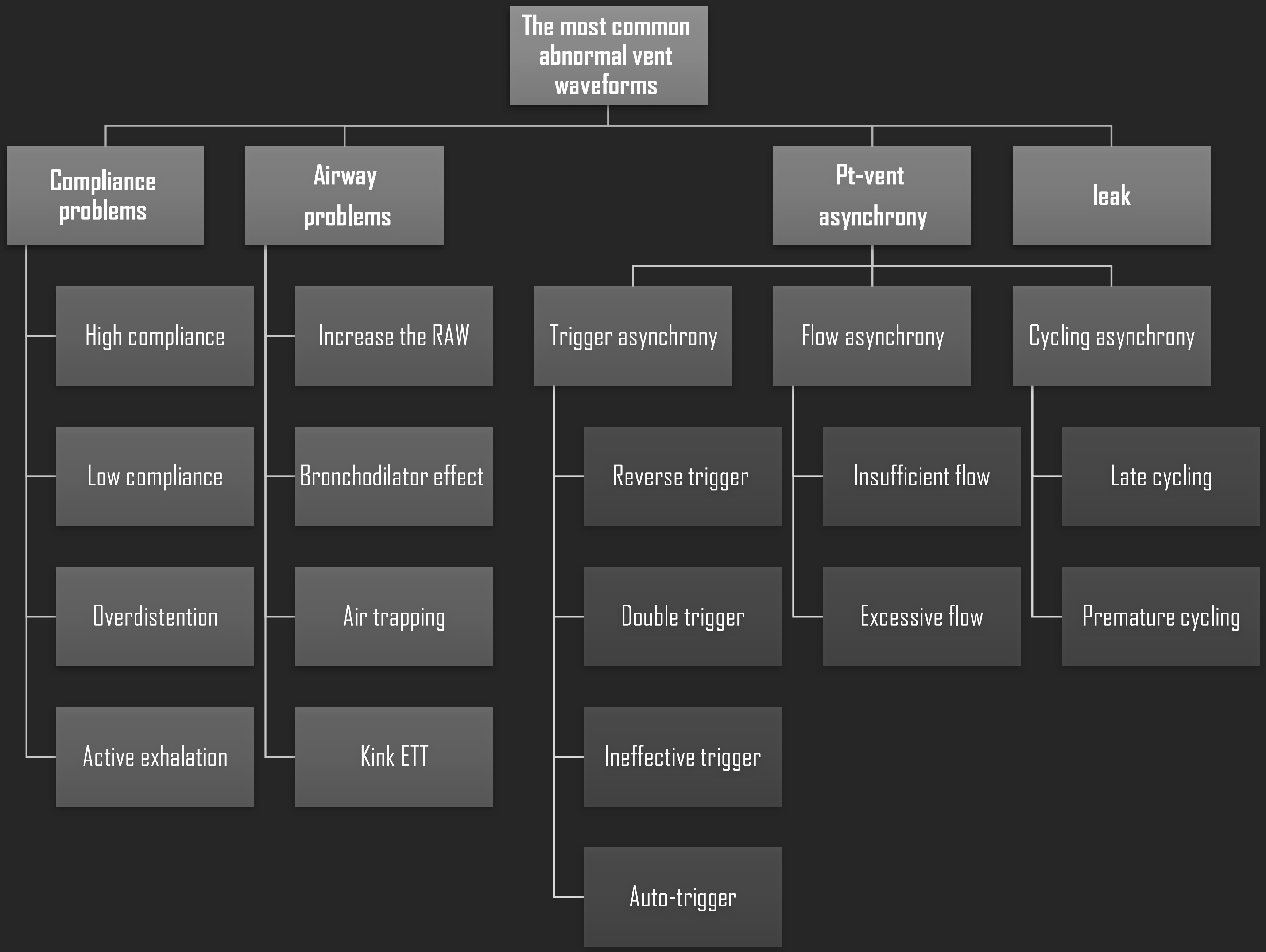
The most common abnormal ventilator waveforms

Moayed Abdullah


The most common abnormal vent waveforms
Compliance problems
Airway problems
Pt-vent asynchrony
leak
High compliance
Low compliance
Overdistention
Active exhalation
Increase the RAW
Bronchodilator effect
Air trapping
Kink ETT
Trigger asynchrony
Flow asynchrony
Cycling asynchrony
Reverse trigger
Double trigger
Ineffective trigger
Auto-trigger
Insufficient flow
Excessive flow
Late cycling
Premature cycling

1. Lung compliance problems..

The changes in Respiratory System Compliance that display on Vent Waveform.

1. lung compliance problems..

1.1 (decrease lung compliance).

1. Definition: low lung compliance (high elastance) conditions, a higher-than-normal inspiratory pressure is required to inflate the lungs and deliver a set volume[13].

2. Causes:

- **gradual changes:** consolidation, pulmonary fibrosis, atelectasis, ARDS and retained secretions.
- **Sudden changes:** tension pneumothorax, large airway plugged by mucous or by ETT advancing into the right mainstem bronchus[13,12].

3. Side effects:

- refractory hypoxemia.
- increase WOB.
- low lung volumes/ capacities and low minute ventilation[13].

4. Correction:

- surfactant therapy.
- increase PEEP.
- decrease TV to prevent ↑ alveolar pressure.
- increase RR (lung recruitment maneuver).
- maintain DP less than 18.

(review pilbeam's book chapter 13 5th edition).

5. determine by: V-P LOOP and P-T Scalar [13,15].

V-P loop the first option wave to determine the **decrease of the compliance.**

Decreased Compliance (PC mode): V-P Loop

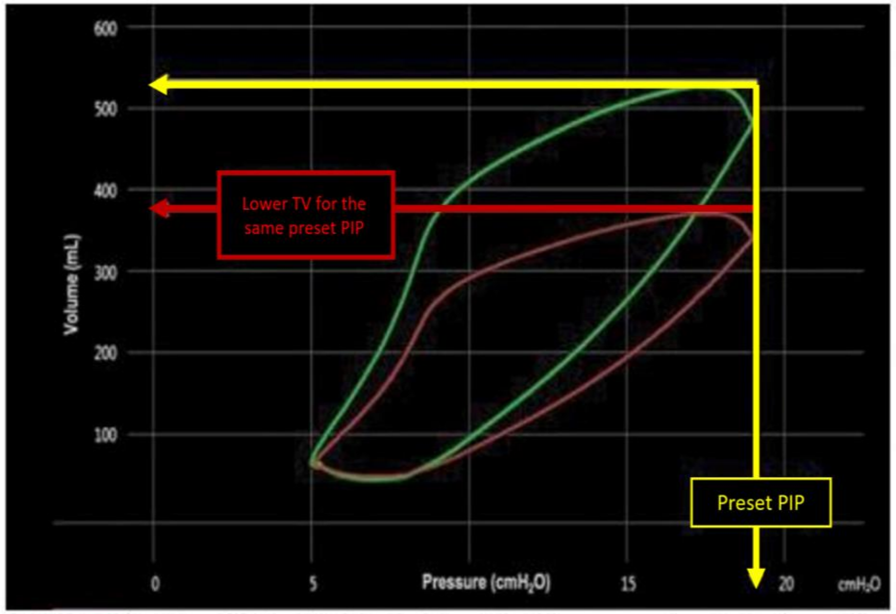


FIGURE 7-19 A similar shift to the right of the inspiratory limb of the pressure-volume loop is observed in a pressure-controlled mode. However, a preset peak inspiratory pressure (PIP) will be associated with a lower VT as a result of decreased lung compliance.

Decreased Compliance (VC mode): V-P Loop

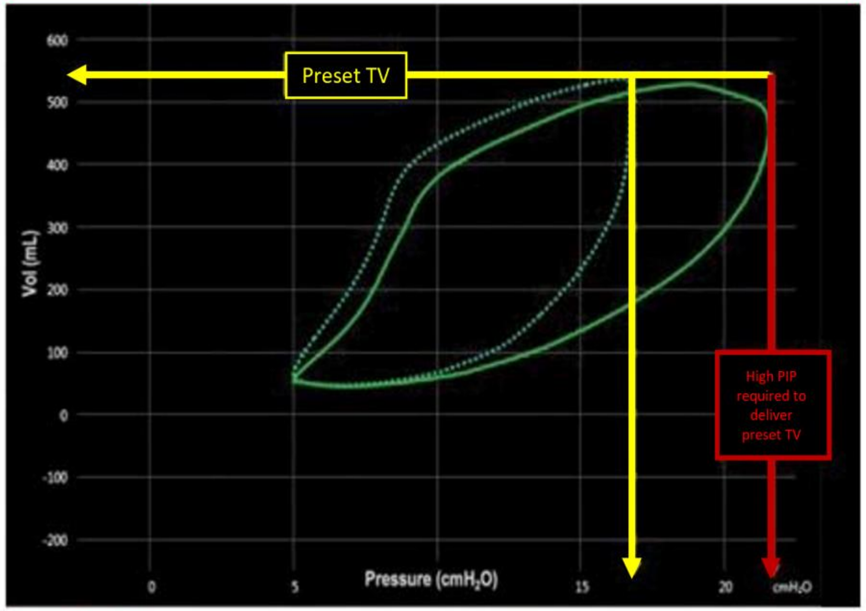


FIGURE 7-18 Pressure-volume loop (PVL) changes observed with alterations of pulmonary mechanics. Two PVLs are depicted. The dotted loop is the initial tracing, whereas the solid loop shows a typical shift to the right of a PVL indicating that a higher peak inspiratory pressure (PIP) is required to deliver the same tidal volume (decreased compliance).

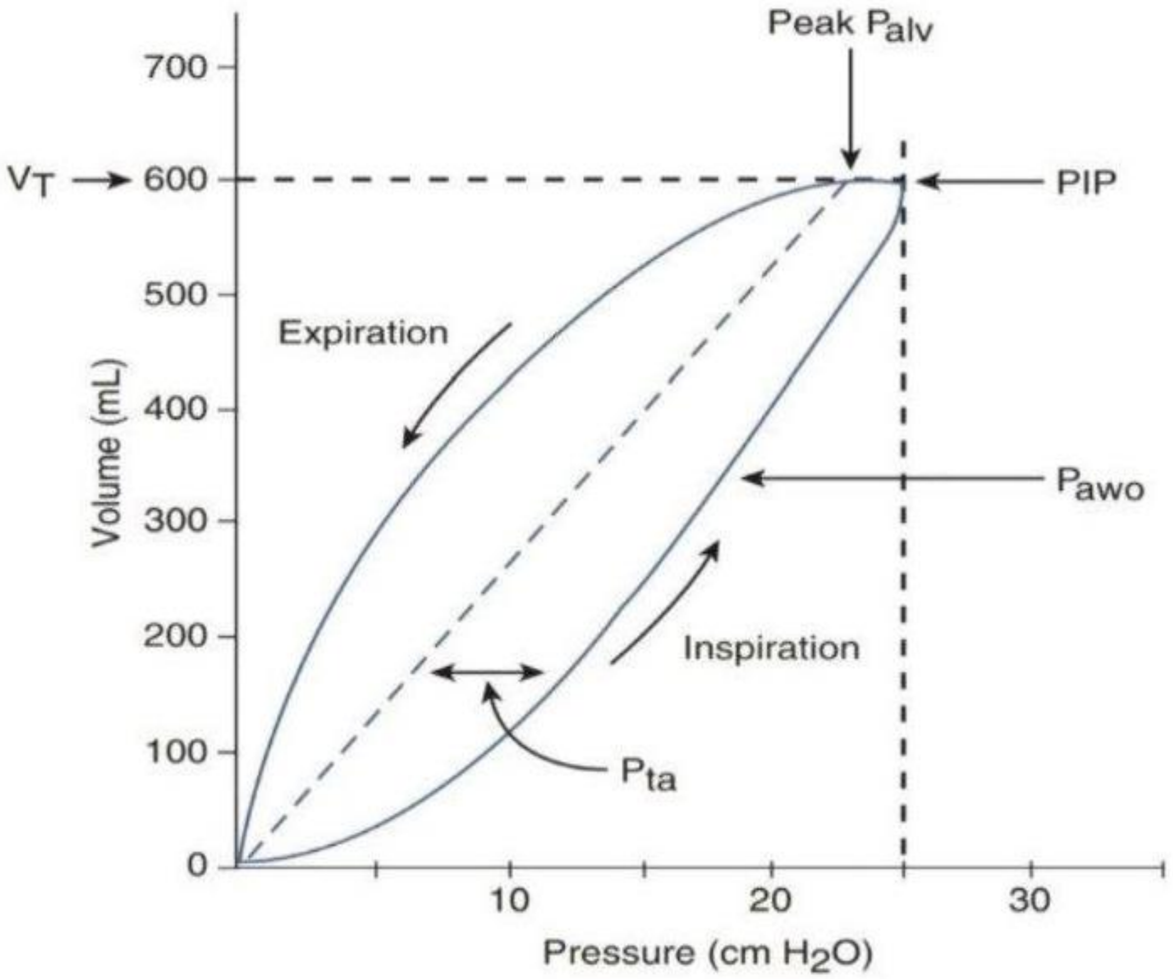


Fig. 9-23 P-V loop showing the peak inspiratory pressure (PIP), pressure at the airway opening (P_{awo}), alveolar pressure (P_{alv}), and transairway pressure (P_{ta}). (See text for additional information.)

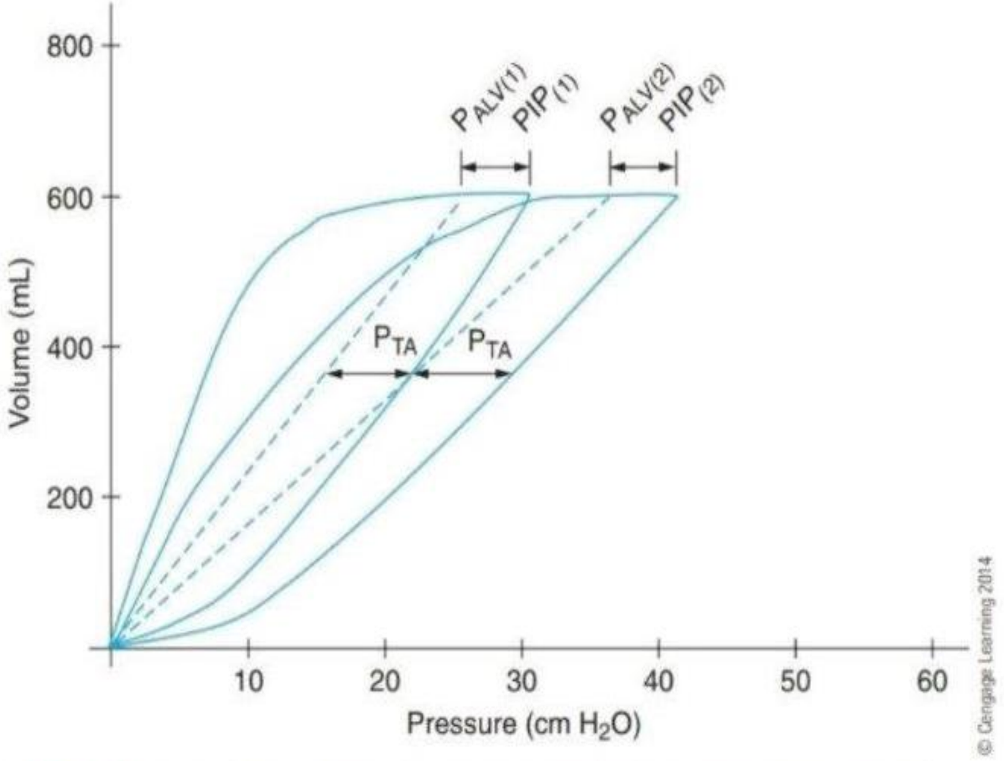


FIGURE 11-39 The effects of lung-thorax compliance (C_{LT}) on the pressure-volume loop during volume-controlled, constant flow ventilation. A decreased C_{LT} shifts the curve toward the pressure axis.

The increase in PIP (from 30 to 40 cm H2O) is proportionate to the increase in PALV (from 25 to 35 cm H2O) that is caused by the reduction in CLT. The PTA gradient throughout inspiration (and between PIP and peak PALV) is held constant. PTA is affected by changes in resistance, not by the changes in CLT.

TABLE 8-2 **Simplified Examples of Changes in Delivered Tidal Volume (V_T) and Peak Inspiratory Pressure (PIP) and Pressure Plateau ($P_{plateau}$) Reflecting Changes in Dynamic Compliance (C_D)**

A. DECREASING C_D DURING PC-CMV

Time	PIP	V_T	C_D*
1:00	25	500	20
2:00	25	400	16
3:00	25	300	12

Constant pressures with decreasing volume.

B. DECREASING C_D DURING VC-CMV

Time	PIP	V_T	C_D
1:00	25	500	20
2:00	30	500	17
3:00	35	500	14

Constant volume with increasing pressures.

C. DECREASING C_S AND C_D DURING VC-CMV WITH CONSTANT Raw

Time	PIP	C_D	$P_{plateau}$	C_S*	P_{ta}	Volume†
1:00	25	20	20	25	5	500
2:00	30	17	25	20	5	500
3:00	35	14	30	17	5	500

Increasing PIP and $P_{plateau}$. Volume and pressure lost to the airways are constant. The lung is less compliant.

D. DECREASED C_D, CONSTANT C_S DURING VC-CMV WITH INCREASED Raw

Time	PIP	C_D	$P_{plateau}$	C_S	P_{ta}	Volume
1:00	25	20	20	25	5	500
2:00	30	17	20	25	10	500
3:00	35	14	20	25	15	500

Increasing PIP with constant volumes and $P_{plateau}$. Raw is increased (P_{ta} = PIP − $P_{plateau}$).

E. IMPROVING C_D AND C_S DURING VC-CMV

Time	PIP	C_D	$P_{plateau}$	C_S	P_{ta}	Volume
1:00	25	20	23	22	2	500
2:00	23	22	21	24	2	500
3:00	20	25	18	28	2	500

PIP and $P_{plateau}$ are decreasing; delivered volume and P_{ta} are constant; the lungs are more compliant.

F. COMPLIANCE MEASUREMENTS WITH PEEP DURING VC-CMV

Time	PIP	C_D	$P_{plateau}$	C_S	P_{ta}	PEEP	Volume
1:00	30	20	28	22	2	+5	500
2:00	35	20	33	22	2	+10	500
3:00	40	18	37	20	3	+12	500

The addition of increasing PEEP results in increasing PIP and $P_{plateau}$. Delivered V_T and P_{ta} remain constant.

C_D, Dynamic compliance (C_D = Volume/[PIP − EEP]); C_S, static compliance (C_S = Volume/[$P_{plateau}$ − EEP]); *EEP*, end-expiratory pressure; *PEEP*, positive end expiratory pressure; *PIP*, peak inspiratory pressure (cm H_2O); P_{ta}, transairway pressure (cm H_2O); $P_{plateau}$, plateau pressure (cm H_2O); *PC-CMV*, pressure-controlled, continuous mandatory ventilation; *Raw*, airway resistance; *VC-CMV*, volume-controlled, continuous mandatory ventilation; V_T, tidal volume (mL).

*Volume is shown in mL throughout the table.

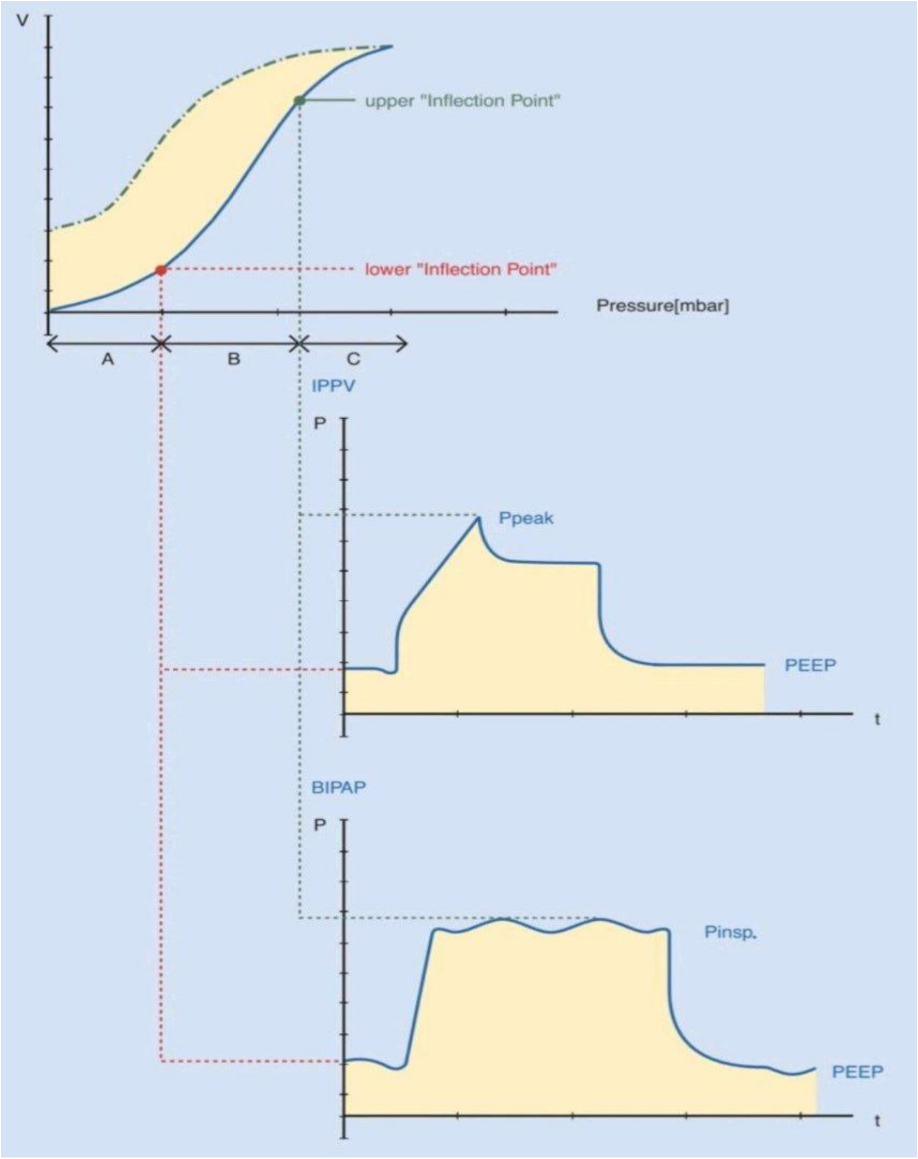
†Compliance is shown in mL/cm H_2O throughout the table.

6. Rapid nots:

-For the pt with low lung compliance..

The ventilation volume (in IPPV/ CMV, SIMV) or inspiratory pressures (in BIPAP, PCV) must be selected such that the upper inflection point will not be exceeded.[16].

- Low lung compliance is usually related to conditions that reduce the patient's FRC[13].



- **refractory hypoxemia**: A persistent low level of oxygen in blood that is not responsive to medium to high concentration of inspired oxygen. It is usually caused by intrapulmonary shunting[12].

-Diseases that reduce the compliance of the lungs or chest wall increase the pressure required to inflate the lungs[11].

1. lung compliance problems..

1.2 (increase lung compliance).

1. Definition: diminished elastic recoil (the lung easily opened and inflated at a given inspiratory pressure)[13].

2. Causes:

- Emphysema.
- surfactant therapy.
- old age [14].

3. Side effects:

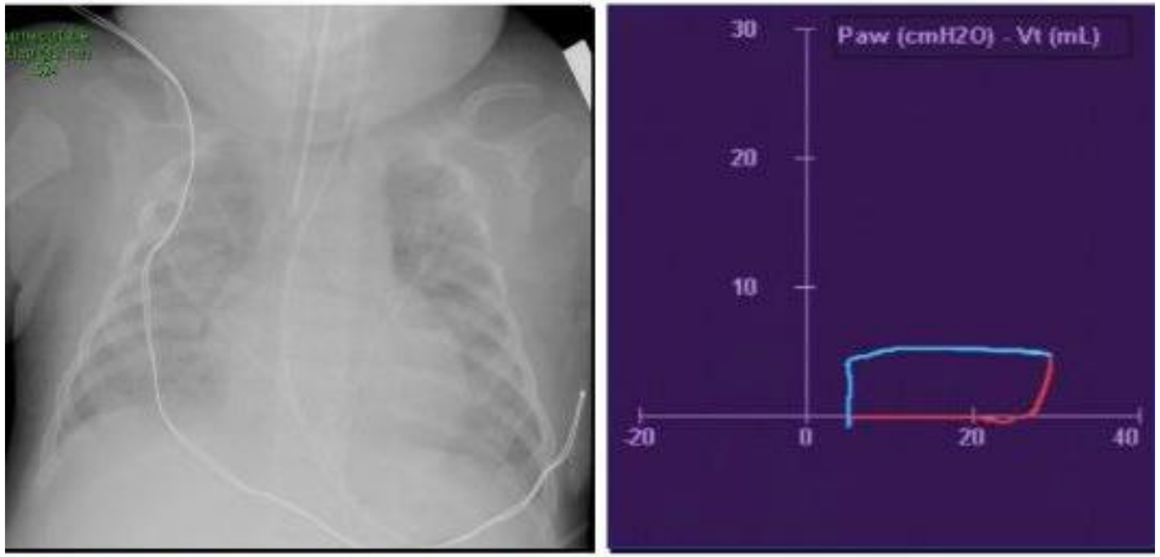
- incomplete exhalation.
- co2 retention.
- air trapping or auto-PEEP.
- poor gas exchange.
- increase (RV, FRC and TLC) [12,13].

4. Correction:

- emphysema patient (decrease the CO_2 retention or accept permissive hypercapnia and try to decrease the auto-PEEP) [11].

