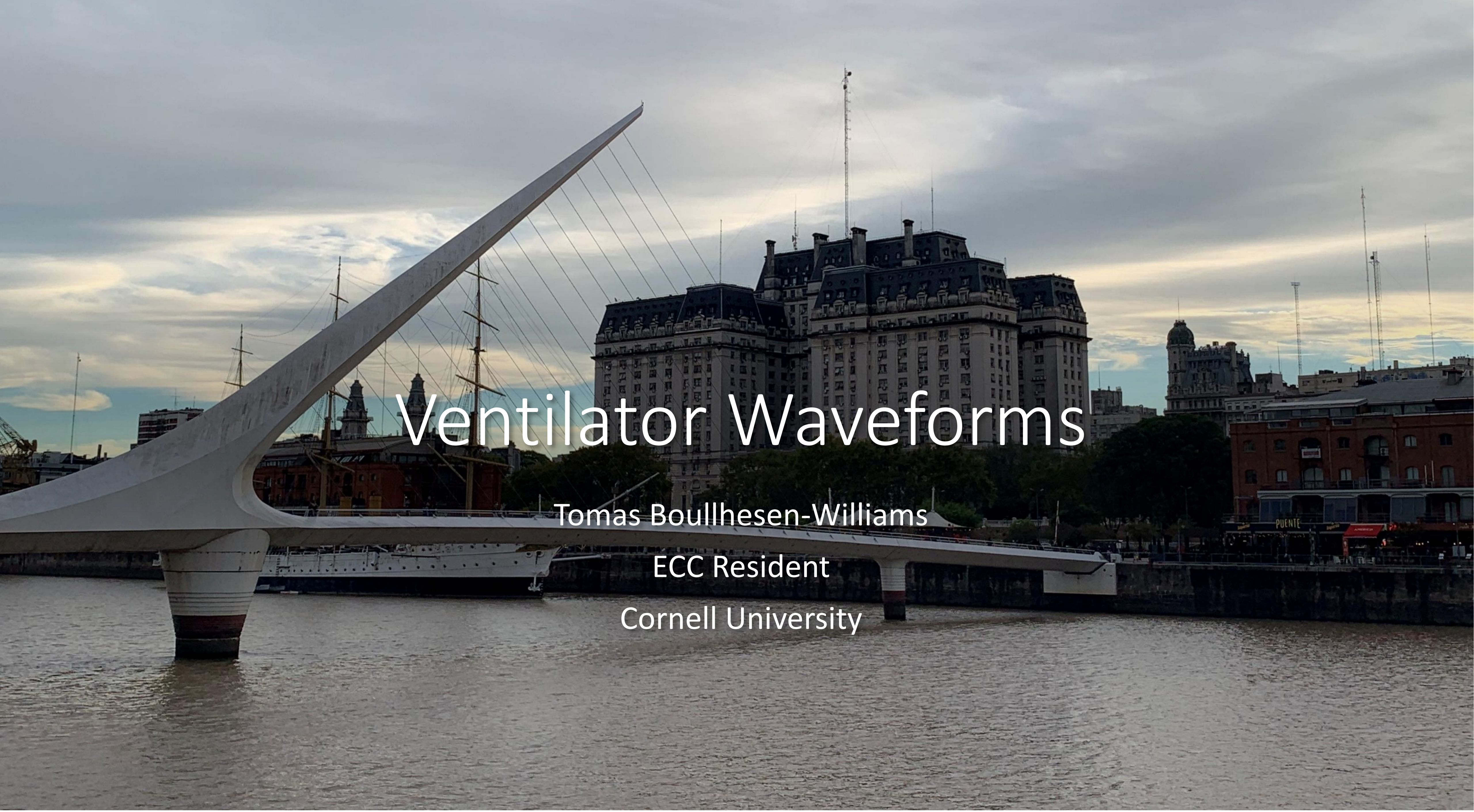

Ventilator Waveforms

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Ventilator Waveforms

What is a waveform?

- Graphic representation of data collected from the vent that reflect patient-ventilator interactions
- Allow to assess changes in respiratory mechanics
- Useful in monitoring the disease progression and response to therapy

2 types of waveforms:
- Scalars
- Loops

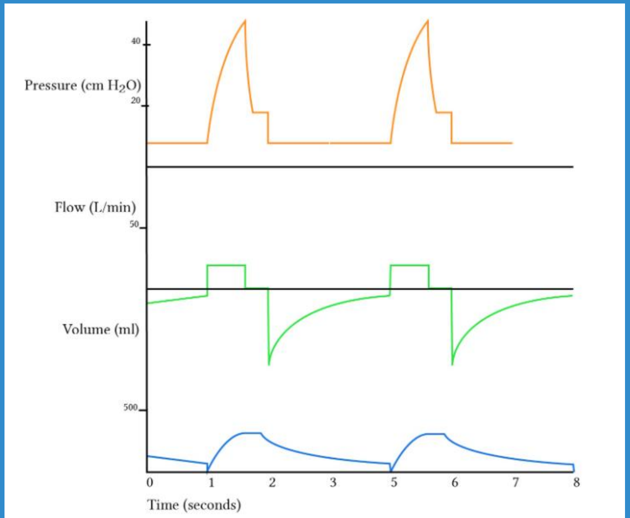
Ventilator Waveforms

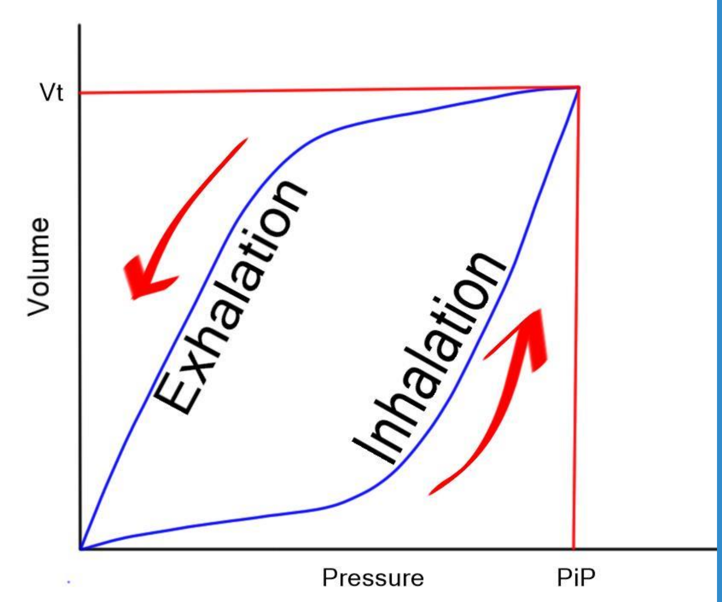
What Is a Scalar (curve)?

- Real-time graphical representations of a variable (pressure, flow, or volume) according to time

What Is a Loop?

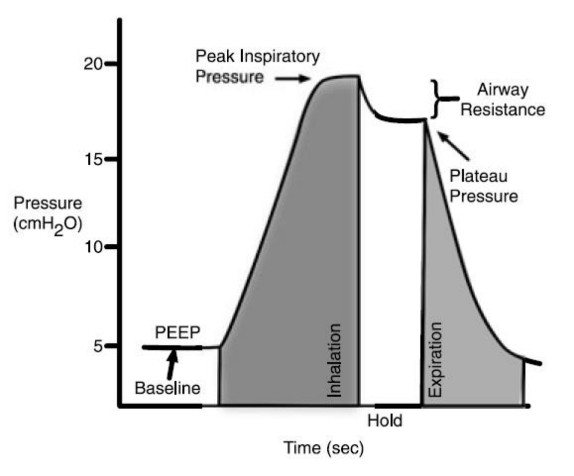
- Real-time graphical representation of two variables (pressure, flow, or volume) plotted against one another
  - One loop displays the values for one breath





Mechanics of spontaneous ventilation

- Air flows through the conductive airway along the pressure gradient from high to low pressure point
- Lung volume changes as a result of air flow
- Air flows into the lungs when the pressure in the alveoli is lower than the pressure at the mouth and nose
- Air flows out when the pressure in the alveoli is greater than at the mouth and nose
- At the end of inspiration or expiration, the pressure in the alveoli and mouth/nose are equal
- There is no pressure gradient and the flow ceases



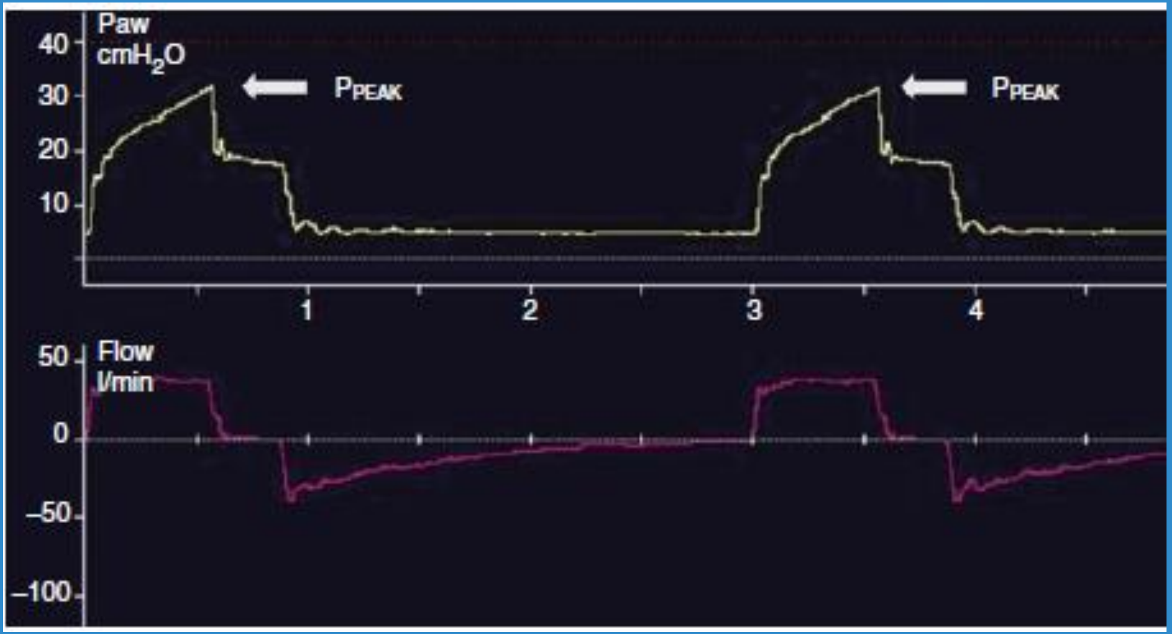
Sone basic definitions

- Airway Pressure/Opening Airway Pressure (Paw):
  - measured at the mouth/nose
  - During spontaneous breathing, the pressure gradient between the mouth and alveoli is -1 to -2 cm H_2O causing air to flow from mouth to the alveoli during inspiration
  - Alveolar pressure during exhalation is positive, about 2 cm H_2O causing air to flow out of the alveoli
  - The Alveolar Pressure is zero (atmospheric) at the end of inspiration or expiration

Basic definitions

Peak Inspiratory Pressure:

- Highest pressure at the end of inspiration – it is the sum of the pressure required to overcome airway resistance (trans-airway Pressure) and the pressure necessary to distend the alveoli



Basic definitions

Plateau Pressure:

- It is an assessment of the alveolar pressure at the end of inspiration
- It is measured by closing the ventilator valves at the end of inspiration
  - Reflects the effect of the elastic recoil on the gas volume inside the alveoli and pressure generated by the recoil of the plastic tubing of the ventilator
  - Used to assess resistance of the airway and static compliance
  - The pressure drop between PIP and Pplat is called trans-airway pressure

Lung characteristics

- Elastic forces and frictional forces oppose inflation of the lungs
- Elastic forces arise from the elastic properties of the lungs and thorax
- Frictional forces are the result of resistance of the tissues and organs against the movement and displacement during breathing and the resistance to gas flow through the airway
- Compliance is the relative ease with which a structure distends

$$C = \text{Delta } V / \text{Delta } P$$

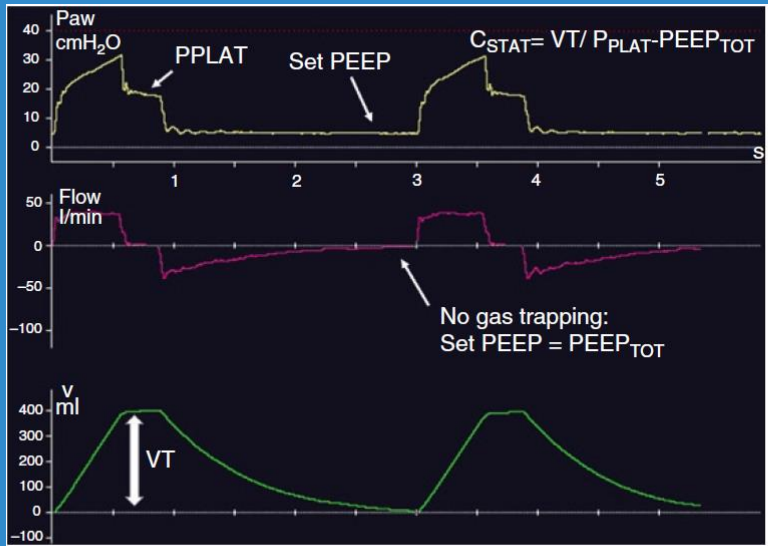
Lung characteristics - compliance

Static compliance:

The ratio of tidal volume to driving pressure and represents the elasticity of the respiratory system

- It is composed of:
  - Chest wall compliance
  - Lung tissue compliance
- It is calculated as the ratio of volume change to pressure change (ΔV/ΔP) between two points in time when flow throughout the respiratory system is zero (during an inspiratory pause maneuver)

$$Cstat = VT/(Pplat - PEEP)$$



Lung characteristics - compliance

Dynamic compliance:

- defined as the change in volume divided by change in pressure, measured during normal breathing, between points of apparent zero flow at the beginning and end of inspiration
- Its components are:
  - Chest wall compliance
  - Lung tissue compliance
  - Airway resistance

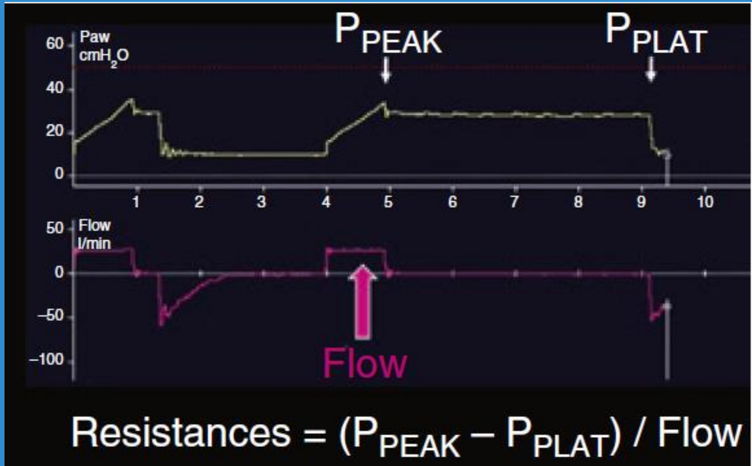
$$Cdyn = VT/(PIP - PEEP)$$

Lung characteristics

Resistance:

- The result of the anatomic structure of the conductive airways and tissues
- It depends on the viscosity and density of the gas, flow rate and the length and diameter of the airway
  - It is the ratio between the pressure driving a given flow and the resulting flow rate
  - In patients ventilated in V/C with a square flow waveform, airway resistance including the resistance of the endotracheal tube can be calculated:

(PIP−Pplat)/flow



Equation of motion

- During mechanical ventilation, the pressure applied to the respiratory system is equal to the sum of the pressure generated by the ventilator and the pressure generated by the respiratory muscles
- These pressures produce motion (flow) to deliver a volume of gas into the lungs
- The vent and respiratory muscles must work against the compliance and resistance
- When the patient is on the vent, the pressure developed by the respiratory muscles is negligible

- The equation of motion describes the relationship between Pressure, Flow and volume delivery:

Vent Pressure + Muscle Pressure = elastic recoil pressure + flow resistance

Equation of motion

- The pressure necessary to deliver a breath must overcome the elastic recoil forces of the tissues and the resistance to air flow
- Elastic recoil pressure = elastance x volume
- Resistive pressure = resistance x flow

Pvent + Pmus = (elastance x volume) + (resistance x flow)

- Because elastance is the inverse of compliance, elastic recoil = volume / compliance

Pvent + Pmus = (volume/compliance) + (resistance x flow)

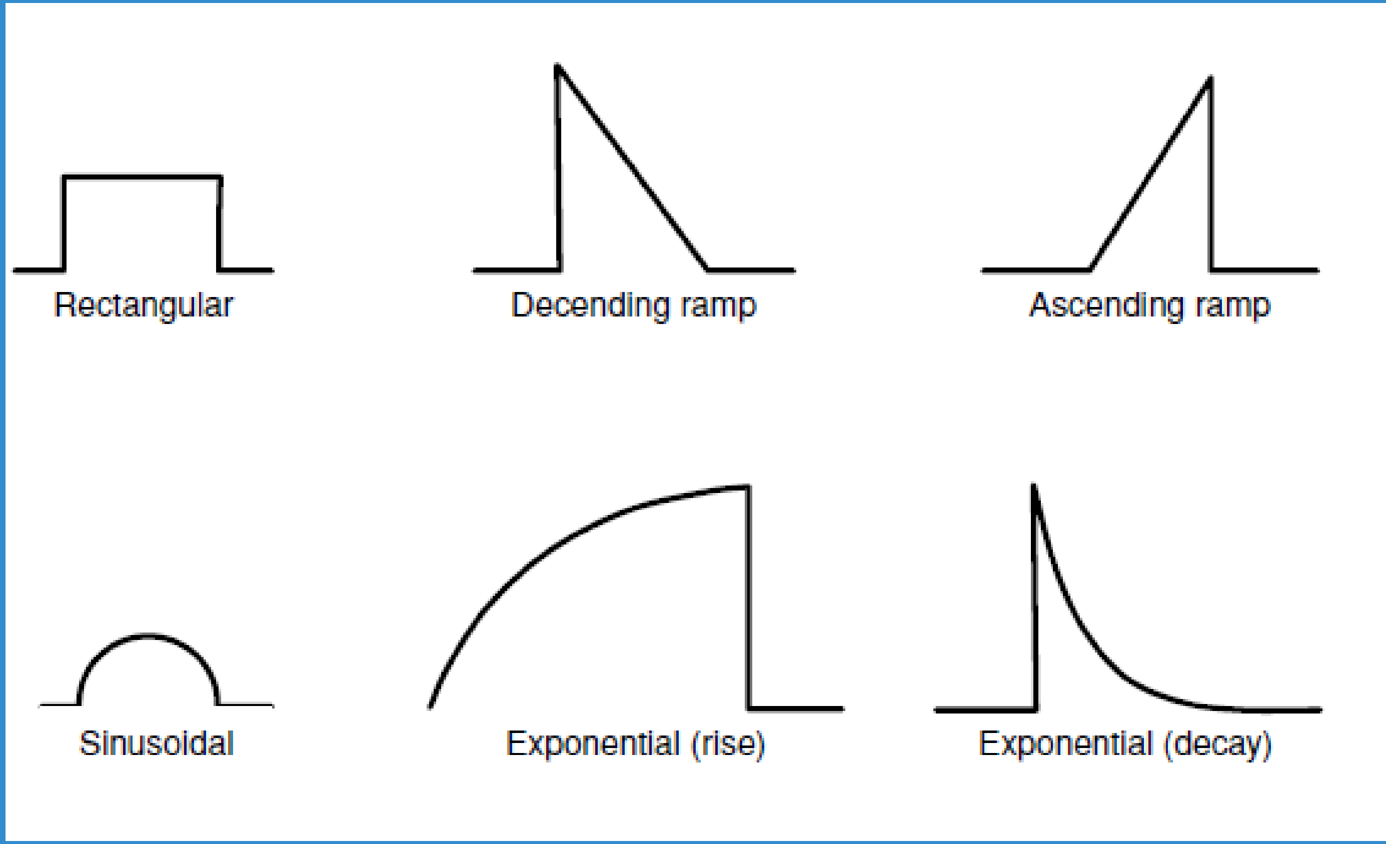
From equation of motion to waveforms

$$P_{vent} + P_{mus} = (volume/compliance) + (resistance \times flow)$$

- The pressure and flow generated by the ventilator are measured by the P and F transducers
- Volume is calculated from the integration of flow waveform
- This equation describes the dynamic relationship between P, V and F, which are three interdependent variables that may be manipulated by the vent
- The vent can control the left-hand side of the equation by controlling the airway pressure and the right-hand side by controlling V and F
- The patient determines compliance and resistance

