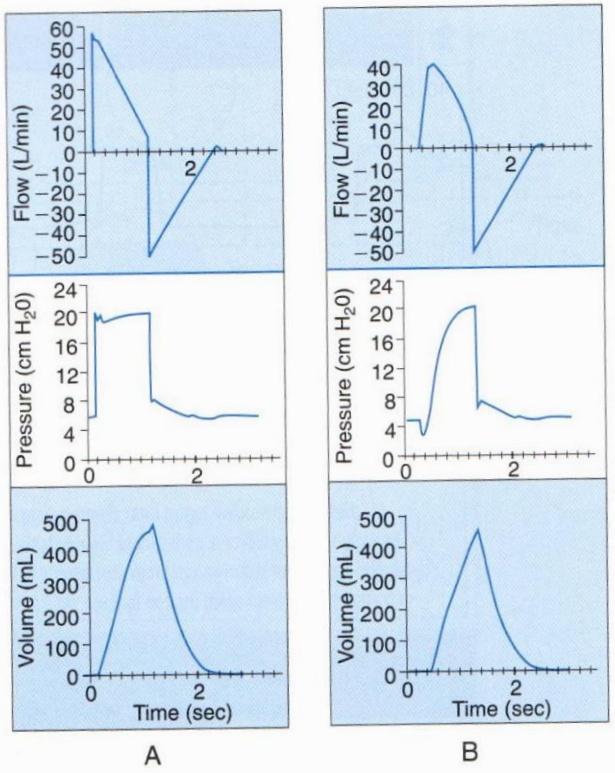
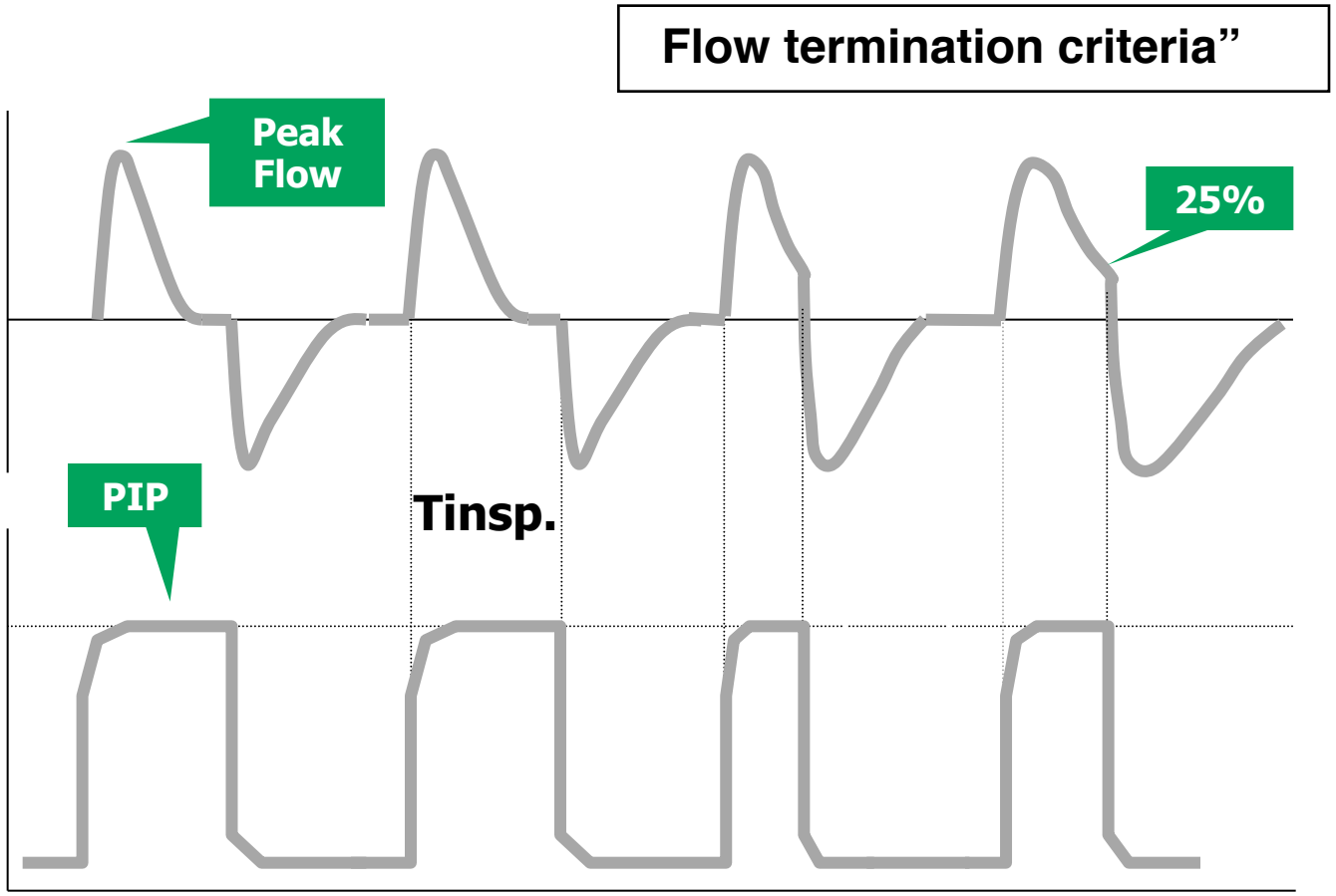


Fig. 5-9 Effect of rise time adjustment during PSV. **A,** Faster rise time. **B,** Slow rise time. (From Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice*, Philadelphia, 2002, Saunders.)

How to set Ti in a spontaneous breathing patient on a pressure support mode ?