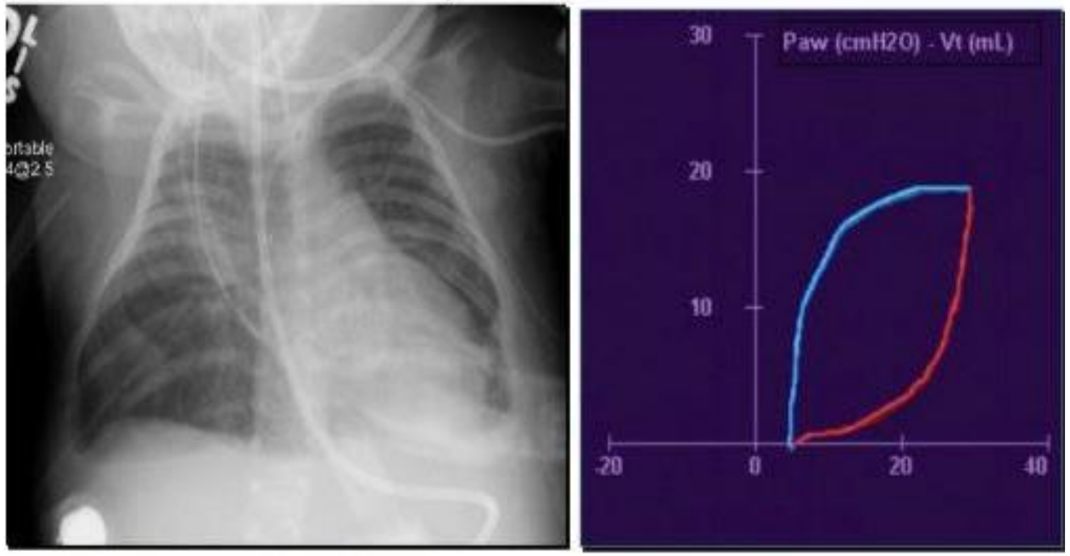
5. Determine by: P-V Loop [11,15].

27 Wk Preemie; 850 grams



Compliance 0.3 mL/cm H2O
SIMV/PC FiO2 0.80 RR 60 PIP 26 PEEP 6 Ti 0.3 sec
Tidal Volume: 6 mL/kg
ABG: 7.20 / 65 / 65 / 14

Case Progression
12 hrs post-surfactant



Compliance 1 mL/cm H2O
SIMV/PC FiO2 0.50 RR 50 PIP 24 PEEP 6 Ti 0.3 sec
Tidal Volume: 20 mL/kg
ABG: 7.49 / 25 / 65 / 18

Decrease lung compliance | **Increase lung compliance** | Overdistension | Active Exhalation

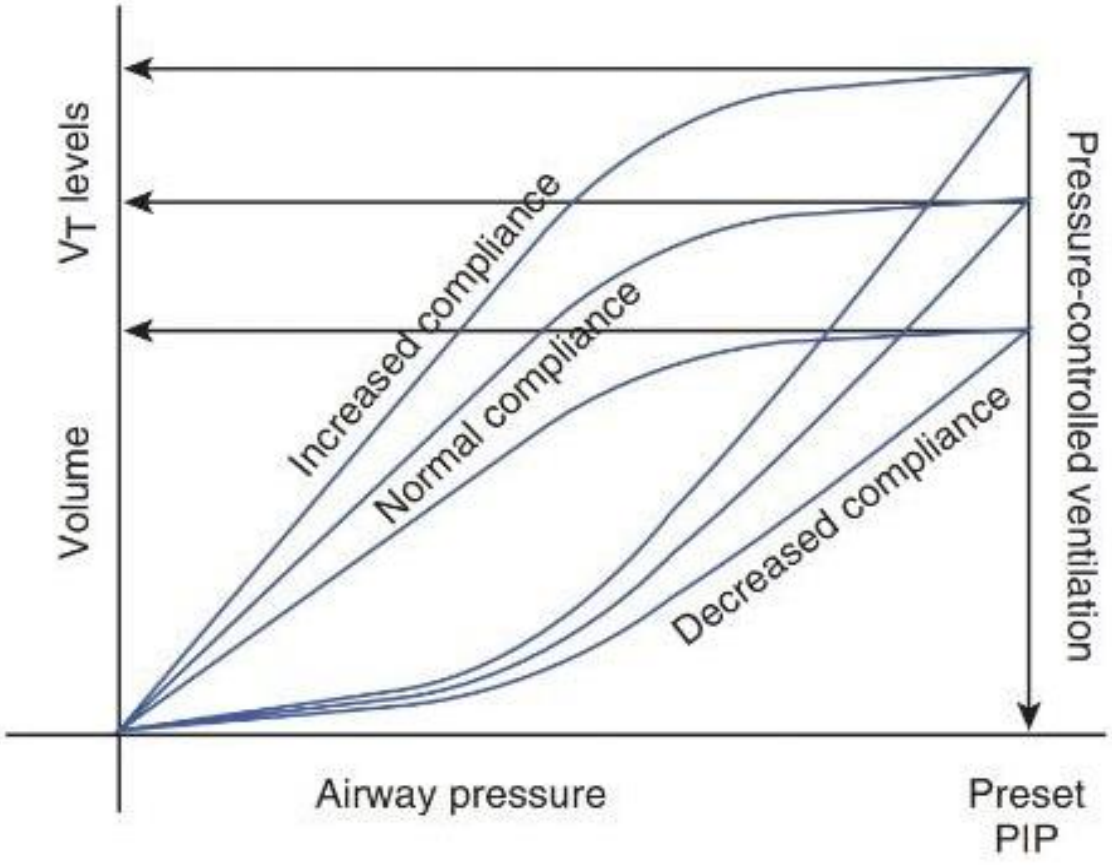


Fig. 9-25 P-V loops during pressure ventilation. As compliance changes, volume delivery changes, but pressure delivery remains constant. *PIP*, Peak inspiratory pressure; V_T, tidal volume. (From Dhand R: Ventilator graphics and respiratory mechanics in the patient with obstructive lung disease, *Respir Care* 50:246, 2005.)

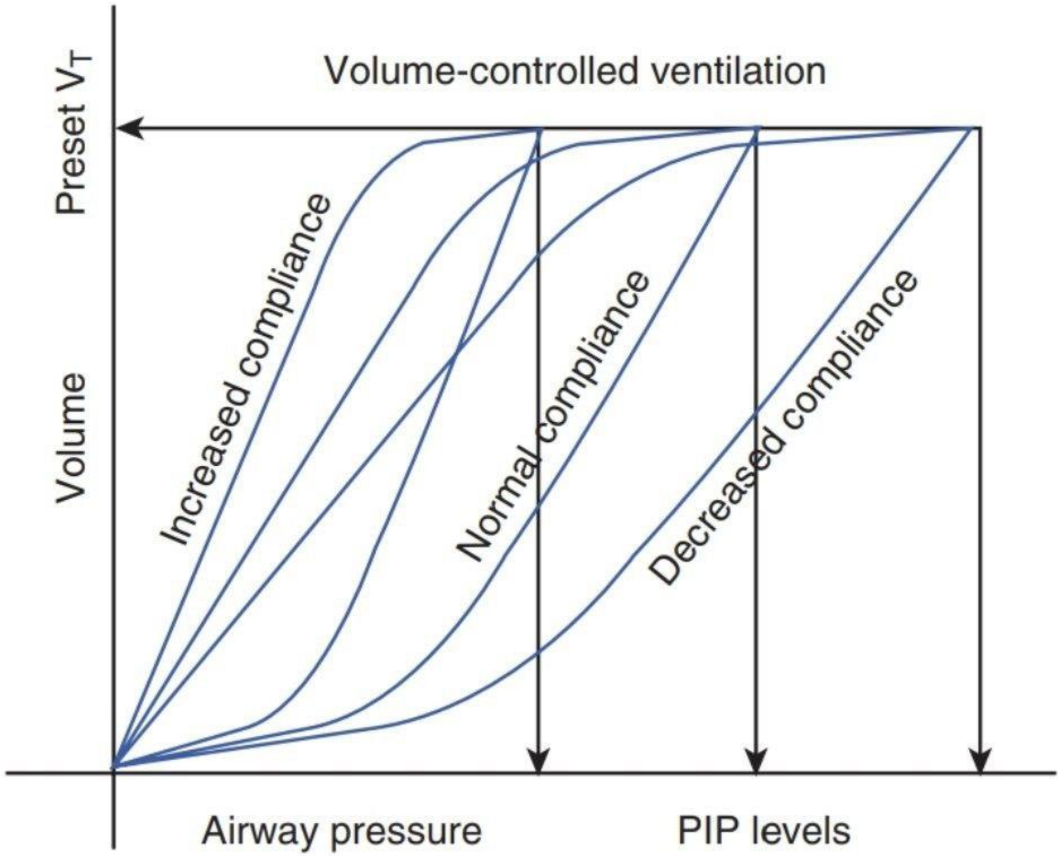


Fig. 9-27 Changes in the P-V loop during volume-targeted ventilation as lung compliances changes. Volume delivery remains constant, but PIP changes. (From Dhand R: Ventilator graphics and respiratory mechanics in the patient with obstructive lung disease, *Respir Care* 50:246, 2005.)

PC mode

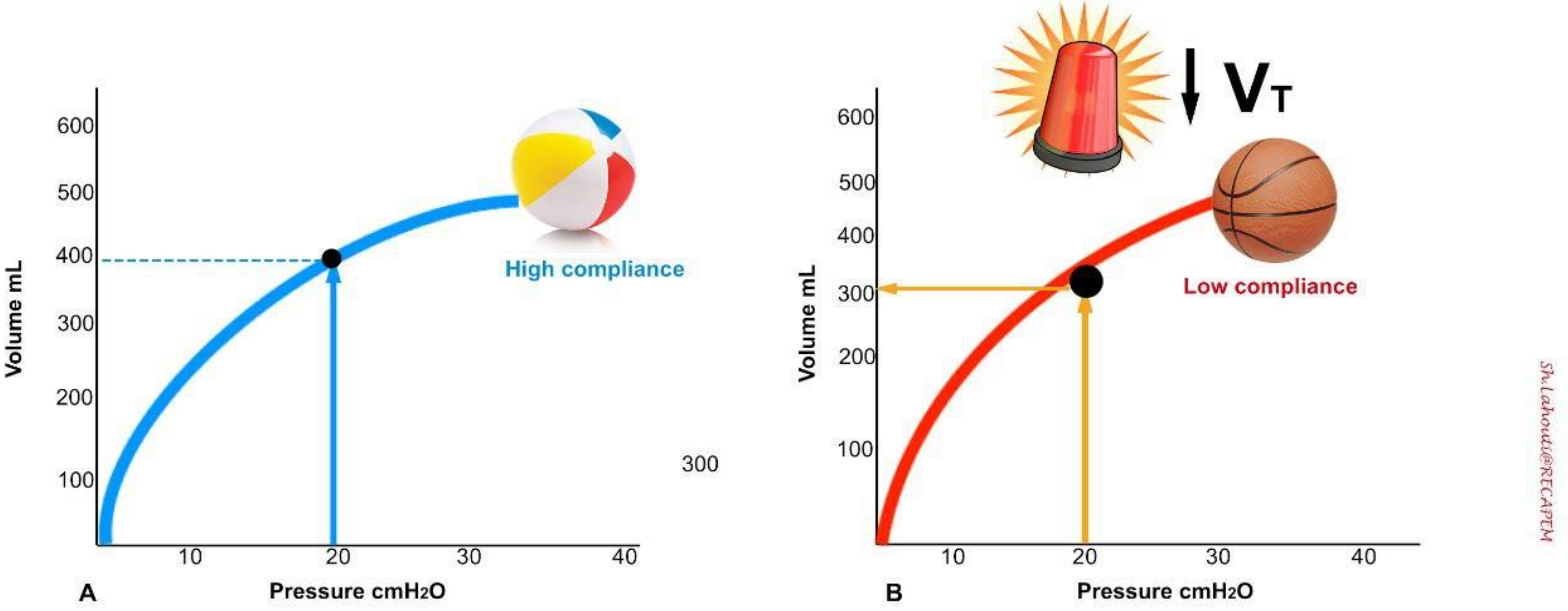


Figure 30. Schematic illustration of ventilator alarm going off (Low V_T alarm) in Pressure control mode (PC). Remember that in pressure control modes, you set the PIP in ventilator and it's your independent variable. A. PIP is set at 20cmH_2O, and it happens to give a tidal volume of 400cc. B. In the same patient, the Low V_T alarm goes off days later *"probabely"* because the patient's lung is stiffened (compared to basketball). Here the preset PIP of 20cmH2O is applied **but** it happens to give a tidal volume of 300cc which is lower than the threshold which you have set into the ventilar alarm map (i.e tidal volume of 400cc).

VC mode

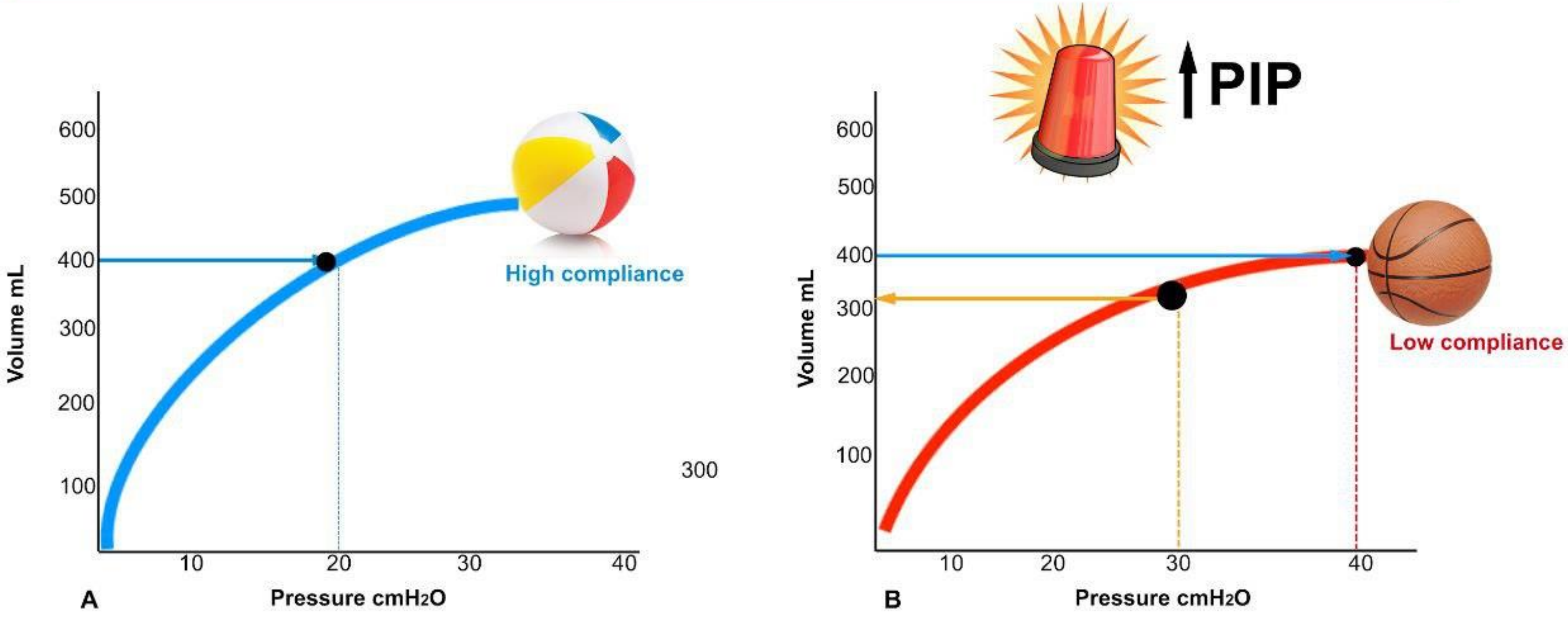


Figure 31. Schematic illustration of ventilator alarm going off (high PIP alarm) in volume control mode(VC). Remember that in volume control modes, you set the tidal volume in ventilator and it's your independent variable. A. Tidal volume is set at 400 cc, and it happens to give a PIP of 20 cmH2O. B. In the same patient, the high PIP alarm goes off days later *"probabely"* because the patient's lung is stiffened (compared to basketball). Here the preset tidal volume of 400cc is delivering **but** it happens to give a pressure of 40 cmH2O which is beyond the threshold that you have set into the ventilar alarm map (usually PIP is set at 30cmH2O. The ventilator will cuts off the breath at the preset threshold of 30cmH2O and in this condition, the ventilator will give a tidal volume of 300 cc.

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6. Rapid nots:

-Pt with high compliance often develop ventilatory failure and require non invasive or invasive mechanical ventilation.

-pt with emphysema typically have both wide P-V loops and increase compliance (widening the loop is caused by airway resistance)[10].

1. lung compliance problems..

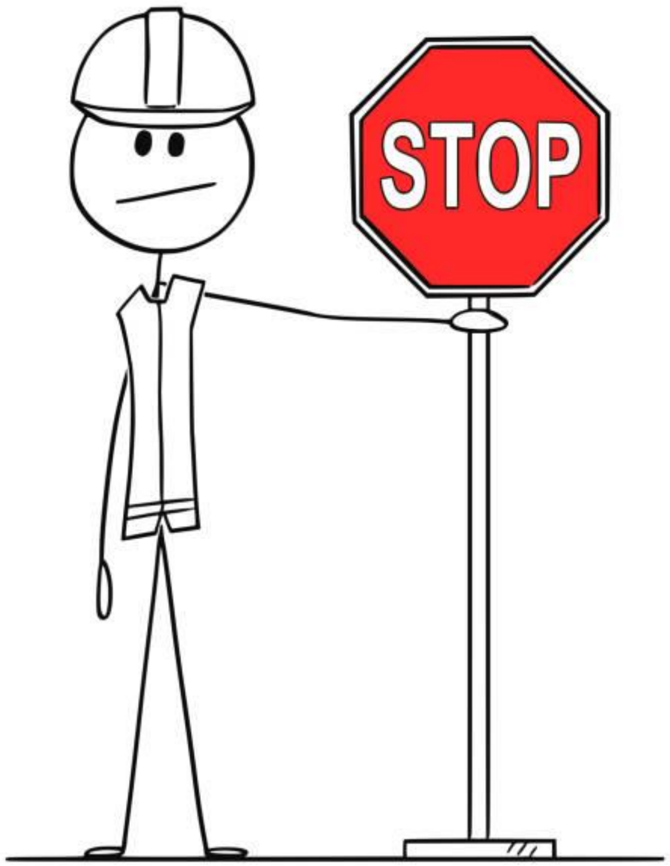
1.3 (alveolar overdistention).

1/Alveolar overdistention:

- increases alveolar wall tension or alveolar distending pressure above normal.

-Lungs may be overdistended (severe ARDS) and not hyperinflated.

-associated with the presence of increased levels of inflammatory mediators[11].

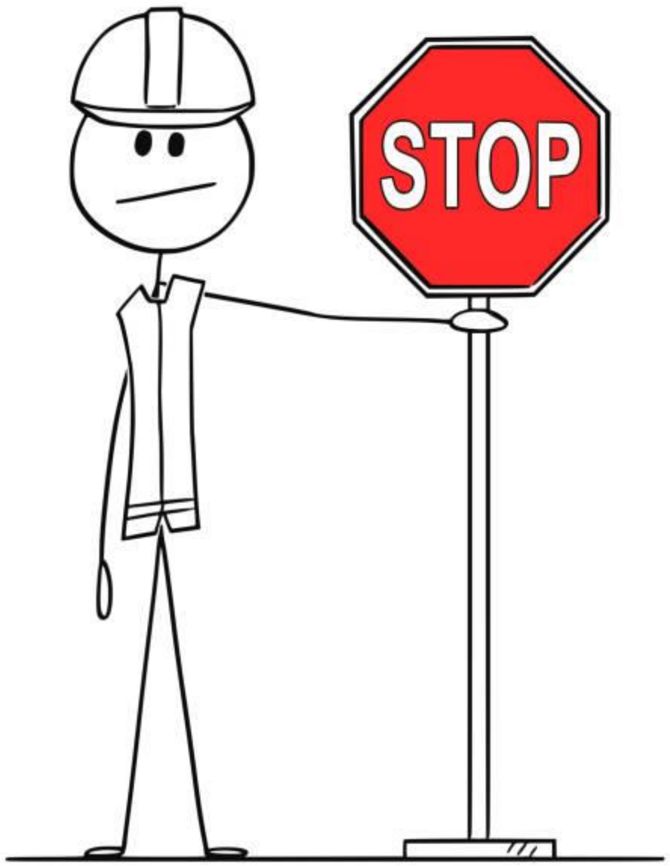


2/Alveolar Hyperinflation:

-gas overfilling.

-higher-than-normal ratio of gas to tissue.

-emphysema patient may be hyperinflated but not overdistended[11].

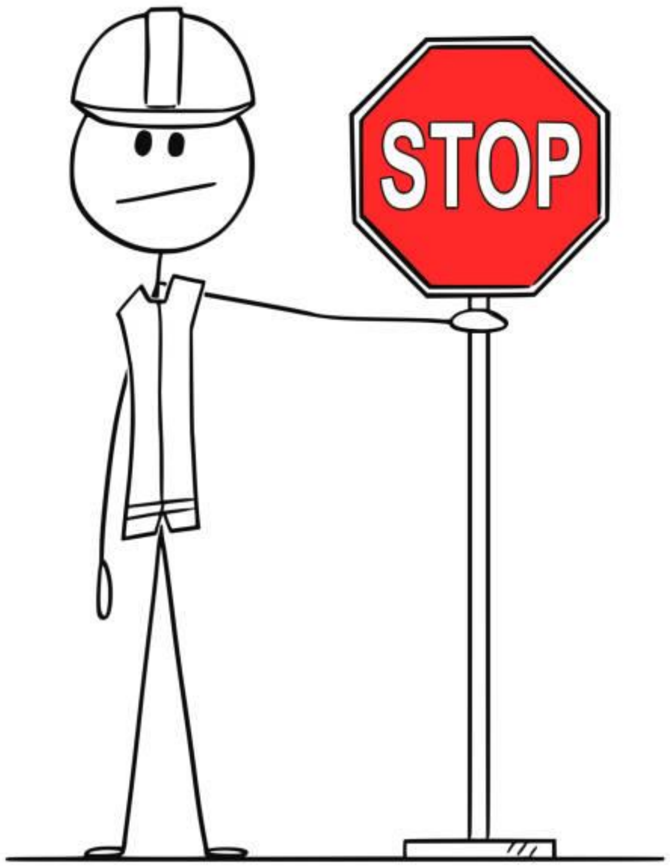


3/Barotrauma: trauma that results from using high pressures[11].

4/Volutrauma: damage from high distending volumes[11].

5/Atelectrauma: the repetitive opening and closing of lung units in regions of atelectasis[17].

6/ biotrauma: Overdistention causes the release of inflammatory mediators from the lungs that can lead to multiorgan failure. This latter response has been termed biotrauma.[11].



1. Definition:

increases alveolar wall tension or alveolar distending pressure above normal.

2. Causes:

- increase the set TV
- increase the set pressure
- PEEP above the normal range[14].

3. Side effects:

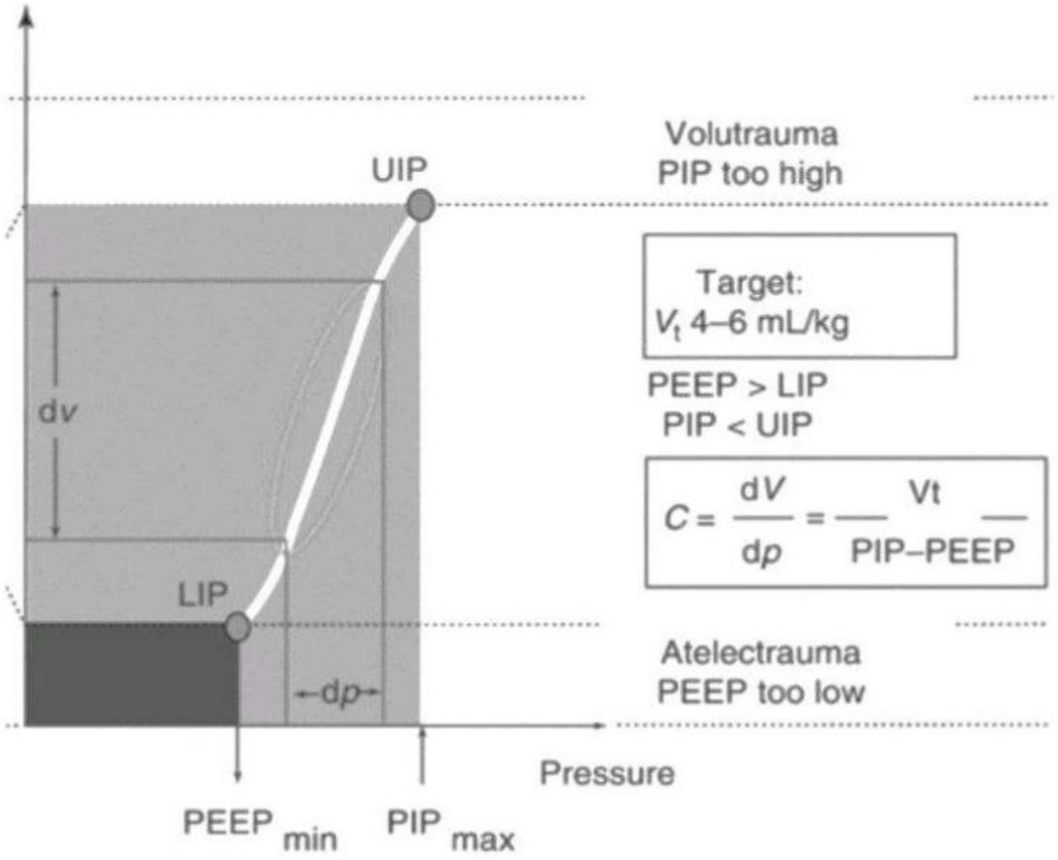
- decrease C.O.
- hemodynamic compromise.
- volutrauma and barotrauma.
- pulmonary edema.
- VILI.
- ventilation/perfusion mismatch.
- pneumothorax or pneumomediastinum[11,18].