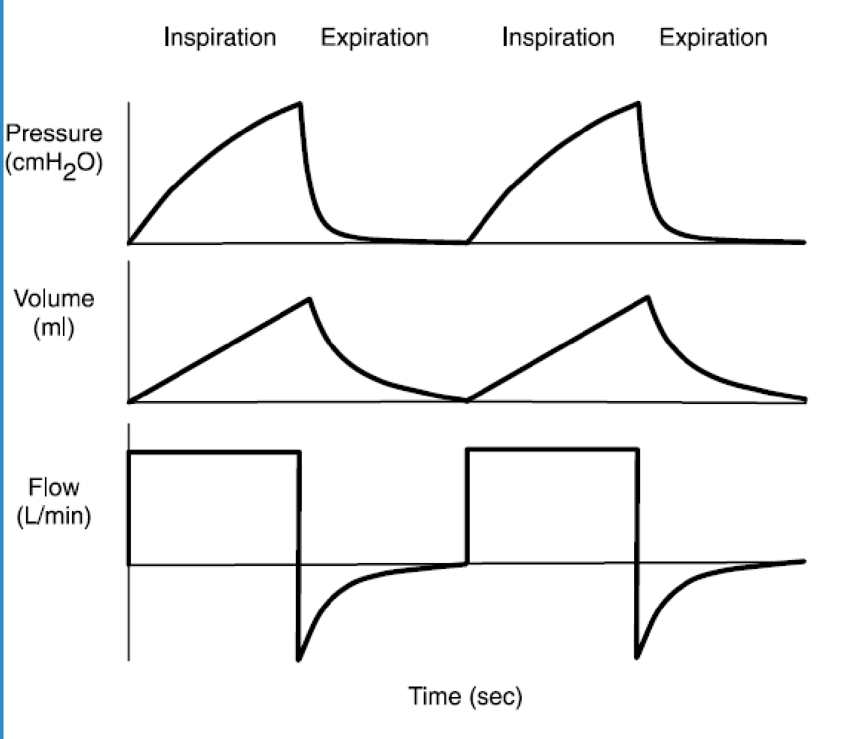
Waveforms – basic concepts

- From the 4 parameters (P, V, F and time), 6 basic waveforms can be derived
- Rectangular, descending ramp, ascending ramp, sinusoidal and exponential rising and exponential decay
  - Ramp and exponential waveforms are functionally similar enough that exponential waveforms are lumped into the ramp category, leaving 3 characteristic shapes: square, ramp and sine
  - Sine waveforms are commonly seen in spontaneous ventilation with CPAP or SIMV
  - Square waveforms indicate that the given parameter abruptly changes but is then held near a constant value for a time
  - Ramp and exponential waveforms indicate that a parameter is changing gradually over time, with a rate of change that is either constant (ramp) or variable (exponential)


Rectangular
Decending ramp
Ascending ramp
Sinusoidal
Exponential (rise)
Exponential (decay)

Waveforms – basic concepts

- P waveforms are usually rectangular or rising exponential
- V waveforms are usually ascending ramp or sinusoidal
- Flow waveforms can take various forms



Waveforms – basic concepts

- Typically, 3 different graphs consisting of P versus time, V versus time and F versus time are used
- Time is always plotted on the x-axis and P, F or V on the y-axis
- Changes in the vent settings result in predictable changes in the graphs
- Changes in the characteristics of the lungs (Resistance or Compliance) can also be recognized

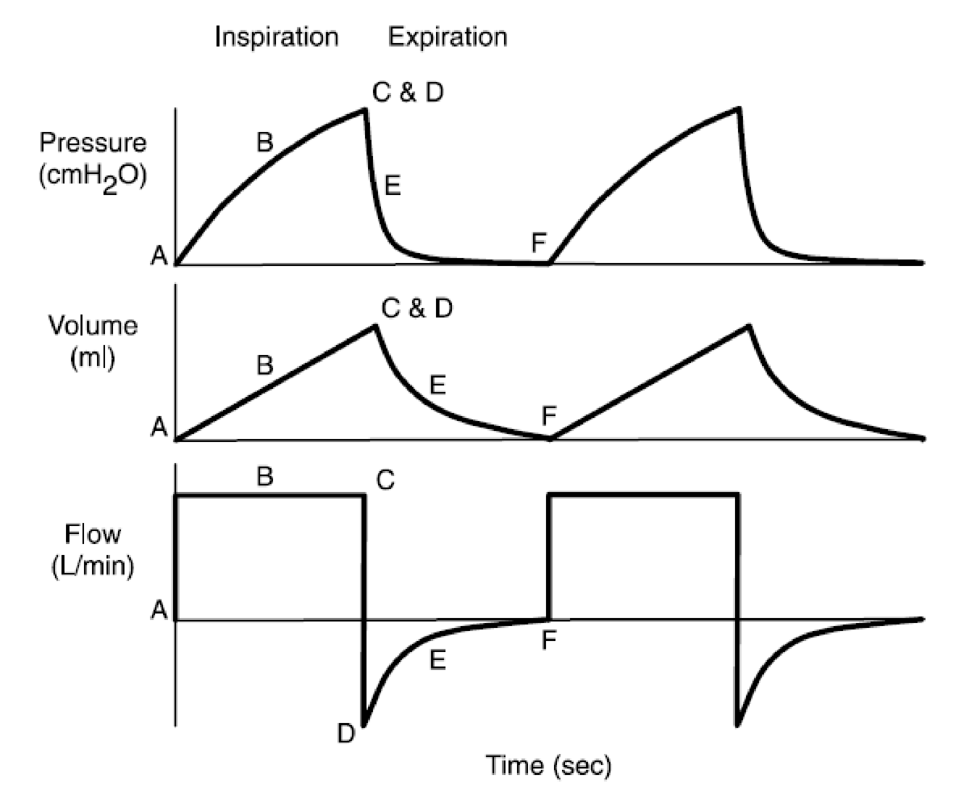
Phases of a mechanical breath

A: beginning of inspiration:

- The ventilator-triggered breath is initiated after a predetermined time - called time-triggered
- The P scalar on vent-triggered breath starts at baseline
- Patient-triggered one has a negative deflection at the onset of the breath (due to the negative alveolar pressure)

B: the mechanical breath is delivered

C: termination of the breath and switch from inspiration to expiration

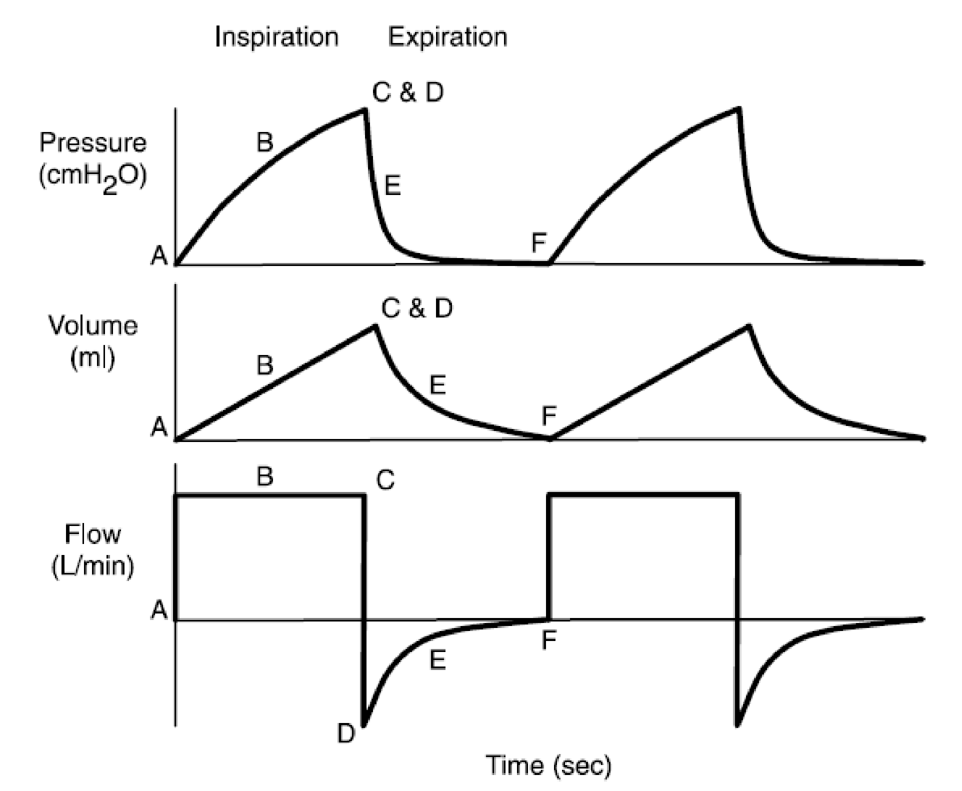


Phases of a mechanical breath

D: beginning of expiration – marked by the opening of the exhalation valve

- On the V and P versus time scalars, C and D are at the same point
- On the F versus time scalars, they are separated
- E: the expiratory phase begins with a negative deflection indicating flow away from the patient
  Exhalation occurs passively

F: termination of exhalation and beginning of the next breath



Modes of MV and corresponding scalars

Quick review

Continuous mandatory ventilation (CMV)

- Includes Control Mode and Assist Control
- Control Mode is time-triggered, Assist Control is either patient- or time triggered
- If the patient makes no respiratory effort, then the vent delivers the breath at a preset rate
- In the assist-control mode, the operator sets a minimum RR and the patient can trigger additional breaths each of which is assisted by the vent
- Ventilator assisted breaths can be pressure- or flow-triggered
- The inspiratory effort of the patient leads to a drop in pressure (-2 cm H2O) or in flow (2 L/min) in the patient's circuit which is sensed by the vent and a breath is delivered

Intermittent mandatory ventilation (IMV)

- The vent delivers a set number of mandatory breaths (P/C or V/C), however the patient can take spontaneous breaths in between
- In SIMV, the vent attempts to synchronize the mandatory breaths with the patient’s respiratory effort, which helps avoid discomfort due to breath stacking

Continuous spontaneous ventilation (CSV)

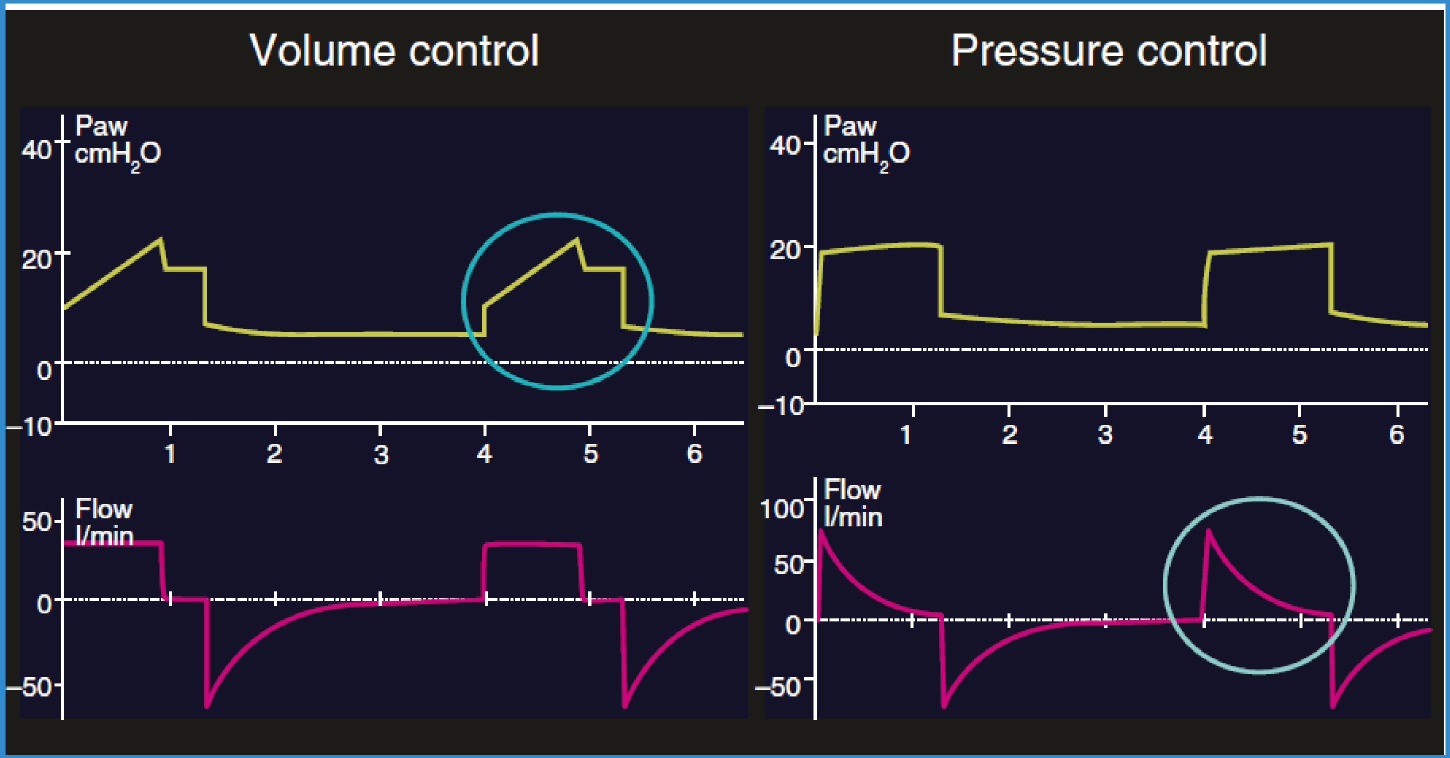
- All the breaths are spontaneous
- CPAP can be used to enhance CSV
  - A constant level of positive pressure us applied during inspiration
- Typically used in conjunction with other modes of ventilation such as SIMV or CPAP

Which curves are important?

- Ventilators measure airway pressure and airway flow
- Volume is derived from the flow measurement
- Pressure and flow provide all the information necessary to explain the physical interaction between ventilator and patient

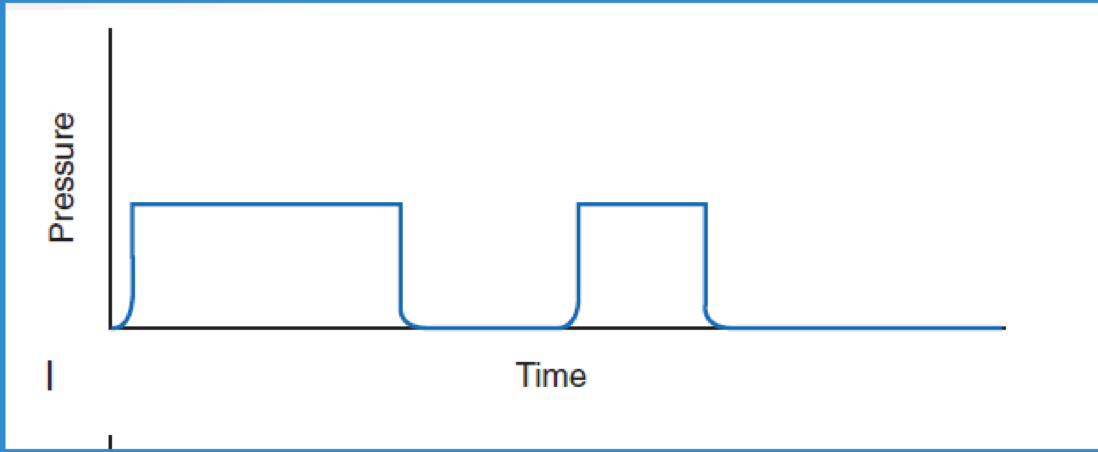
Which curves should be monitored during inspiration?

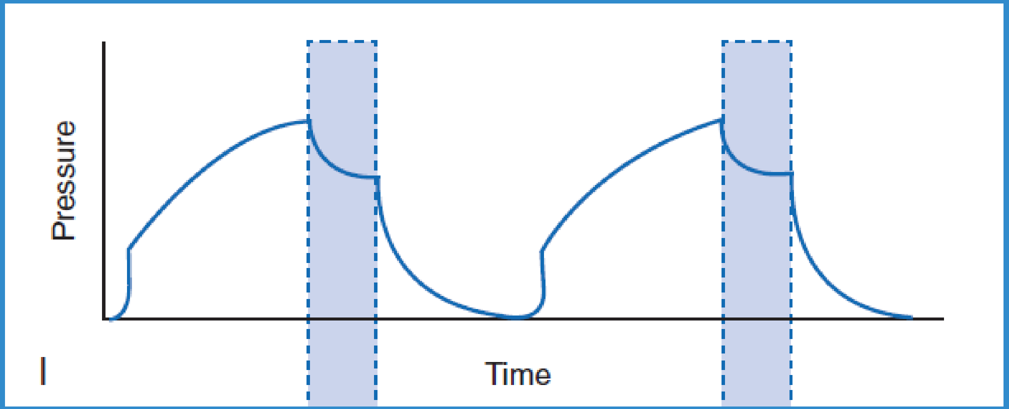
- The independent-variable curve provides information on the control variable of the ventilator
- For monitoring the patient, the essential information is obtained by looking at the *dependent-variable curve*



Pressure-time scalar

- The pressure curve is always positive during mechanical ventilation
- Baseline pressure above zero appears when PEEP is applied
- Assisted inspiration (i.e., work done by the ventilator on the patient) is shown as an increase in pressure above PEEP during volume delivery

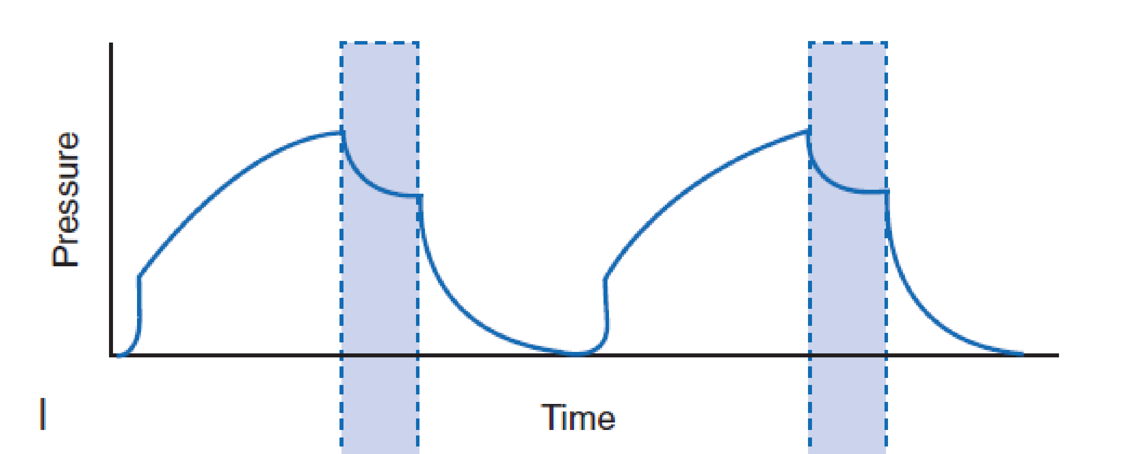




Pressure-time scalar

During V/C

- Characteristic exponential rise (shark fin)
- The airway pressure rises abruptly at the beginning of inspiration when gas flow encounters the frictional resistance of the airway
- After the resistance is overcome, gas flows into the alveoli where it meets elastic resistance
- The more gradual increase in pressure is seen due to elastic resistance and is dependent on volume and flow delivered as well as compliance of the lungs
- The volume delivery ends when the preset Vt is reached
- The down-slope represent exhalation

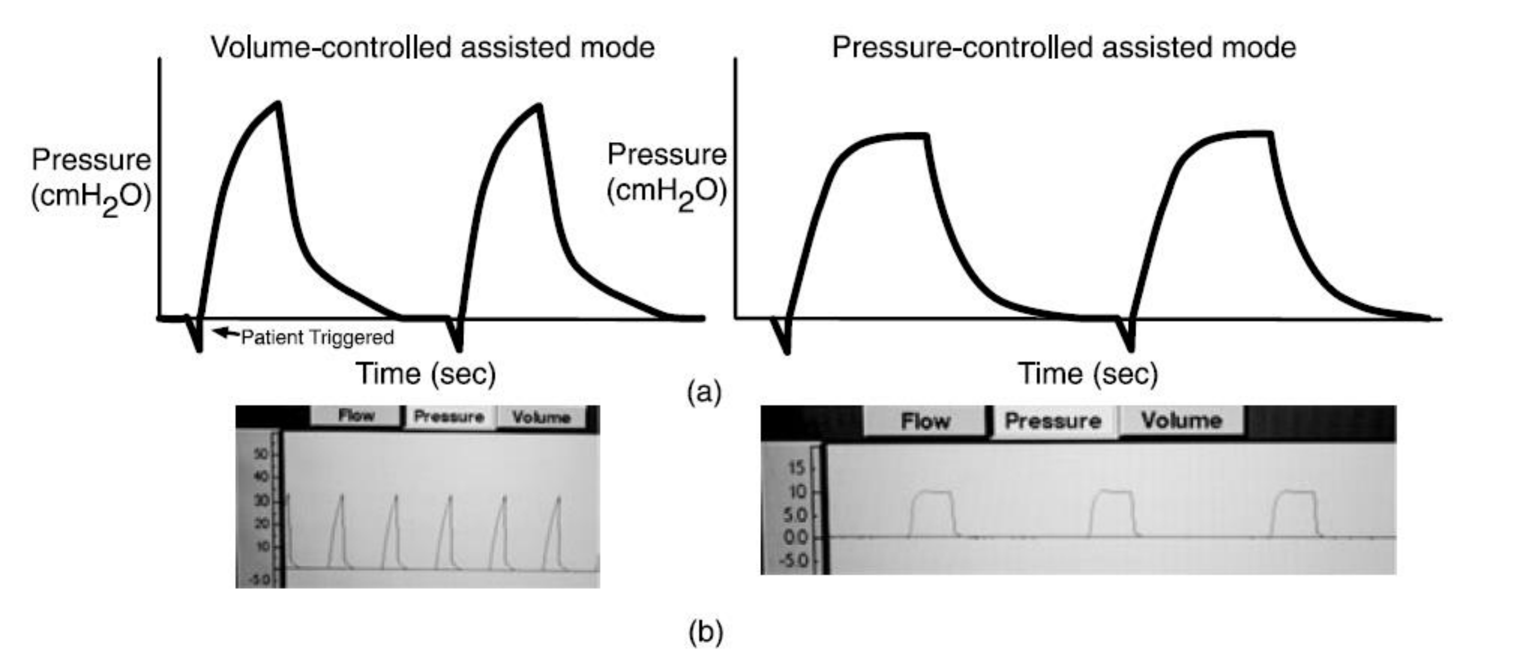


Pressure-time scalar

During P/C:

- The airway pressure rises rapidly to the set pressure and remains constant throughout the inspiratory phase
- The shape of the pressure-time scalar changes according to the rise time and the inspiratory time
- Usually takes on a square waveform
- When an inspiratory pause is in place, inspection of the pressure waveform may help evaluate pulmonary mechanics

Pressure-time scalar



In V/C:

- Scalars have a curvilinear shape and the PIP will vary with the resistance, compliance, and flow

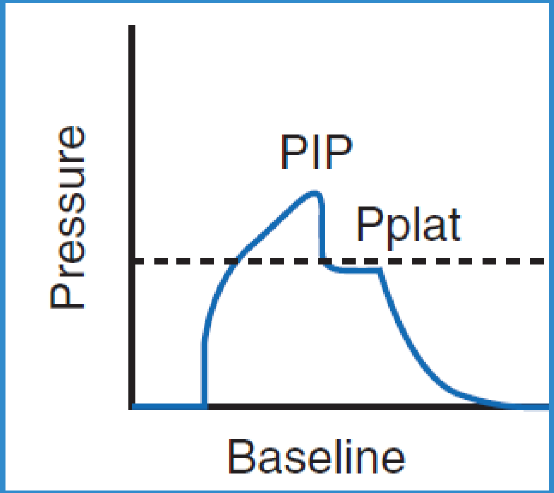
In P/C:

- The scalar shows a rise in pressure during inspiration to the preset PIP
- The negative deflection at the onset of the breath helps to differentiate between controlled and assisted breaths

Pressure-time scalar

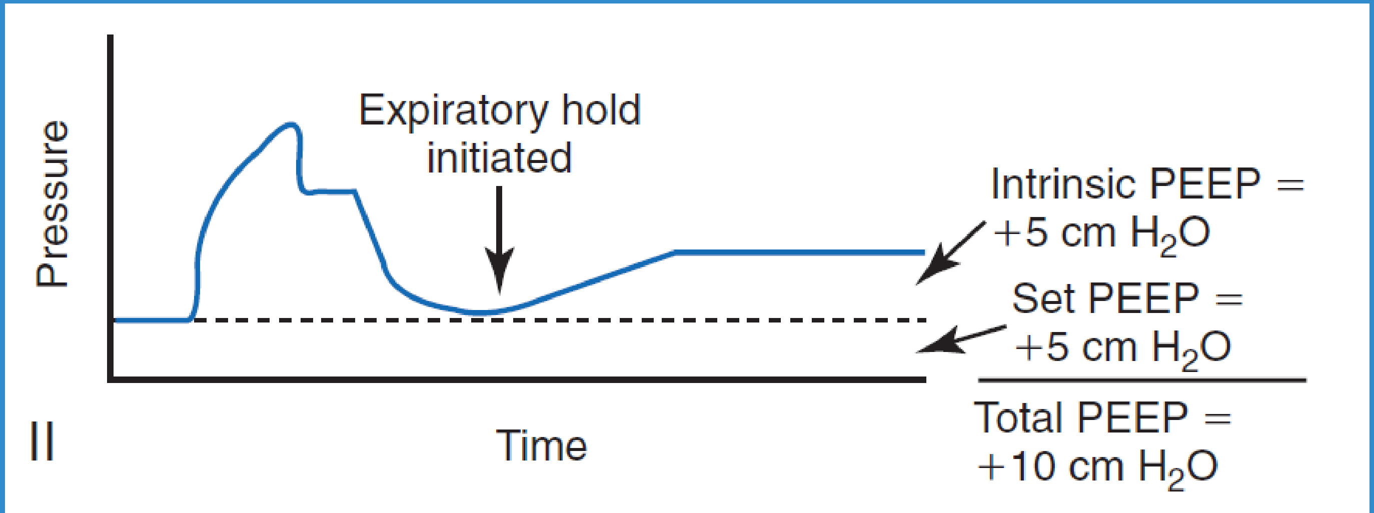
- PIP and Pplat can be determined when an inspiratory pause is in place
- These pressures can help calculate dynamic and static compliance
- PIP on the pressure scalar can be used to estimate Resistance

  (R = Driving pressure / flow)
- An increase in resistance will be seen as an increase in PIP without an accompanying increase in Pplat
- A decrease in compliance is evidenced by an increase in PIP and Pplat both with unchanging differences between these two values



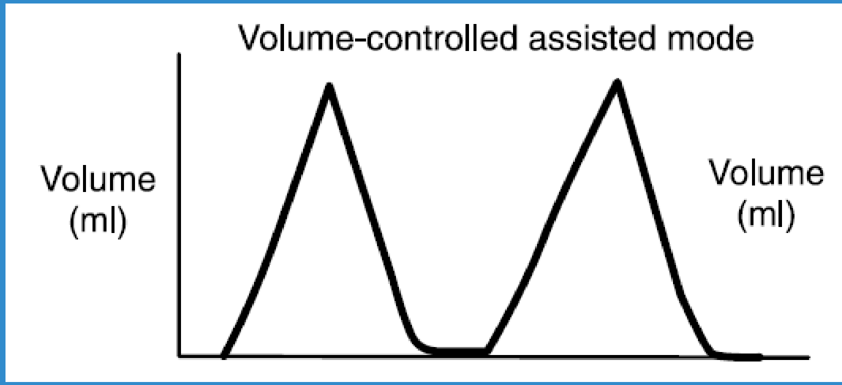
Pressure-time scalar

- An expiratory hold can also yield information:
  - Quantification of intrinsic PEEP:
    - Set an expiratory hold
    - Read the PEEP tot and compare to Set PEEP



Volume-time scalar

- Volume waveform is closely linked to flow waveform
- The flow is determined and used to calculate the delivered or exhaled volume
- The upslope represents inspiration, downslope expiration
- Any plateau between the two represents an end inspiratory pause
- The slope of the curve at any point reflects the instantaneous flow rate (Delta V / Delta t)
- Useful at identifying Vt and air leaks
- If the waveform that takes a vertical plunge to baseline in the middle to late-expiration → more volume came in across the flow sensor that came back



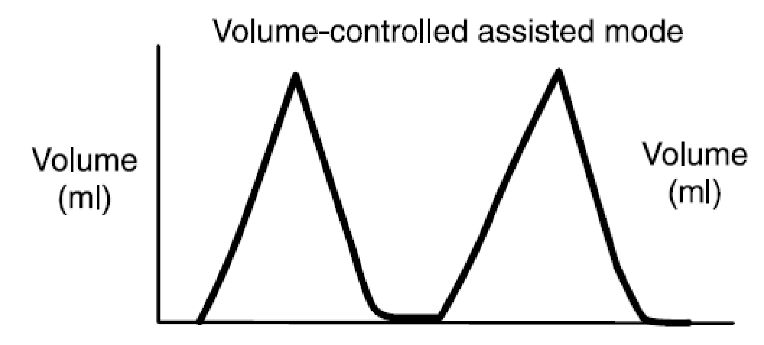
Volume-time scalar

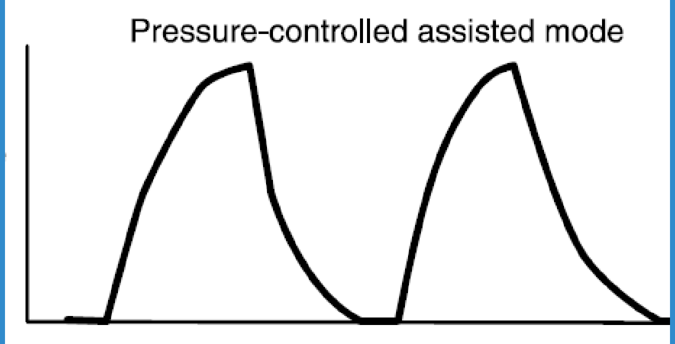
During V/C

- The volume is delivered in fixed increments per unit of time (due to the rectangular flow pattern in V/C) resulting in a straight-line upslope that terminates when the Vt is reached

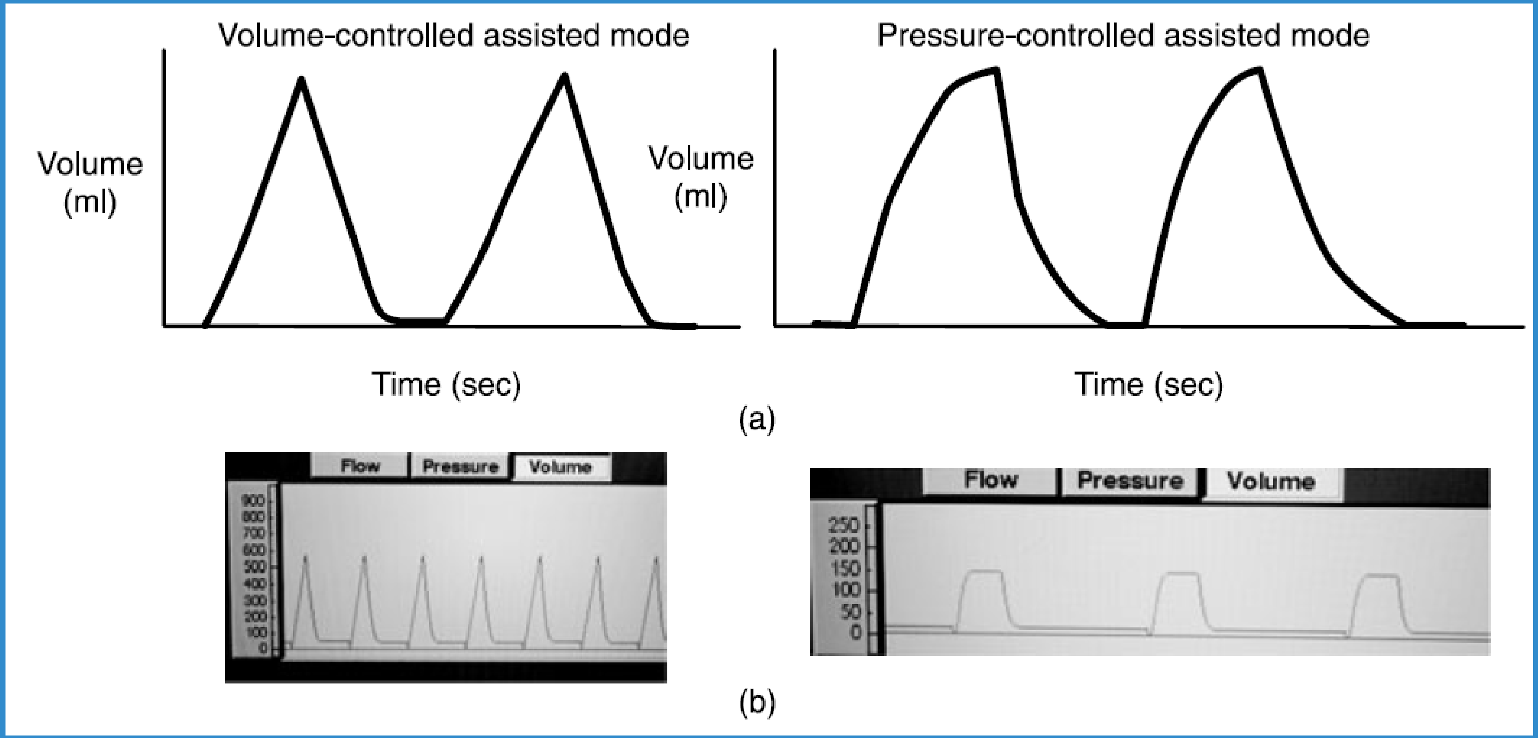
During P/C

- Due to the decelerating flow patter in P/C, the volume-time scalar is curvilinear
- Delivered volume will remain relatively constant during V/C, but will vary in P/C as the patient's lung characteristics change





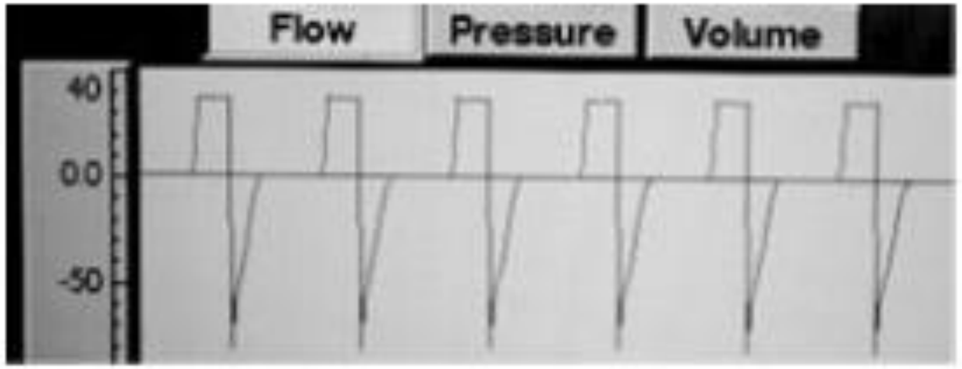
Volume-time scalars

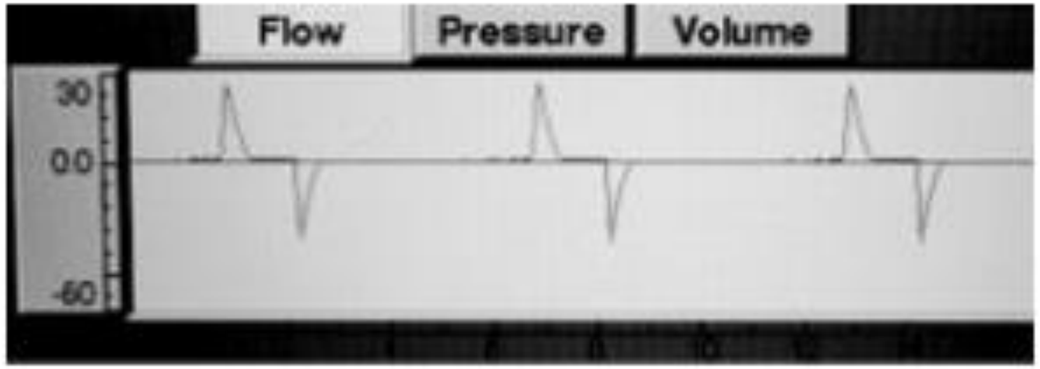


- In V/C the delivered volume will remain constant
- During P/C it may vary depending on changes in airway R and C

Flow-time scalars

- Flow is displayed above the zero-flow line, during inspiration (when gas travels from the ventilator to the patient), and below the zero-flow line during expiration
- If there is a pause at the end of inspiration, it is considered as part of the inspiratory time
- The inspiratory time is therefore measured from the beginning of positive flow to the beginning of negative flow.





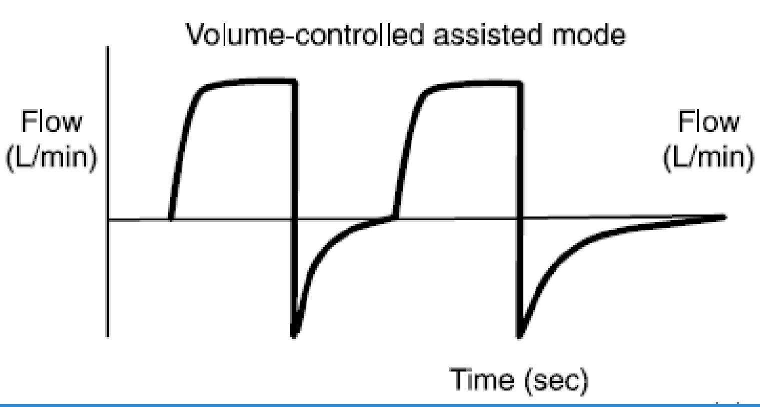
Flow-time scalars

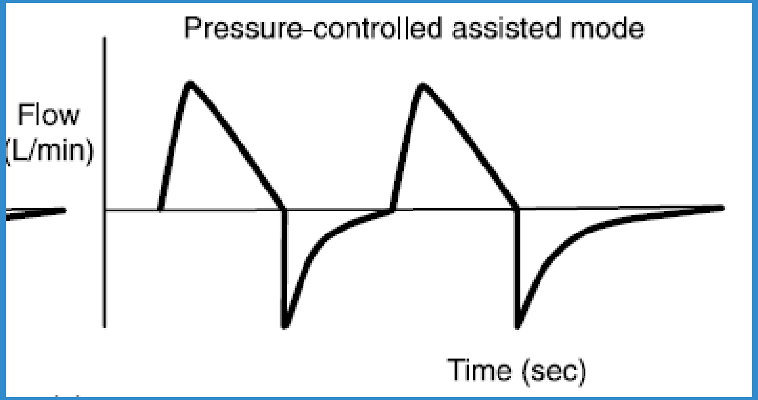
During V/C:

- The vent delivers a constant flow during inspiration depicted by the rectangular inspiratory flow pattern
- The flow instantly reaches the set flow rate, remains constant for the determined inspiratory time and then decreases to zero during expiration
- The rectangular inspiratory flow pattern is characteristic for V/C

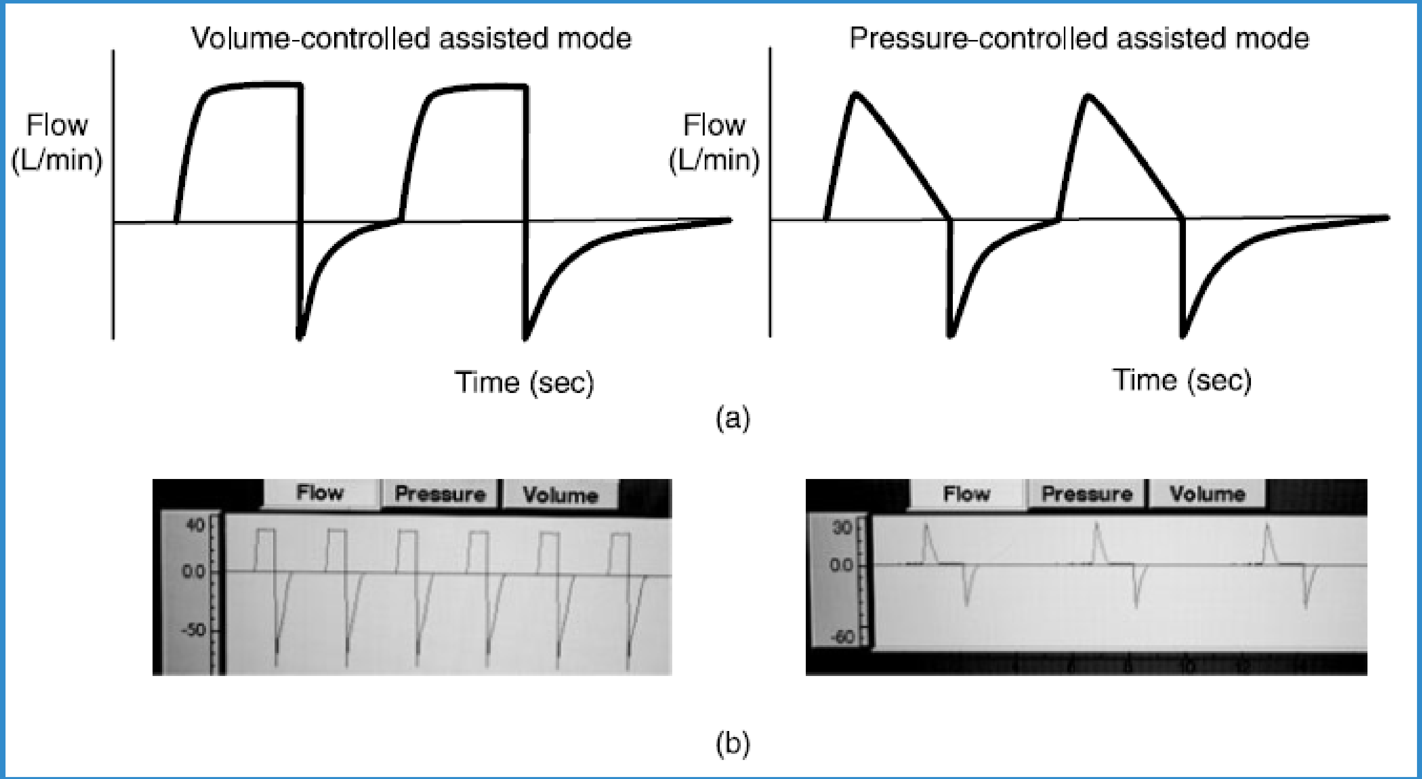
During P/C:

- The inspiratory flow reaches a maximum at the beginning of inspiration and then tapers off throughout the inspiratory phase and may or may not reach zero before the end of inspiration
- A decelerating flow pattern during inspiration is characteristic for P/C ventilation