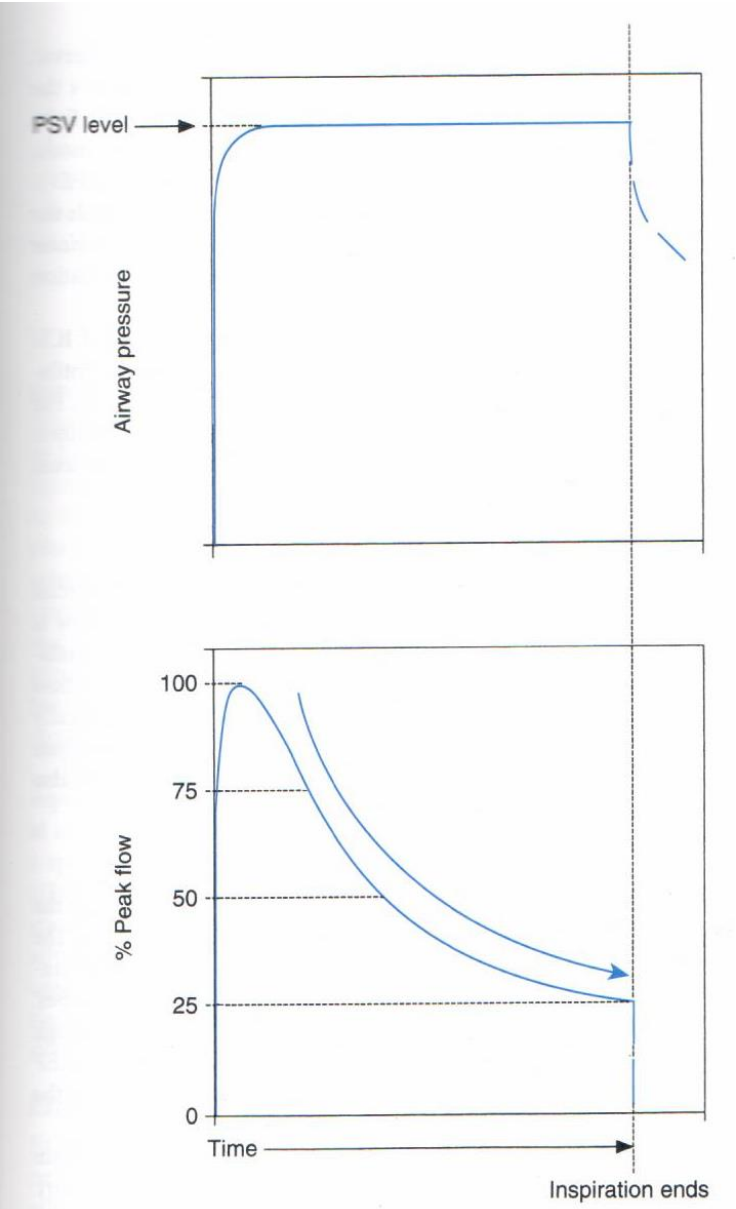
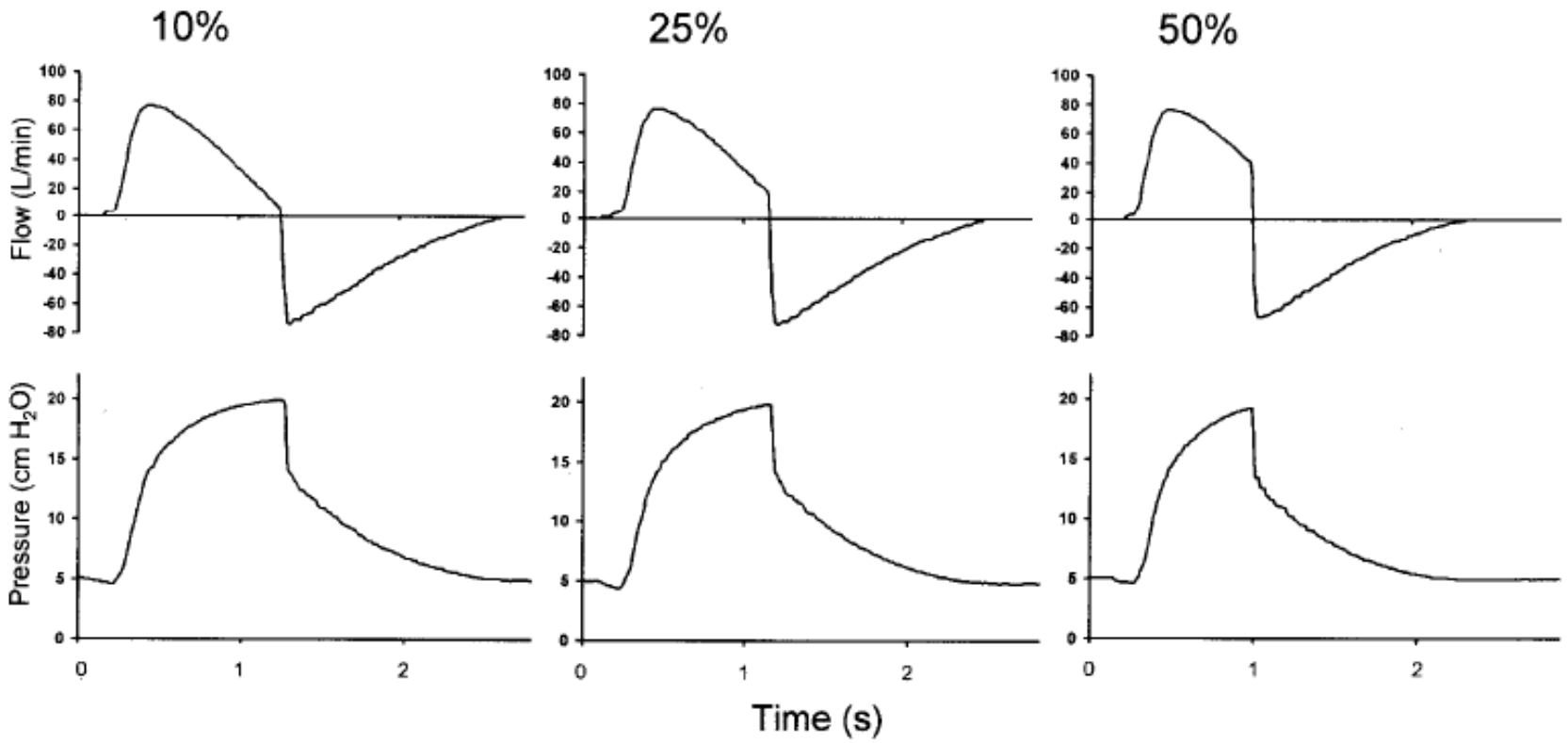
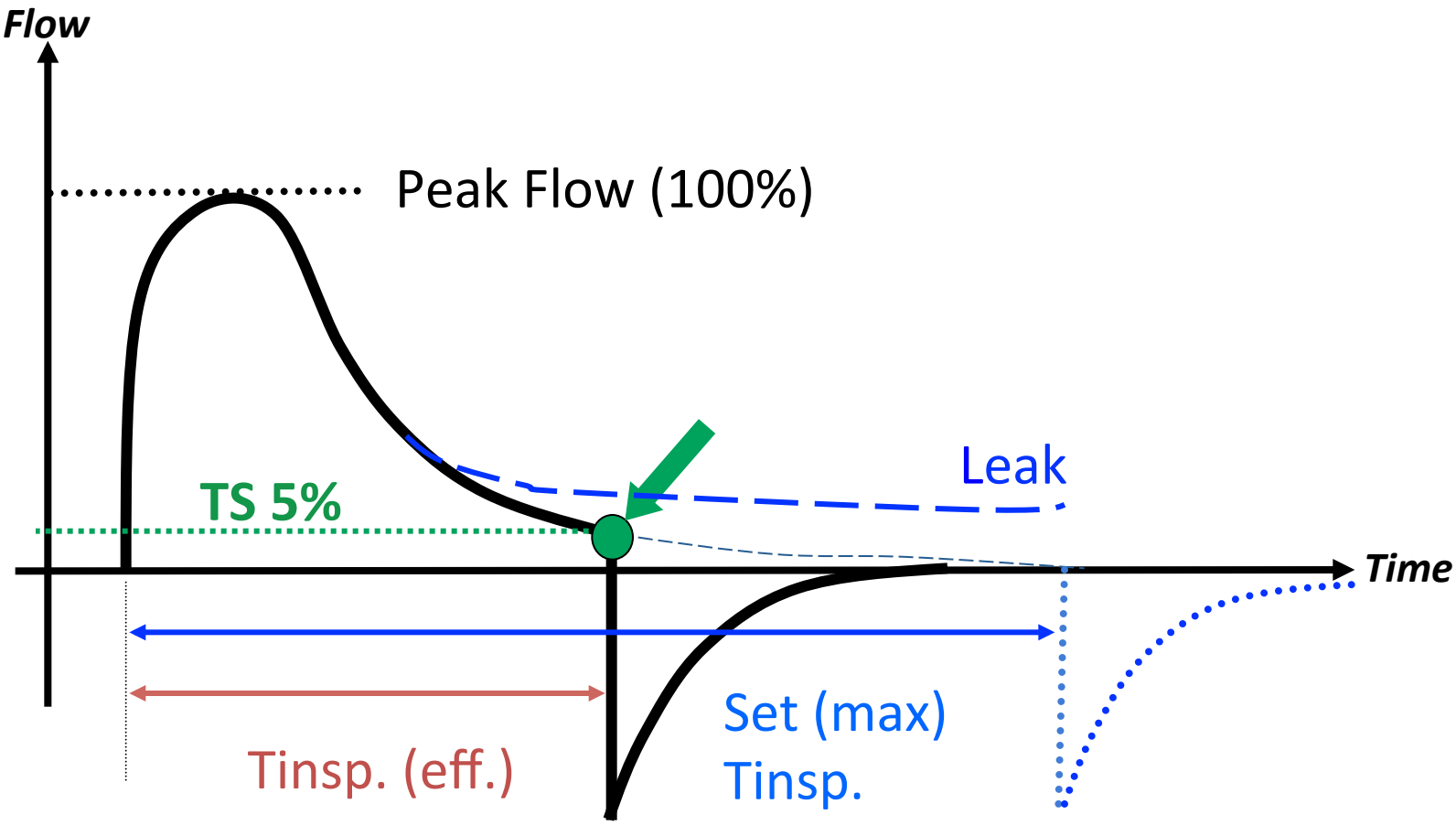


Fig. 3-11 Waveforms from a pressure-support breath showing the pressure and flow curves during inspiration. When flow drops to 25% of the peak flow value measured during inspiration, the ventilator flow-cycles out of inspiration. (From Dupuis Y: *Ventilators: theory and clinical application,* ed 2, St Louis, 1992, Mosby.)