Time	PEEP (cm H_2O)	F_IO_2	PaO_2 (mm Hg)	CI (L/ min/m^2)	C_S (mL/ cm H_2O)
11:00	5	0.5	65	3.1	24
11:30	10	0.5	78	3.3	31
12:00	15	0.5	123	3.9	35
12:30	20	0.5	153	3.5	30

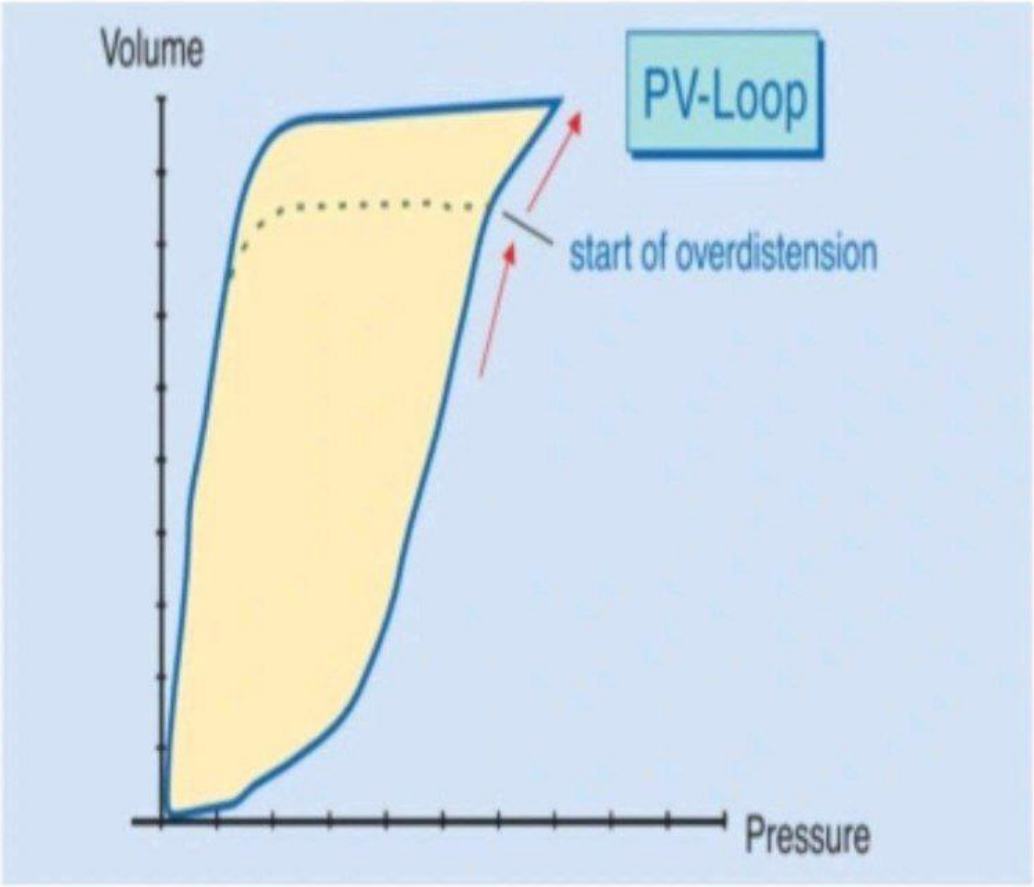
These findings indicate an improvement in parameters up to a PEEP of +15 cm H_2O. At +20 cm H_2O, PEEP, CI, and compliance became worse, suggesting lung overdistention and decreased cardiac output. The use of PEEP in cardiogenic pulmonary edema can improve O_2 transport not only by increasing PaO_2 but also by increasing cardiac output in some cases (see Chapter 16).

4. Correction:

- decrease the set TV or set pressure.
- keep Pplateau less than 30cmH2O.
- accept PHY.
- set the PEEP, CPAP, EPAP and IPAP on appropriate level.
- use PC mode and keep the PIP lower than UIP or less than 35 cmH2O[11,17,18].
- Keep the DP less than 18.



5.Determine by: P-V Loop

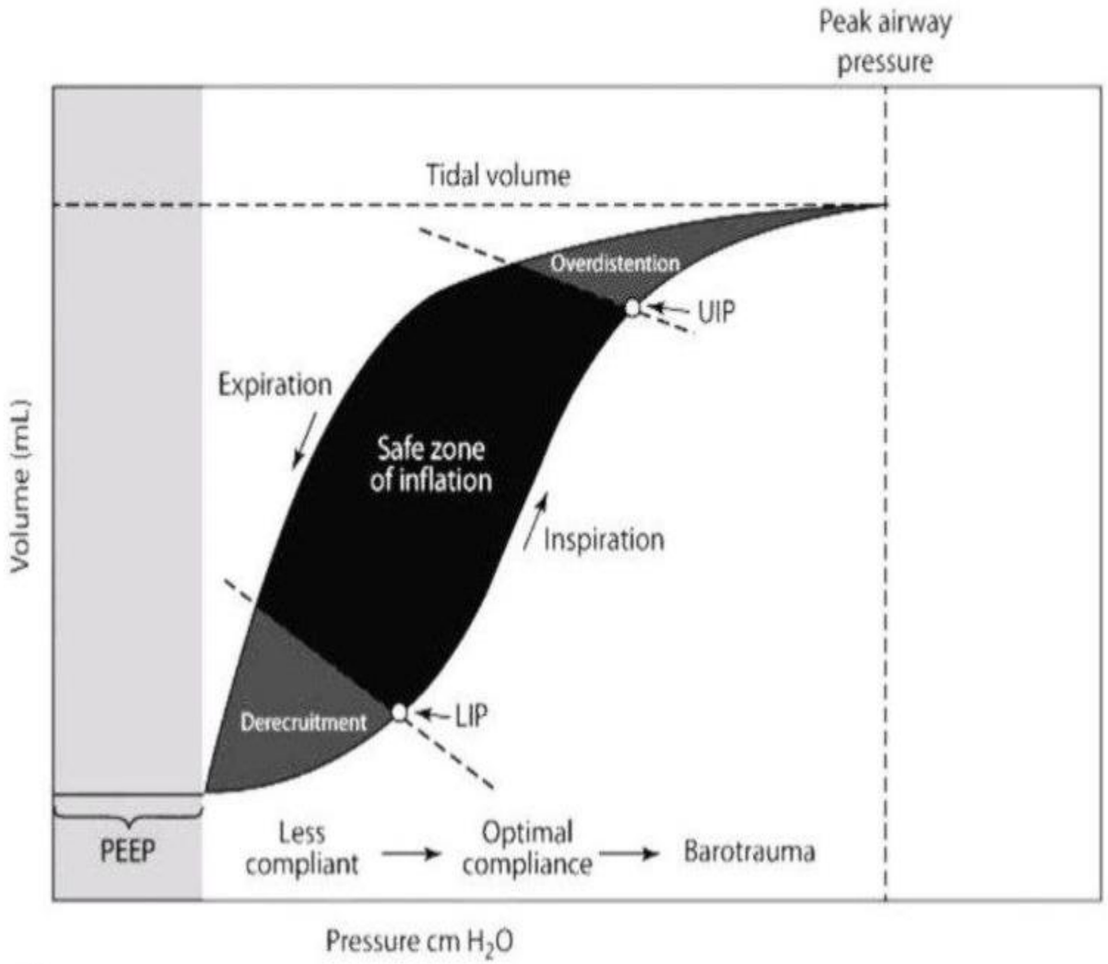


6. Rapid nots:

-lower inflection point ≈ alveolar recruitment.

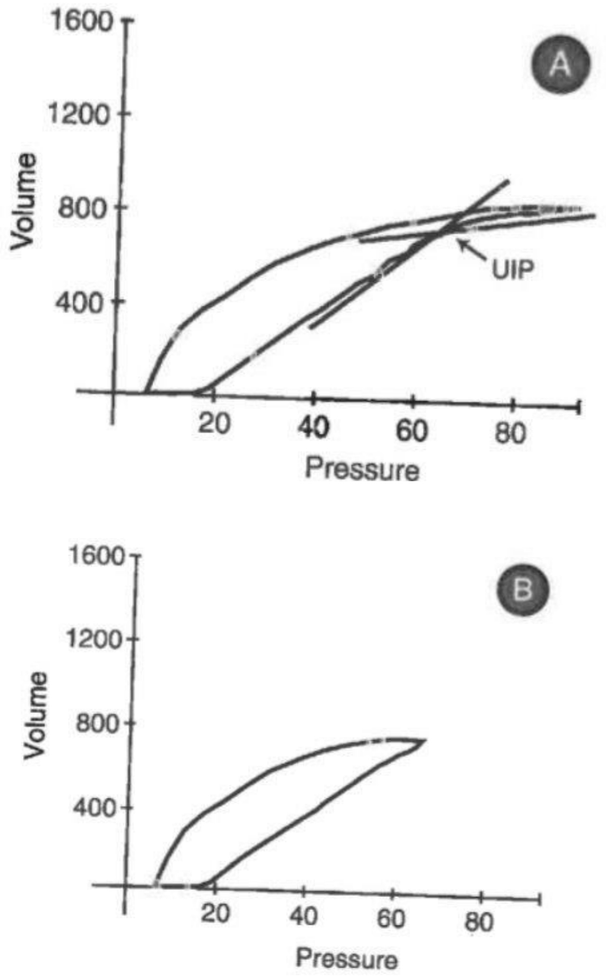
-upper inflection point ≈ allover overdistention.

-PEEP increase + Co2 increase + same TV ≈ lung overdistention is present [11].



- The loop in graph B shows that a small decrease in the set tidal volume produced a large decrease in the PIP.

-This abnormal loop shape is commonly termed beaking and results in a reduced slope having a decreased dynamic compliance[10].



1. lung compliance problems..

1.4 (active exhalation).

1. Definition: the pt exhales more than the inspiratory volume (the pt has to exhale below FRC)[10].

2. Causes:

- severe COPD
- Asthma
- some of paralyzed pt[10,11,19].

3. Side effects:

- increase WOB
- pt discomfort.

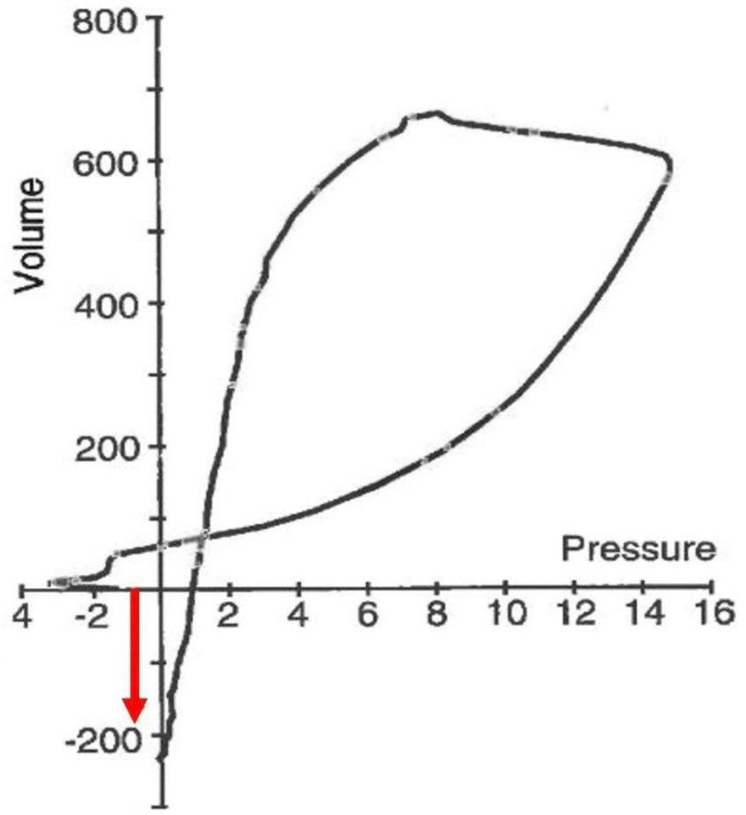
4. Correction: if the pt with air trapping try to decrease the auto-PEEP.

5. Determine by:

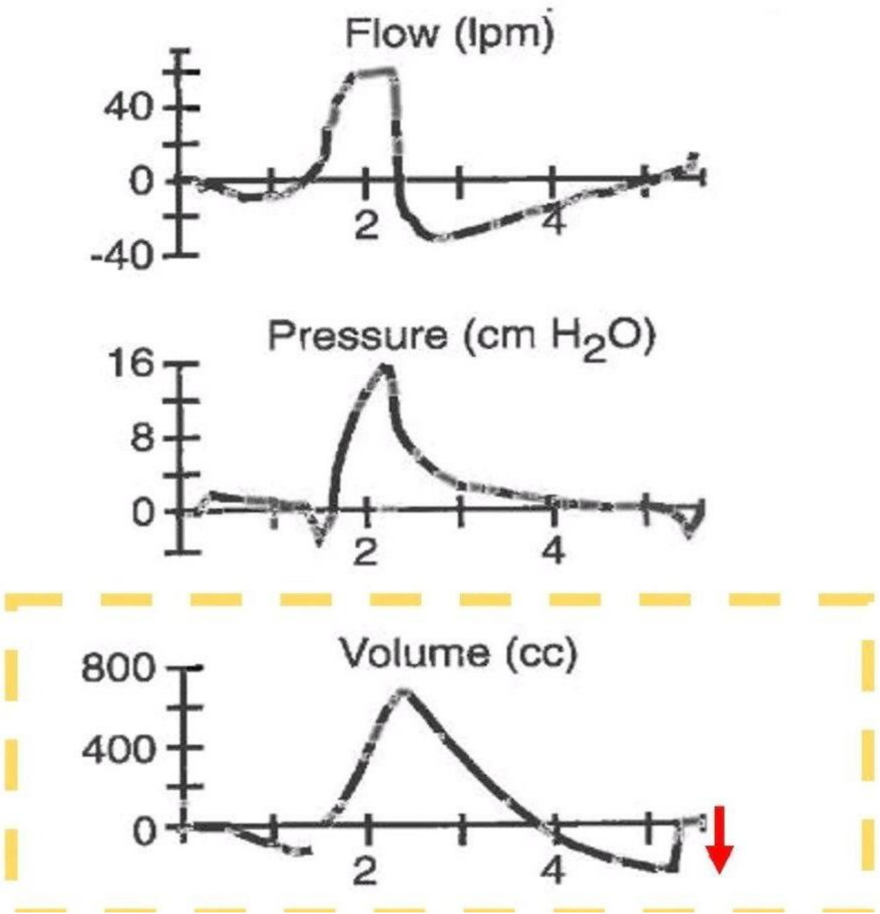
- V-T scalar.
- F-T scalar.
- P-V and F-V loop.

(the P-V, F-V loop and V-T scalar most important)[10,11,19].

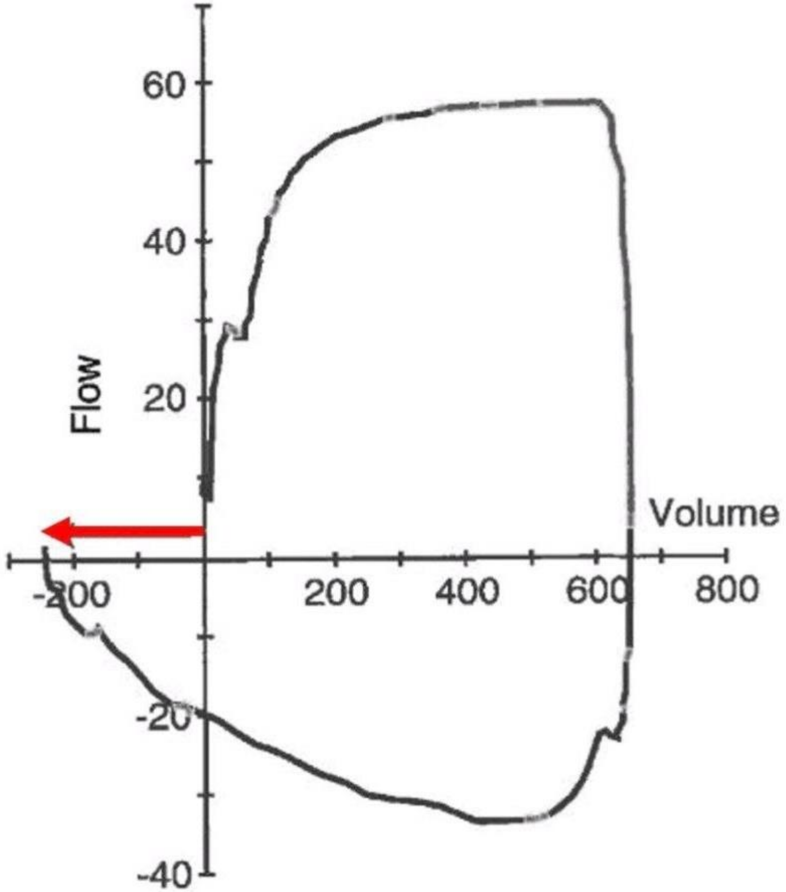
Active exhalation displayed in P-V loop.



Active exhalation displayed in scalars.



Active exhalation displayed in F-V loop.



6. Rapid nots:

- Usually its normal in the clinical setting for example when the pt changes position, experience a twinge of pain and try to cough[10].

- it's not normal if it happens in irregular pattern (pt with air trapping will often show a pattern of an active exhalation occurring every few breaths in attempt to relive the trapped volume)[10].

- the active exhalation usually occur with COPD pt.

- A larger expiratory volume than inspiratory volume on every breath indicates the expiratory flow transducer is out of calibration or some other equipment error exists[10,11].

2- Airway problems..

The changes in the airway that display on Vent Waveform..

2. Airway problems..

2.1 (increase airway resistance).

1. Definition: The resistance to airflow through the conductive airways[11].

2. Causes:

- Secretion.
- ETT problems or condensation in circuit.
- high inspiratory flow, low Ti.
- post intubation swelling or mucosal edema.
- asthma, COPD, bronchospasm.
- pleural effusion.
- foreign body aspiration[10,12,13,14].

3. Side effects:

- increase WOB.
- respiratory muscle fatigue.
- decrease the TV.
- decrease the CO2 elimination.
- increase PIP.
- oxygenation problems[14,12,10,13].

4. Correction:

- reposition the Ett or the pt.
- bronchodilator therapy, steroid administration.
- Suction.
- slow inspiratory flow.
- increase Rise time and Ti.
- treatment the causes if the pt has pleural effusion or pneumothorax[11,14,10].

5. Determine by:

- **P-V loop:**

The movement of the upward inspiratory slope to the right is indicative of <u>inspiratory resistance.</u>

The movement of the downward expiratory slope to the left is indicative of <u>expiratory resistance</u>[14].

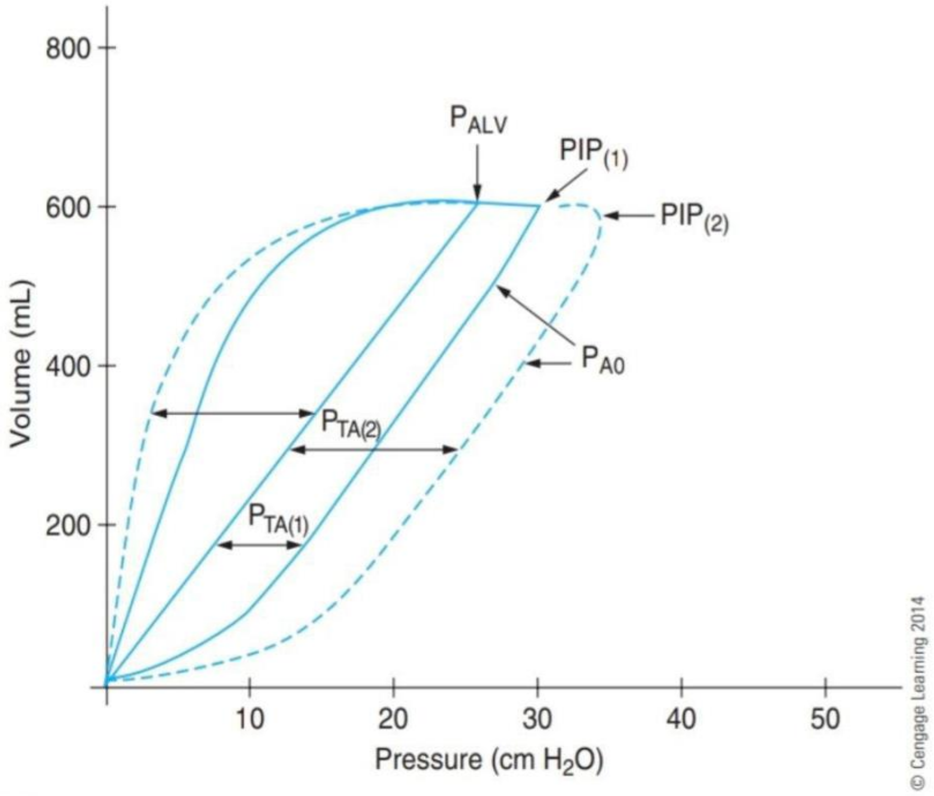


FIGURE 11-40 The effects of airflow resistance on the pressure-volume loop during volume-controlled, constant flow ventilation. An increased airflow resistance causes increase in PIP, inspiratory and expiratory P_{TA}, and P_{AO}. Note that the P_{ALV} is unchanged.

- **F-V loop:**
  decrease peak expiratory flow, concave mid-expiratory flow curve and decrease the TV[14,12].

- **P-T scalar:**
  the difference between PIP and Pplateau more than 5 cmh2o[11,13].

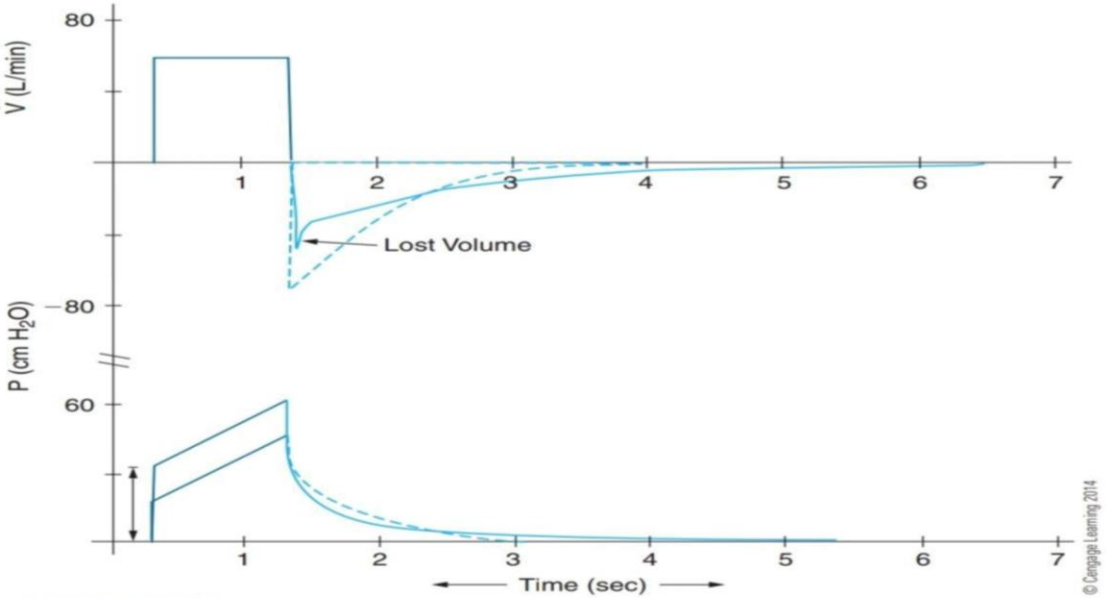


FIGURE 11-32 The effects of normal airflow resistance (dotted lines) and increased airflow resistance (solid lines) on the expiratory flow and pressure-time waveforms. When the airflow resistance is increased, a lower expiratory flow and a higher peak inspiratory pressure are noted.

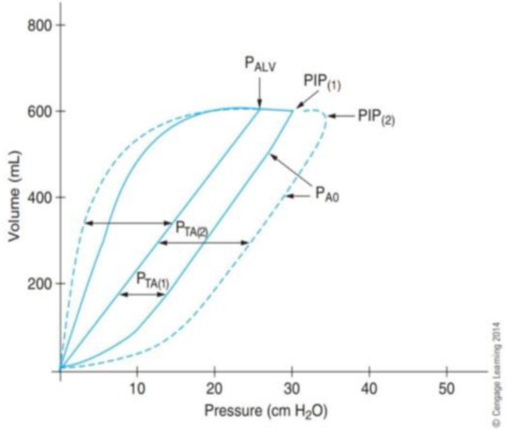


FIGURE 11-40 The effects of airflow resistance on the pressure-volume loop during volume-controlled, constant flow ventilation. An increased airflow resistance causes increase in PIP, inspiratory and expiratory P_{TA}, and P_{AO}. Note that the P_{ALV} is unchanged.

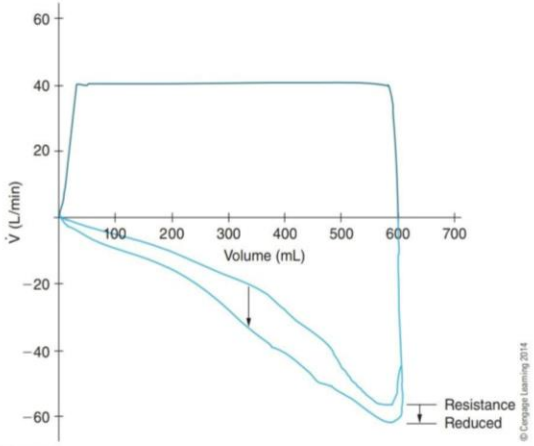


FIGURE 11-43 The effect of airflow resistance on the flow-volume loop. A reduction in airflow resistance increases the peak expiratory flow rate.