Flow-time scalars

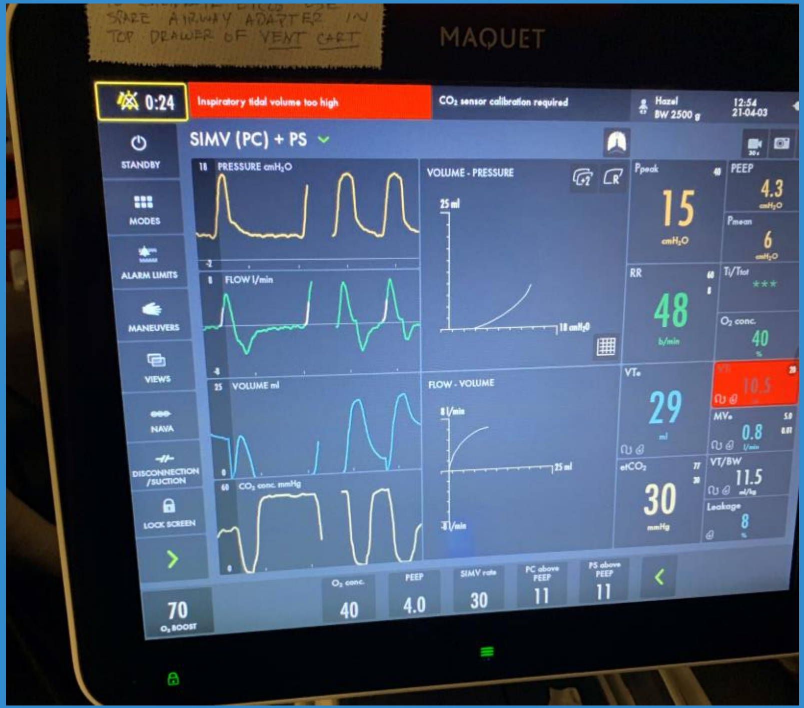


- V/C: rectangular inspiratory flow pattern due to delivery of a preset tidal volume at a constant inspiratory flow rate
- P/C: inspiratory flow reaches a maximum at the beginning of inspiration and then tapers off throughout the inspiratory phase resulting in a decelerating flow pattern

Synchronized Intermittent Mandatory Ventilation

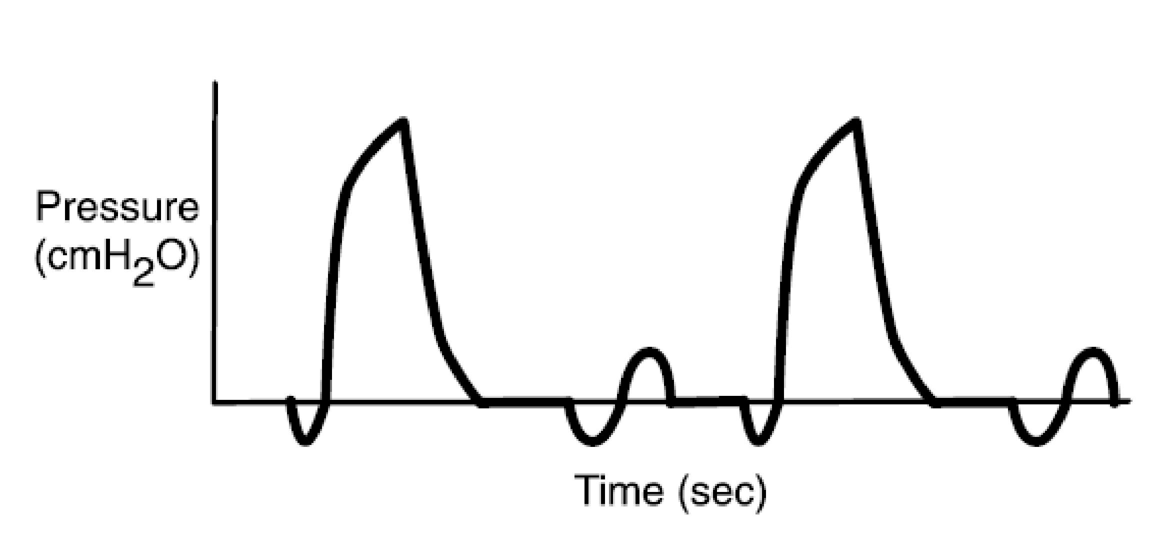
SIMV

- SIMV can be distinguished from CMV by the presence of spontaneous, ventilator unassisted breaths
- Spontaneous breaths look different from the mandatory or assisted breaths, as well from each other depending on the scalar being evaluated



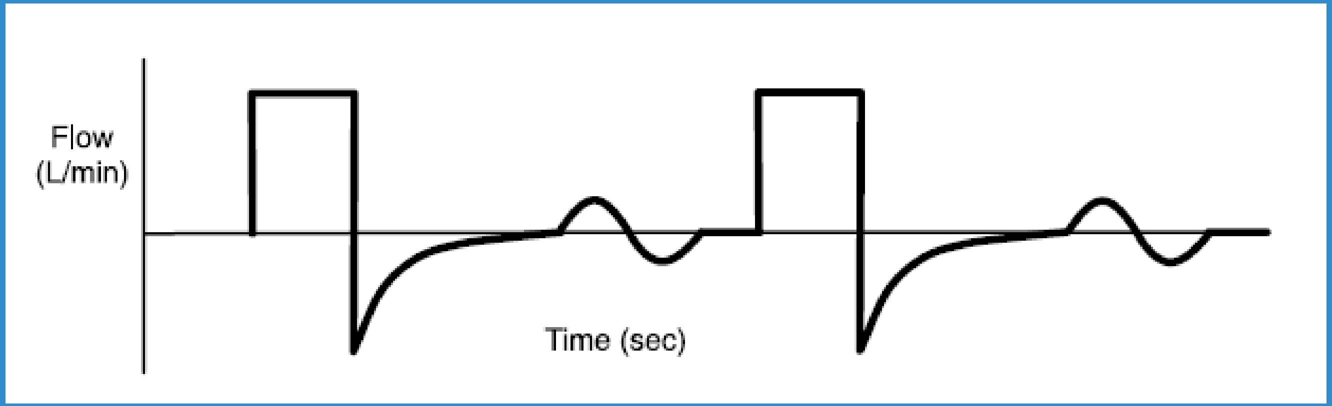
Pressure-time scalar

- Spontaneous breaths are sinusoidal with a negative deflection (negative pressure during inspiration) and a positive deflection (positive pressure during expiration)
- The ventilator assisted breaths show positive pressure during inspiration
- The amplitude of the pressures generated during spontaneous breaths are smaller than those generated during ventilator breaths



Flow-time scalar

- Sinusoidal shape of waveform
- Inspiratory portion above baseline and expiratory portion below the baseline

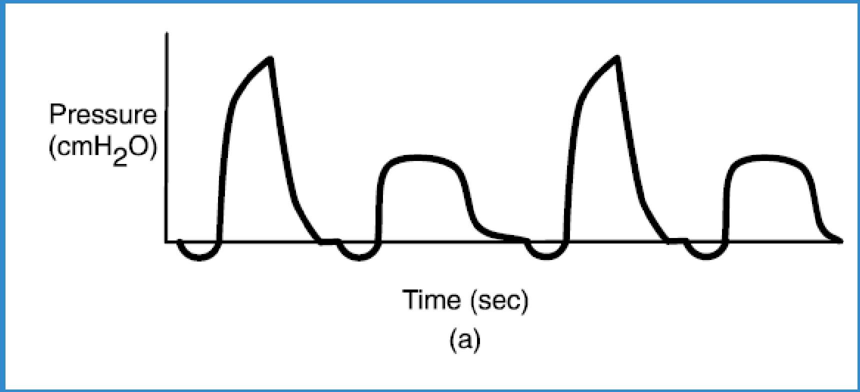


SIMV with Pressure Support Ventilation

- Adding PS to a spontaneous breath may increase Vt and decrease the work of breathing

Pressure-time scalar:

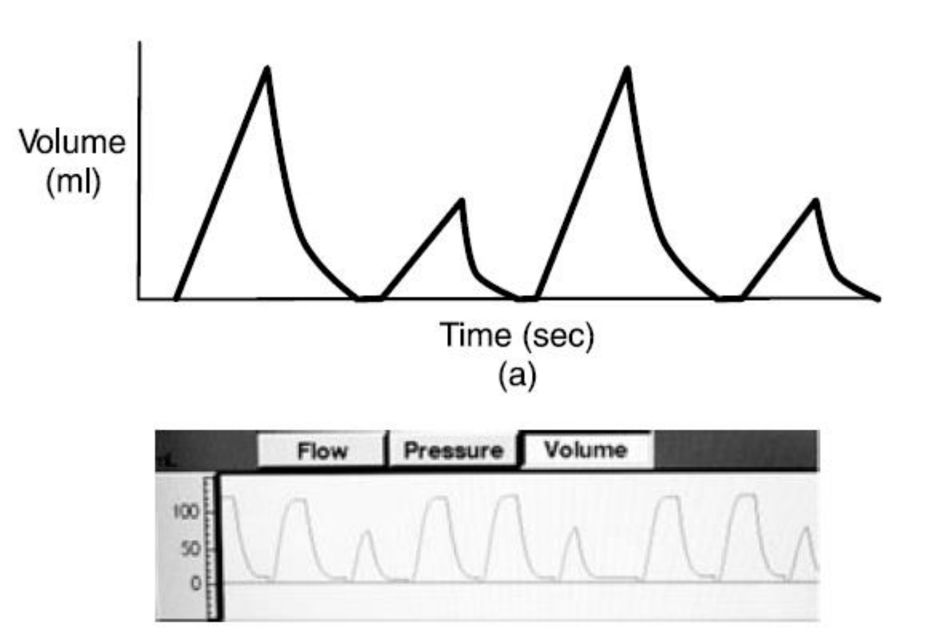
- The pressure in this type of ventilation is set to reach a lower peak pressure than during a pressure control-assisted breath
- The PSV breath maintains the set pressure throughout the inspiratory phase
- Since these breaths are patient triggered, they show a negative deflection during inspiration
- The pressure decreases to baseline during inspiration



SIMV with Pressure Support Ventilation

Volume-time scalar

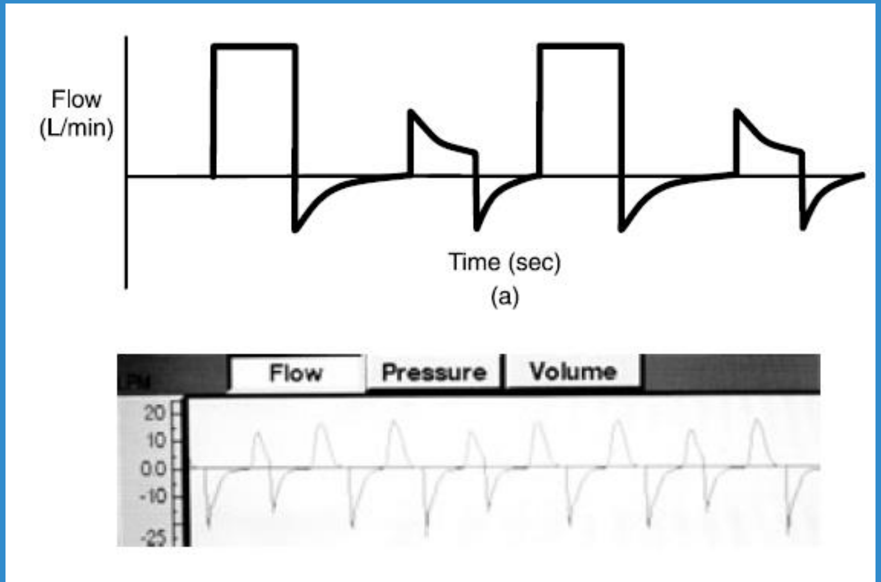
- The Vt of these breaths tends to be greater than the Vt of a spontaneous breath without PS



SIMV with Pressure Support Ventilation

Flow-time scalar

- The inspiratory pattern during PSV tapers towards baseline as the inspiratory phase progresses, contrasting the typical square flow waveform seen V/C
- PSV breaths are flow-cycled, which means that the inspiratory flow terminates when the rate of flow decreases below a certain level of peak flow – typically 25%



Continuous positive airway pressure - CPAP

- May be used in spontaneous breathing patients that do not require full ventilatory support but demonstrate refractory hypoxemia
- Maybe useful in recruitment maneuvers and spontaneous breathing trials
- Pressure-time scalar is the scalar that identifies the presence of CPAP:
    - There is an elevation of the baseline from zero
    - Inspiratory and expiratory airway pressures remain positive and do not return to zero baseline

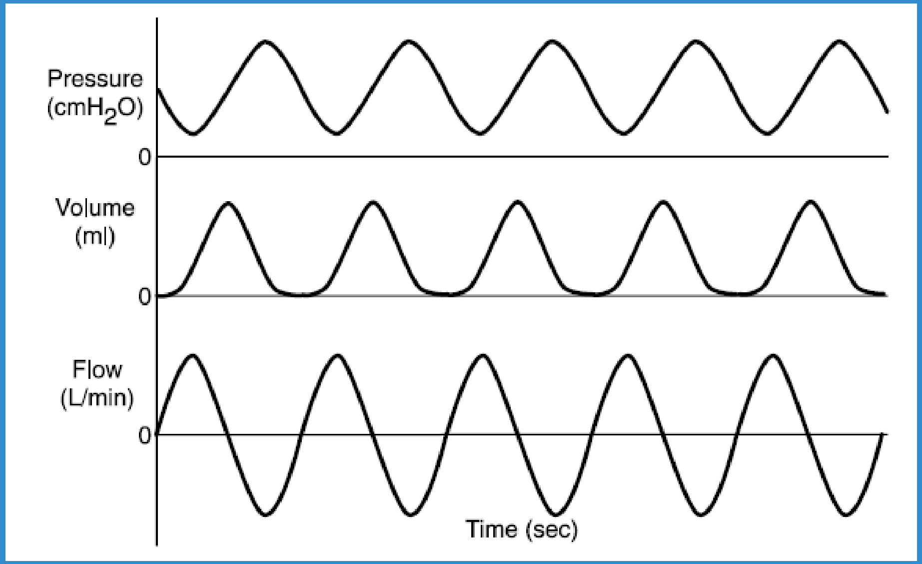
Continuous positive airway pressure - CPAP

Volume-time scalar

- Shows variable spontaneous Vt

Flow-time scalar

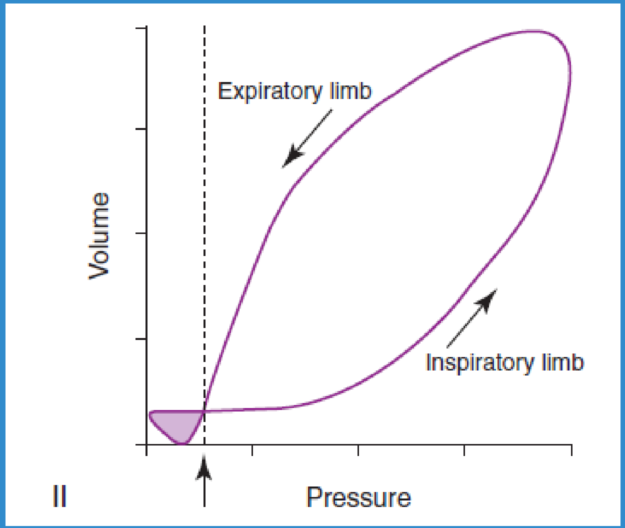
- Inspiratory and expiratory spontaneous flow

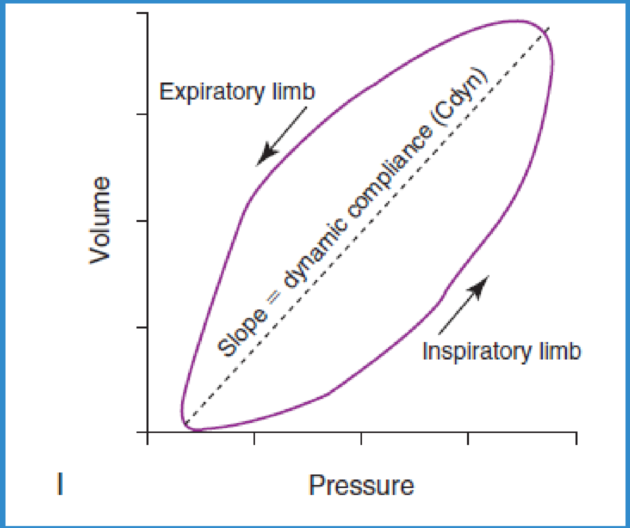


Pressure-Volume Loops

Pressure-Volume Loops

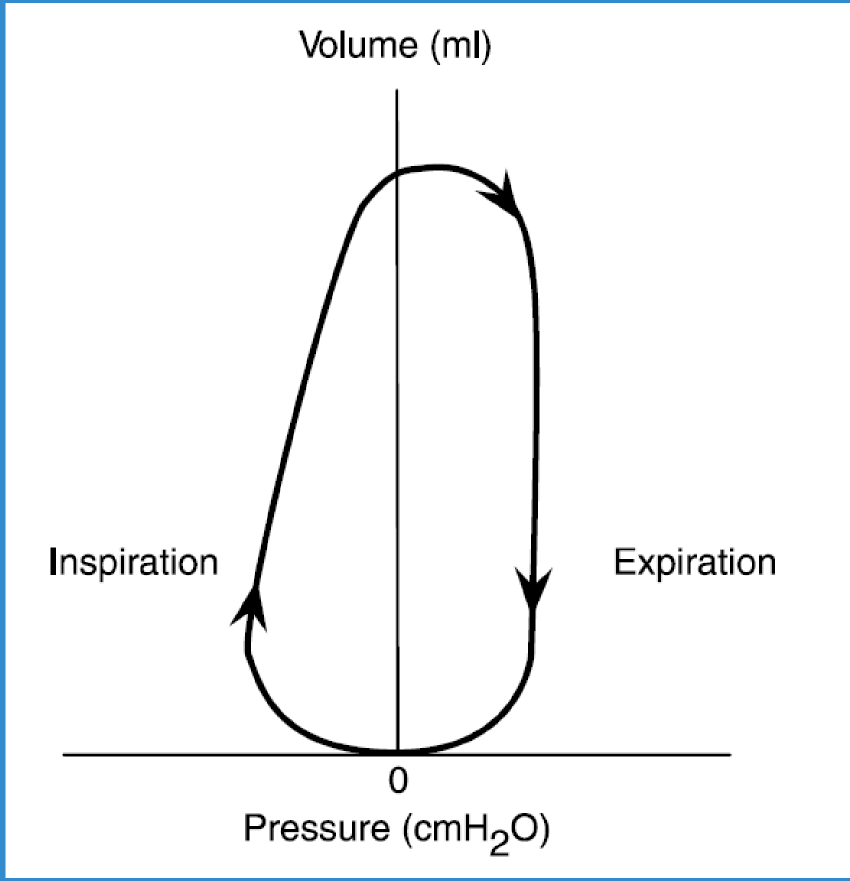
- Display the interaction between pressure and volume
- Can be used to assess the patient’s respiratory system compliance
- They also provide information on airway resistance
- They help differentiate between spontaneous and assisted or controlled breaths





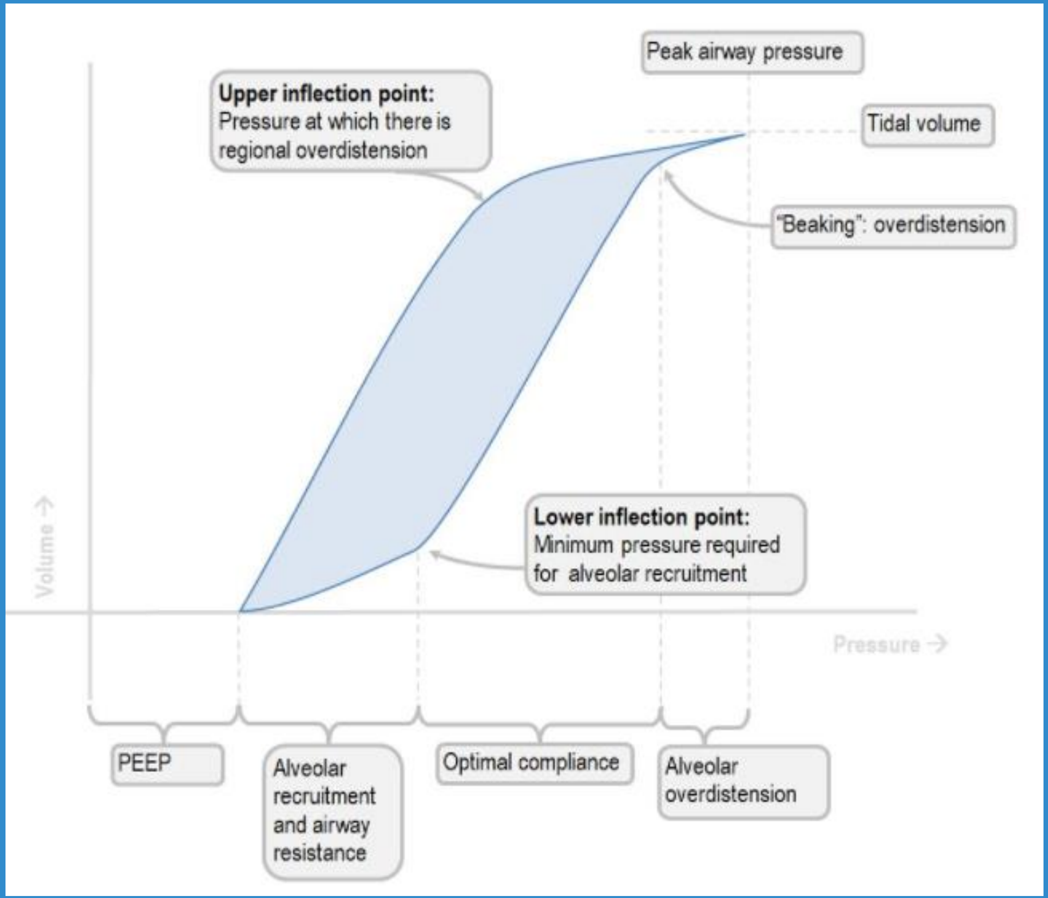
Pressure-Volume loops – Spontaneous breath