10%
25%
50%
Flow (L/min)
100
80
60
40
20
0
-20
-40
-60
-80
Pressure (cm H_2O)
20
15
10
5
0
0
1
2
Time (s)

Termination Sensitivity = Cycle-off Criteria



Combination “Dual Control” Modes

Combination or “dual control” modes combine features of pressure and volume targeting to accomplish ventilatory objectives which might remain unmet by either used independently.

Combination modes are pressure targeted

- Partial support is generally provided by pressure support
- Full support is provided by Pressure Control

Combination “Dual Control” Modes

Volume Assured Pressure Support (Pressure Augmentation)

Volume Support (Variable Pressure Support)

Pressure Regulated Volume Control

(Variable Pressure Control, or Autoflow)

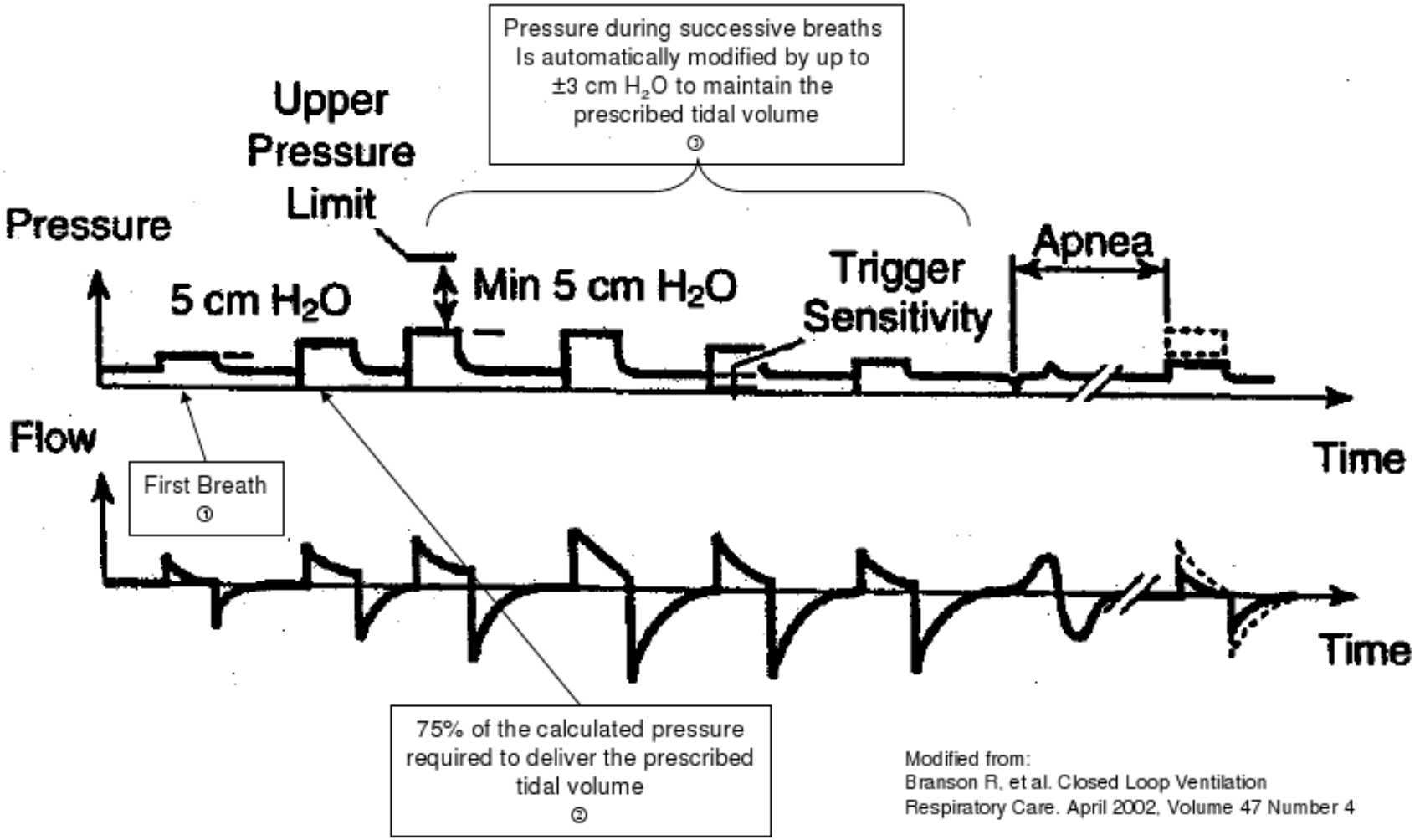
Airway Pressure Release (Bi-Level, Bi-PAP)

PRVC (Pressure regulated volume control)

A control mode, which delivers a set tidal volume with each breath at the lowest possible peak pressure.

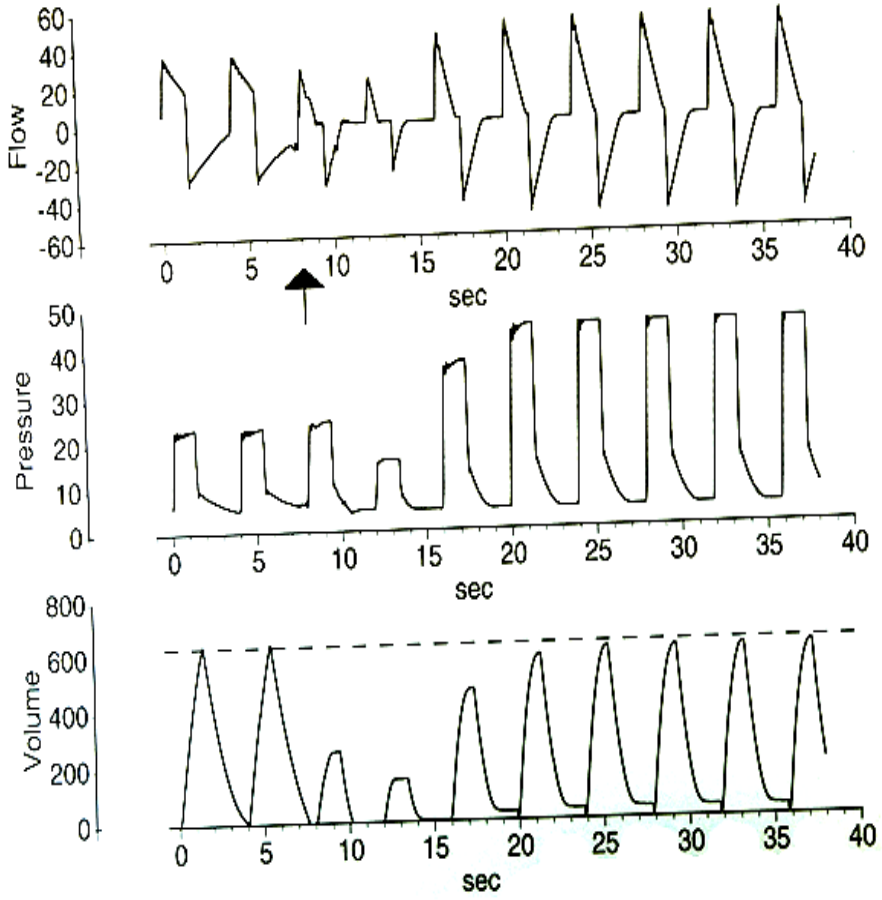
Delivers the breath with a decelerating flow pattern that is thought to be less injurious to the lung…… “the guided hand”.