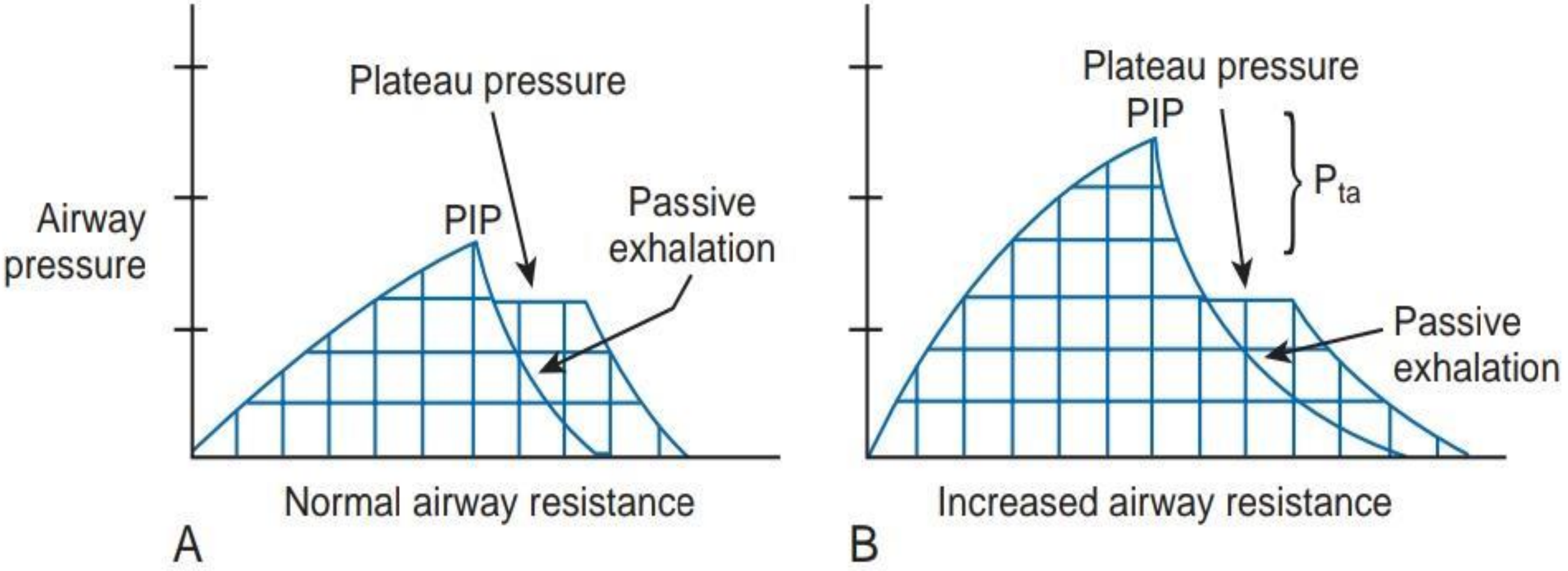
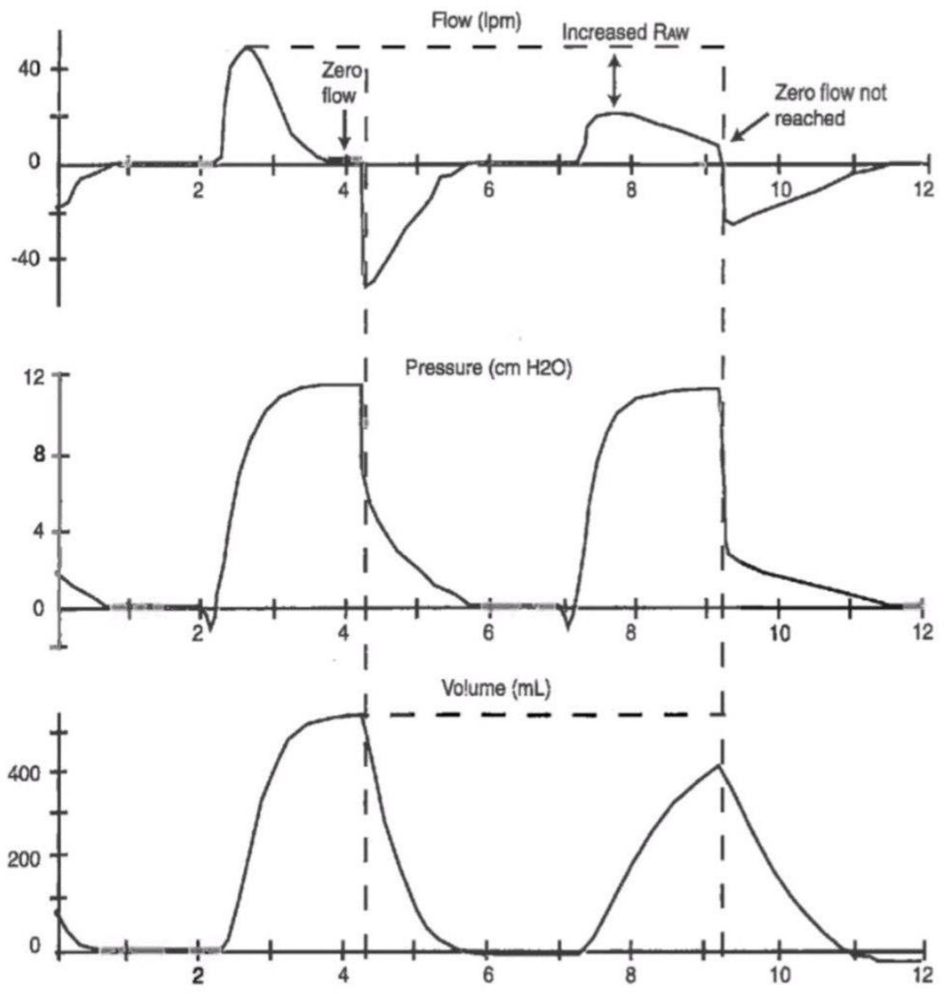


Fig. 16-8 **A,** Normal pressure difference between PIP and $P_{plateau}$, during VC-CMV with a normal R_{aw}. When R_{aw} is increased, the difference between PIP and $P_{plateau}$ is increased (i.e., more pressure goes to the airways [P_{ta}]). **B,** Note that PIP is also increased.

The effect of airway resistance on pressure- targeted ventilation.

- **F-T scalar:**
  normal, PEF decrease, EF decrease and the time for expiration is prolonged[14].

- **V-T scalar:**
  decrease the TV or increase the time for volume empty[14,10].



The effect of increase airway resistance on volume-targeted breaths.

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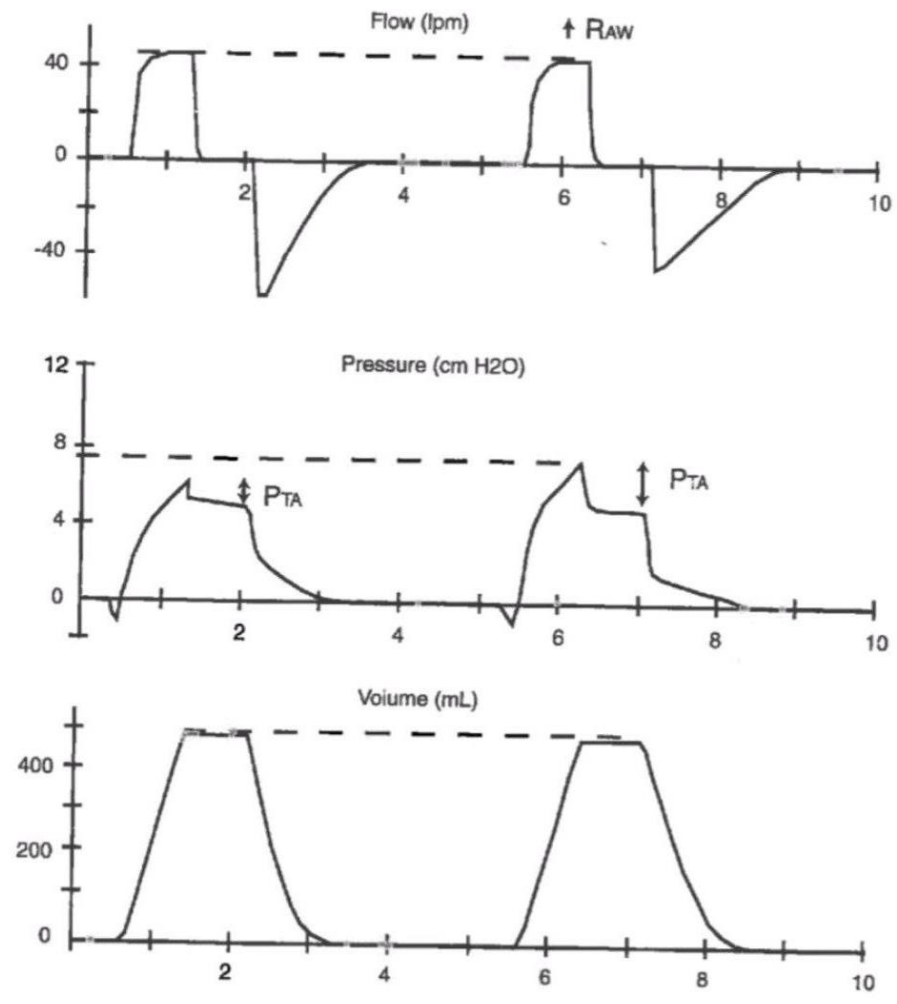
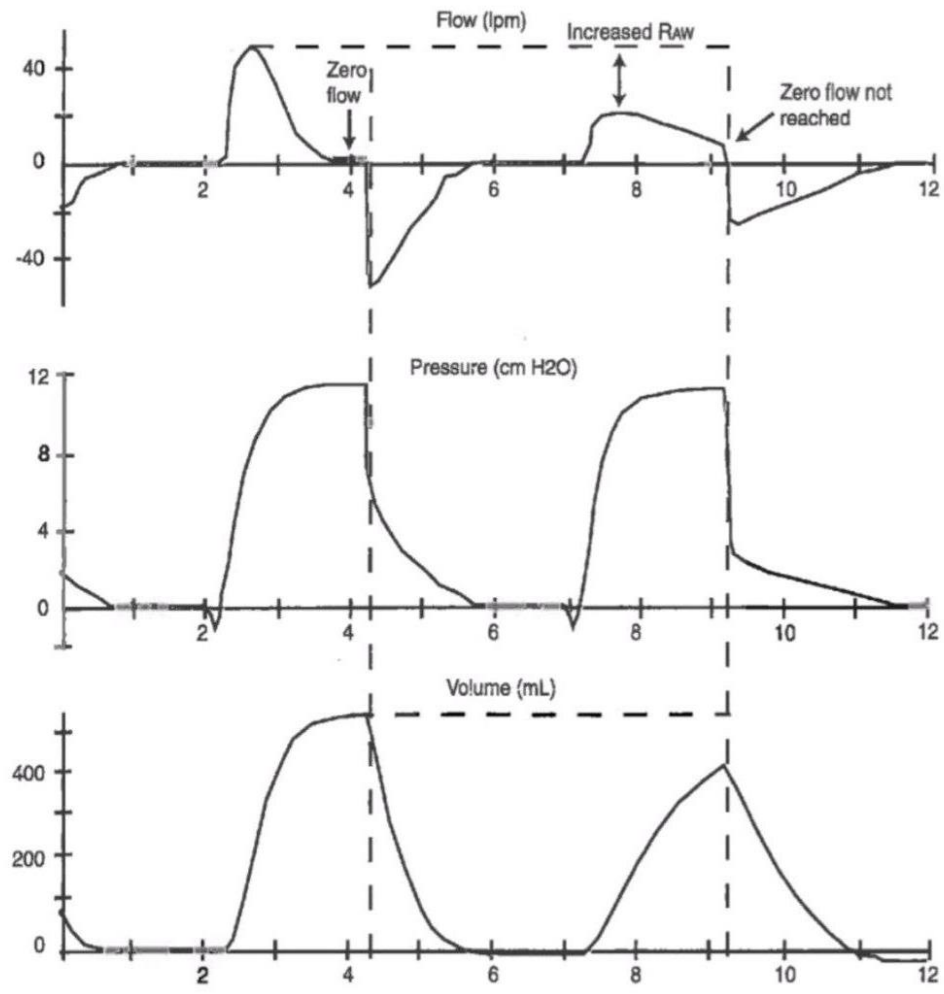


The effect of airway resistance on pressure- targeted ventilation.



6. Rapid nots:

-The normal range for airway resistance:

Normal : 0.6_2.4.

Vent pt ≈ 5_7 cm h2o/l/s.

In conscious, un-intubated subjects with emphysema and asthma, resistance may range from 13 to 18 cm H2O/(L/s)[11].

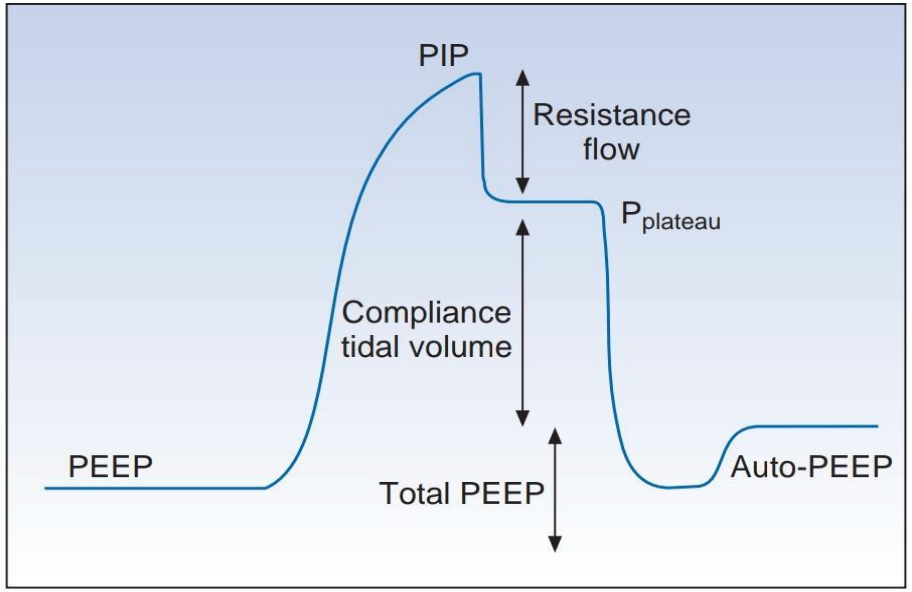


Fig. 8-3 Airway pressure waveform during volume control ventilation. An end-inspiratory breath hold and an end-expiratory breath hold are applied to measure the plateau pleasure and the auto-PEEP, respectively. Note the difference between the peak inspiratory pressure (PIP) and the plateau pressure ($P_{plateau}$); this is the transairway pressure (P_{TA}), which is produced by the interaction of the set flow and airway resistance. The V_T is the product of the pressure difference between $P_{plateau}$ and total PEEP (set PEEP and auto-PEEP) and lung compliance. (From Hess DR, MacIntyre NR, Mishoe SC, et al: Respiratory care principles and practice, Philadelphia, 2002, WB Saunders.)

$$Raw = \frac{PTA}{flow} = \frac{PIP - Pplateau}{flow} \quad (cm\ H2O/[L/s])$$

-The Resistance: measurement of the frictional forces that must be overcome during breathing.

These frictional forces are the result of:

A- anatomical structure of the airways

B- the tissue viscous resistance offered by the lungs and adjacent tissues and organs.

Tissue resistance > ascites, fluid buildup in the peritoneal cavity, obese and fibrosis[11].

-The resistance depends on (Poiseuille's law):

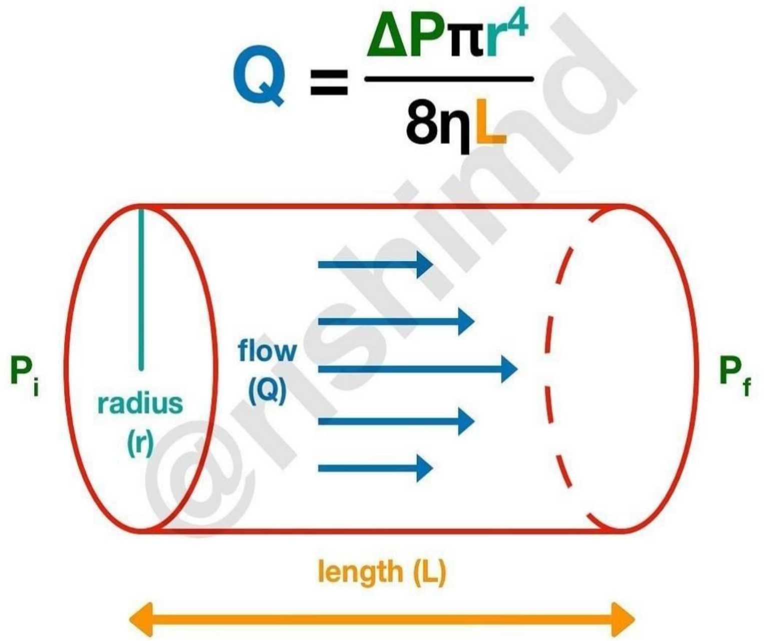
A- gas viscosity.

B- gas density.

C- length and diameter of the tube.

D- flow rate[11].

POISEUILLE'S LAW



Q	Flow rate
P	Pressure
r	Radius
η	Fluid viscosity
l	Length of tubing

2. Airway problems..

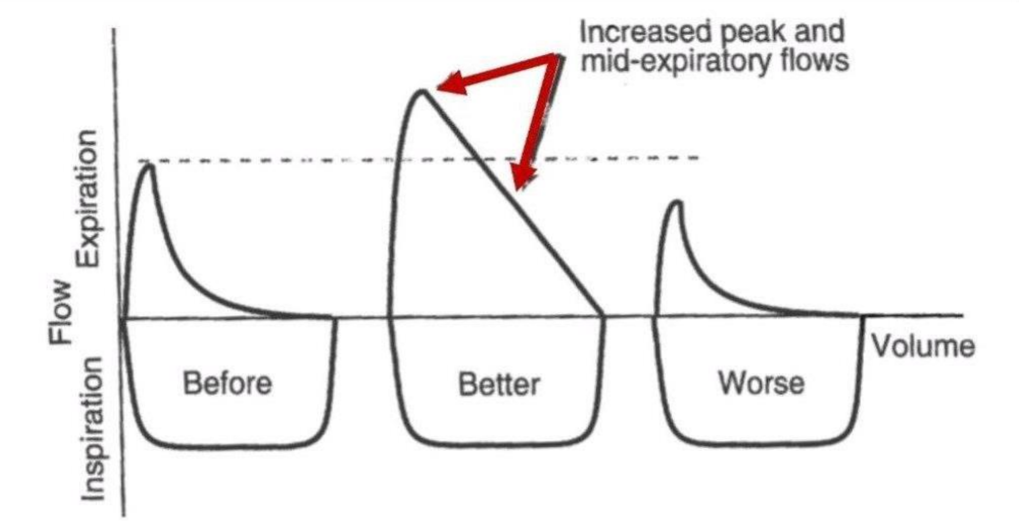
2.2 (bronchodilator effect assessment).

1. The bronchodilator effect Determine by:

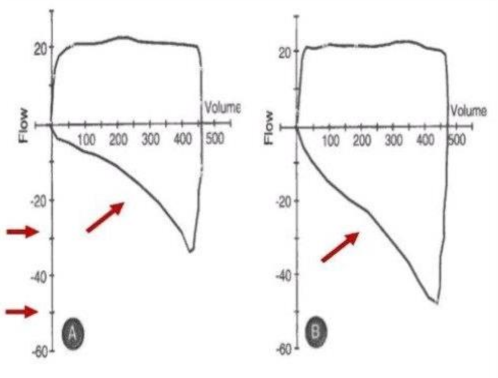
- **F-V LOOP** (Most important):
  - increase the peak expiratory flow rate.
  - increase mid expiratory flow rate [10].

- **P-V LOOP:**
  - decrease loop hysteresis [10].

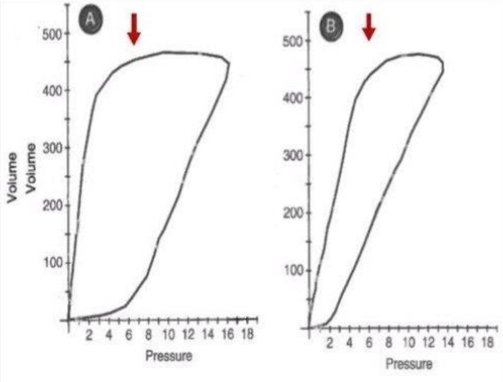
The bronchodilator effect on vent waveform:



Indicators of airway improvement in the F-V loop as result of response to bronchodilator.



Pre and post bronchodilator F-V loops of VC mode.



Pre and post bronchodilator p-v loops of VC mode.

- **F-T SCALAR:**
  - increase the peak expiratory flow rate.
  - increase mid expiratory flow rate.
  - prolonged expiratory flow [10,13].

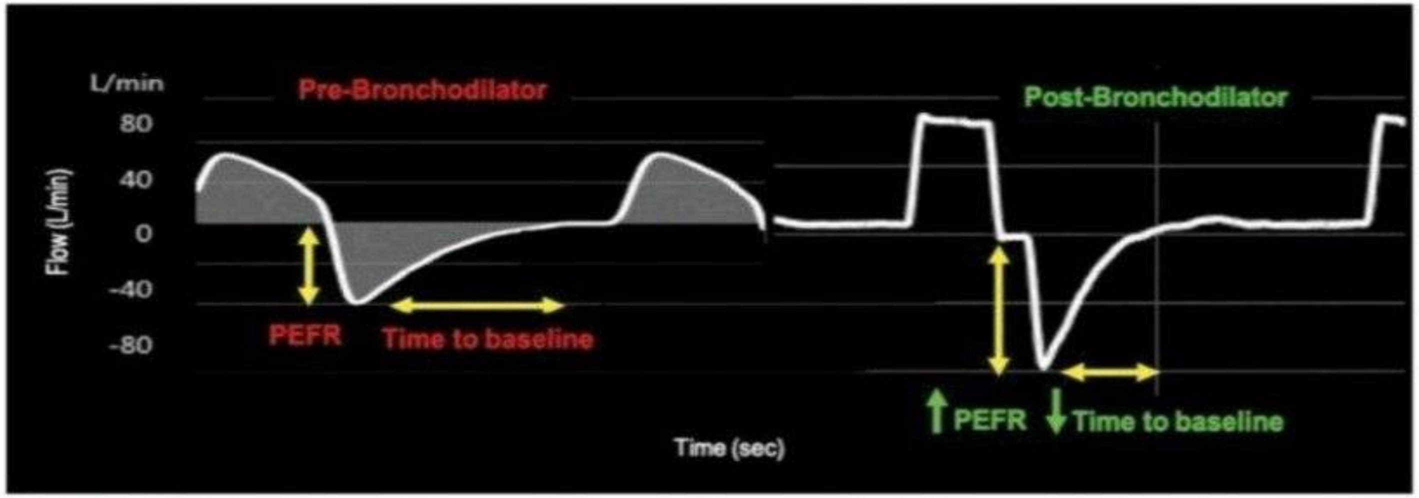


FIGURE 7-7 The presence of airway obstruction typically results in decreased peak expiratory flow rate (PEFR) and a prolonged expiratory flow (left). A positive response to bronchodilator administration (right) increases PEFR and shortens the time it takes for the expiratory flow tracing to return to baseline.

Description

Increase airway resistance | **Bronchodilator effect** | Air-trapping | ETT Kink

2. The effect of bronchodilator:

- Higher peak inspiratory flow.
- Lower plateau pressure.
- Higher peak expiratory flow.
- Shorter time to exhale.
- A shorter expiratory time constant.
- decrease in auto-PEEP.
- increase the TV in PC mode[10,13,19].

Bronchodilator effect on F-T scalar and F-V loop:

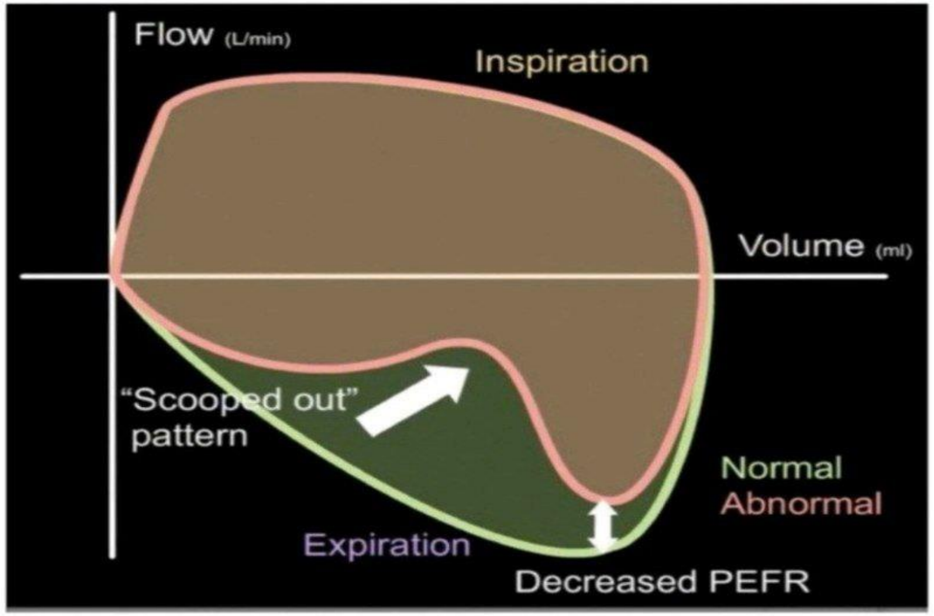


FIGURE 7-24 Typical scooping of the expiratory tracing of the flow-volume loop and decreased peak expiratory flow rate (PEFR) observed on patients with airway obstruction.
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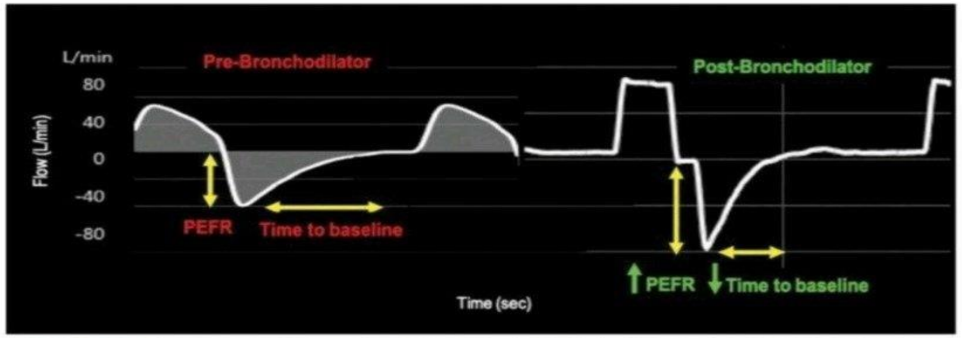


FIGURE 7-7 The presence of airway obstruction typically results in decreased peak expiratory flow rate (PEFR) and a prolonged expiratory flow (left). A positive response to bronchodilator administration (right) increases PEFR and shortens the time it takes for the expiratory flow tracing to return to baseline.
The Bellavista images are © 2019 Vyaire Medical, Inc.; Used with permission.
Description

3. Rapid nots:

- Lack of response to bronchodilator may indicate that increased airways resistance is not due to bronchospasm. Airway narrowing may be due to fluid in the airways or swelling of the mucosa due to an inflammatory process not responsive to beta 2 agonists, or parasympatholytic agonist. Pre- and post-loops after a trial of steroids may be helpful for guiding therapy [10].