- The PV loops moved in a clockwise direction, starting at zero (intersection between x and y)
- The inspiratory portion of the loop occurs on the left side of the y-axis as airway pressure drops (pressure more negative during inspiration)
- The expiratory portion of the loop occurs on the right side of the y-axis as pressure increases



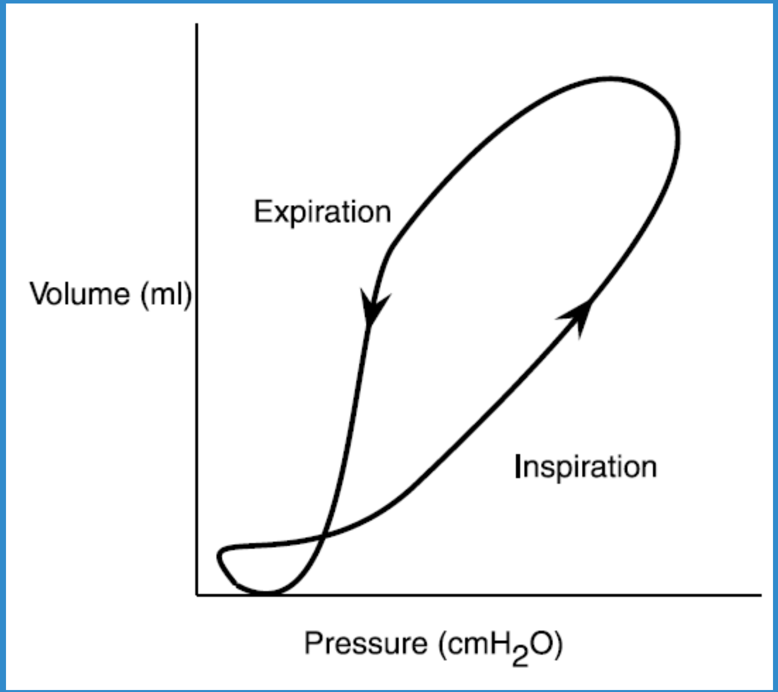
Pressure-Volume loops - Positive pressure breaths

- The PV loop moves in a counter-clockwise direction
- The starting point of the loop depends on the amount of PEEP applied
- Both inspiratory and expiratory portions of the loop are on the right side of the y-axis
- The maximum pressure reached on the x-axis is the PIP
- The maximum volume reached on the y-axis is the Vt



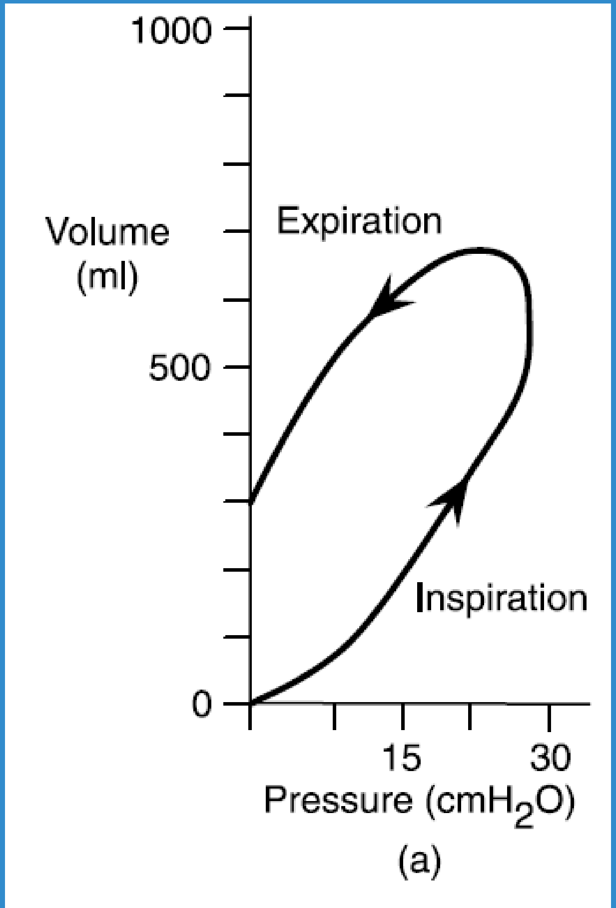
Pressure-Volume Loops

- A patient triggered breath when on CMV creates a ‘trigger tail’ at the beginning of inspiration
- The initiation of the breath is associated with a drop in airway pressure below baseline, and the tracing moves to the left (clockwise) reflecting patient’s effort
- Subsequently the tracing moves to the right (counter-clockwise) as the vent delivers the breath
- The size of the ‘trigger tail’ is a reflection of the patient’s effort to trigger the vent
- The bigger the tail, the bigger the effort
- An increased effort to trigger the breath will increase the work of breathing
- The trigger level is influenced by the sensitivity settings of the vent



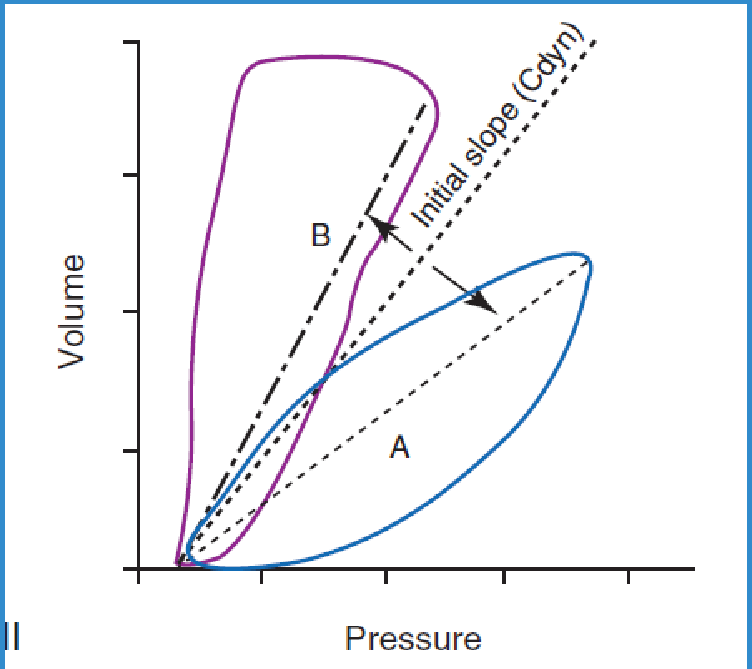
Pressure-Volume Loops

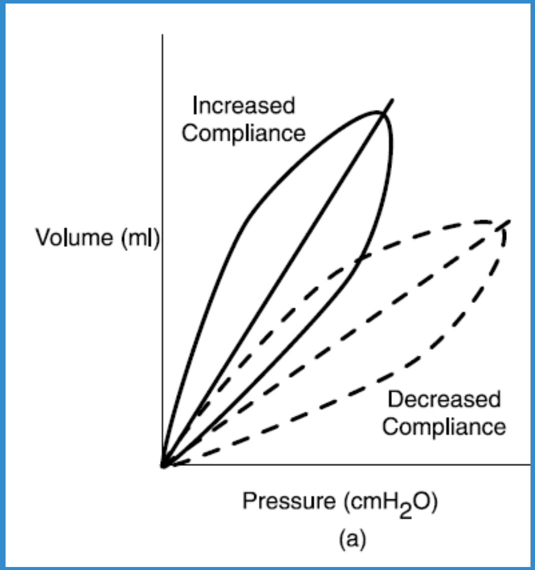
- An incomplete PV loop is an indication of an air leak either on the vent circuit of the patient (bronchopleural fistula)
- The loss of volume can be quantified by identifying the end point of the expiratory limb of the loop



Pressure-Volume Loops

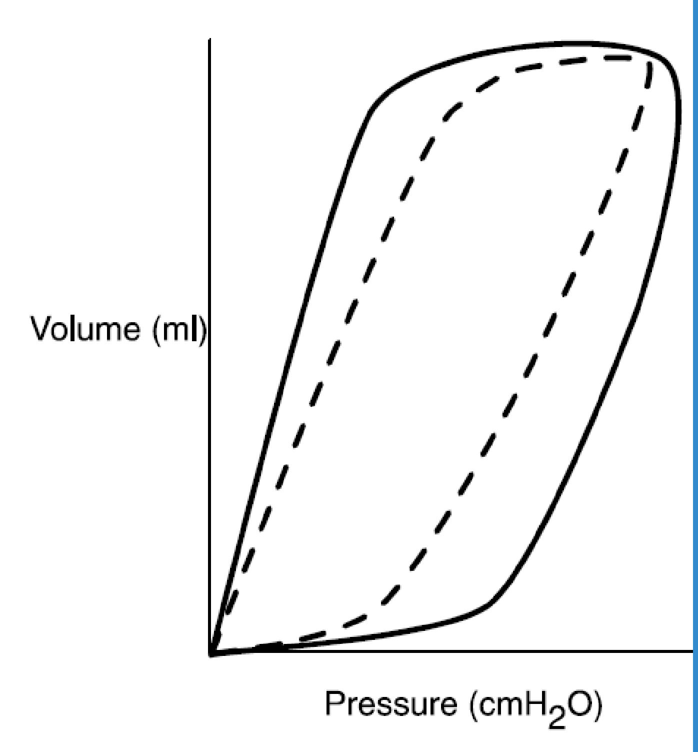
- Evaluation of the slope of the PV loop can help assess changes in respiratory compliance
- A decrease in compliance (the Vt decreases for the same distending pressure) results in a shift of the PV loop to the right and downward (decrease slope)
- An increase in compliance will result in a shift of the PV loop to the left and upward (increase slope)

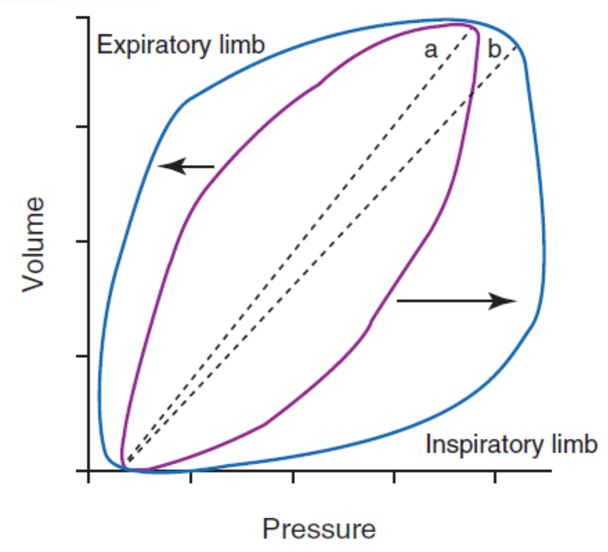




Pressure-Volume Loops

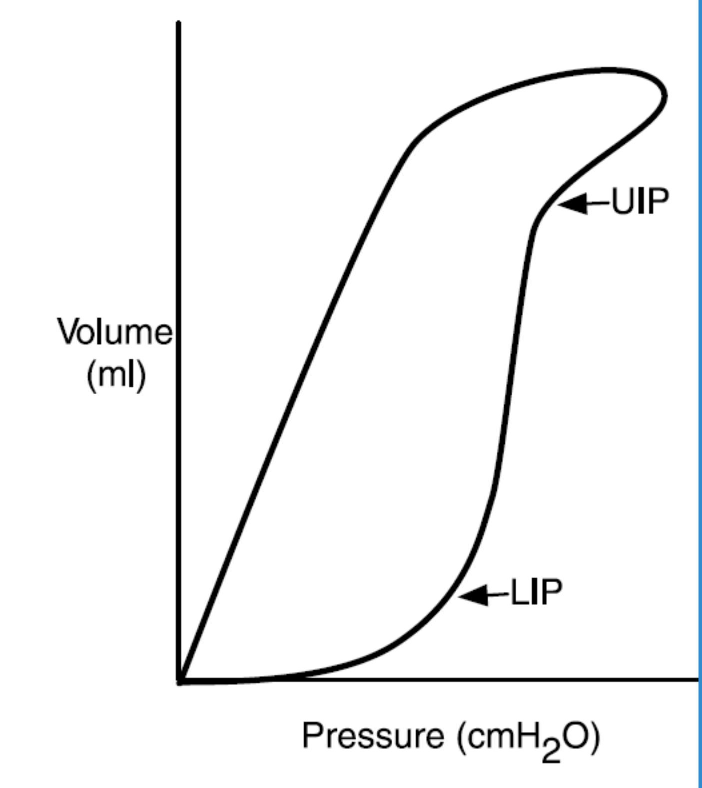
- Allow for assessment of the airway resistance
- When compliance remains constant, and resistance increases the amount of pressure needed to overcome that resistance also increases





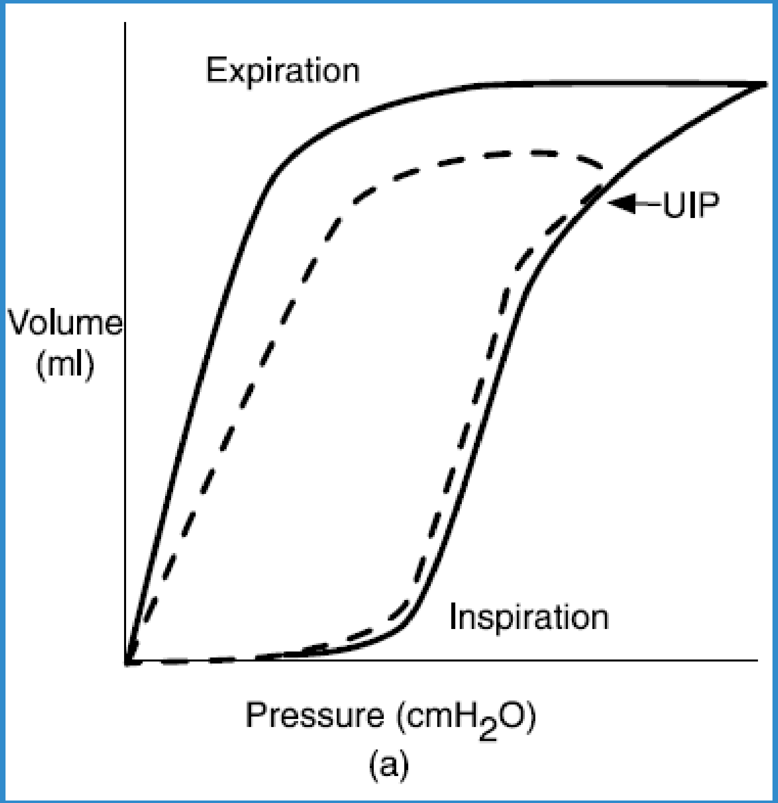
Pressure-Volume Loops

- The PV loop may exhibit a lower inflection point (LIP) and an upper inflection point (UIP) during inspiration
  - An inflection point is the point where the slope of line changes
- LIP indicates the pressure at which a large number of alveoli are recruited
- UIP indicates the pressure at which the alveoli become overdistended
- When the volume capacity of the lungs has been exceeded, application of additional pressure causes very little increase in volume
- The volume limit is identified in the PV loop as UIP and signifies an abrupt change in compliance in the terminal phase of inspiration

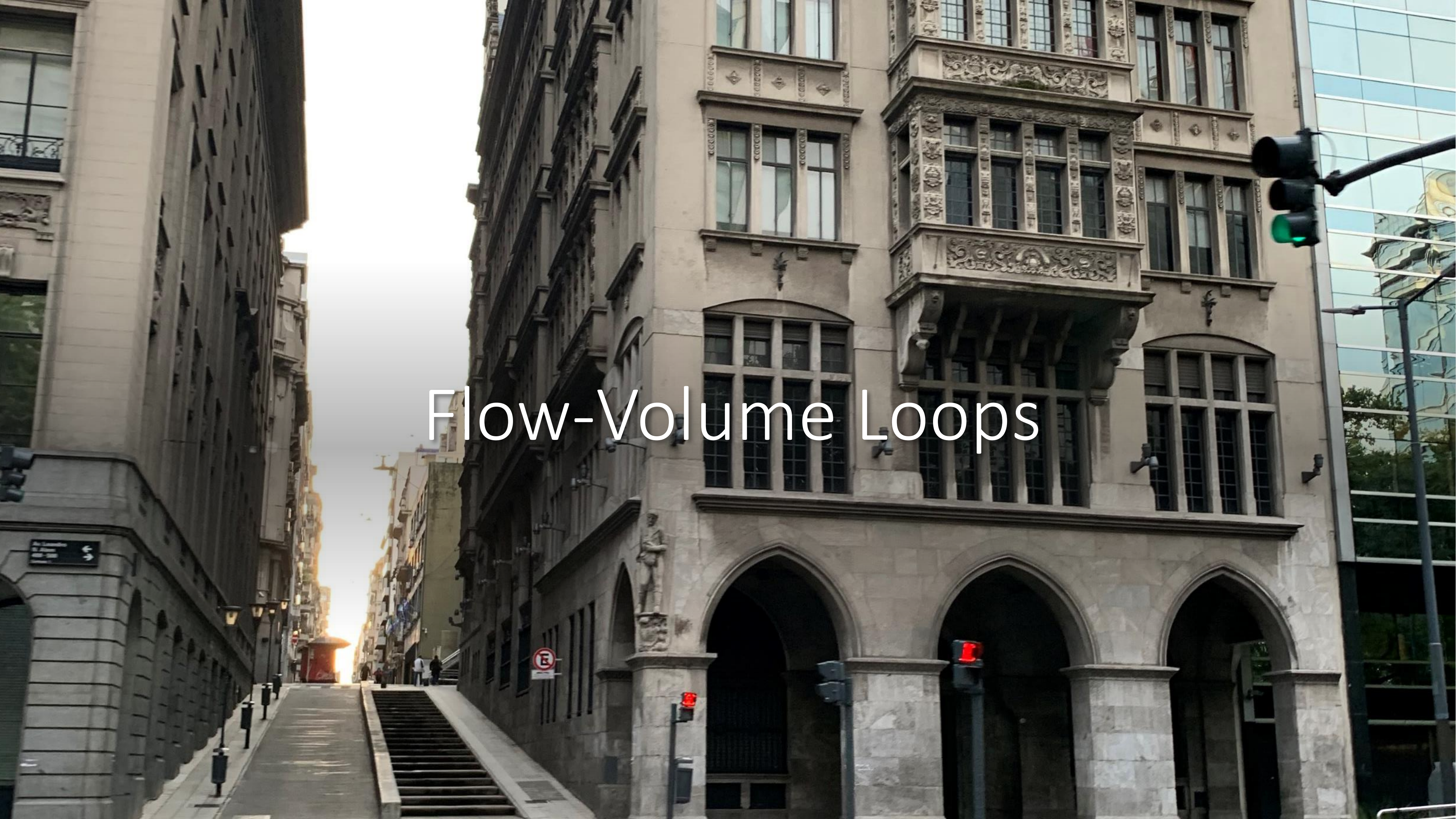


Pressure-Volume Loops

- “Beaking” of the PV loop – overdistention of the lungs
- Ways to avoid “Beaking”:
  - Decreasing the pressure in P/C or decreasing the volume in V/C
  - Try ventilate patients within the LIP and UIP
    - This can be achieved by setting the PEEP above the LIP and the Vt below the UIP
- This strategy aims at avoiding alveoli from collapsing (barotrauma) and from high distending pressures (volutrauma)