Understanding PRVC
(Pressure-Regulated Volume Control)



Modified from:
Branson R, et al. Closed Loop Ventilation
Respiratory Care. April 2002, Volume 47 Number 4

PRVC Automatically Adjusts To Compliance Changes



Servo PRVC

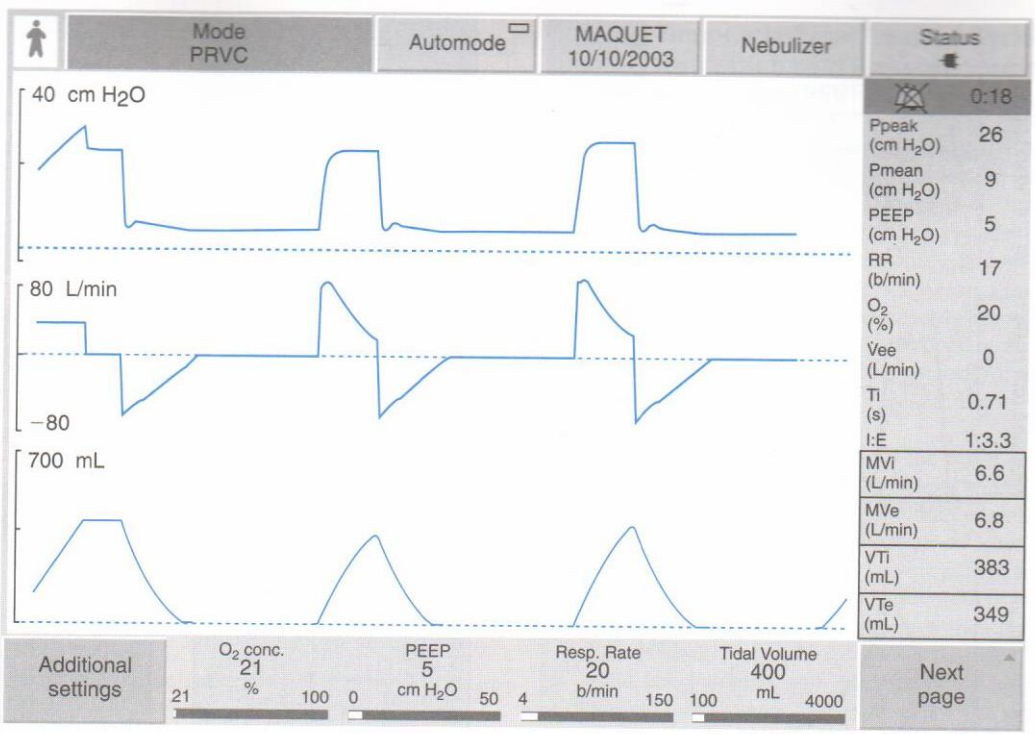


Fig. 5-10 A screen capture of pressure-regulated volume control (PRVC) in an adult patient on the Servo^{i} ventilator. The first breath (*left*) is a volume-targeted test breath with an inspiratory hold to measure plateau pressure. The second breath is a pressure-targeted breath with a pressure equal to the measured plateau pressure. Set tidal volume is 400 mL. Measured exhaled tidal volume is about 350 mL. Note how the pressure is increased by a few centimeters of H_2O on the third breath for the ventilator to achieve the set tidal volume.

PRCV: Advantages

Decelerating inspiratory flow pattern

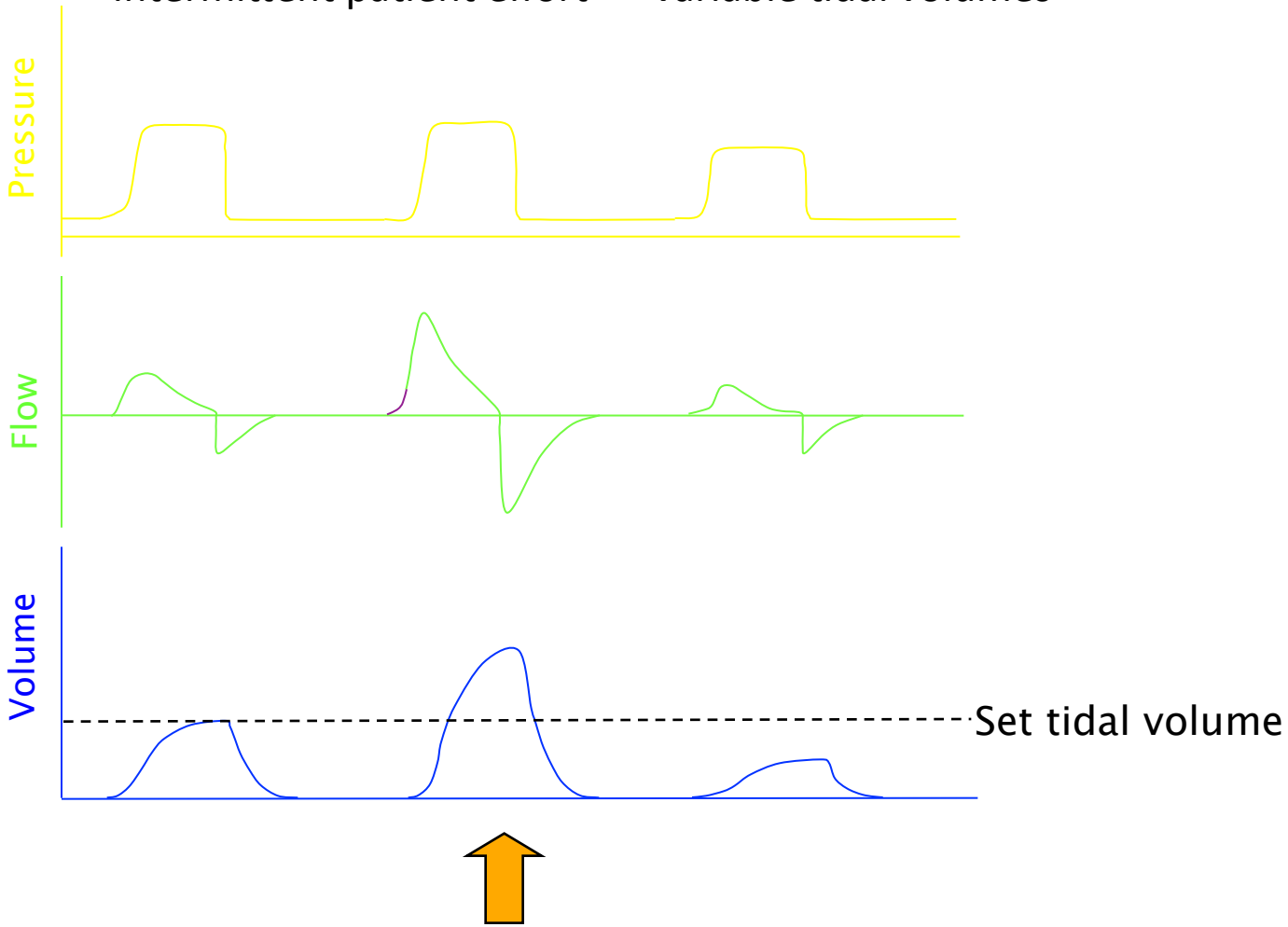
Pressure automatically adjusted for changes in compliance and resistance within a set range