- A post-drug loop that is worse than the pre-drug loop may indicate the patient is reacting to the drug propellent or preservative[10].

- Pre- and post loops can also be used for assessing which type of bronchodilator works best for a particular patient or if some combination of drugs has a superior effect[10].

- The two major changes that indicate improvement are an increased peak expiratory flow rate and an increased mid-expiratory flow rate.

- Treatment of acute severe asthma (status asthmatics):

- ✓ Hospital admission.
- ✓ Oxygen (Spo2 94-98%).
- ✓ Beta 2 agonists: use high dose by inhalation.
- ✓ Add ipratropium bromide by inhalation to the beta 2 agonist.
- ✓ Hydrocortisone: 200 mg I.V. /6h.
- ✓ Consider a single dose of IV magnesium sulfate (1.2-2 g over 20 min) to patients who failed to respond to initial inhaled bronchodilator therapy
- ✓ Correction of acidosis and dehydration by i.v. fluids [20].

2. Airway problems..

2.3 (air trapping).

1. the physiological factors that lead to Auto-PEEP:

- **auto-peep due to early small airway collapse:**
  Lung diseases that cause destruction of normal airway structure result in tissue being replaced by scar tissue that collapses more easily during expiration[10,11].

- **auto-peep due to dynamic hyperinflation:**
  occurs when the respiratory rate does not allow sufficient time for complete exhalation before the next breath [10,11].

- **the expiratory muscles are actively contracting during exhalation**[11].

Increase airway resistance | Bronchodilator effect | Air-trapping | ETT Kink

BOX 7-1 Definitions of Positive End-Expiratory Pressure (PEEP)

PEEP = Positive end-expiratory pressure; airway pressure greater than zero at the end of exhalation

Extrinsic PEEP ($PEEP_E$) = the level of PEEP set by the operator on the ventilator

Auto-PEEP (Intrinsic PEEP, or $PEEP_I$) = the amount of pressure in the lungs at the end of exhalation when expiration is incomplete (i.e., expiratory flow is still occurring) and no $PEEP_E$ is present ($PEEP_E$ is excluded from this value)

Intrinsic PEEP can occur in three situations: (1) strong active expiration, often with normal or even with low lung volumes (e.g., Valsalva maneuver); (2) high minute ventilation (>20 L/min), where expiratory time (T_E) is too short to allow exhalation to functional residual capacity; or (3) expiratory flow limitation due to increased airway resistance, as may occur in patients with chronic obstructive pulmonary disease on mechanical ventilation or with small endotracheal tubes or obstructed (clogged) expiratory filters.

Total PEEP = $PEEP_E$ + auto-PEEP

2. Caused by:

- high Mv, RR, Tv and Ti.
- low TE and inspiratory flow.
- inverse ratio and Reverse triggering.
- Increased Raw (small ET, bronchospasm, secretions and mucosal edema).
- COPD and asthma.
- Increased lung compliance.
- Age more than 60 years.
- Increased intra-abdominal pressure and A large pleural effusion>
- pt vent asynchrony[10,11,12,13,14,19,21].

3. side effect:

- increase WOB, decrease venous return and C.O.
- Barotrauma, alveolar overinflated and tension pneumothorax.
- missed-trigger asynchrony.
- respiratory muscle fatigue[11,12,13,21].

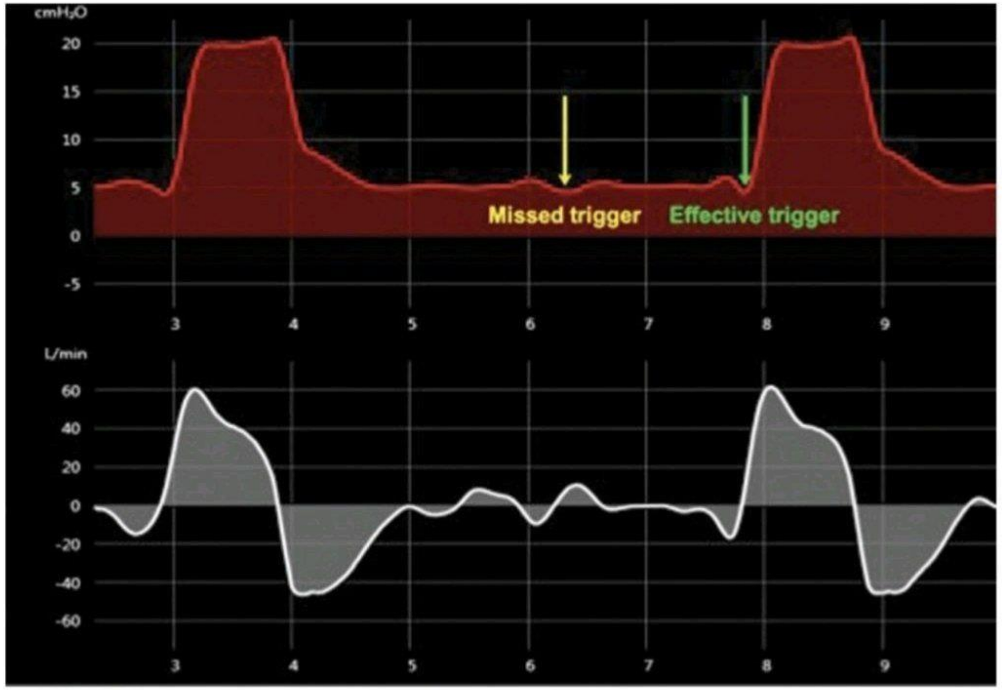


FIGURE 7-33 Pressure-time and flow-time (F-T) scalars showing trigger asynchrony. An inspiratory effort (yellow arrow) is not followed by delivery of a mechanical breath (missed trigger). The F-T displays small spontaneous fluctuations of flow compared to flow characteristics of two mechanical breaths. Paw, airway pressure.

Description

4: correction:

- PEEPe.
- increase inspiratory flow and Te.
- decrease RR, Ti and TV.
- large ET.
- SIMV, CPAP, PS and APRV
- decrease RAW by bronchodilator or Suction[10,11,12,13,21].

5. auto-peep determine by:

- **F-T curve** (most important):
  the expiratory flow does not return to zero before the next inspiration begins[10].

- **P-T curve:**
  when an expiratory hold is employed.
  During the hold, baseline pressure line rises to the auto-PEEP level[13].

The effect of air trapping on ventilator waveform

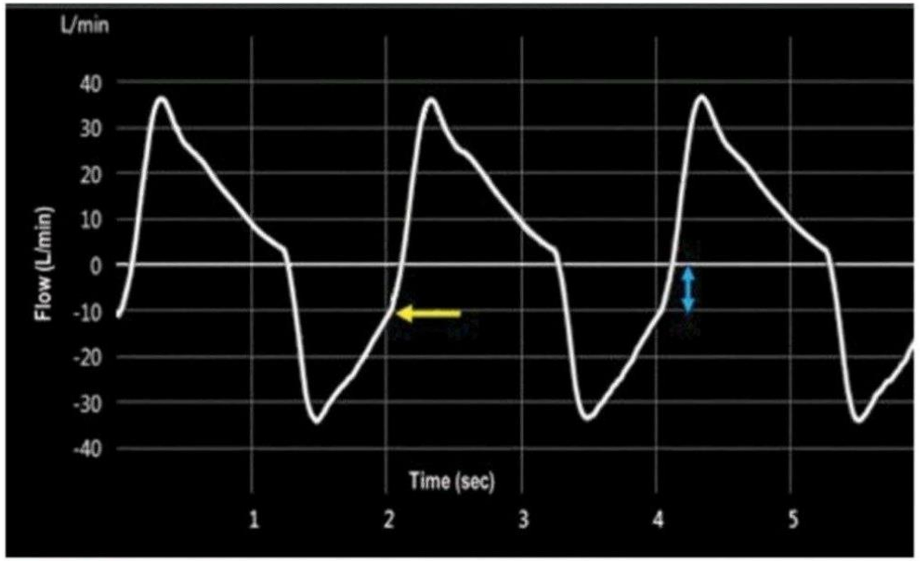


FIGURE 7-8 Flow-time scalar displaying a descending ramp flow pattern. Expiratory flow fails to return to zero before the next breath (yellow arrow) is delivered. The magnitude of trapping is indicated by the blue arrow.

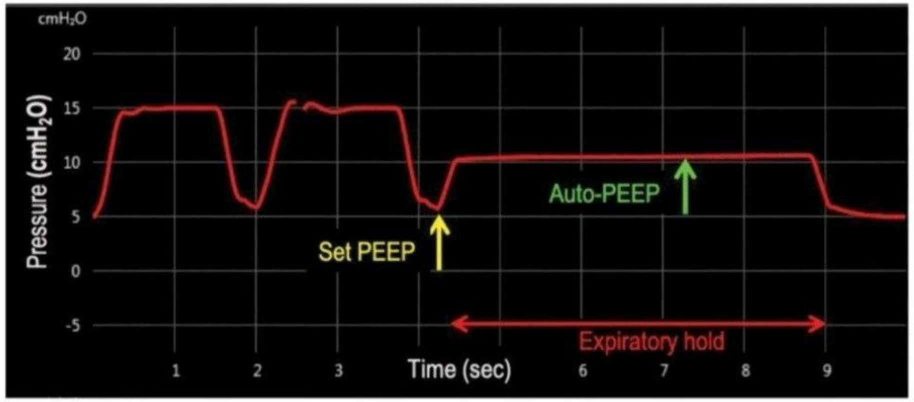


FIGURE 7-15 Pressure-time waveform showing a set/machine positive end-expiratory pressure (PEEP) of

Increase airway resistance | Bronchodilator effect | **Air-trapping** | ETT Kink

Increase airway resistance | Bronchodilator effect | **Air-trapping** | ETT Kink

- **F-V LOOP:**
  the expiratory volume < inspiratory volume[10,14].

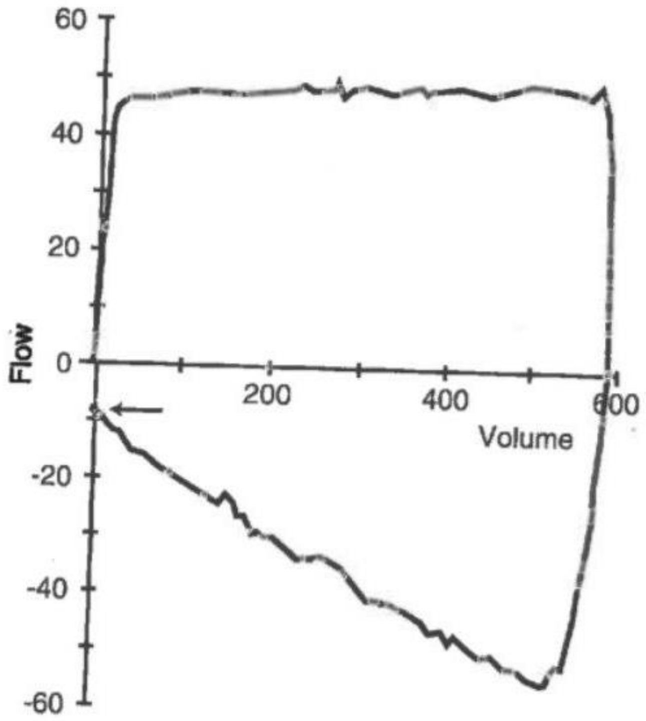


Figure 5-14. Air-trapping identified in the F-V loop of a volume-targeted breath.

6. Rapid nots:

- If dynamic hyperinflation is due to an excessive patient triggered respiratory rate it may be helpful to switch to SIMV mode or if necessary, sedate the patient[10].

- If a high respiratory rate is necessary and dynamic hyperinflation occurs, especially when bronchospasm is also present, increasing the inspiratory flow rate may yield improvement by extending the time for exhalation.[10].

- Auto-PEEP associated with premature airway collapse is more likely to resolve with applied (external, therapeutic) PEEP than other causes of auto-PEEP[11,12].

- the patient should be sedated or paralyzed to measure auto-PEEP. In addition, there should be no circuit leaks when making the auto-PEEP measurement[11].

2. Airway problems..

2.4 (ETT Kink).

1. Side effects:

- Patient suffocation, cardiac arrest.
- low TV reach to the pt.
- increase the WOB and PIP.

2. Determine by:

- **V-P LOOP:**

  Hysteresis + high pip + low TV[10,13]

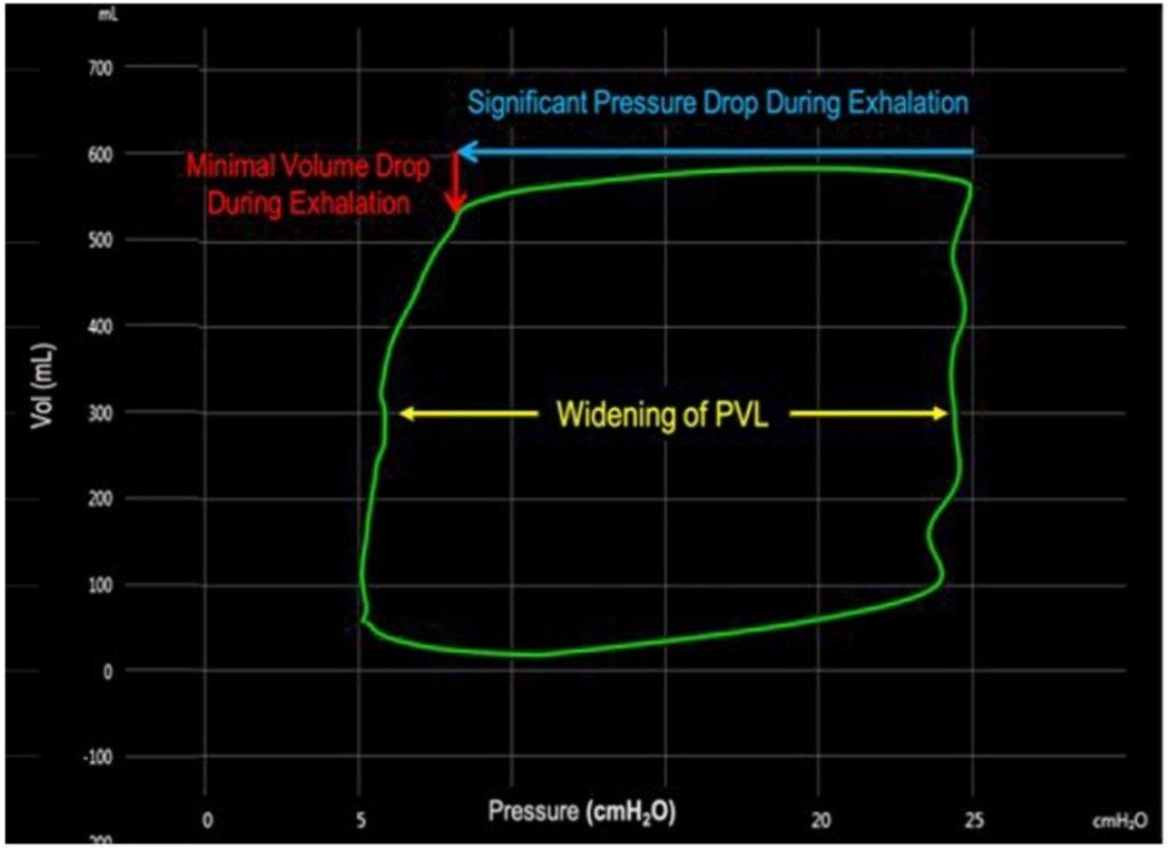


FIGURE 7-20 Pressure-volume loop (PVL) waveform widening of the loop (increased hysteresis). As the exhalation valve opens, airway pressure drops (blue arrow), but expiratory volume does not decrease at the same rate (red arrow) due to air trapping.

Description

3. Correction:

- Reposition the pt head.
- Reposition the tube.
- Change the ETT or TT.
- Make sure you have performed a suction for the patient[10,13].

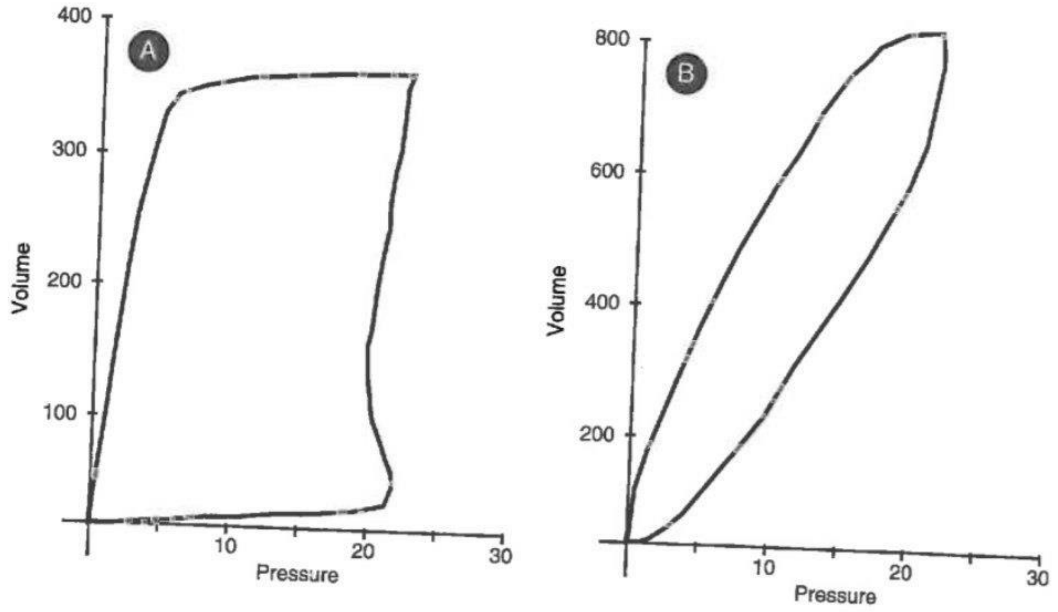


Figure 5-18. The effect of a kinked endotracheal tube on the P-V loop during pressure-targeted ventilation.

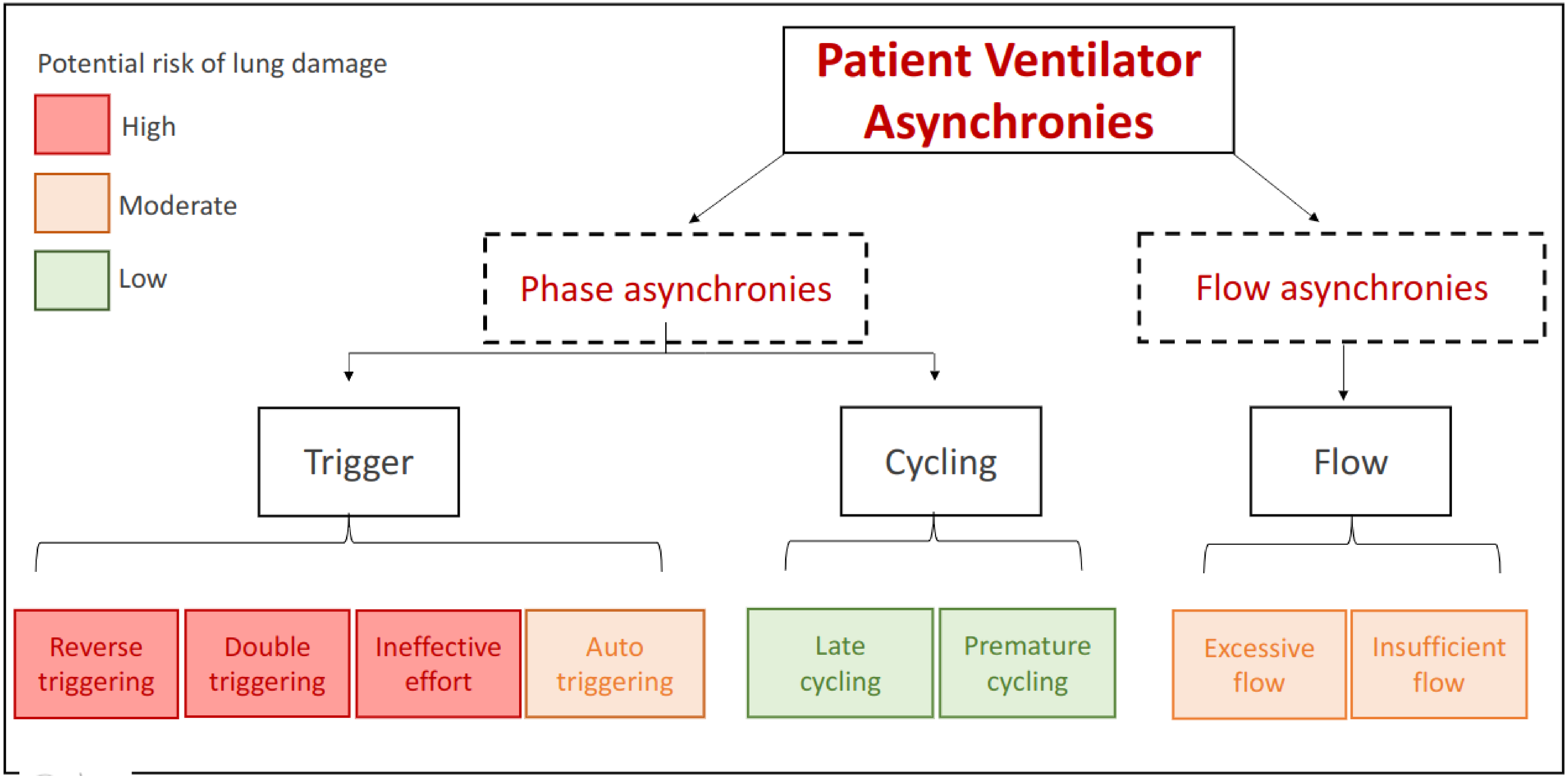
4. Rapid nots:

- the most important way to determine if the pt has kink the tube or not: Insert the Suction catheter >

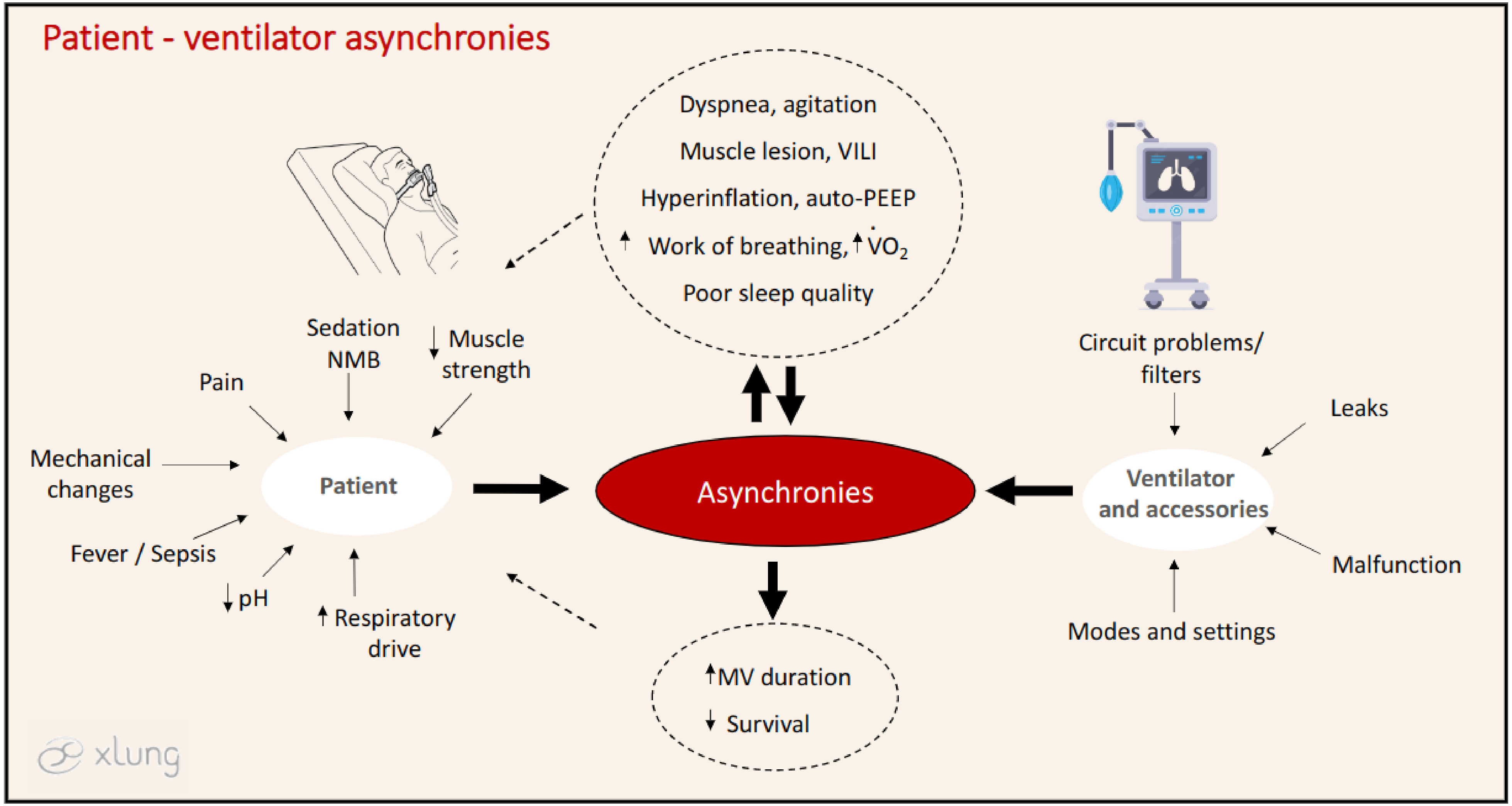
1. not pass through the ETT: ETT kink
2. pass through ETT: ETT normal
3. pass through ETT with resistance: suspect the ETT kink.