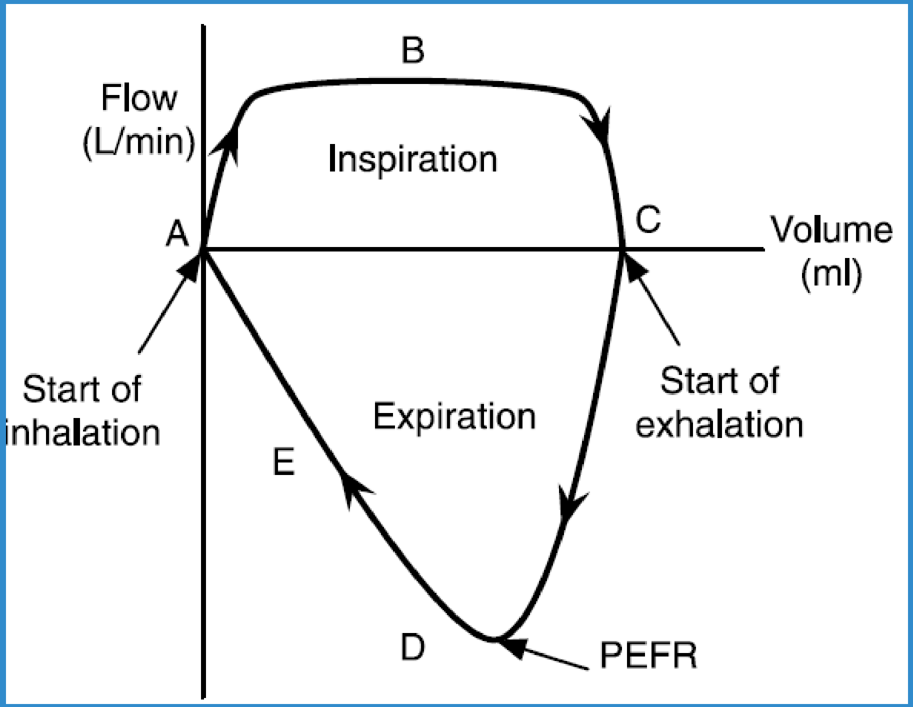


Flow-Volume Loops



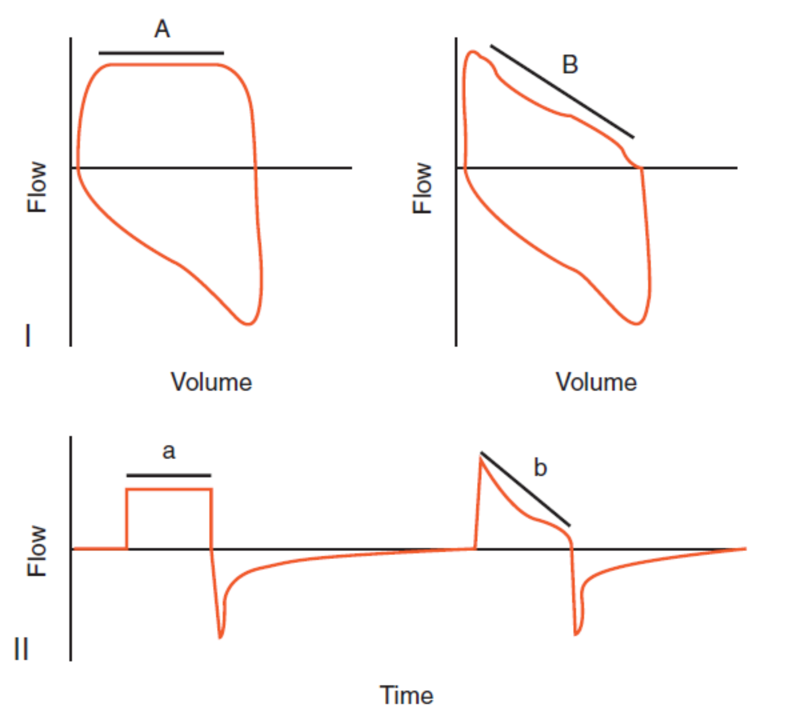
Flow-Volume Loops

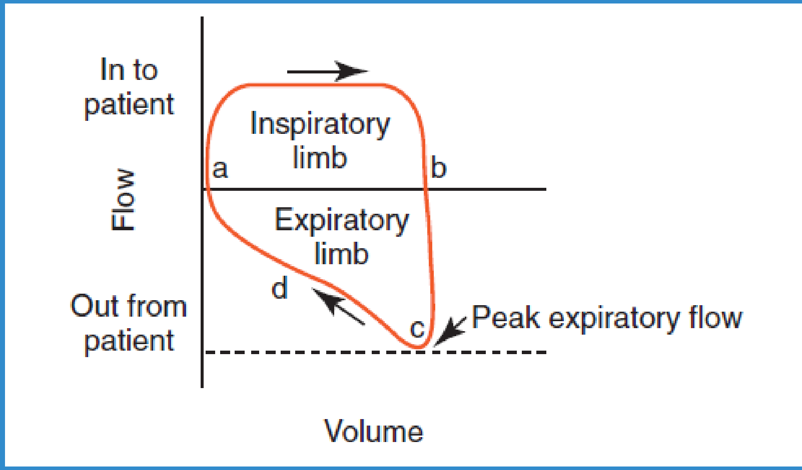
- Used to evaluate changes in resistance
- Can help detect auto-PEEP
- The inspiratory flow is depicted above the x-axis and the expiratory flow below the x-axis
- The transition from expiration to inspiration and back again occurs where the loops crosses the x-axis
- At this point the flow rate is momentarily zero



Flow-Volume Loops

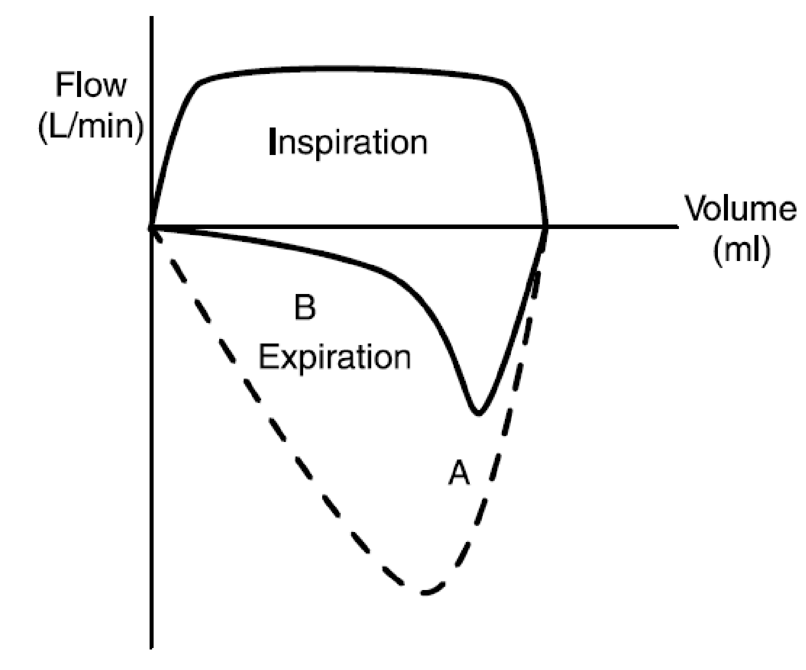
- The shape of the inspiratory portion of the loop reflects the flow pattern set on the ventilator
- The peak point of the expiratory portion of the loop represents the peak expiratory flow rate (PEFR)
- The shape of the passive expiratory portion is influenced by changes in resistance
- Spontaneous and MV breaths look alike on this loop, except for the inspiratory portion of the loop
  - which takes on a more circular shape because of the generally lower peak inspiratory flow rates generated during spontaneous breathing





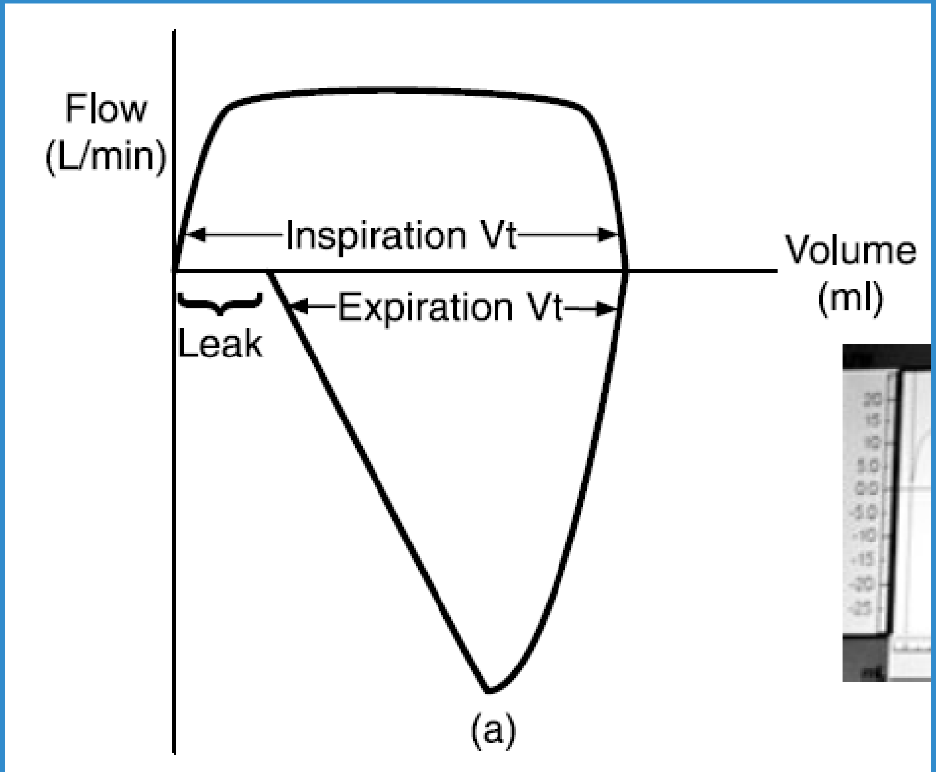
Flow-Volume Loops

- Increases in resistance (due to significant obstruction) will reduce the PEFR
- A curvilinear shape or ‘scooping’ of the descending segment of the expiratory curve is typically seen in patients with medium and small airway obstruction causing decreased expiratory volume and flow
- Oscillations in the expiratory or inspiratory limbs are known as ‘saw tooth’ signs and result most commonly from increased airway secretions



Flow-Volume Loops

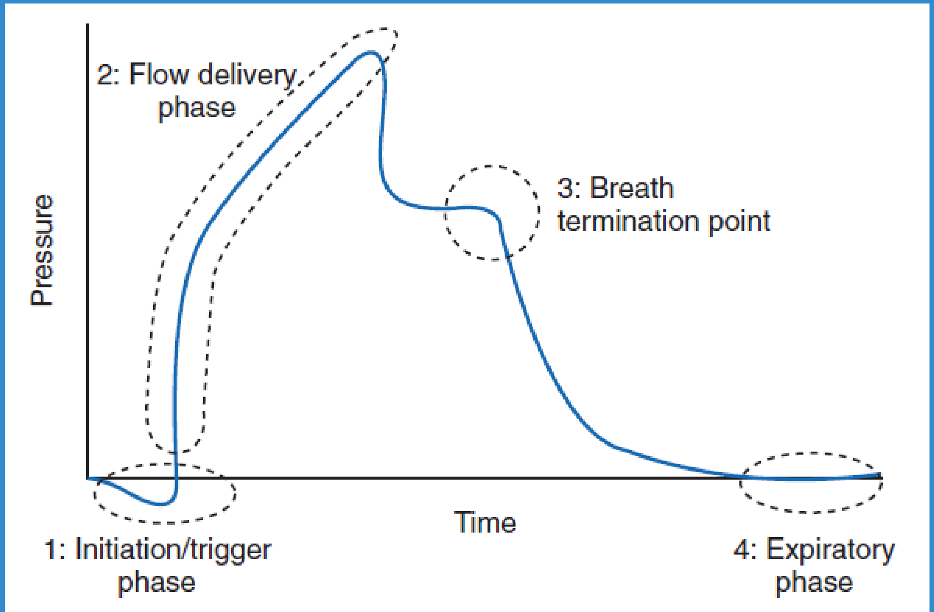
- A gap between the end of expiration and the beginning of inspiration is indicative of an air leak



Use of waveforms to identify Patient-Ventilator Dyssynchrony

Patient-Ventilator Dyssynchrony

- Dyssynchrony – lack of harmony between patient and ventilator respiratory mechanisms
- To evaluate patient-ventilator dyssyncrhony one has to evaluate:
  - Triggering
  - Flow delivery
  - Breath termination
  - Expiratory phase
- Dyssynchrony can be identified relative to these 4 phases using scalars and loops



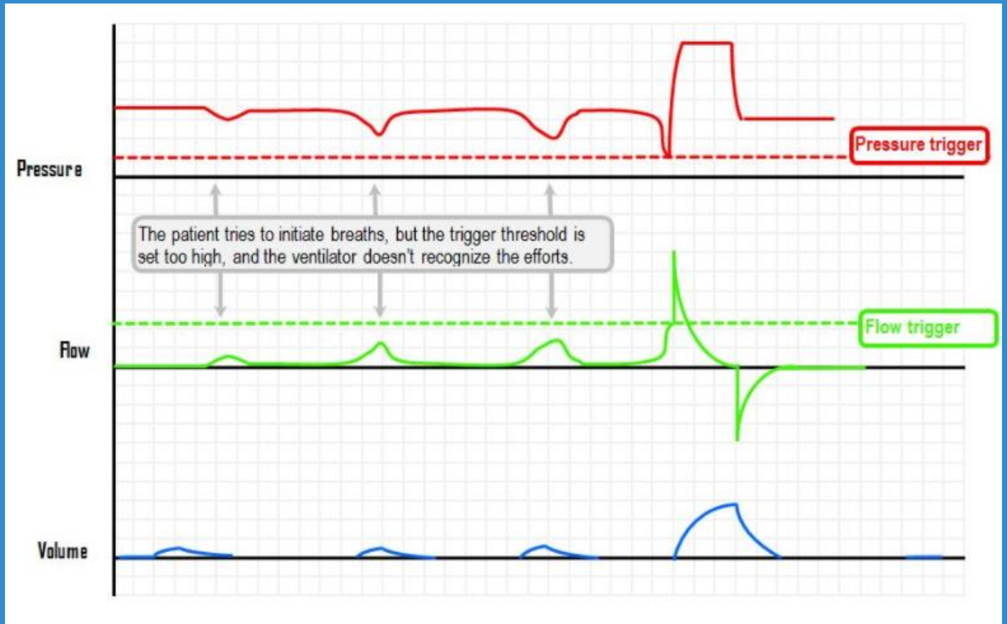
Why are Dyssynchronies bad?

- The work of breathing increases, thus oxygen demand increases, tachycardia develops, and bad hearts get worse
- The patient becomes distressed (the experience of being dyssynchronous with one's ventilator resembles asphyxiation in people)
- The patient begins to cough and/or vomit, which is a sub-optimal level of comfort

Trigger Dyssynchrony

Three forms:

1) Ineffective triggering (wasted effort)
   - when a patient's inspiratory effort is not sufficient to trigger the vent due to inappropriate trigger sensitivity

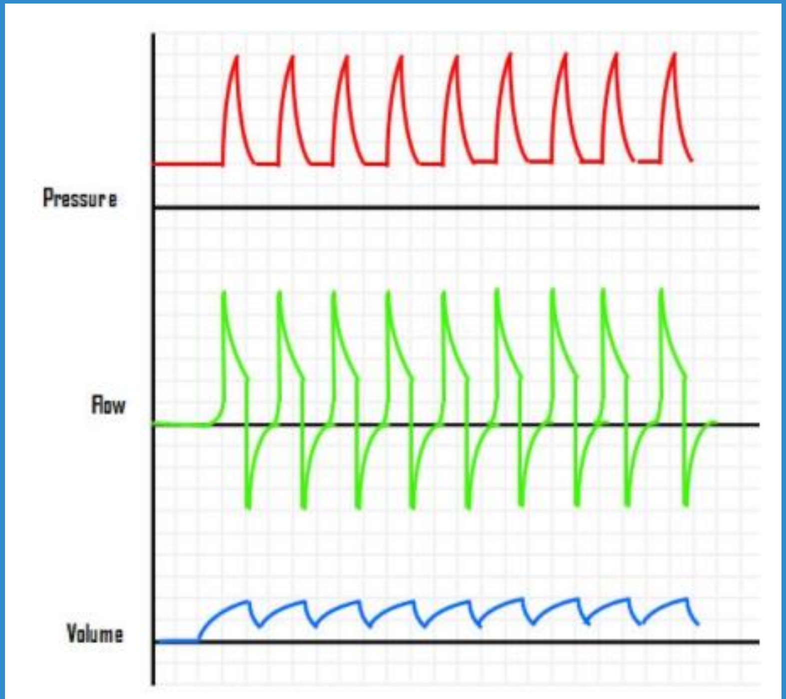


2) Auto-triggering
   - A breath is delivered by the ventilator because of a change in airway pressure or flow not caused by patient effort – due to a small threshold/sensitivity setting (cardiac oscillations, fluid within the circuit, leak from circuit etc)

Trigger Dyssynchrony

Auto-triggering due to cardiac oscillations:

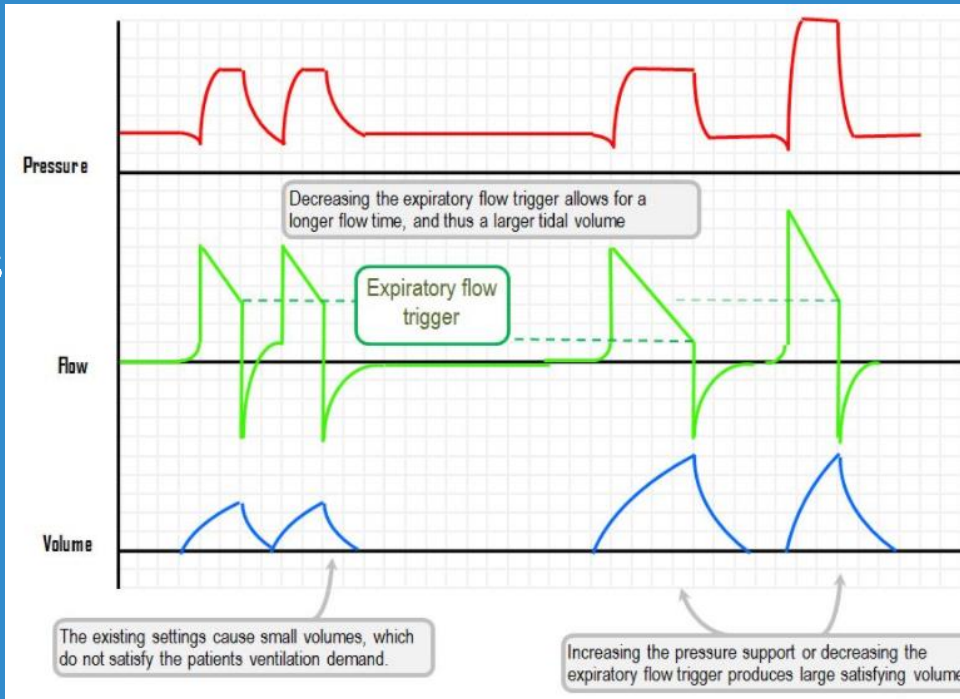
- Cardiac contractions cause a small amount of air movement, and in someone with a hyperdynamic ventricle and a sufficiently sensitive flow trigger these air movements can trigger ventilator breaths
  - The resp rate will resemble the heart rate



Trigger Dyssynchrony

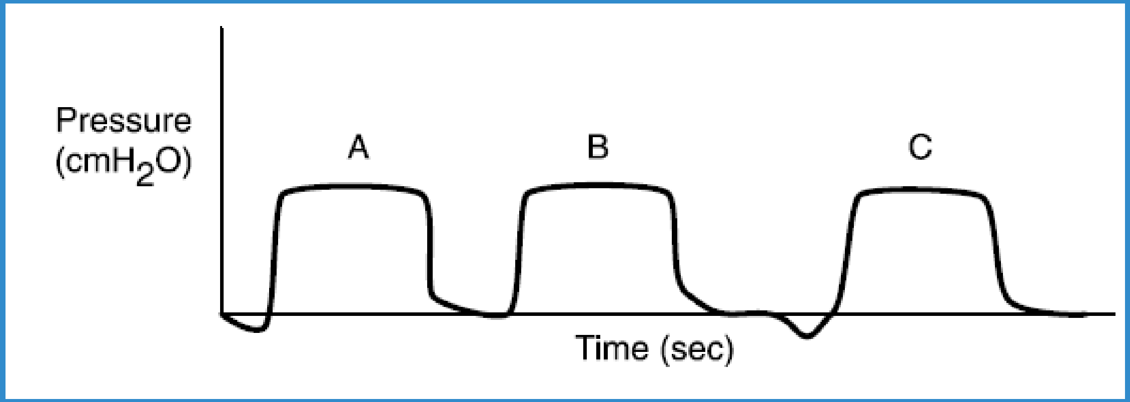
3) Double triggering:

- 2 delivered breaths separated by an expiratory time less than half the mean expiratory time
  - Occurs when a patient's inspiratory effort continues throughout the ventilator's preset I-time and thus remains present after the I-time has been completed
  - This prolonged effort triggers another breath
  - The result Is the patient receiving a Vt twice the desired – risk of alveolar trauma
  - Causes include exceptionally high ventilatory demands on the part of the patient, low Vt and I-time too short
- It is the most common form of dyssynchrony in humans
- Can occur in any ventilation mode



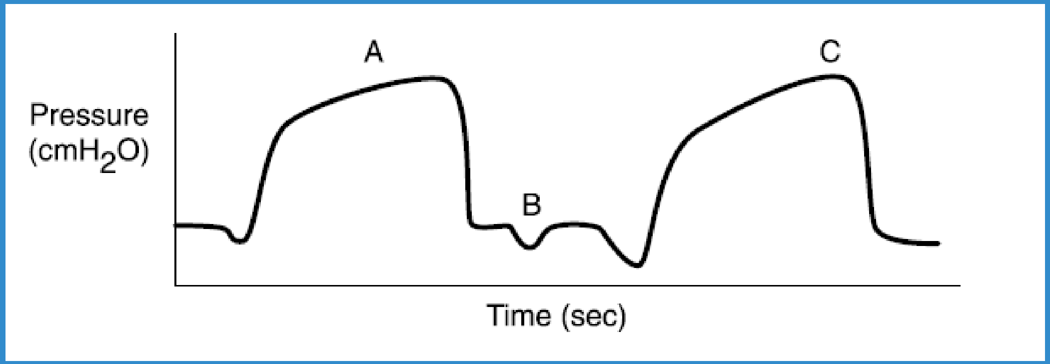
Trigger Dyssynchrony

- Breaths A and C are patient-triggered as indicated by the negative deflections before the onset of inspiration
- Breath B shows a pressure supported breath without a preceding patient effort suggestive of auto-triggering