- Tidal volume guaranteed
- Limits volutrauma
- Prevents hypoventilation

PRVC: Disadvantages

Pressure delivered is dependent on tidal volume achieved on last breath

Intermittent patient effort ⇒ variable tidal volumes



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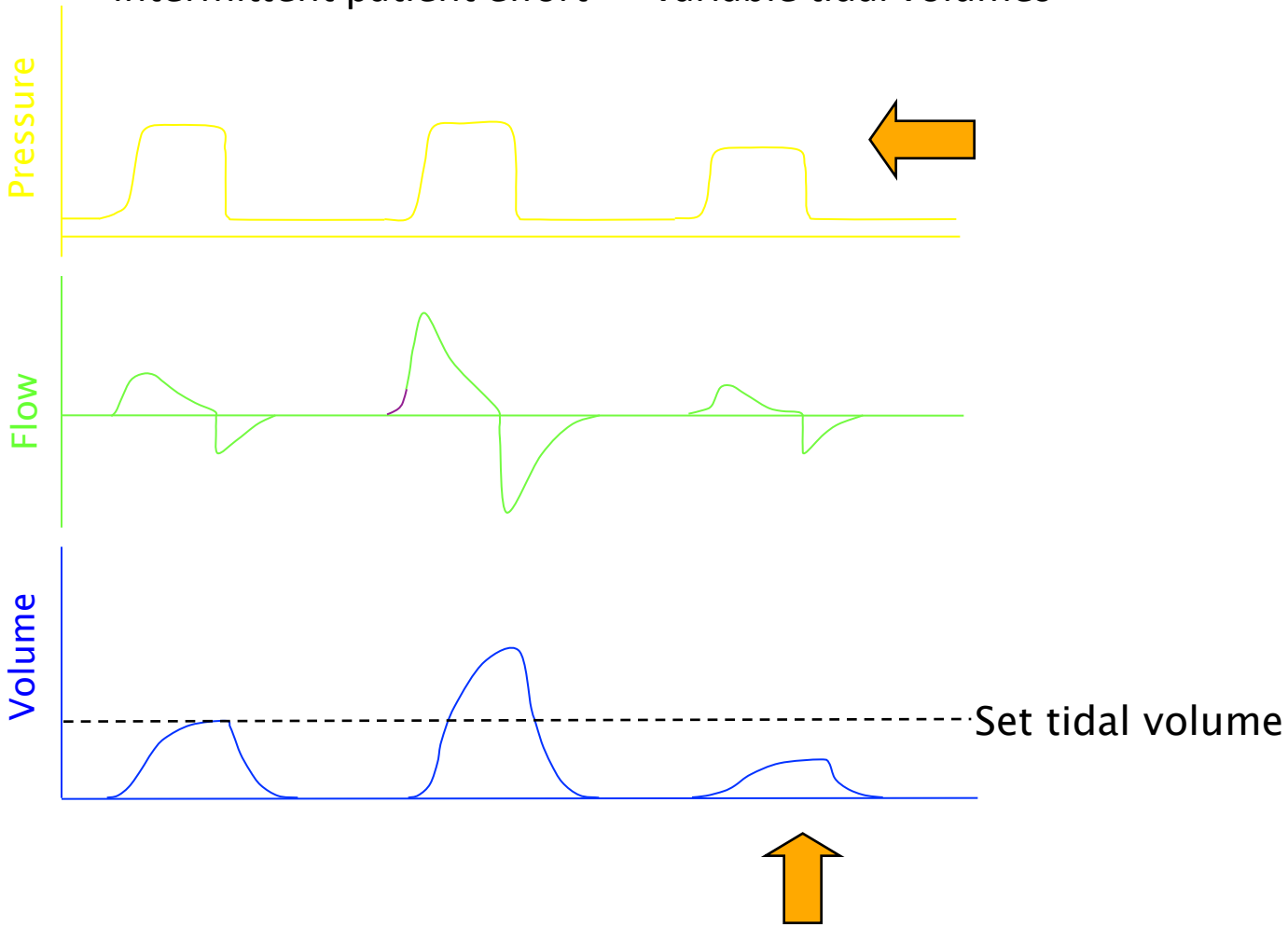
PRVC: Disadvantages

Pressure delivered is dependent on tidal volume achieved on last breath

Intermittent patient effort ⇒ variable tidal volumes



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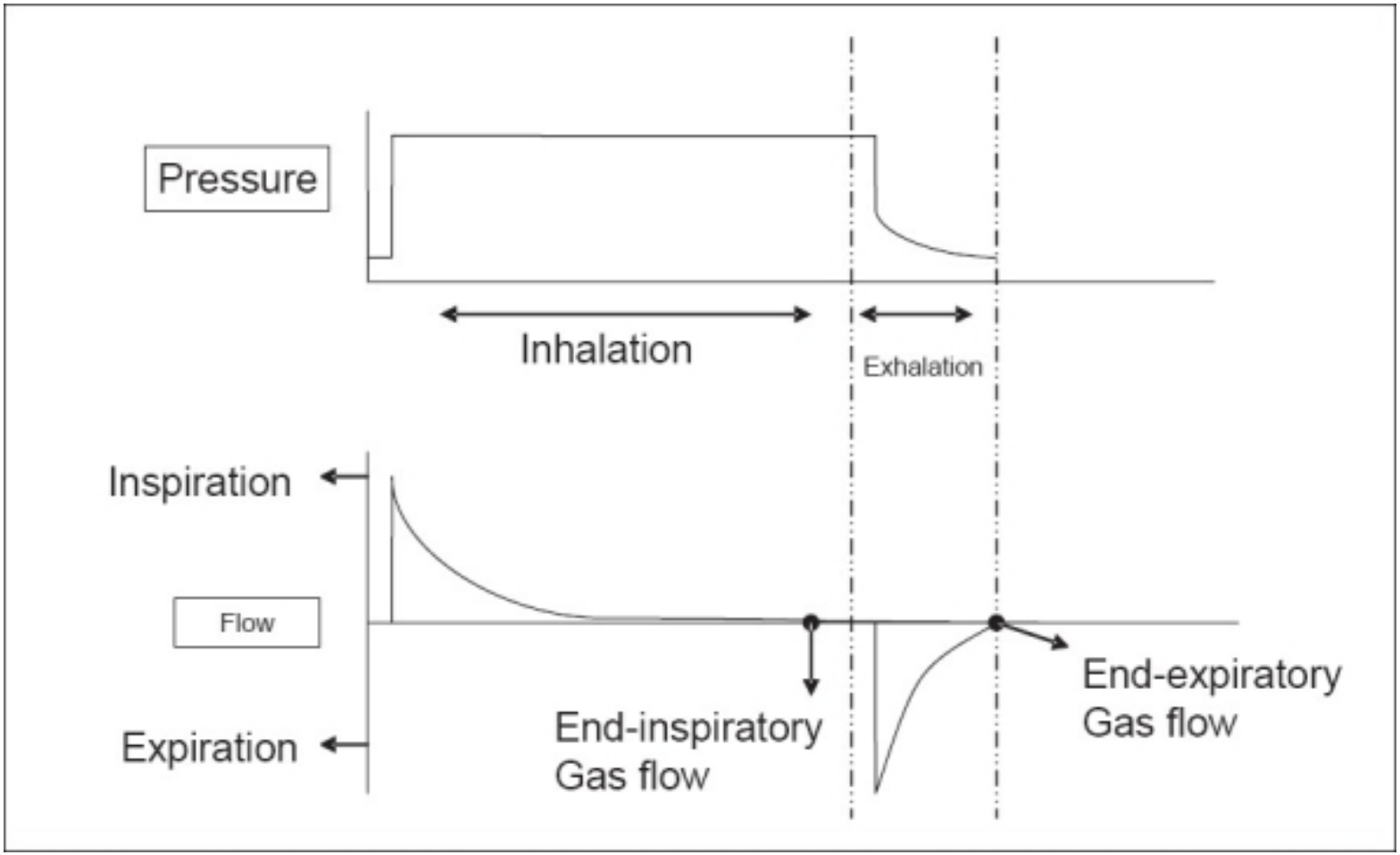
APRV

- BiVent - (Servo-i ventilator by Maquet)
- BiLevel - (Puritan Bennett 840 ventilator by Covidien)
- DuoPAP - (C-1 ventilator by Hamilton)