- partially obstruction the airway can caused also by dried secretion or blood in the lumen[10].

3- Pt-vent asynchrony..


Potential risk of lung damage
High
Moderate
Low
Patient Ventilator Asynchronies
Phase asynchronies
Flow asynchronies
Trigger
Cycling
Flow
Reverse triggering
Double triggering
Ineffective effort
Auto triggering
Late cycling
Premature cycling
Excessive flow
Insufficient flow

Trigger asynchrony | Cycle asynchrony | Flow asynchrony



3. Pt-vent asynchrony..

3.1 (trigger asynchrony).

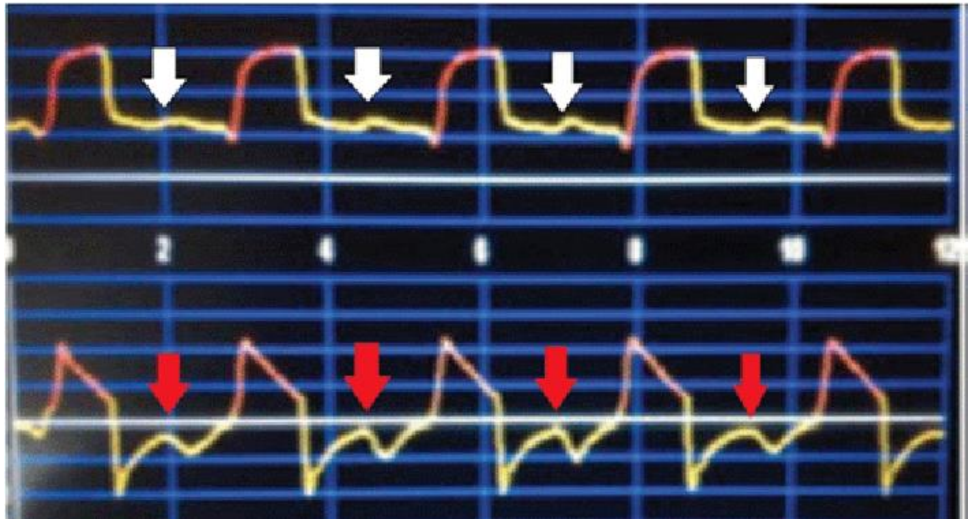
3. Pt-vent asynchrony..

3.1 (trigger asynchrony).

3.3.1 (Ineffective effort).

1. Definition: Missed trigger, Wasted efforts.
Respiratory muscular effort which is insufficient to initiate mechanical breath[1,2,3].

2. Determine by:
- F-T scalar.
- P-T scalar.



(Manifests as a decrease in airway pressure associated with a simultaneous increase in airflow).

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Ineffective effort | Auto-trigger | Reverse trigger | Double trigger

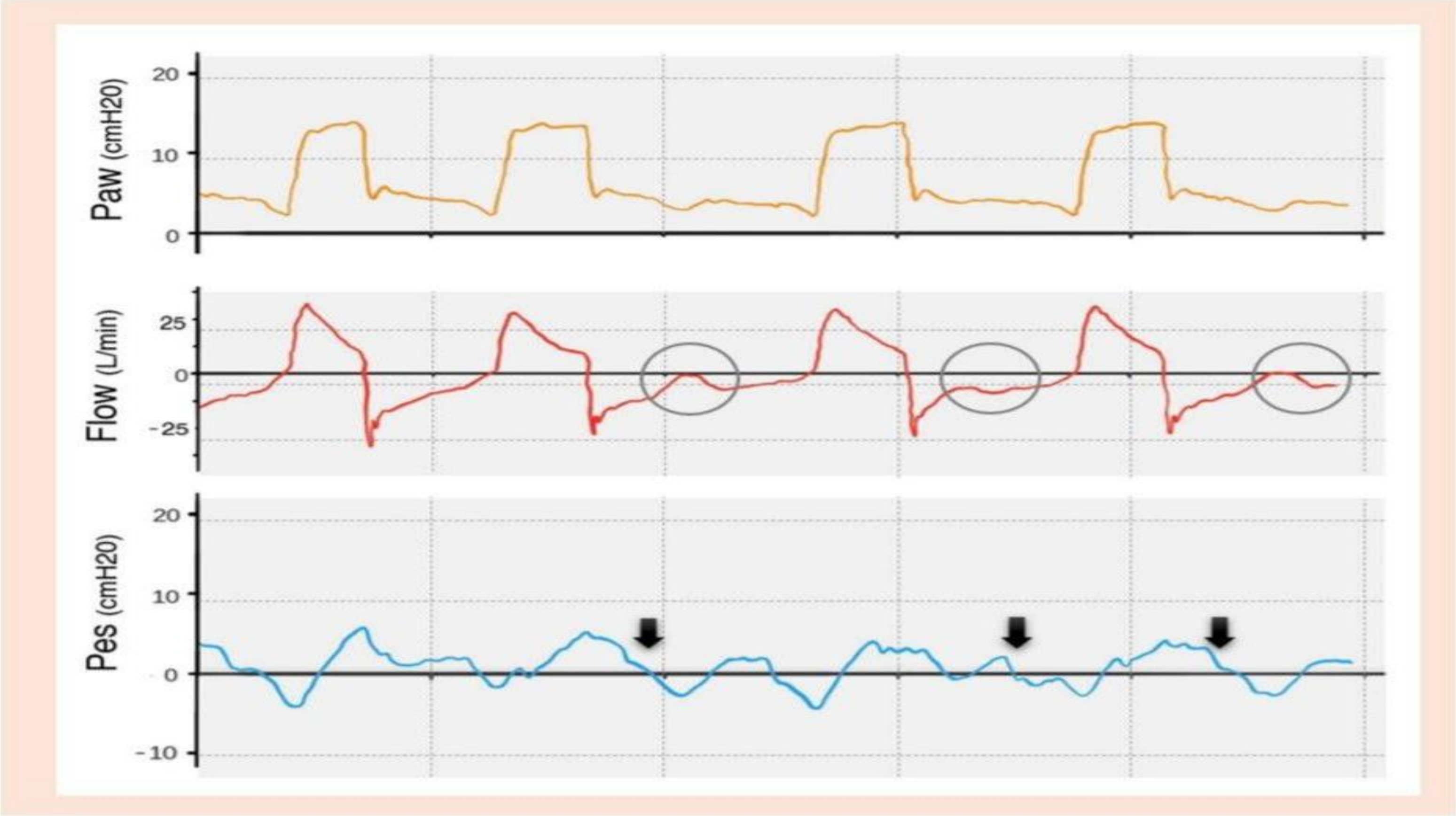


Figure 2. Ineffective trigger—only discrete alterations may be present, such as negative deflection in the pressure scalar or a positive deflection in the expiratory flow curve with no subsequent mechanical breath (circled areas). In this particular scenario, the simultaneous negative deflections depicted in the Pes curve indicate that these correspond to the patient's active inspiratory, but there are unsuccessful efforts (arrows). Pes: esophageal pressure.

3. Causes:

Patient:

- muscle weakness, diaphragmatic atrophy.
- blunted respiratory drive due to sedation or neurological problems, including the use of sedatives and neuro-muscular blockers.
- presence of auto-PEEP with dynamic hyperinflation, especially in patients with COPD[1].

<u>the ventilator:</u>

- problems in the ventilator trigger function (sensitivity too low).
- ↑ respiratory rate with ↓ time for expiration.
- poorly programmed external PEEP.
- obstructions in HME filters, circuits, or tube.
- over assistance (too large of volume or pressure delivered leading to auto-PEEP)[1,2,3,4].

4. correction:

- titrate peep and sensitivity (depend on the cause).
- Try to decrease the auto-peep by increase the Te or bronchodilator.
- Reducing the depth of sedation and aiming at a target Richmond Agitation-Sedation Score (RASS) score of between −2 and 0 is another option to enhance the patient's respiratory drive and thus ease effective triggering.
- If the pt has secretion try to do suction[3]

5. Rapid nots:

- This type of PVA is common in patients with (COPD).
- Ineffective effort consider the most frequent PVAs observed in the ICU.
- patients with diaphragmatic atrophy (prolonged neuromuscular blockade and/or prolonged controlled mechanical ventilation) or dysfunction, as in certain neuromuscular diseases, may impair the patient's ability to generate enough strength to trigger the ventilator[2,3,4].

- the addition of extrinsic PEEP aids the weaning of patients with autoPEEP.
- In these patients, if no external PEEP is applied, the inspiratory effort needed to trigger the ventilator is higher (from the value of autoPEEP present to the trigger threshold).
- In contrast, if external PEEP is set (below the autoPEEP present), then the inspiratory effort required will be less pronounced (the decrease in the amplitude of the effort is equal to the set external PEEP)[3].

- leading to reduced work of breathing and less frequent ineffective inspiratory efforts[3].

3. Pt-vent asynchrony..

3.1 (trigger asynchrony).

3.3.2 (Auto-trigger).

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

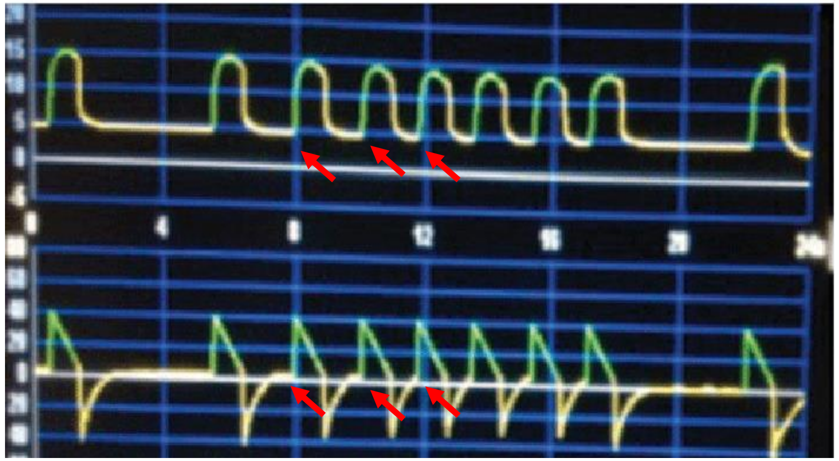
Ineffective effort | Auto-trigger | Reverse trigger | Double trigger

1. Definition:

Assisted breaths delivered which were not patient triggered.

2. Determine by:

- F-T scalar
- P-T scalar
- V-T scalar



- Note that there is <u>no drop of the airway pressure in the pressure/time waveform (Upper waveform)</u> at the beginning of the inspiratory phase which means that the breaths are not patient triggered[2]

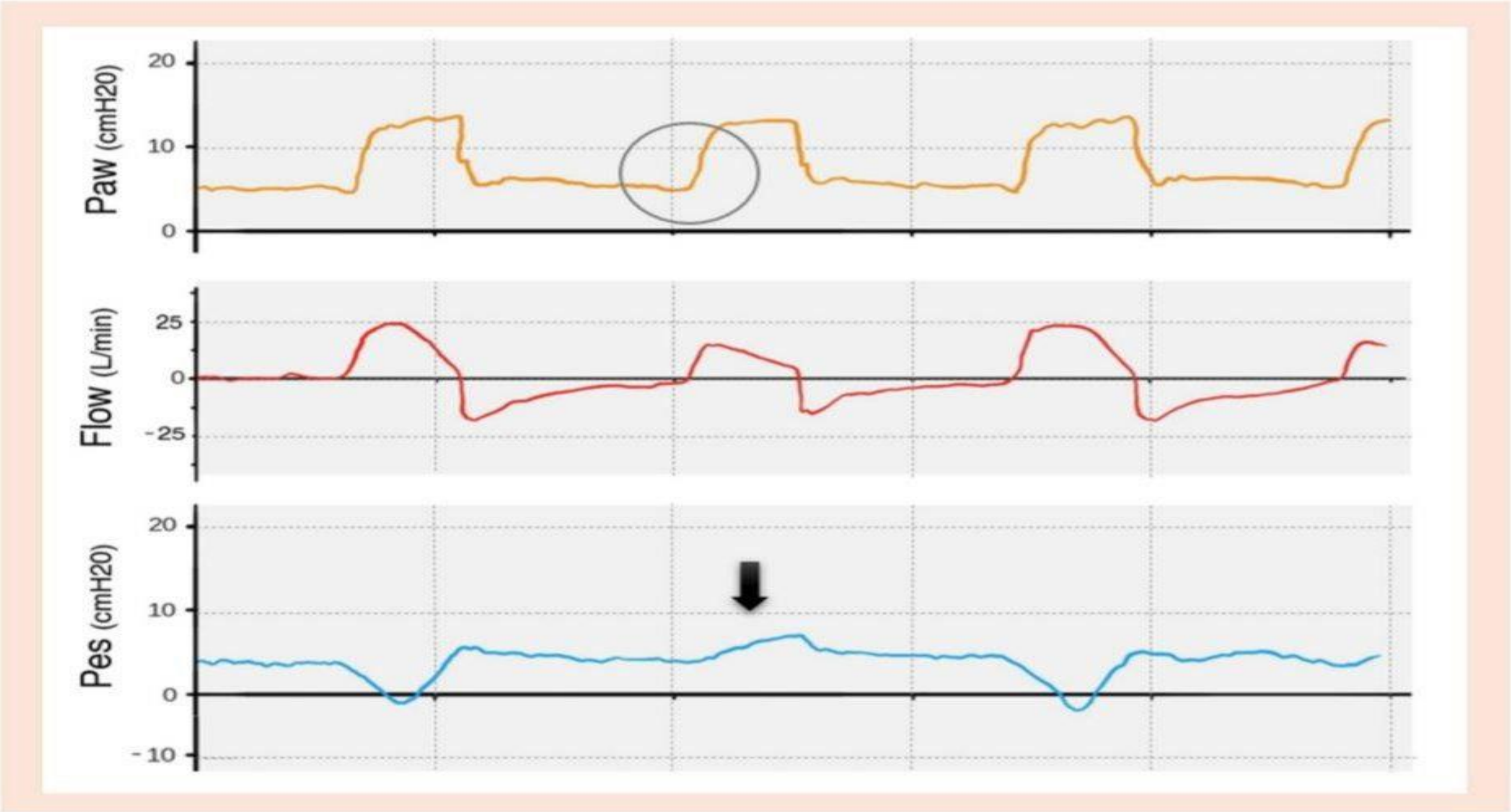


Figure 3. Autotriggera—a high degree of clinical suspicion is required to detect the presence of autotrigger. The presence of mechanical breaths without a previous effort by the patient, i.e., with the absence of negative deflection in the pressure (circled area) and the Pes (small arrow) waveforms, strongly suggests it. Its occurrence simultaneous with the patient's heart rate may indicate strong cardiac oscillations as one of the possible causes. Pes: esophageal pressure.

3. Causes:

- Secretion and Fluid in circuit, ETT or airway.
- Leak.
- cardiac oscillations.
- low trigger threshold.
- hiccups.
- chest drains with high negative pressure[1,2,3,4].

4. Correction:

- circuit cleaning.
- adjust the trigger setting or shift the pt to pressure trigger.
- Correct the leak[3].

5. Rapid nots:

- There are 2 techniques to help diagnose this:

-First is to assess P mus in the patient. Observe the neck muscles for evidence of effort, look at the abdomen, and place your hand on the patient[4].

-The second is to do an end-expiratory pause and observe for patient effort and for negative deflections in the airway pressure, a manifestation of P-mus[4].

- Auto-triggering is more frequent in flow-trigger settings.

3. Pt-vent asynchrony..

3.1 (trigger asynchrony).

3.3.2 (reverse-trigger).

1. Definition:

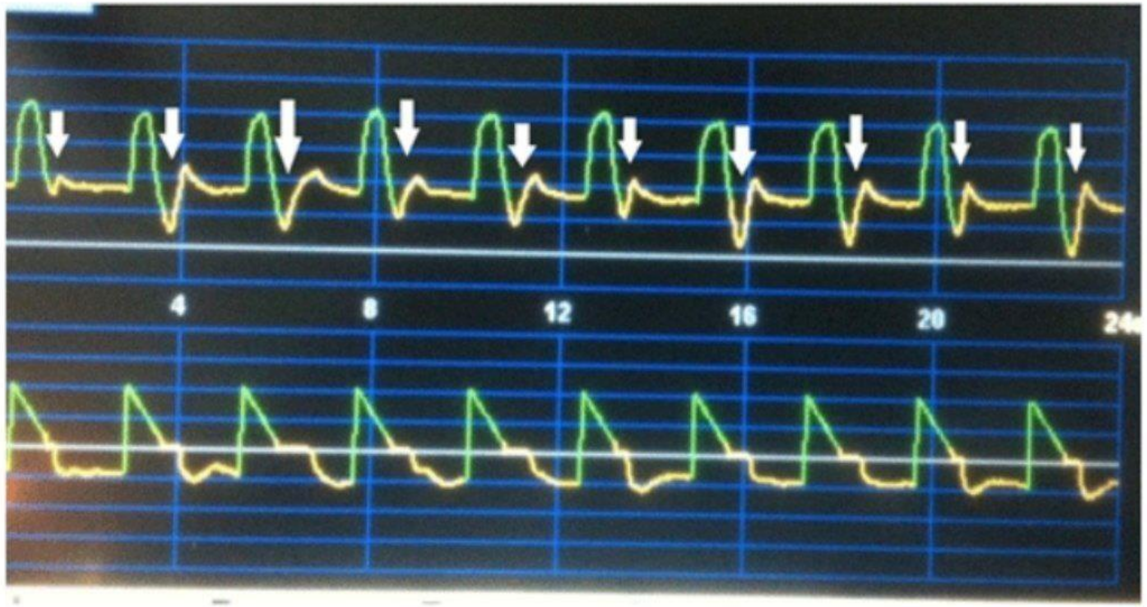
- type of PVA in which the patient's respiratory center is activated in response to a passive insufflations of the lungs[2].

- In general terms, reverse triggering takes place in profoundly sedated patients without neuromuscular blockade when a programmed ventilator breath leads to a reflex inspiratory diaphragmatic contraction by the patient, which in turn may trigger the ventilator to deliver a second mechanical breath [3].

2. Determine by:

- F-T scalar.
- P-T scalar.
- V-T scalar.

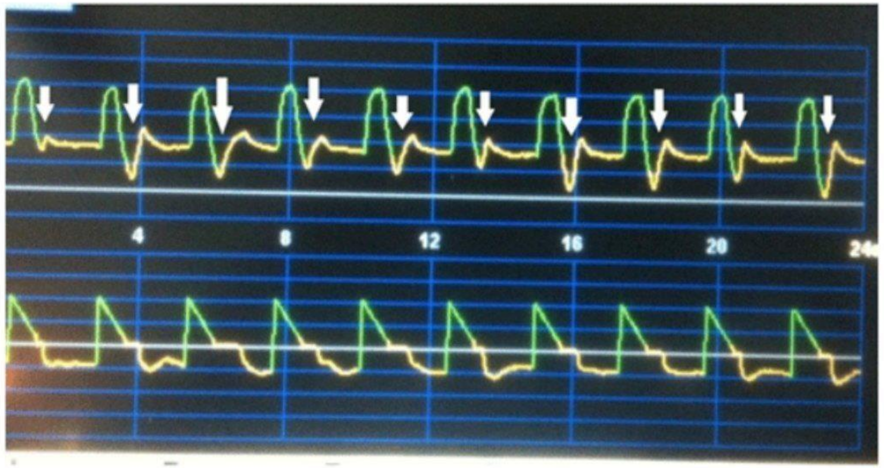
P-T scalar



F-T scalar

- During reverse triggering, there is a delay between the start of the machine-triggered breath and the start of the patient's inspiratory effort[2,5].

- As a result, the patient's effort usually persists when the inspiratory phase is completed, which could generate a double triggering if the inspiratory effort of the patient is able to overcome the threshold of programmed sensitivity [2].

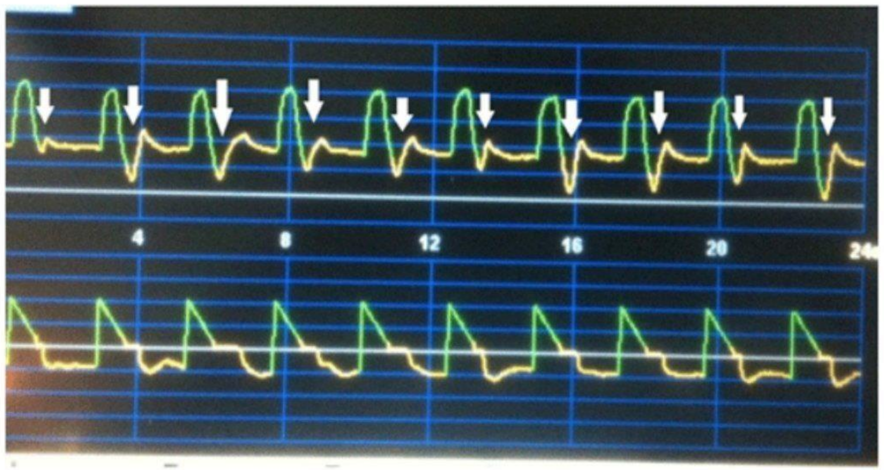


Trigger asynchrony | Cycle asynchrony | Flow asynchrony

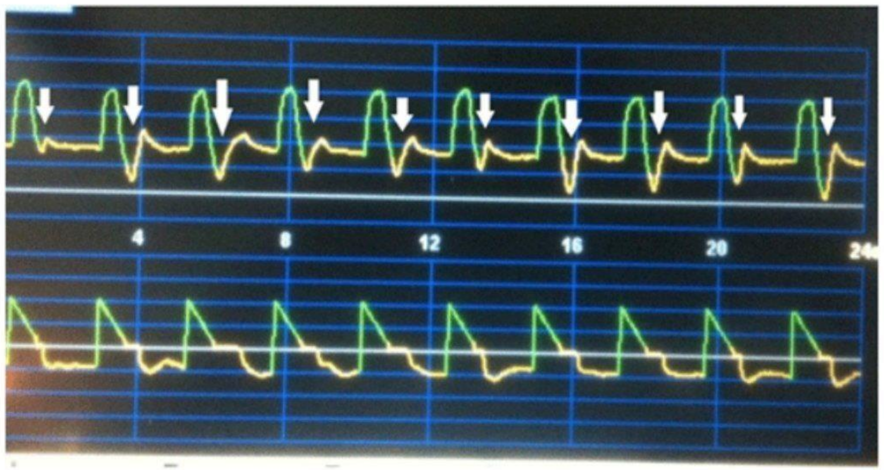
Ineffective effort | Auto-trigger | Reverse trigger | Double trigger

- The pressure/time waveform shows a breath that is initiated by the ventilator (there is no airway pressure drop at the beginning of the breath)[2]

- an airway pressure drop during the inspiratory phase and part of the expiratory phase produced by the activation of the respiratory of the patient with the consequent contraction of the inspiratory muscles[2].



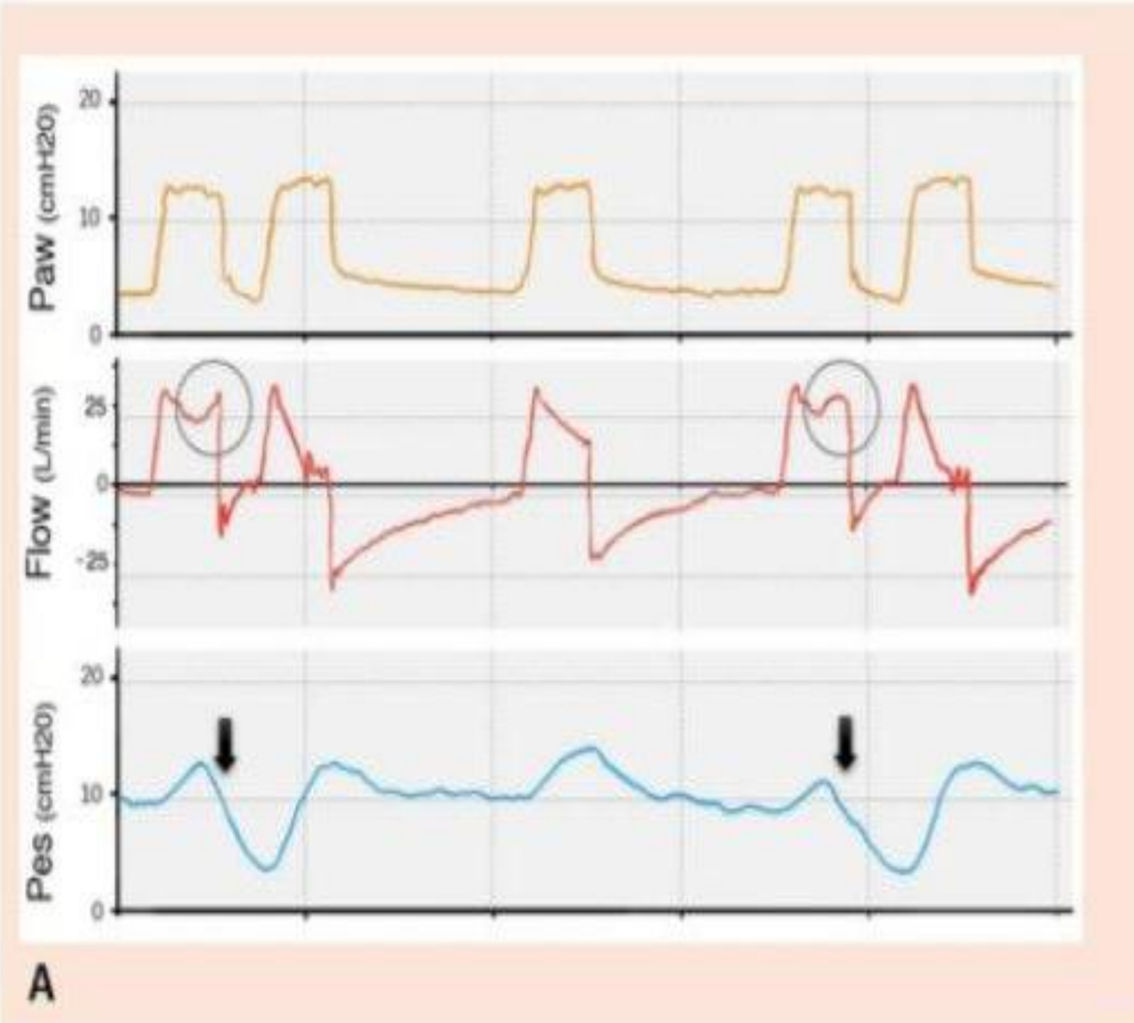
- In addition, an amputation or deformation of the peak. expiratory flow evidenced in the flow / time waveform product of the inspiratory effort of the patient is observed[2].