Trigger Dyssynchrony

- When the patient's effort and sensitivity is adequate the patient's breath successfully triggers the vent (A)
- If there is a weak inspiratory effort relative to the sensitivity, the effort may be ineffective at triggering a vent breath; there is no rise in pressure following the patient effort (B)



Trigger Dyssynchrony

- How to diagnose it
  - Flow-time and pressure-time scalars
- Most common causes:
  - Auto-PEEP
    - Makes triggering the vent more difficult. In the presence of Auto-PEEP, a patient’s effort not be sufficient to generate a large enough change in baseline pressure or flow to trigger a mechanical breath
  - Inappropriately set trigger sensitivity

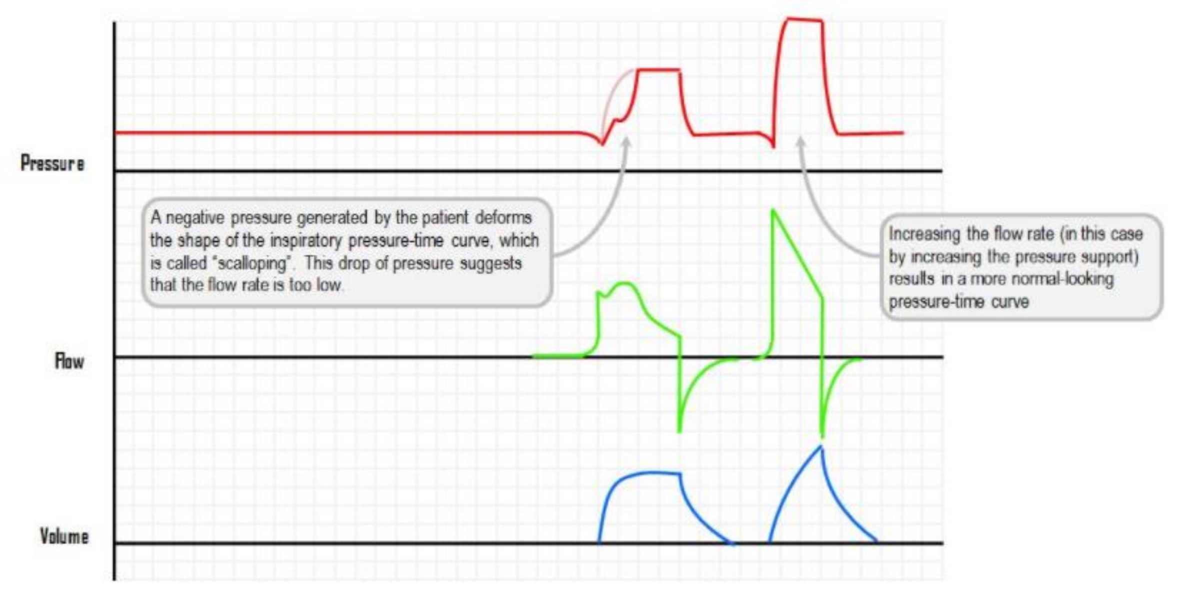
  - If the flow-trigger is too sensitive, auto-triggering can happen

Flow Dyssynchrony

- Occurs whenever the vent flow does not match the patient's flow demand
- The fresh gas supply flow to the circuit too slow
- Also called 'Flow starvation'
- Common problem

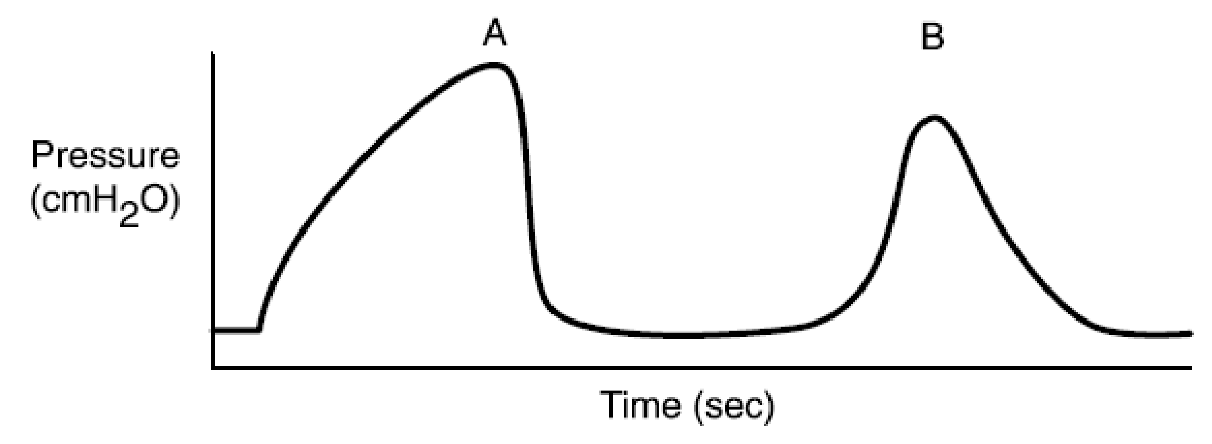
Most common causes:

- Inappropriate flow parameter setting



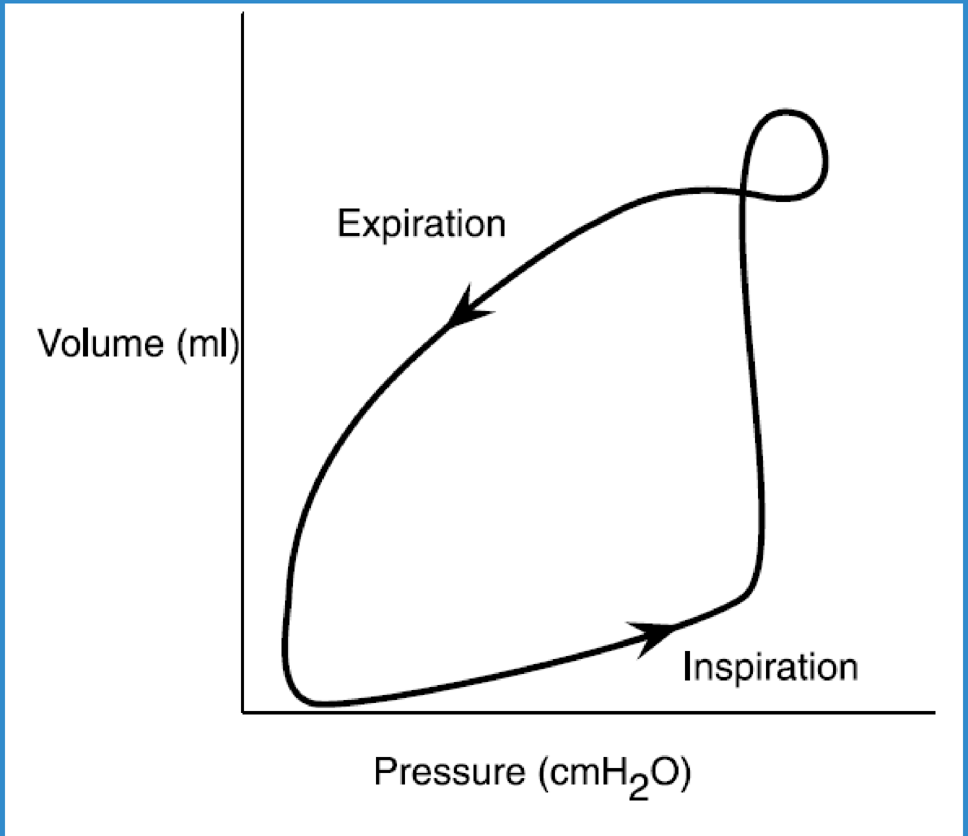
Flow Dyssynchrony

- A shows a normal pressure-time scalar
- B that shows a drop in airway pressure and a concave or scooped-out appearance of the ascending inspiratory limb indicating inadequate flow



Flow Dyssynchrony

- Figure eight appearance of the PV loop resulting from a decrease in airway pressure secondary to active patient inspiration to increase airflow



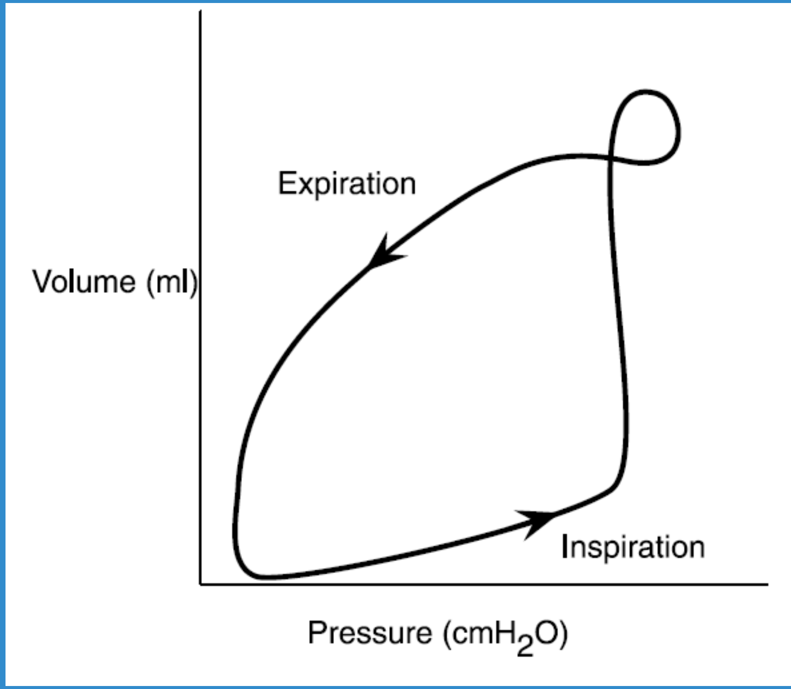
Flow Dyssynchrony

- In V/C ventilation, with constant flow, the flow values may not be sufficient
  - Adjusting the peak flow and/or selecting a different flow-pattern may help
- In P/C ventilation, the vent rapidly provides a high flow to achieve and maintain the set pressure, however this high flow rate at the beginning of inspiration may be too excessive or uncomfortable for the patient
  - In that case, adjusting the rise time may be helpful
  - As long as the set pressure is adequate, the flow will be adequate
- P/C tends to be more synchronous in patients with high-flow demands

Flow Dyssynchrony

How to diagnose it: Pressure-time scalars and PV loops

- On pressure-time scalar: concave or scooped out appearance of the inspiratory limb indicating inadequate flow
- On PV loop: concave appearance of the inspiratory limb of the tracing or figure 8 appearance of the tracing



Cycle dyssynchrony

- Occurs when the patient starts to exhale before the vent has completed inspiration (delayed breath termination), or when the vent's inspiratory flow stops before the patient's breath has completed (premature breath termination)
- How to diagnose it
  - Pressure-time and flow-time scalars

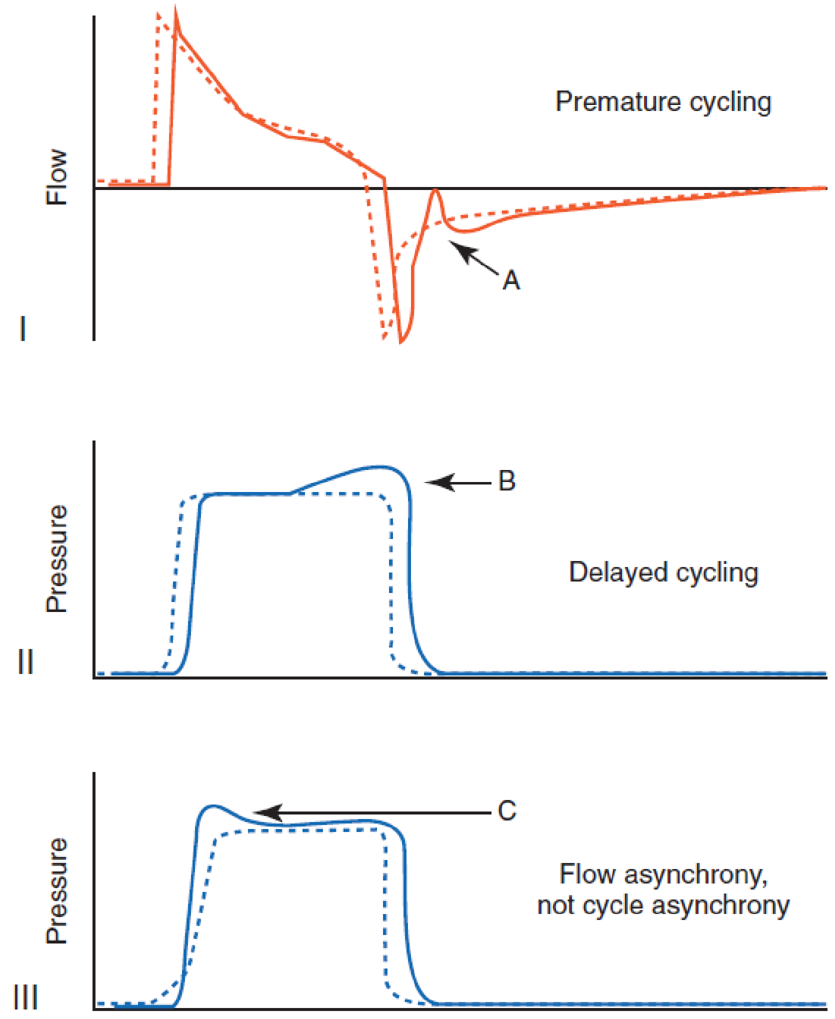
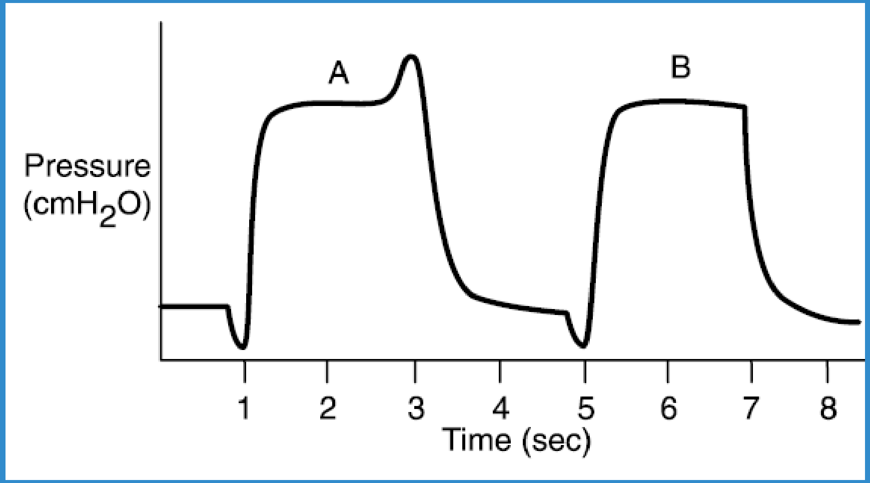
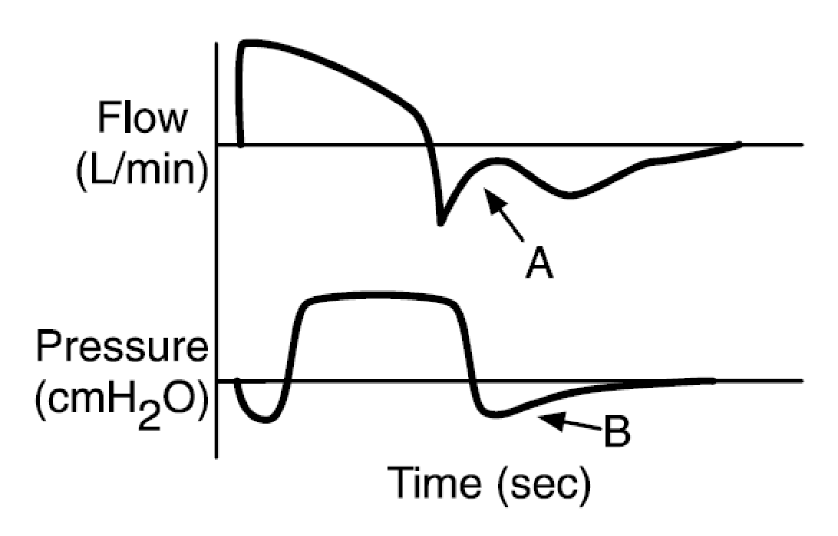


FIGURE 33-21 **I-III,** Waveform appearance of cycle asynchrony.

Cycle dyssynchrony

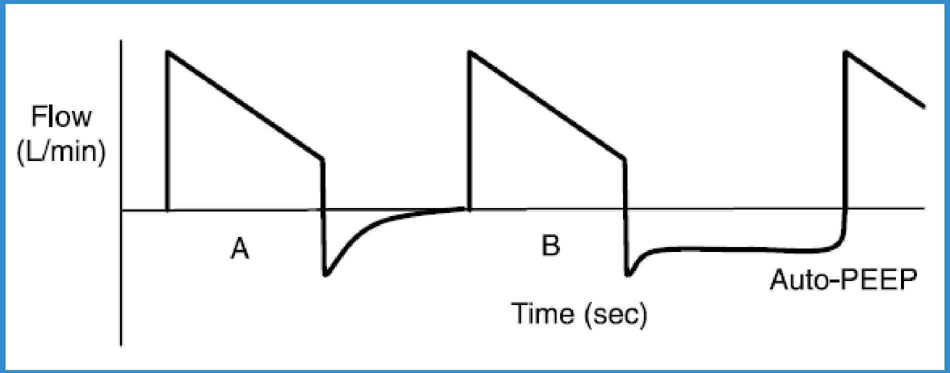
- The expiratory portion of the pressure-time scalar returns more rapidly toward baseline giving it a concave appearance
- Flow-time scalar depicts and abrupt reversal in expiratory portion of the waveform indicating continuation of the patient's inspiratory effort
- In extreme cases, the continued patient inspiratory effort may result in double triggering of the vent
- Early breath termination may substantially decrease the Vt and increase the work of breathing

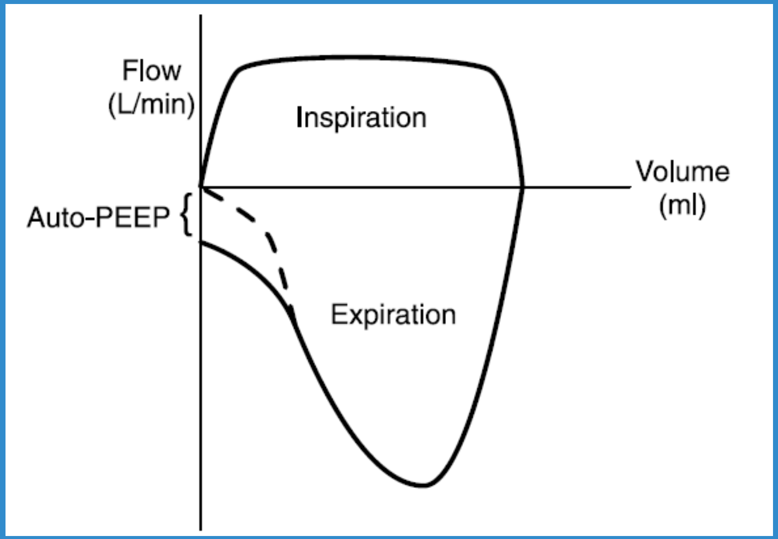




Expiratory Dyssynchrony

- Occurs due to a prolonged or shortened expiratory time
- Prolonged expiratory times can lead to hypoventilation
- Shortened expiratory times can lead to auto-PEEP, and auto-PEEP can lead to trigger dyssyncrhony and increased work of breathing
- How to diagnose it: flow-time, pressure-time scalars and FV and PV loops
- In flow-time scalar the expiratory portion does not return to baseline before the next breath is delivered indicating the presence of auto-PEEP
- In FV loop the expiratory limb does not return to zero at the end of expiration (Auto-PEEP)



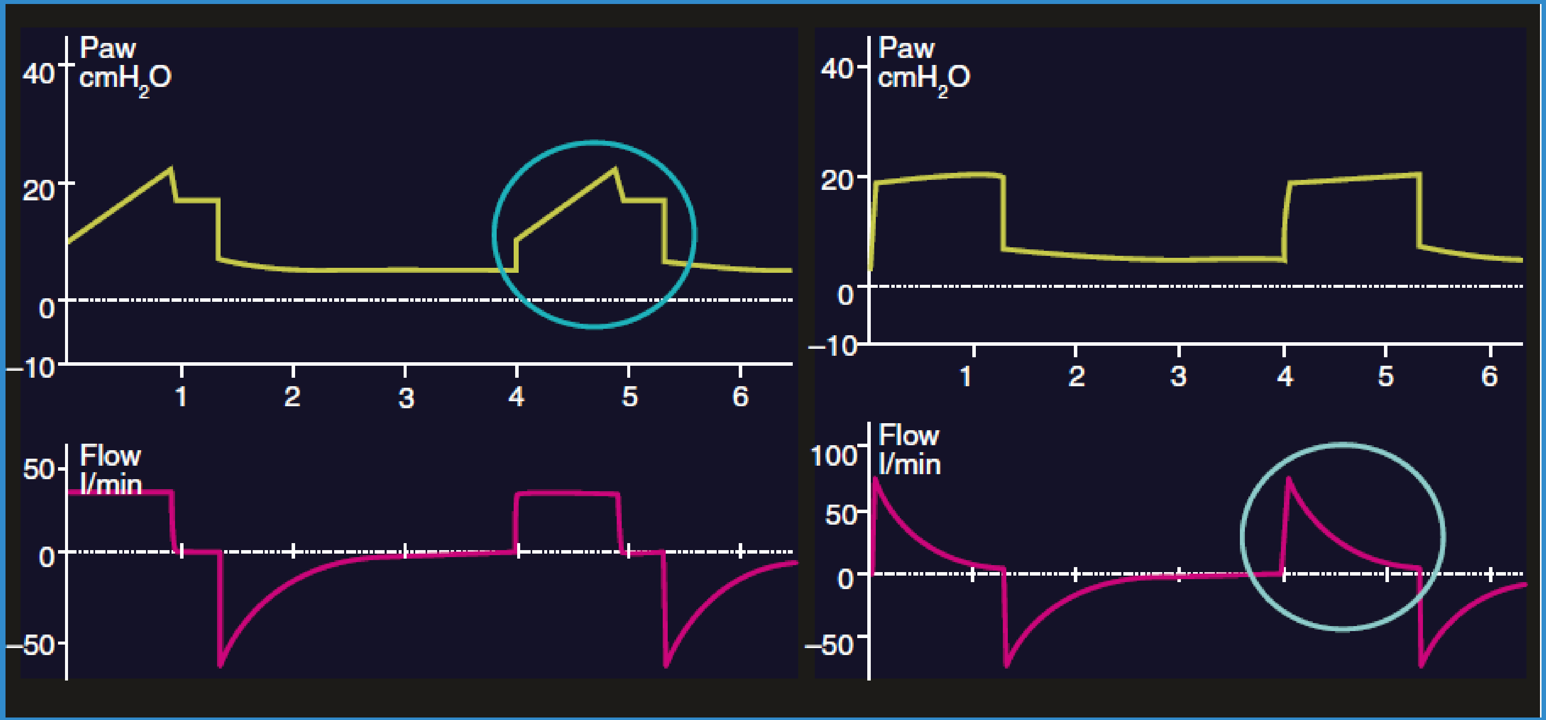


Expiratory Dyssynchrony

How to manage this type:

- Provide sufficient time for expiration by modifying:
  - Trigger sensitivity
  - Peak flow
  - Rise time
  - I-time
  - I/E ratio
  - RR
- Trigger dyssynchrony associated with Auto-PEEP may improve with the application of external PEEP approximately equal to the auto-PEEP

Name the mode of ventilation: which one is V/C?