APRV


Pressure
Inhalation
Exhalation
Inspiration
Flow
Expiration
End-inspiratory
Gas flow
End-expiratory
Gas flow

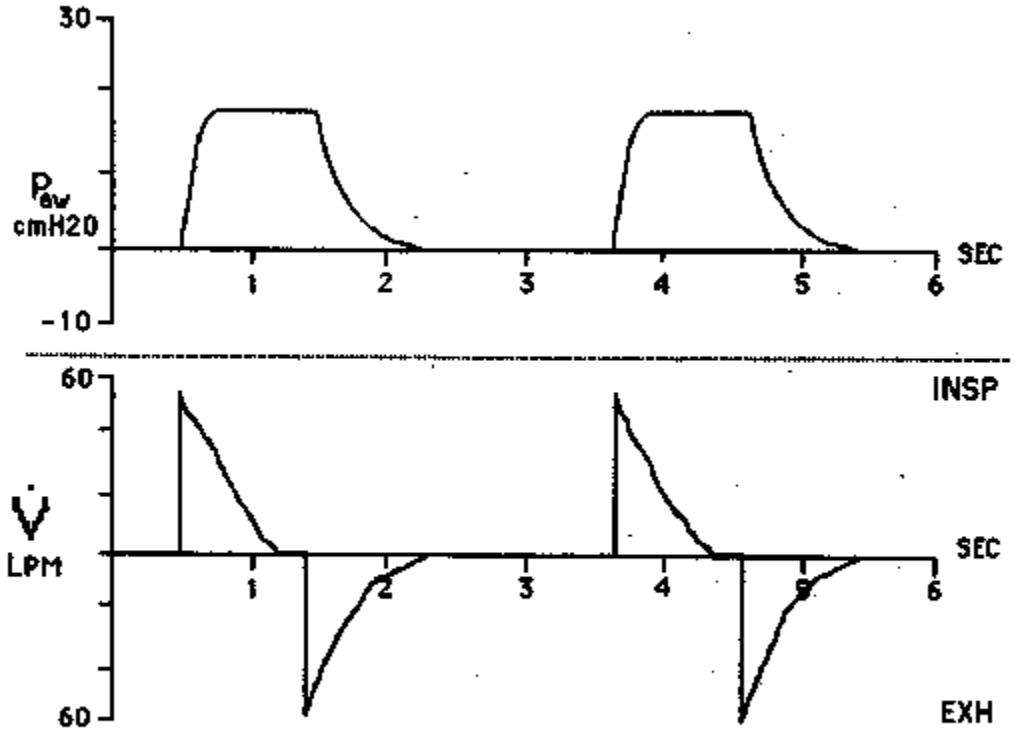


Figure 5. Pressure and Flow Curves in PCV

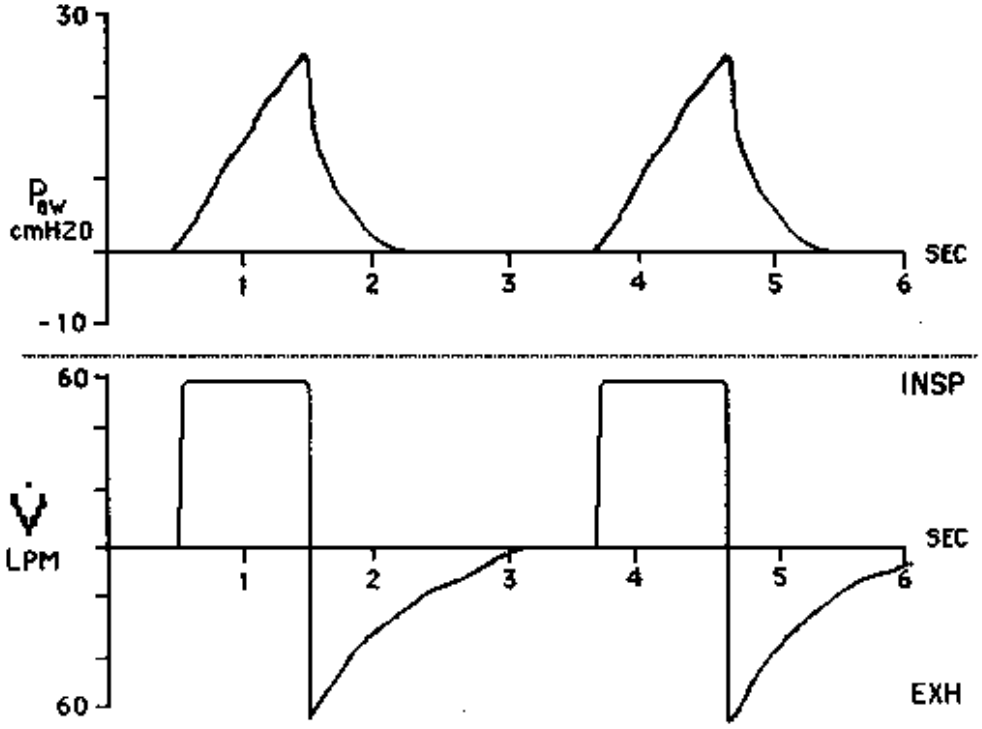
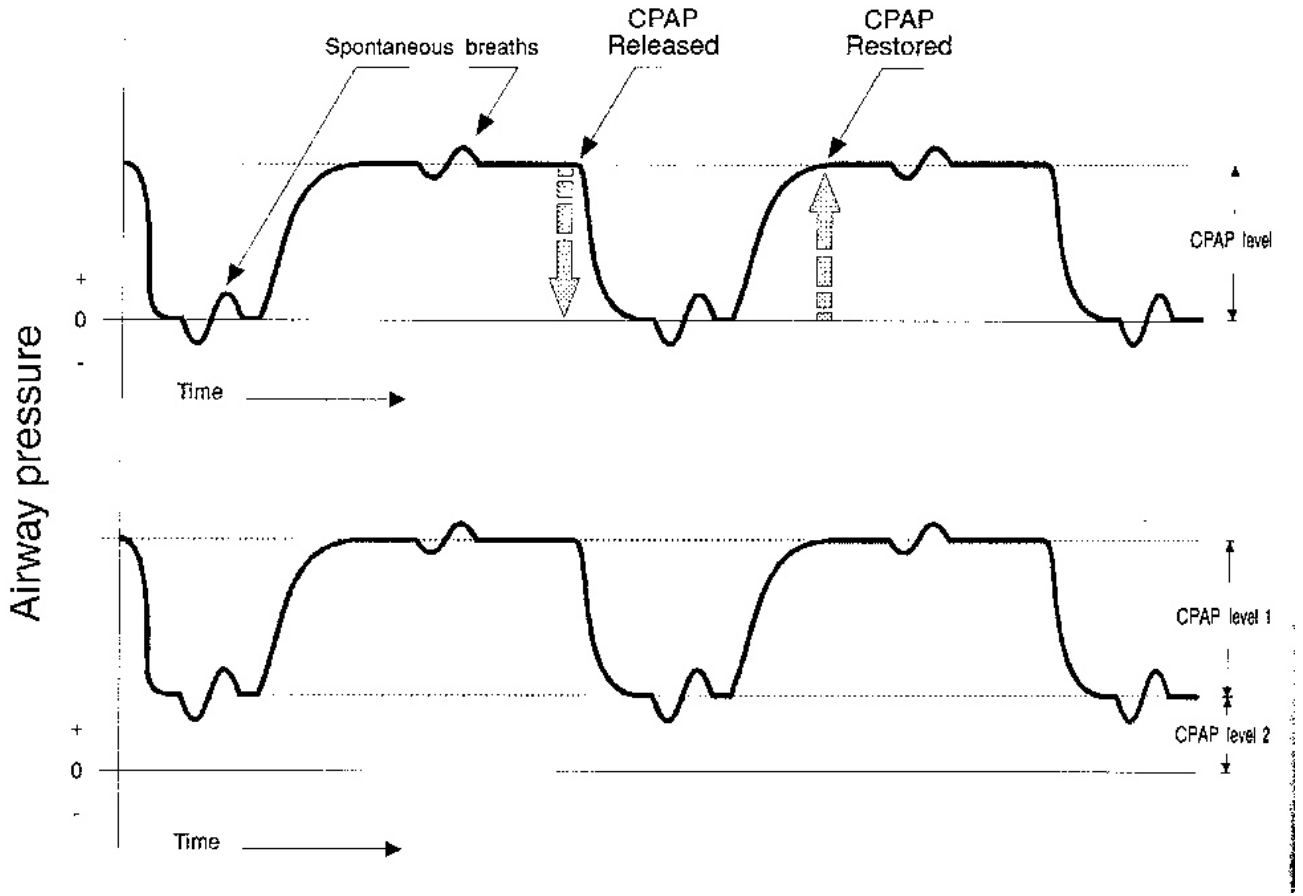