- If the mode is PC (Figure 5A):

- increase in the flow scalar during the deceleration part of the inspiratory phase

- slight decrease in pressure due to the contraction of the diaphragm[3].

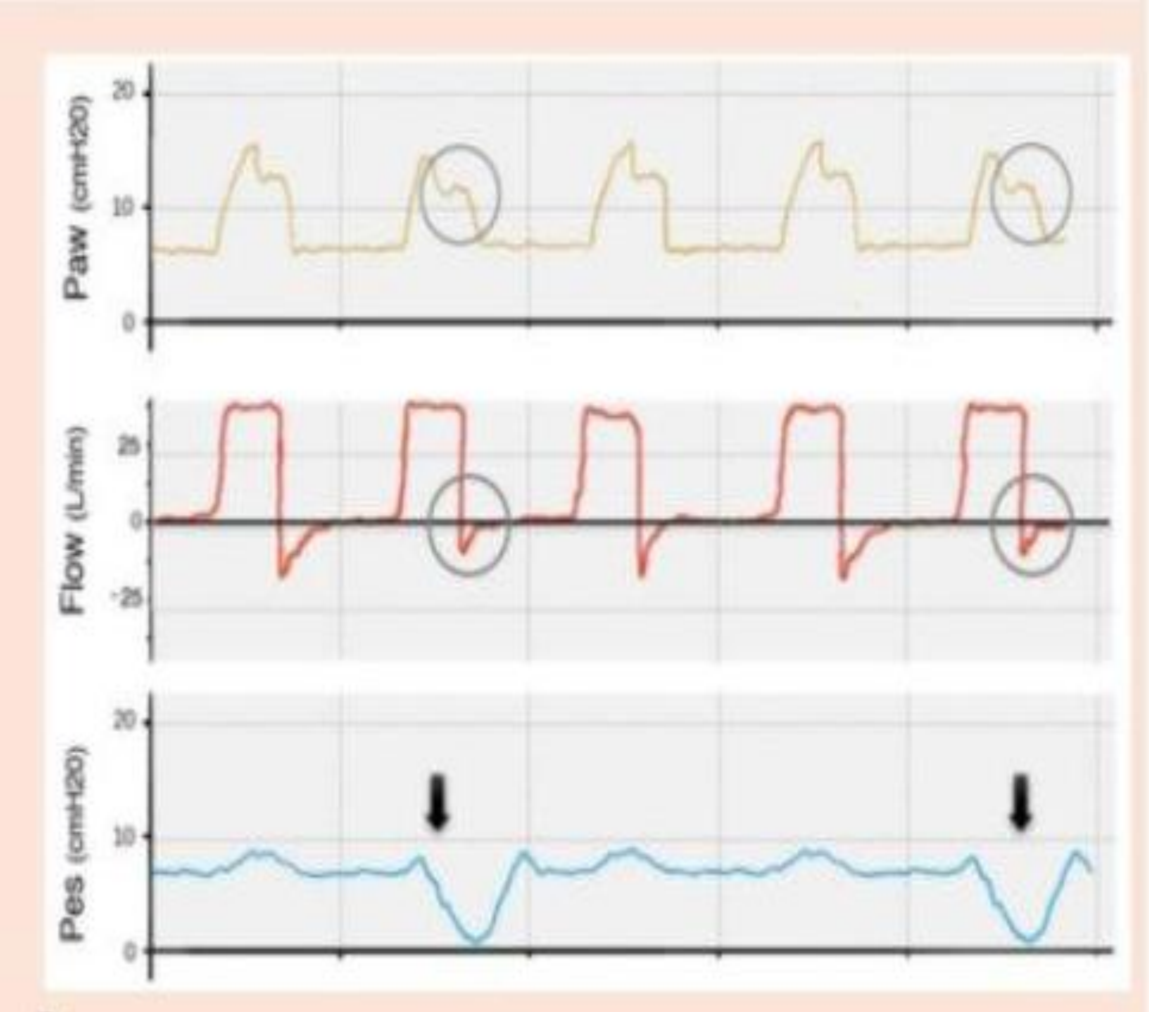


- if a V-C mode: (Figure 5B):

- the peak airway inspiratory pressure ↓.

- total expiratory flow ↓.

- If the contraction induced by the first mechanical breath is vigorous enough may induce the triggering of a second breath, with consequent breath stacking [3].



B

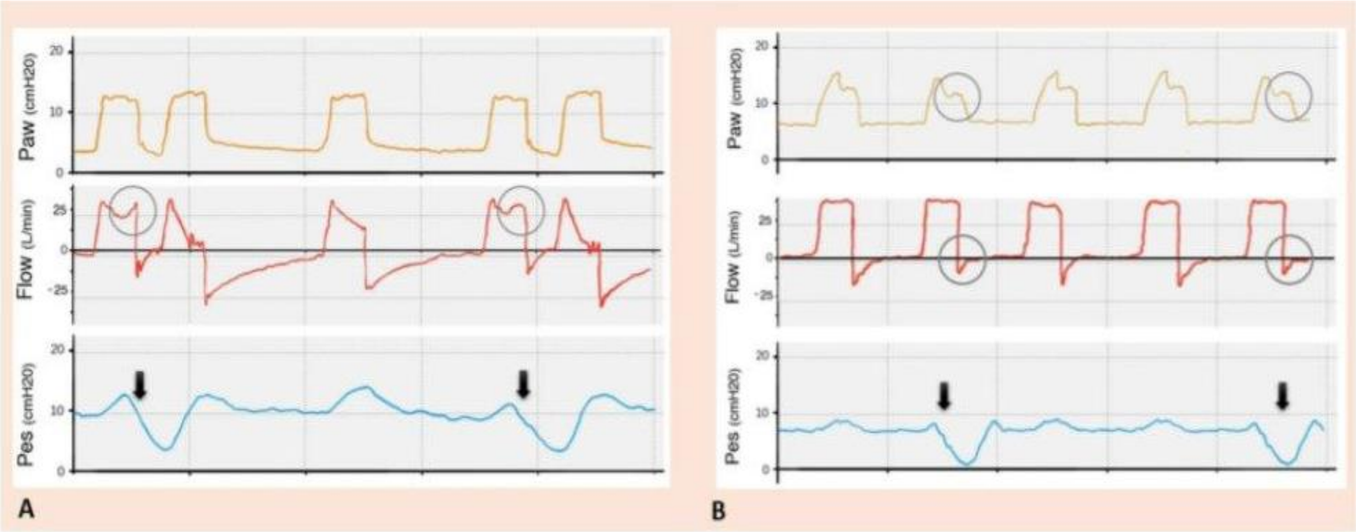


Figure 5. Reverse trigger—This PVA, unlike the others, is present only in deeply sedated patients under controlled mechanical modes. (**A**) In pressure control mode, a small increase in the flow waveform during the deceleration period of the inspiratory phase (circled areas), simultaneous to a small decrease in the pressure waveform, all explained by the diaphragmatic contraction. The Pes graph is essential to highlight the negative swings occurring after the initial mechanical breath (arrows). (**B**) In volume control mode, the mechanical breath will demonstrate reduced peak airway inspiratory pressure and total expiratory flow (circled areas). Once again, the negative deflections in Pes after the first breath are present (arrows). Pes: esophageal pressure; PVA: patient–ventilator asynchrony.

3. Causes:

- spinal reflexes.
- hiccups (reflex arch)[1].

4. Correction:

- reduce the sedation or NMB infusion depend on clinical context.
- Decrease the mandatory RR.

both targeting the patient to become more independent from the ventilator; on the other hand, if refractory cases appear, vigorous efforts, breath stacking, and increased tidal volumes with possible VILI, and the initiation of neuromuscular blockade are advised[3].

5. Rapid nots:

- The key finding is the start of inspiratory flow followed by evidence of Pmus, which may or may not trigger another breath. The patient effort may occur any time during inspiration or early during expiration[4].

- Very common for pt receiving sedation[1].

- the physician must attempt to distinguish whether the first mechanical breath is patient or ventilator-elicited, where the first scenario is probably related to premature cycling and the latter to reverse triggering[3].

- In General: When a machine-triggered inspiration precedes patient effort. Patient effort may occur at any phase of inspiration or early expiration[4].

3. Pt-vent asynchrony..

3.1 (trigger asynchrony).

3.3.2 (double-trigger).

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Ineffective effort | Auto-trigger | Reverse trigger | **Double trigger**

1. Definition:

Patients inspiration continues after the ventilator inspiration and triggers another breath immediately after the inspiration.

2. Determine by:

- F-T scalar.
- P-T scalar.
- V-T scalar.

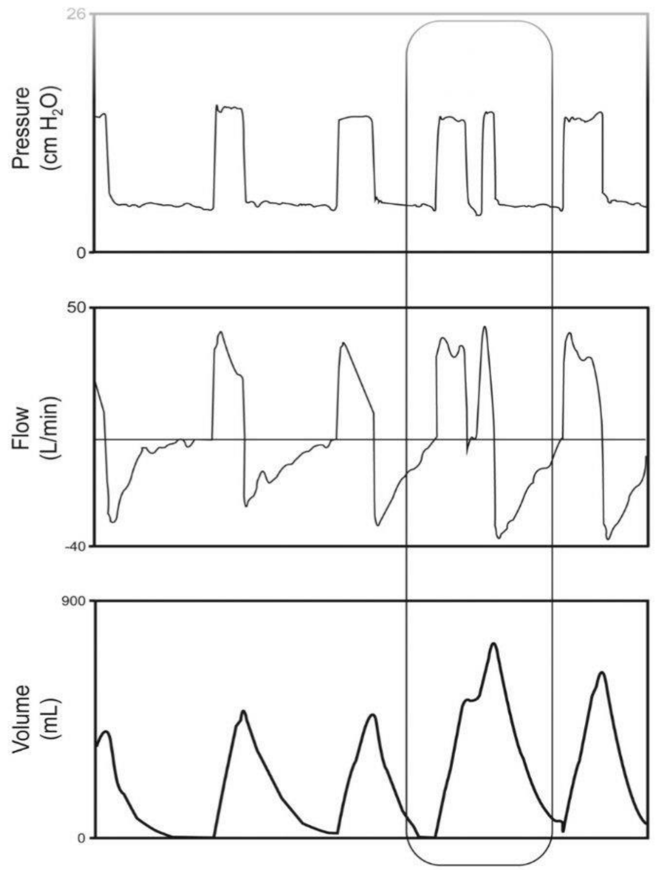


Fig. 4. An example of double triggering. Patient demand continues beyond the set inspiratory time, resulting in triggering of a second mandatory breath during the same patient effort.

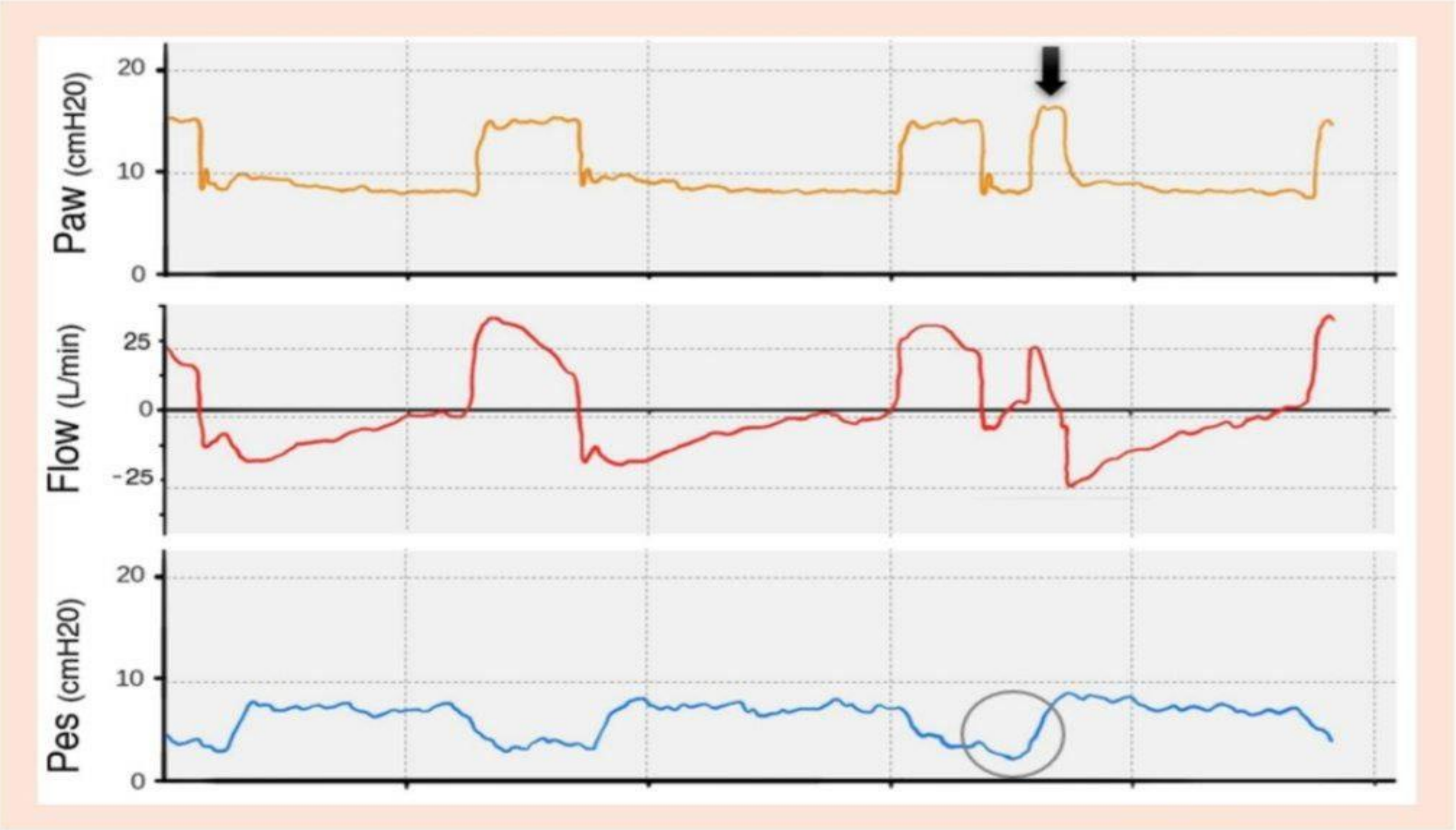
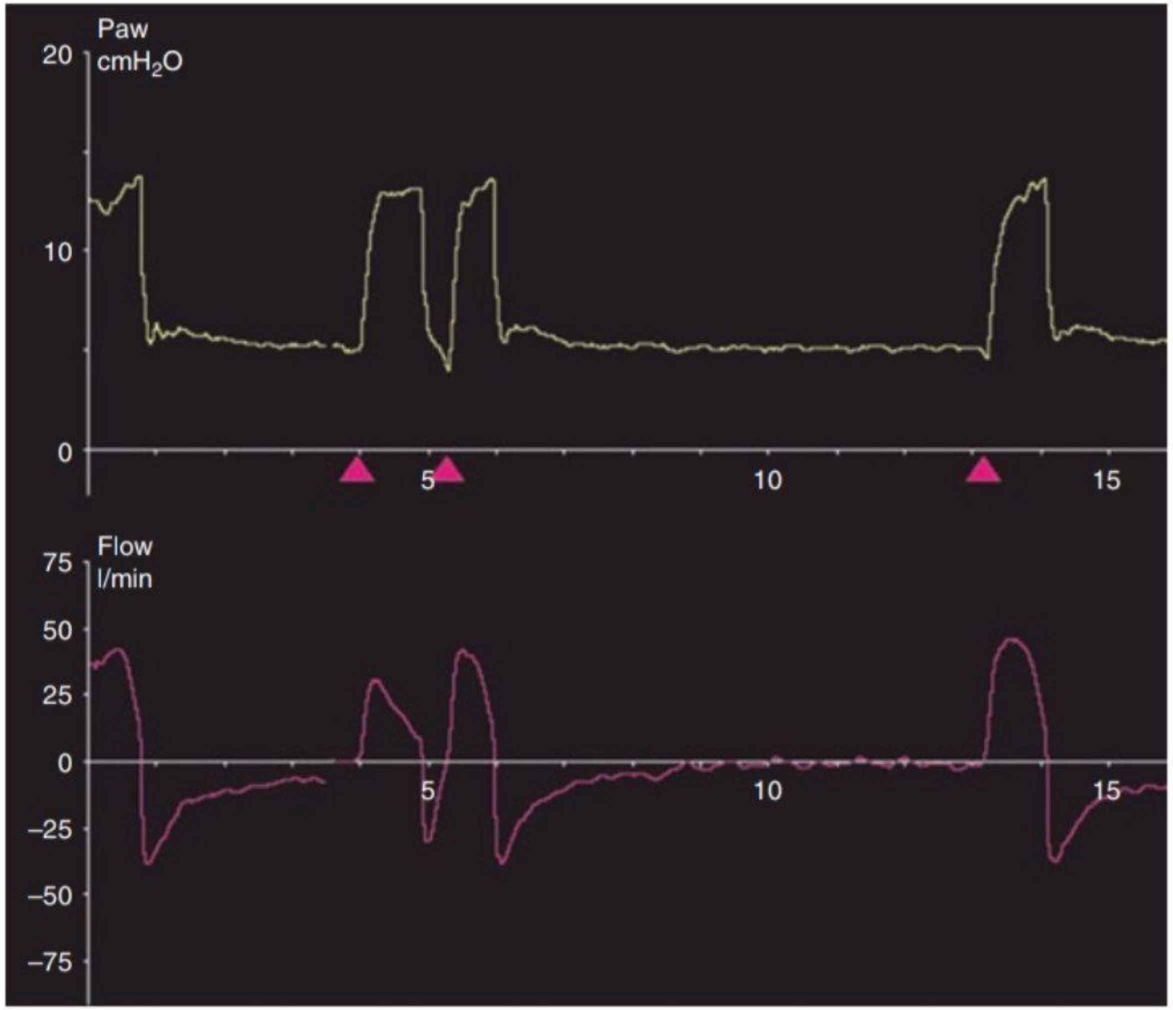


Figure 4. Double trigger—Two consecutive mechanical breaths will be present, albeit they will present certain dissimilarities—in the second breath, the decrease in airway pressure after the inspiratory phase will occur faster than in the initial breath (arrow). The Pes tracing will demonstrate the patient is performing only a prolonged inspiratory effort (negative deflection), that persists and originates the second triggering of the ventilator (circled area). Pes: esophageal pressure.

Trigger asynchrony
Cycle asynchrony
Flow asynchrony
Ineffective effort
Auto-trigger
Reverse trigger
Double trigger



3. Causes:

- Inappropriate settings: Low tidal volume, short inspiratory time, high ETS.
- High ventilatory demand of the patient (ARDS).
- increased respiratory drive.
- early cycling.
- reduced inspiratory pressure support.
- coughing[1,3,7].

4. Correction:

- increase vent Ti.
- managing: pain, fever, or anxiety are crucial steps.
- If the patient requires more inspiratory flow without the need for an overtly excessive tidal volume, providing higher pressure support may be adequate.
- if the problem resides in early cycling, then the cycling parameter should be, in this case, thoroughly decreased (e.g., from 30% to 25% or less) until the patient is more comfortable[3].

5. Rapid nots:

-It is very frequent and may originate significant clinical implications, with excessive tidal volumes, predisposing the patient to ventilator-induced lung injury (VILI)[3].

-The patient will show signs of discomfort and cough.

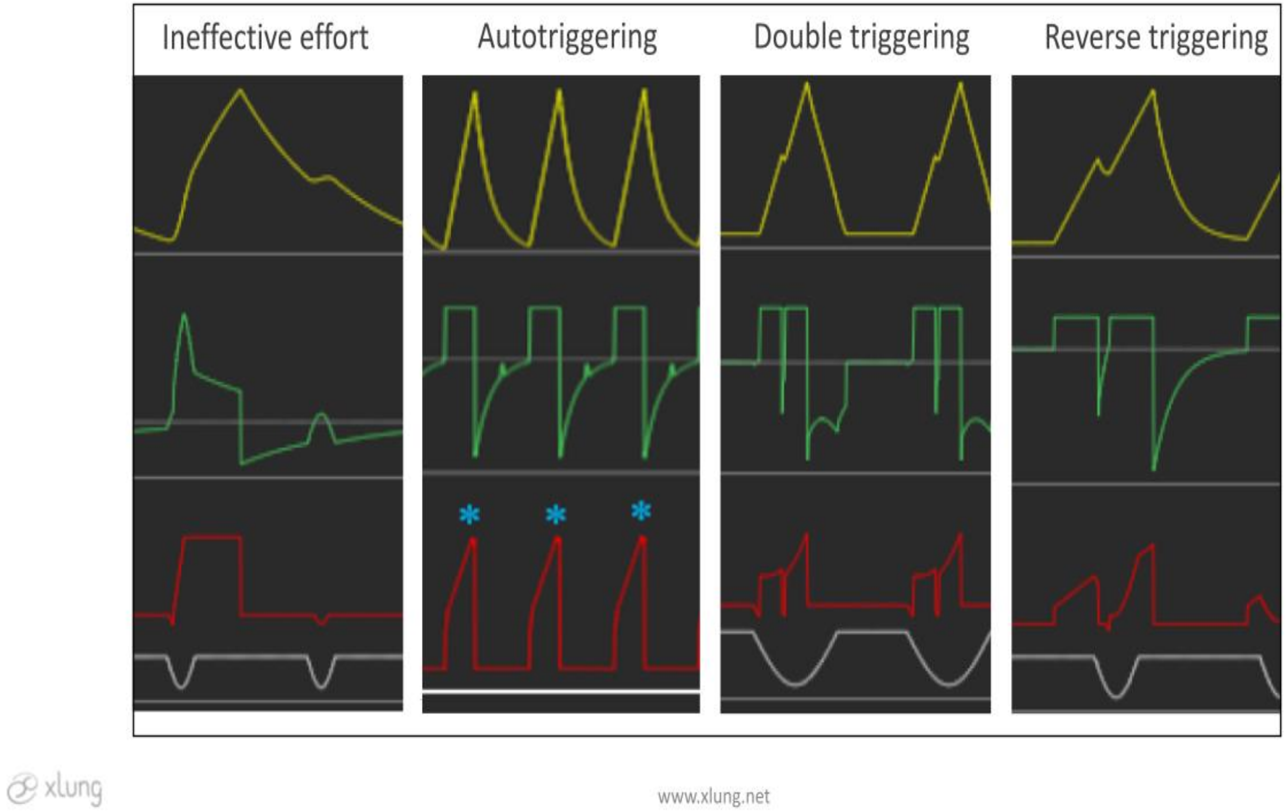
-Patients with an elevated respiratory drive (fever, anxiety, pain, etc.) exert a very intense and prolonged inspiratory effort, resulting in an additional mechanical breath even before the complete expiration of the first breath has ceased[3].

Trigger asynchronies
Mechanisms, risks and possible solutions

Variants	*Reverse triggering*	*Double triggering*	*Ineffective effort*	*Autotriggering*
Mechanisms	Diaphragm activation due to reflex mechanisms induced by a mechanically controlled cycle	Patient's neural respiratory time > ventilator mechanical time	Decreased Pmus / respiratory drive Decreased sensitivity Auto-PEEP	Leaks Heartbeat transmissions Secretions/condensate into the circuit
Risks	Breath stacking VILI	Breath stacking VILI	Muscle injury Dyspnea Respiratory drive increase	Hyperventilation Auto-PEEP
Possible solutions	Reduce sedation or NMB infusion depending on the clinical context	Increase of the ventilator inspiratory time	Reduce/remove sedation Increase sensitivity Increase/titrate PEEP	Circuit cleaning Appropriate trigger setting

ATTENTION PLEASE!