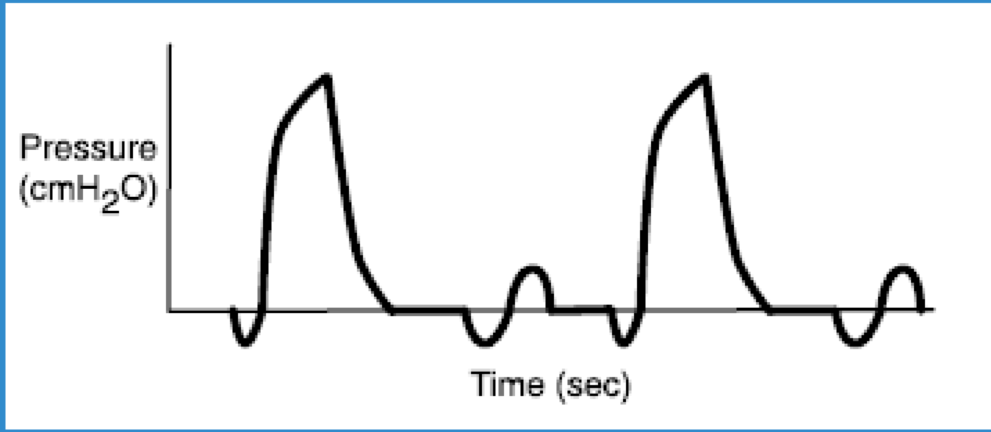


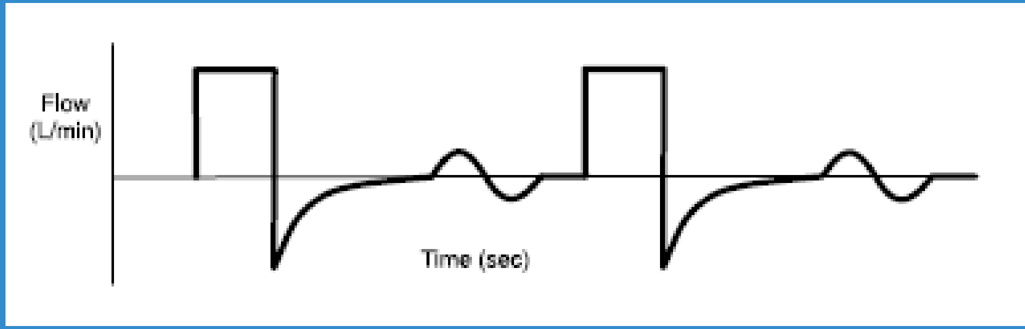
Hey yo, look at the flow

V/C

P/C

Name the mode of Ventilation

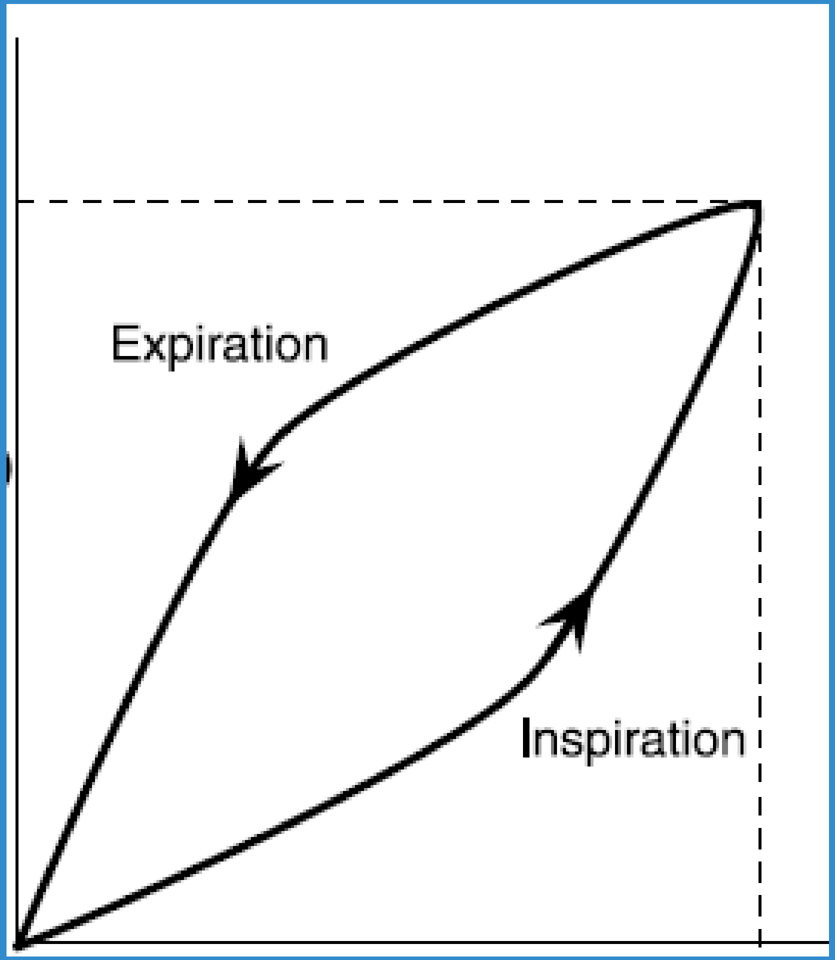




SIMV

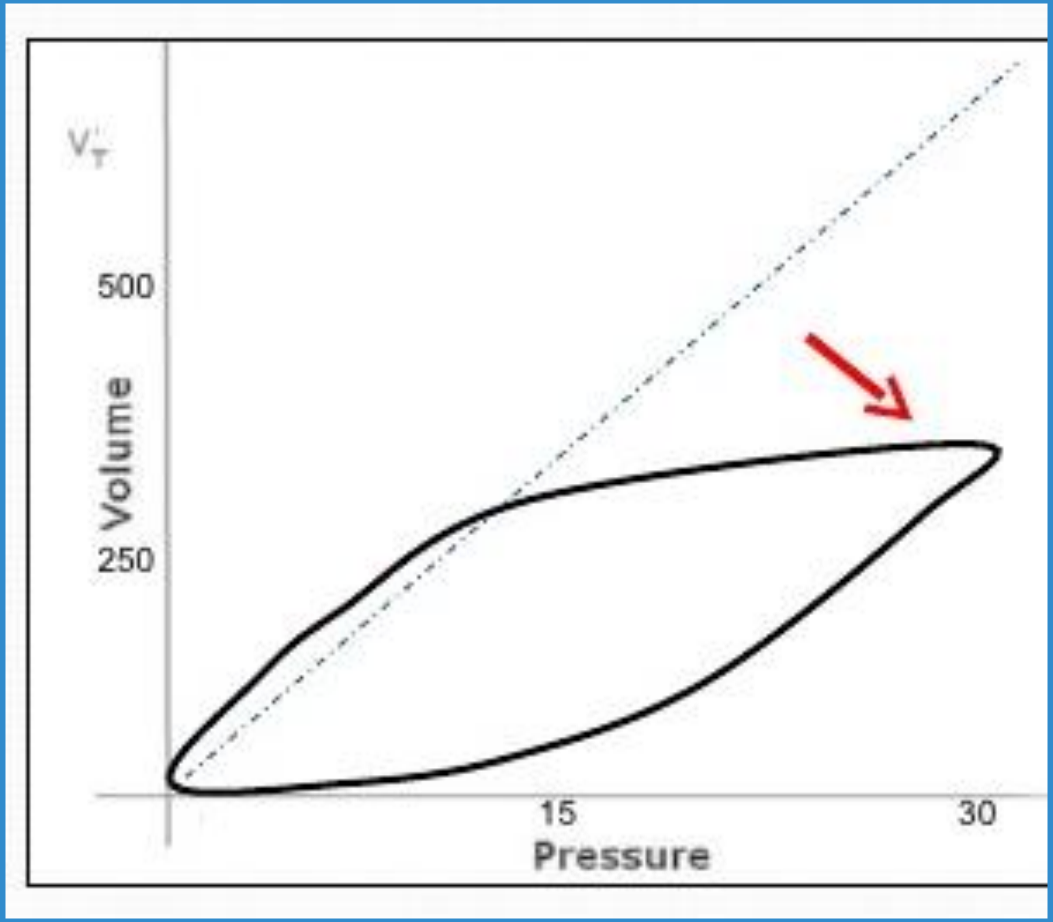
Ventilator-assisted breaths in contrast to the sinusoidal shape of spontaneous (ventilator-unassisted) breaths

Name that Loop: PV or FV?



PV loop

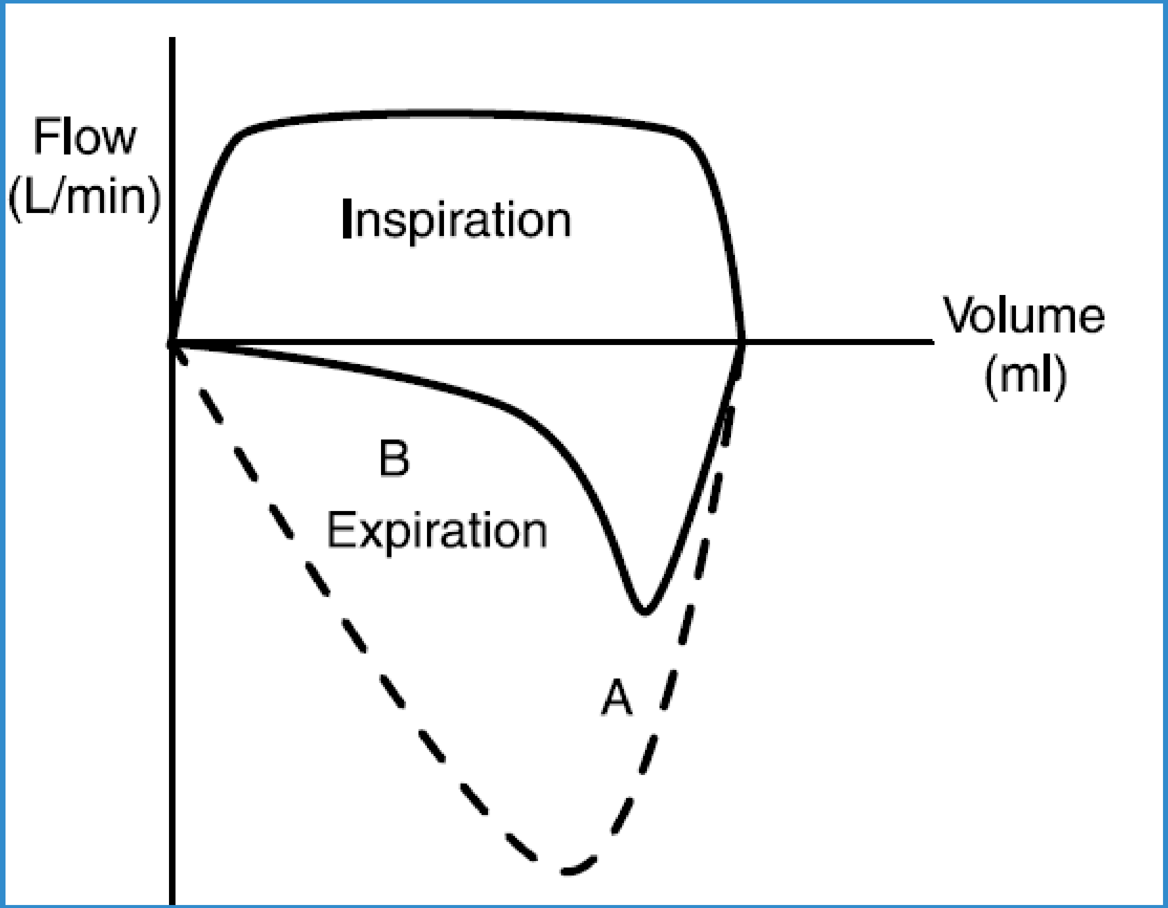
What does this PV loop tell you about compliance?



Decreased compliance

results in a shift of the loop to the right and downward

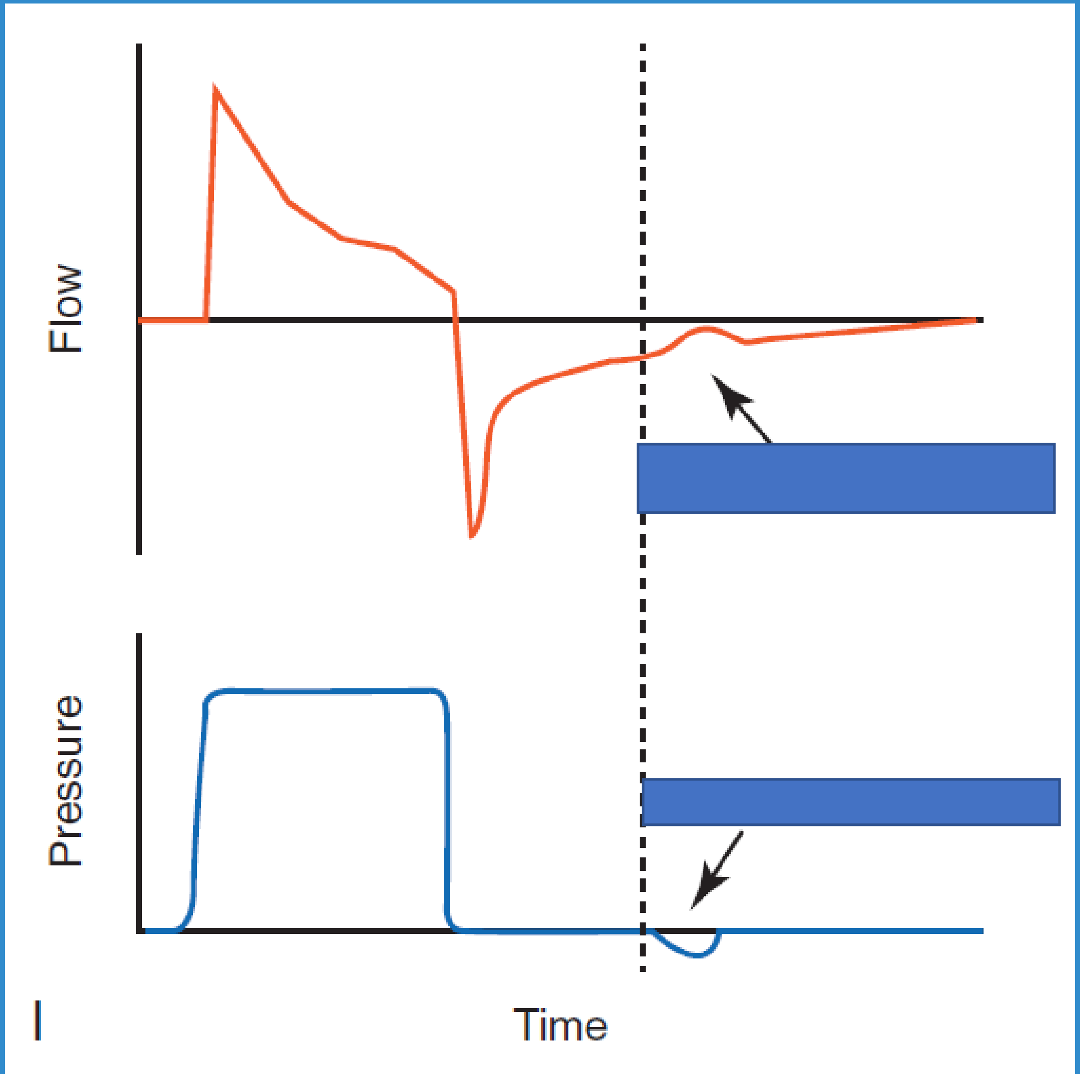
What is this FV loop telling you



Increased airway resistance

Scooped-out appearance of descending limb (B) typically seen in patients with medium and small airway obstruction

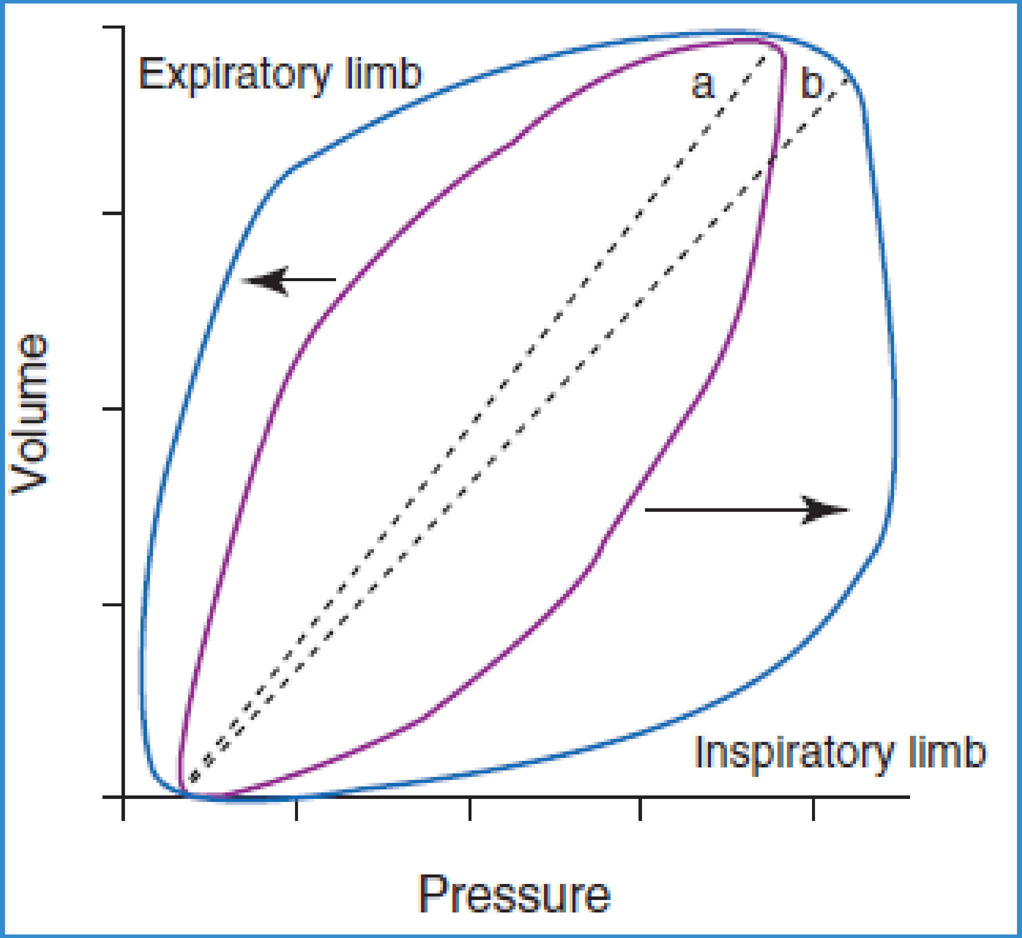
Name that type of dyssynchrony



Infective triggering

A patient-generated decrease in pressure with a simultaneous increase in airflow without triggering a machine-delivered breath

On this PV loop, what's happening to the resistance?



Increased resistance

The loop bows out farther from the dynamic compliance line, indicating that relatively greater applied pressure is required to overcome resistance and reach a given volume

Note that the Cdyn (b) has decreased
The value of Cdyn is altered by changes in resistance because flow is not allowed to cease entirely


Thank you!