Figure 1. Typical Pressure and Flow Curves (Volume Ventilation)

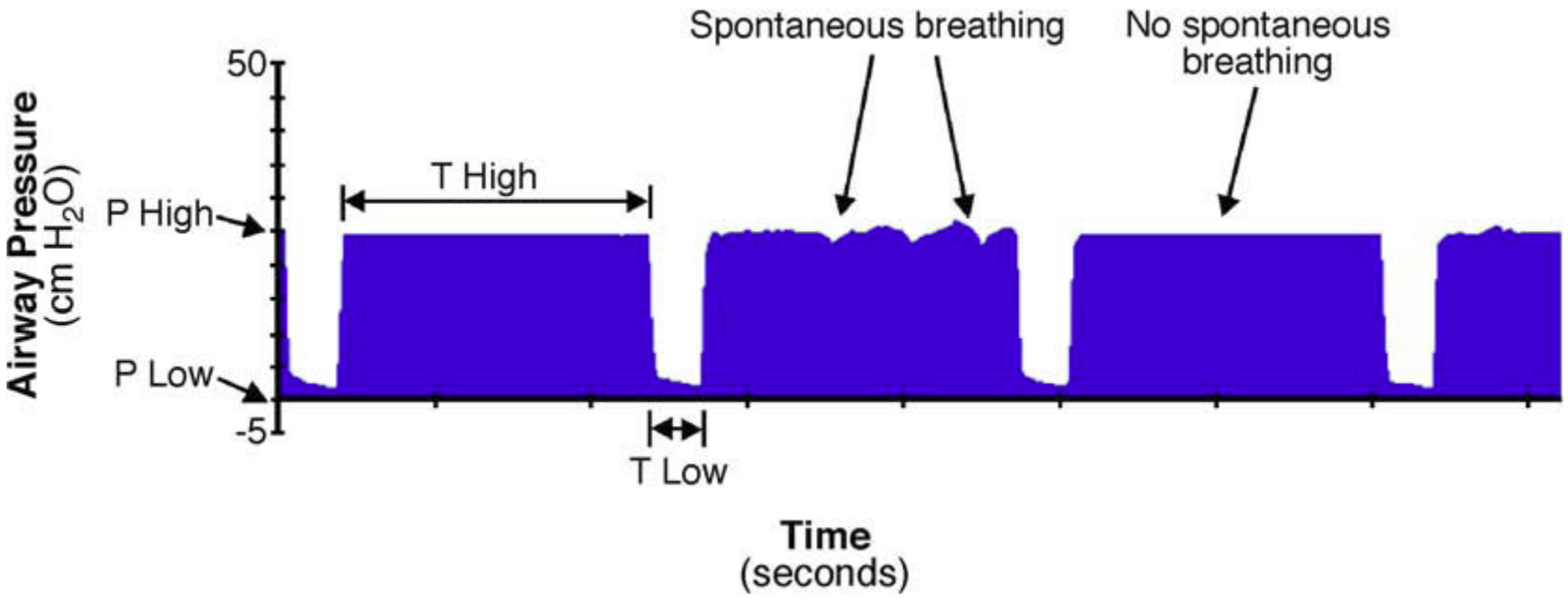
- An application of CPAP
- Continuous positive airway pressure (CPAP) with an intermittent release phase.
- Patient cycles between two levels of CPAP—higher one **P High(P1), the lower P Low(P2)**
- The patient can breath spontaneously at either level
- Maintains an optimal FRC maintain adequate lung volume and alveolar recruitment.
- Occasional pressure releases augments CO2removal

- P High–the upper CPAP level. Analogous to MAP (mean airway pressure) and thus affects oxygenation
- P Low/PEEPis the lower pressure setting.
- T High-is the time spent at P High
- T Low-is the release time allowing CO2elimination

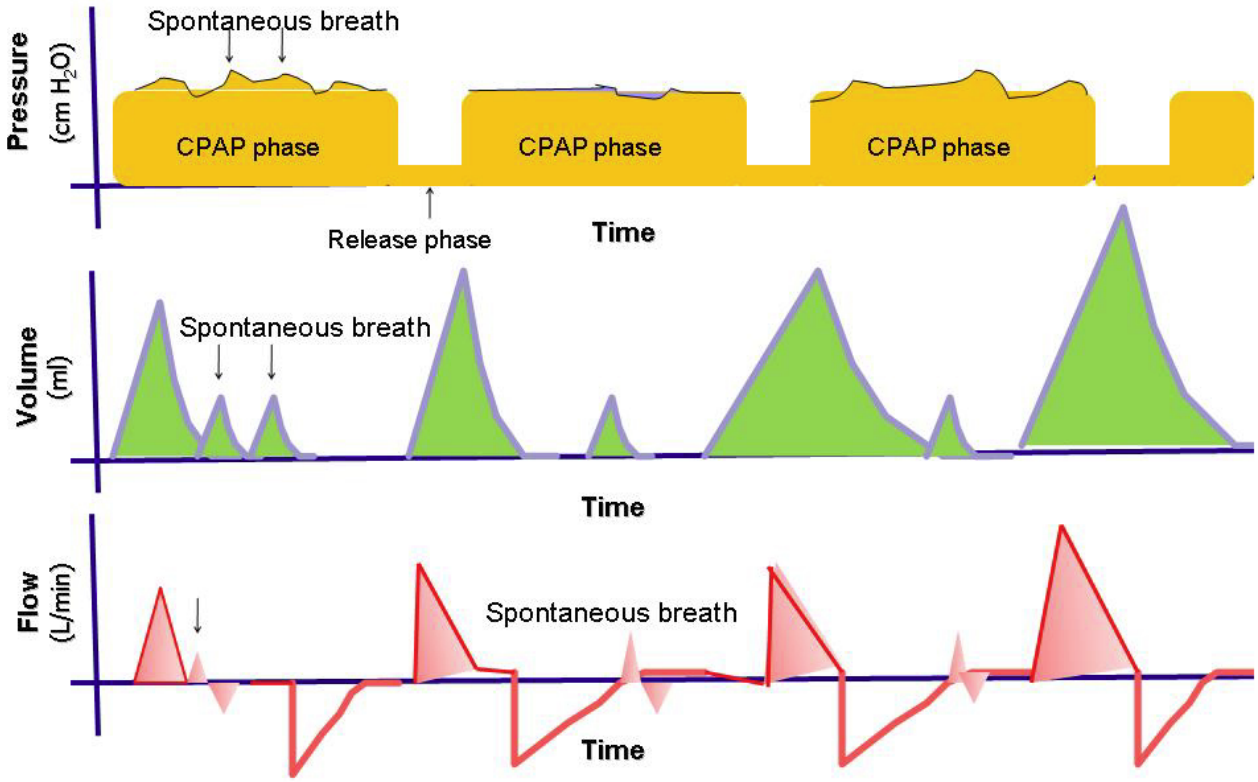

Spontaneous breaths
CPAP Released
CPAP Restored
CPAP level
Airway pressure
+
0
-
Time
CPAP level 1
CPAP level 2
+
0
-
Time

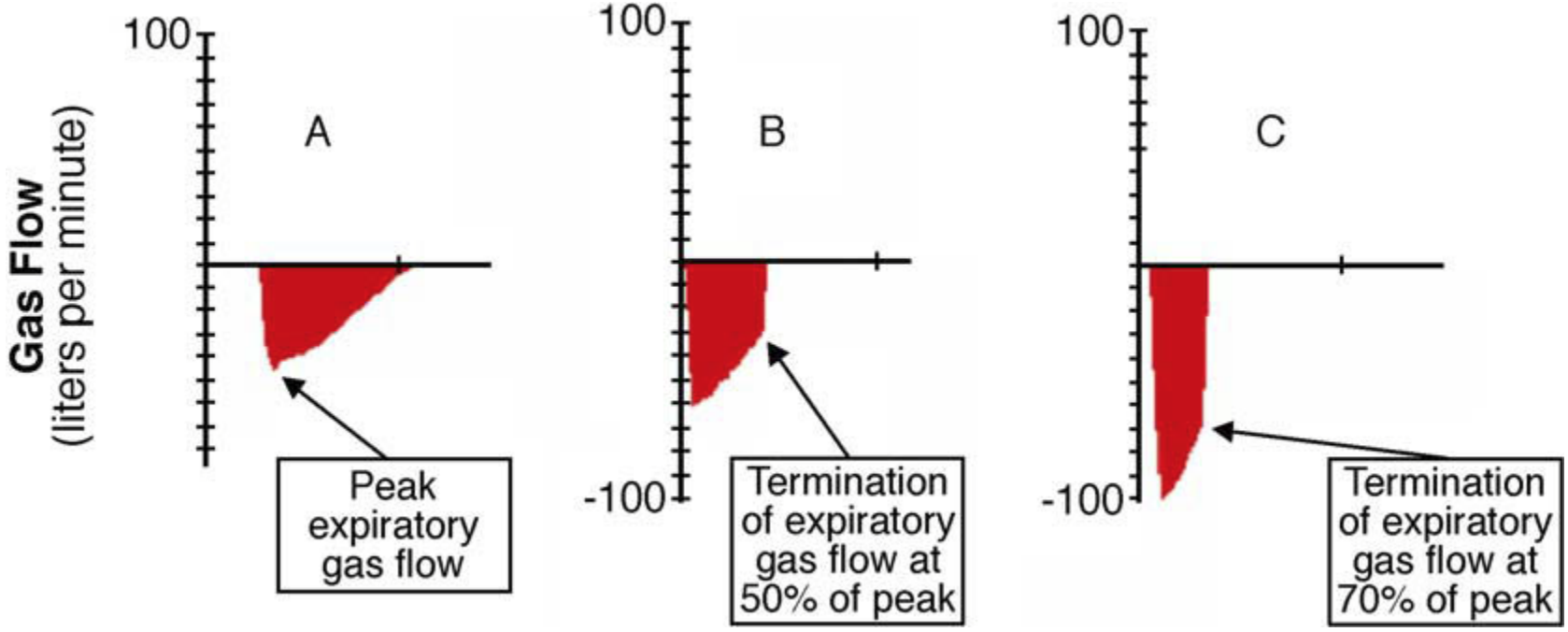
- Application of ‘P high’ and ‘T high’:(80-95%) of the cycle time—”open lung”
- Mean airway pressure (MAP) is increased
- Insures almost constant lung recruitment
  - Decreases repetitive inflation/deflationDecreases risk of VILI
  - Decreases need for recruitment maneuvers

- Minute ventilation/CO2 removal depend upon:Lung compliance
- Airway resistance
- Magnitude and duration of pressure release
- Patient's spontaneous breathing efforts


Spontaneous breathing
No spontaneous breathing
50
T High
P High
P Low
-5
T Low
Airway Pressure
(cm H_2O)
Time
(seconds)

APRV


Pressure
(cm H_2O)
Spontaneous breath
CPAP phase
CPAP phase
CPAP phase
Release phase
Time
Volume
(ml)
Spontaneous breath
Time
Flow
(L/min)
Spontaneous breath
Time


Gas Flow
(liters per minute)
100
A
Peak
expiratory
gas flow
100
B
-100
Termination
of expiratory
gas flow at
50% of peak
100
C
-100
Termination
of expiratory
gas flow at
70% of peak

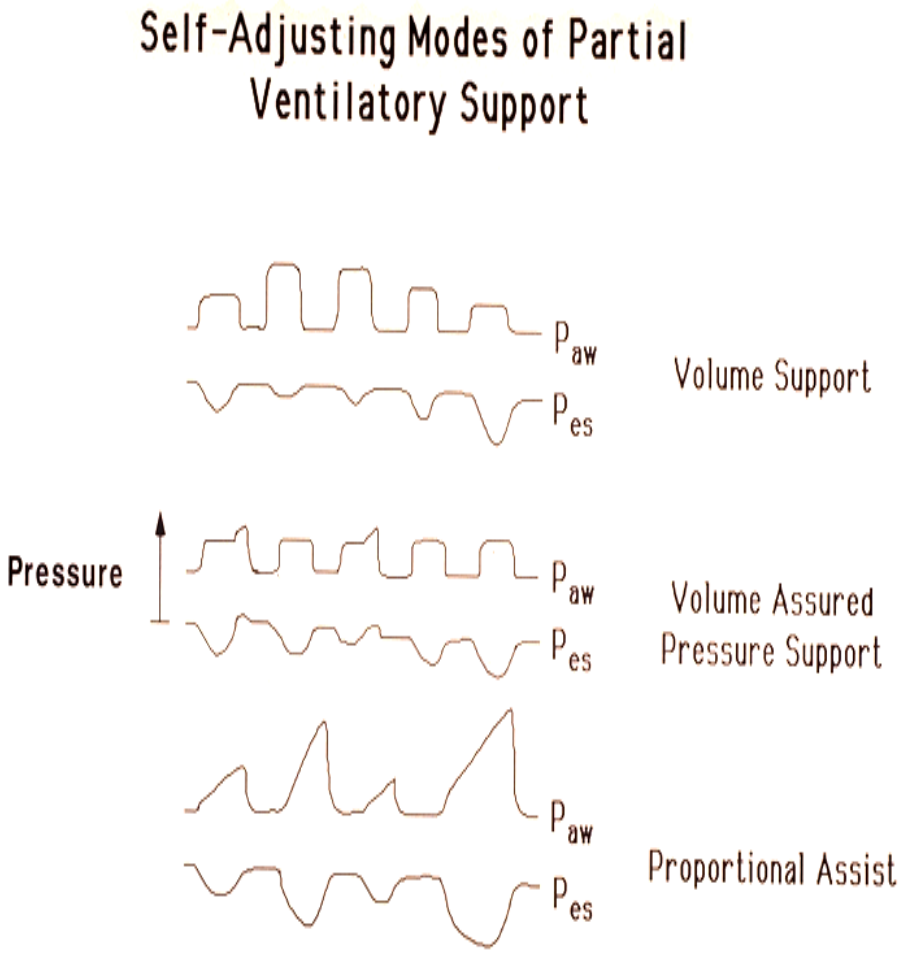
- Pressure settings P High–desired mean airway pressure + 3 cmH2O (20 to 30 cm)
- P Low–usually set at 0 cm H2O (0 to 5 cm)
- Time SettingsT High–usually set at 5.0 seconds (4.5-6.0 sec)
- T Low–usually set at 0.6 seconds (0.5-.8 sec)
- FiO2

Several modes allow for variability in patient efforts while achieving a targeted goal.

1) Volume support monitors minute ventilation and tidal volume , changing the level of pressure support to achieve a volume target.

2) Volume assured pressure support allows the patient to breathe with pressure support, supplementing the breath with constant flow when needed to achieve the targeted tidal volume within an allocated time.

3) Proportional assist varies pressure output in direct relation to patient effort.



- Patient status

- Alarm