Trigger asynchronies



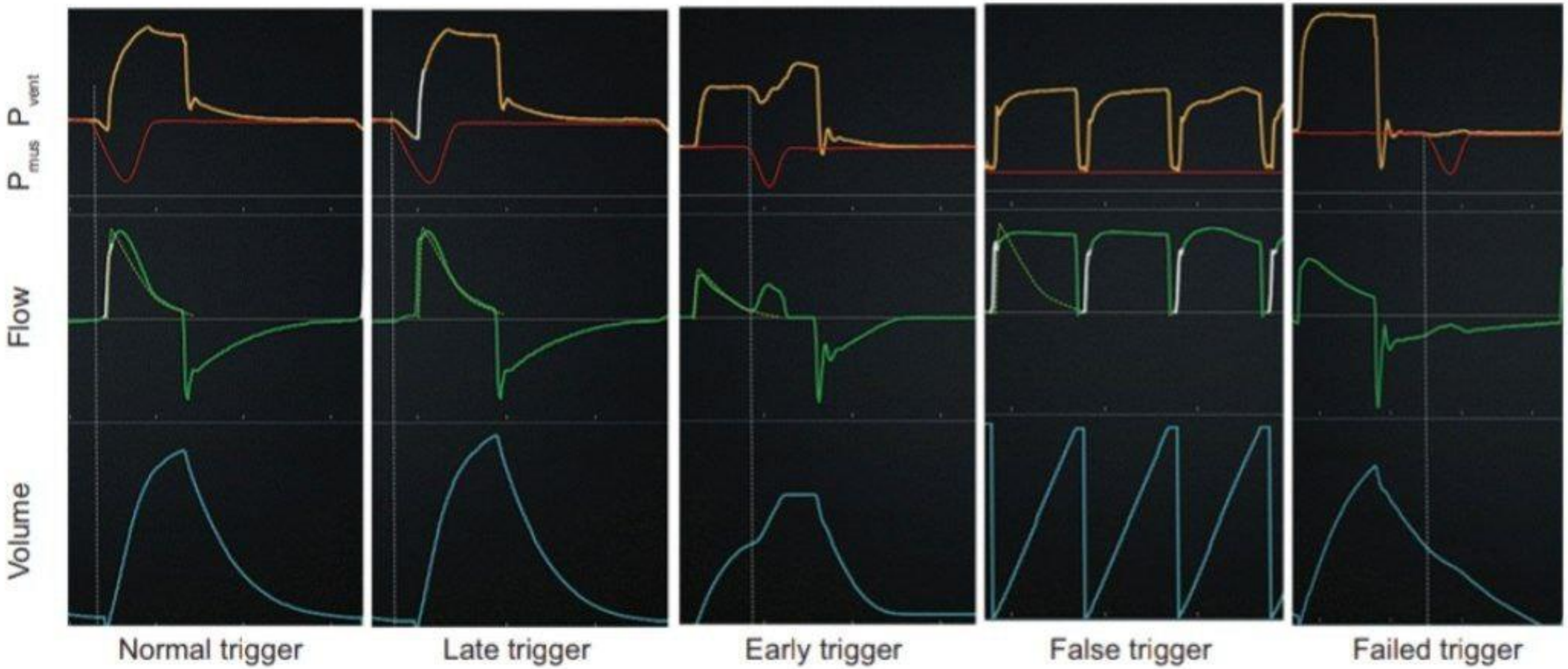


Fig. 5. Classification of trigger patient-ventilator interactions. Mode: PC-CMVs. P_{vent}: airway pressure waveform displayed by ventilator. P_{mus}: patient-generated pressure waveform, simulated, overlay to demonstrate effect across waveforms. Vertical white dotted lines are for reference of the start of the P_{mus}. Normal trigger: minimal drop in pressure with immediate pressurization. Late trigger: note flow crossing baseline and a prolonged drop in pressure below baseline. Early trigger: machine-triggered breath followed by evidence of patient effort (rise in flow above baseline). False trigger: patient-triggered breaths; however, no evidence of P_{mus}, in this case triggered by circuit leak. Failed trigger: P_{mus} does not trigger a mechanical breath. P_{mus} is manifested as flow waveform moving toward baseline and a concomitant drop in airway pressure. PC = pressure control, CMV = continuous mandatory ventilation, s = set point targeting.

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In cases of double and reverse triggering

- breath-stacking occurs.
- This fact is associated with tidal volumes much higher than those set in the ventilator.
- In cases of patients with ARDS or at risk of this condition, there is a potential for additional lung damage and ventilator-induced lung injury (VILI).

3- Pt-vent asynchrony..

3.2 (cycling asynchrony).

3. Pt-vent asynchrony..

3.2 (cycle asynchrony).

3.2.1 (premature).

1. Definition:

inspiratory muscles continue to contract after the ventilator has switched to exhalation phase. Vent Ti < Pt Ti.

2. Causes:

- excessive inspiratory efforts by the patient
- inadequately short cycling parameters (a high % of maximum inspiratory flow, in the case of pressure support).
- brief inspiratory machine time (in volume-controlled and pressure-controlled ventilation modes) [3].

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Premature cycle | Delay cycle

3. Side effects:

- double trigger
- breath staking
- dyspnea
- respiratory discomfort.

4. Determine by:

- F-T scalar (flow-time scalar most important).
- P-T scalar.
- V-T scalar.

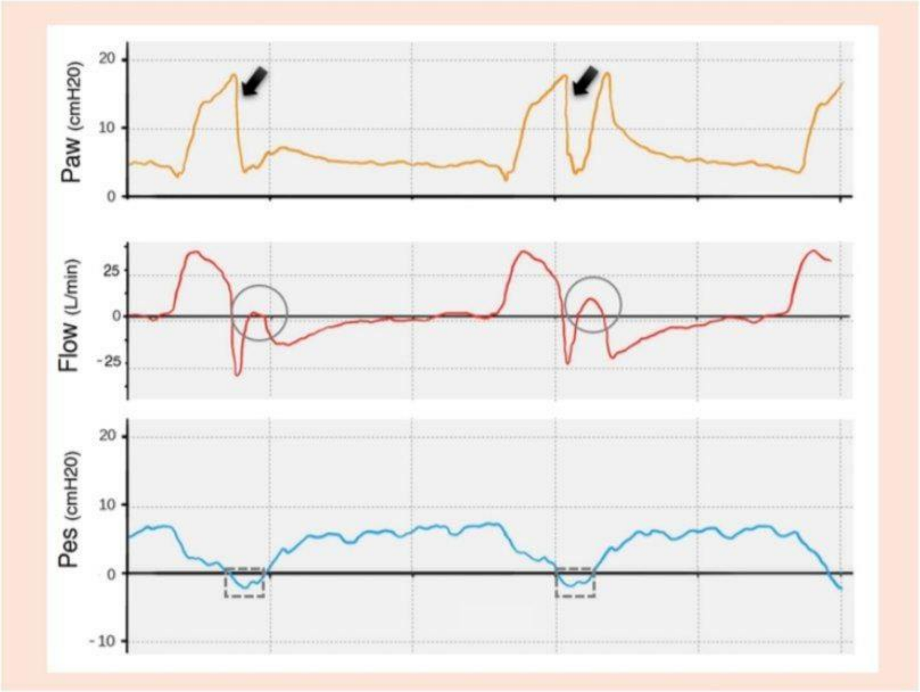

Figure 6. Early cycling—The patient's inspiratory neural time exceeds the ventilator inspiratory time, mainly leading to distortion with an initial upward deflection of the expiratory flow waveform (circled areas). Furthermore, the deceleration after inspiration will be accelerated, with a near-vertical drop in the airway pressure waveform (arrows). In the Pes waveform, the patient's effort persisting throughout inspiration and expiration, is unmasked (dashed line square). Should this asynchrony be strenuous enough, a phenomenon of double-trigger with breathstacking may occur (see second respiratory cycle). Pes: esophageal pressure.

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Premature cycle | Delay cycle

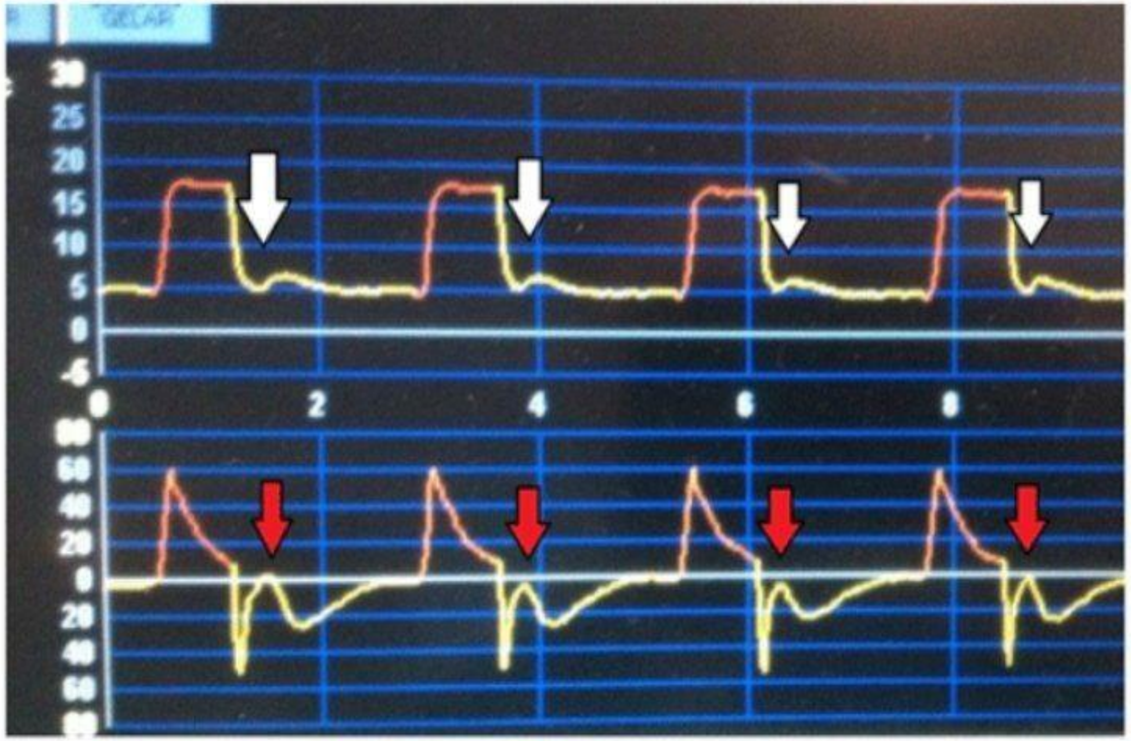

Figure 6: Example of premature cycling. White arrows show an inspiratory effort that continues after the inspiratory phase ended in the pressure/ time waveform. Red arrows show a sudden change in the expiratory flow caused by the inspiratory effort of the patient

5. Correction:

- controlling the respiratory rate.
- prolonging the duration of the inspiratory phase either by reducing the cycling parameter (i.e., decreasing the % of maximum inspiratory flow) in pressure support mode or by increasing the inspiratory time in controlled mandatory modes[3].

In general:

- VC mode → increase the Ti → increase the TV
- PC mode → increase the set Ti
- PS mode → decrease cycle threshold eg 30% or 20%.[9].

6. Rapid nots:

- Premature cycle: the ventilator waveforms present a near-normal inspiratory flow wave, followed by a distortion of the expiratory flow wave, characterized by an initial upward deflection. This is explained by the patient's maintained inspiratory effort with respiratory muscle contraction[3].

- A patient with a high respiratory drive and ventilator settings with a low tidal volume and short inspiratory time will be at risk for double triggering.[8]

- Early cycle can also occur if the ventilator cycles inspiration by a non-patient signal. This is typically recognized as an unusually short inspiratory time; for example, a patient with very low compliance and a rapid rise time in pressure support mode. This causes a high peak flow followed by rapid decay due to a short time constant, thereby too rapidly reaching the flow cycle threshold. It can also occur if ventilator safety features, such as a pressure limit or a spontaneous tidal volume limit, are reached.[4].

- Premature cycling as well as double triggering is a type of asynchrony that occurs when the patient's neural inspiratory time is greater than the inspiratory time programmed in the ventilaton. The difference, with the double triggering, is that in premature cycling the inspiratory effort of the patient is not enough to trigger a second breath. Premature cycling produces a significant decrease in airway pressure, which can be seen immediately after the end of the inspiratory phase programmed in the ventilator, accompanied by an increase of the inspiratory flow which can be seen in the flow/time waveform[2].

3. Pt-vent asynchrony..

3.2 (cycle asynchrony).

3.2.2 (delay cycle).

1. Definition: the patient wants to terminate inspiration before the ventilator does. Vent Ti > Pt Ti.

2. Causes:

- a prolonged programmed inspiratory time (in PC or VC mandatory ventilation).
- a late cycling parameter (very low % of maximum inspiratory flow in pressure support ventilation)[3].
- More TV for pt on VC mode[9].

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Premature cycle | Delay cycle

3. Side effects:

- dynamic hyperinflation.
- increase respiratory muscle workload.
- pt discomfort, dyspnea and increase the PIP.

4. Determine by:

- P-T scalar.
- F-T scalar.
- V-T scalar.

5. Correction:

- reducing the inspiratory time in controlled mandatory modes.
- shortening the breath by increasing the % of maximum inspiratory flow (e.g., from 30% to 40%)[3].

In general:

- VC mode → decrease the Ti → decrease the TV or increase insp flow.
- PC mode → decrease the set Ti.
- PS mode → increase the flow threshold for cycling eg 30 to 40%[9].

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Premature cycle | Delay cycle

6. Rapid nots:

- The main causes of cycling asynchronies include poor ventilator adaptation to the patient's neural inspiratory time and characteristics of the respiratory mechanics[1,4].

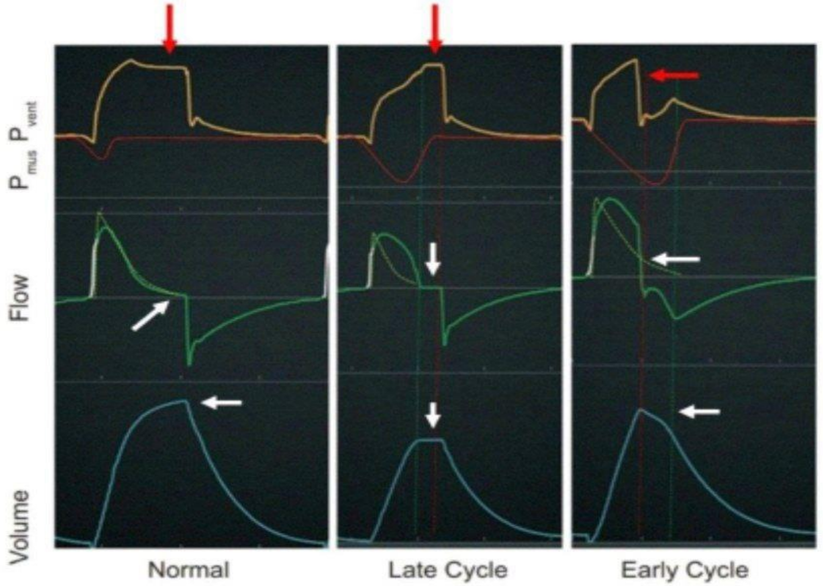

Fig. 11. Classification of cycle patient-ventilator interactions. Mode: PC-CMVs. P_{vent}: airway pressure waveform displayed by ventilator. P_{mus}: patient-generated pressure waveform, simulated, overlay to demonstrate effect across waveforms. Normal cycle: patient-triggered; the effort was small; the flow decays passively to zero flow with no evidence of inspiratory or expiratory effort. Late cycle: Green dotted line demonstrates end of patient breath; flow reaches baseline, and there is an increase of airway pressure due to relaxation of inspiratory muscles against a close valve (zero flow). Red dotted line demonstrates point where ventilator cycles. Early cycle: the machine cycles breath (red dotted line), expiratory flow with evidence of inspiratory patient effort (flow moves toward baseline). Green dotted overlay to demonstrate passive flow waveform as a reference. Note: red P_{mus} line was overlaid by hand onto a ventilator screen image, and P_{mus} is shown inverted for clarity. PC = pressure control, CMV = continuous mandatory ventilation.

ATTENTION PLEASE!

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

Premature cycle | Delay cycle

- For example, patients with COPD have a greater tendency to develop late cycling, and patients with restrictive diseases have a greater predisposition to develop early cycling[1,4].
- As a consequence of this type of asynchronies, these patients may present respiratory distress, airway pressure overshoot, greater need for sedation, and delay in weaning from MV[1,4].

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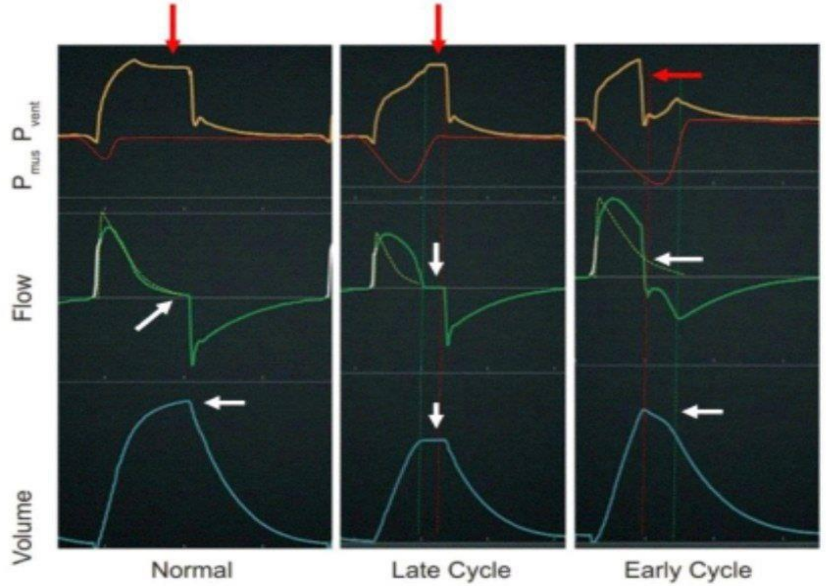

Fig. 11. Classification of cycle patient-ventilator interactions. Mode: PC-CMVs. P_{vent}: airway pressure waveform displayed by ventilator. P_{mus}: patient-generated pressure waveform, simulated, overlay to demonstrate effect across waveforms. Normal cycle: patient-triggered; the effort was small; the flow decays passively to zero flow with no evidence of inspiratory or expiratory effort. Late cycle: Green dotted line demonstrates end of patient breath; flow reaches baseline, and there is an increase of airway pressure due to relaxation of inspiratory muscles against a close valve (zero flow). Red dotted line demonstrates point where ventilator cycles. Early cycle: the machine cycles breath (red dotted line), expiratory flow with evidence of inspiratory patient effort (flow moves toward baseline). Green dotted overlay to demonstrate passive flow waveform as a reference. Note: red P_{mus} line was overlaid by hand onto a ventilator screen image, and P_{mus} is shown inverted for clarity. PC = pressure control, CMV = continuous mandatory ventilation.

- This type of asynchrony is common in COPD patients because of PEEPi and a short expiratory time. In these cases, an effective solution would be decreasing the inspiratory time in controlled modes such as pressure assist/control ventilation and Synchronized Intermittent Mandatory Ventilation (SIMV) [2].

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3- Pt-vent asynchrony..

3.3 (flow asynchrony).

3.3.1 (insufficient flow).

1. Definition: the flow received by the patient is lower than his or her ventilatory demand. pt flow need > set flow.

2. Causes:

- reduced or inadequate assisted pressure/volume.
- prolonged rise time in the presence of air hunger[3].

3. Side effects:

- increase respiratory drive.
- WOB, Dyspnea and weaning failure[3].

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

insufficient flow | excessive flow

5. Determine by: pressure-time scalar.

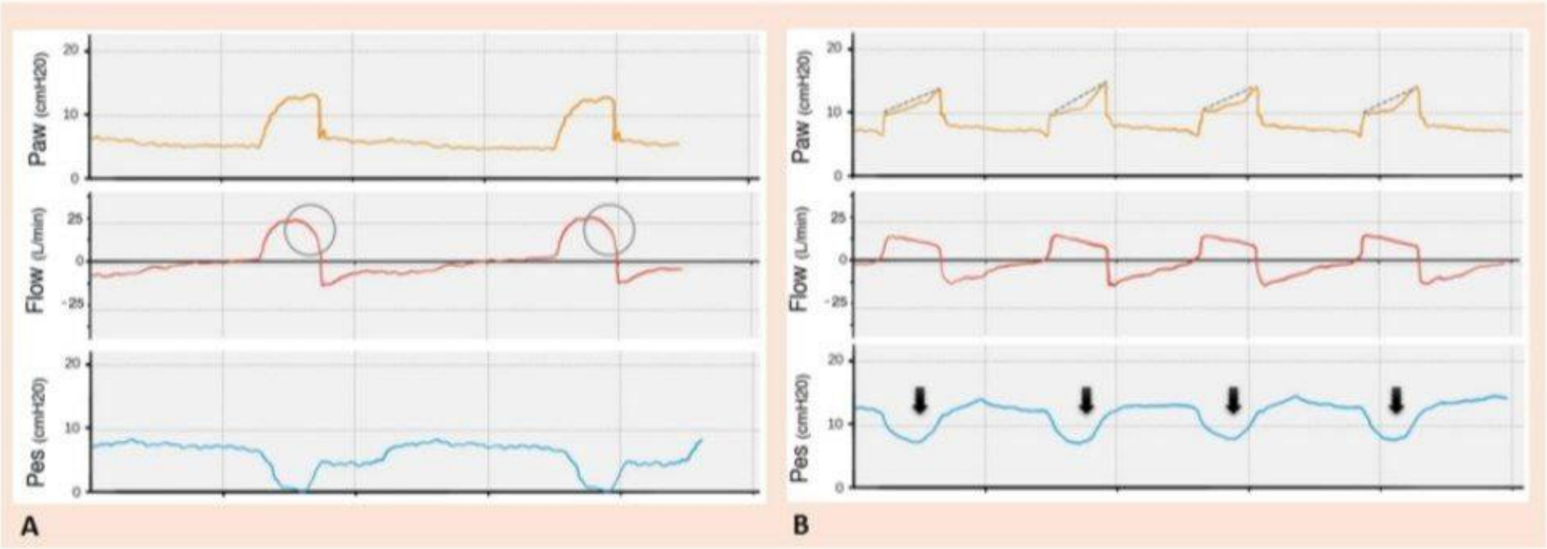


Figure 9. Flow starvation—(**A**) In assisted-pressure mode, the flow curve will have a rounded shape (circled area), contrasting with the generally triangular shape in patients without any PVA. (**B**) In volume-assisted mode, the airway pressure waveform will present a concave shape, which may be progressively more pronounced depending on the patient's effort (dashed line). Once again, the Pes waveform will help by identifying very negative swings during the inspiratory phase, consequent to the patient's vigorous efforts (arrows) due to inadequate flow. Pes: esophageal pressure; PVA: patient–ventilator asynchrony.

Trigger asynchrony | Cycle asynchrony | **Flow asynchrony**

insufficient flow | excessive flow

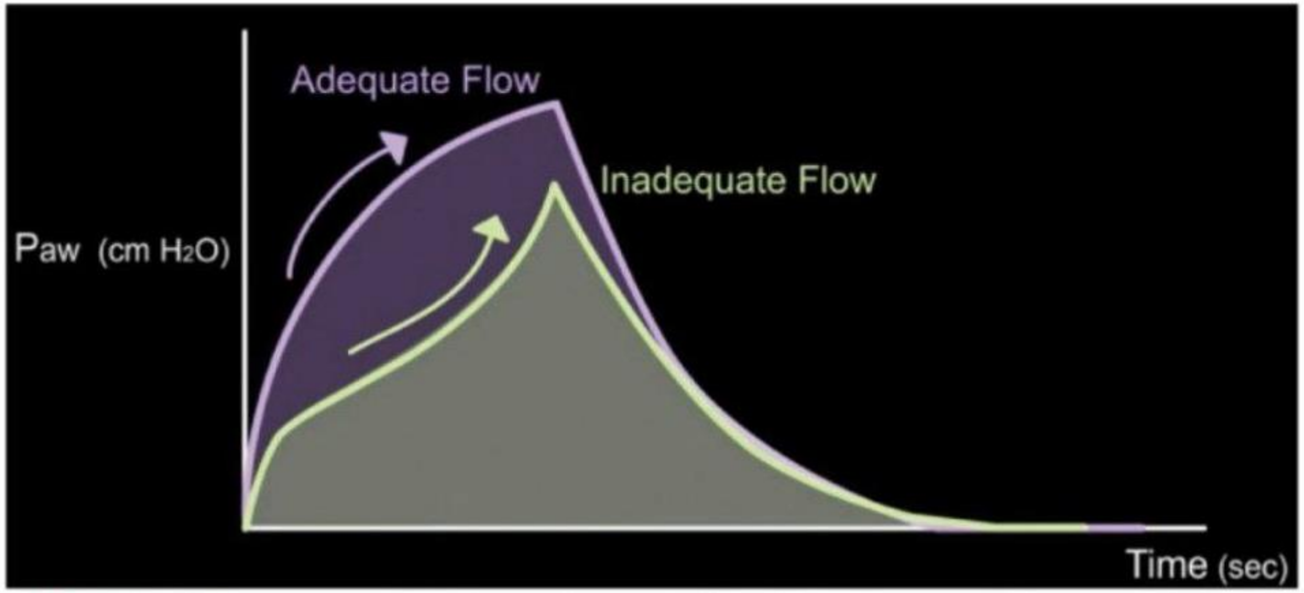


FIGURE 7-36 A pressure vs. time diagram shows a significant drop in pressure during inspiration and a scooped-out pattern due to patient effort demanding more flow than delivered. Paw, airway pressure.

Description

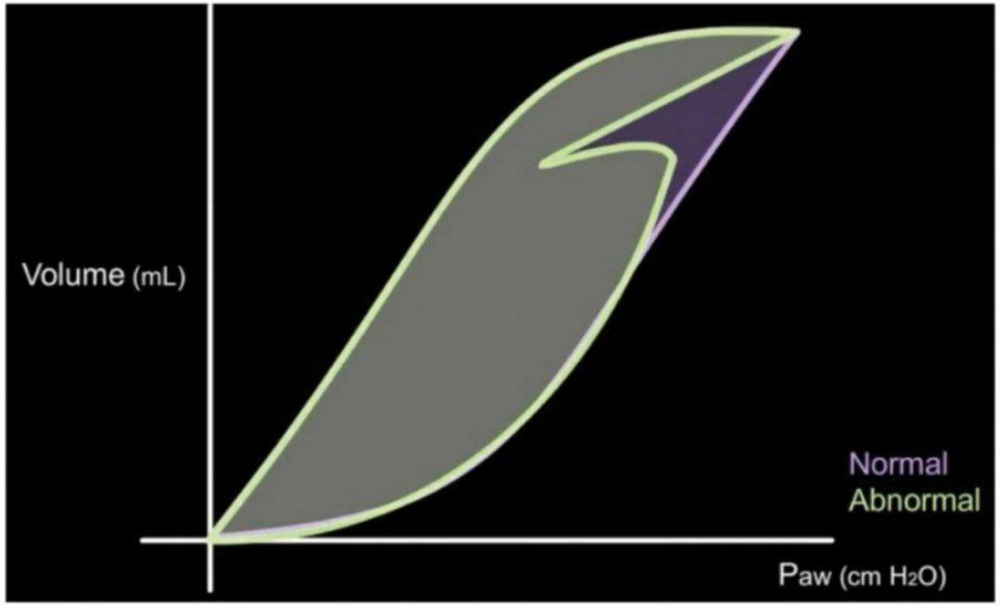
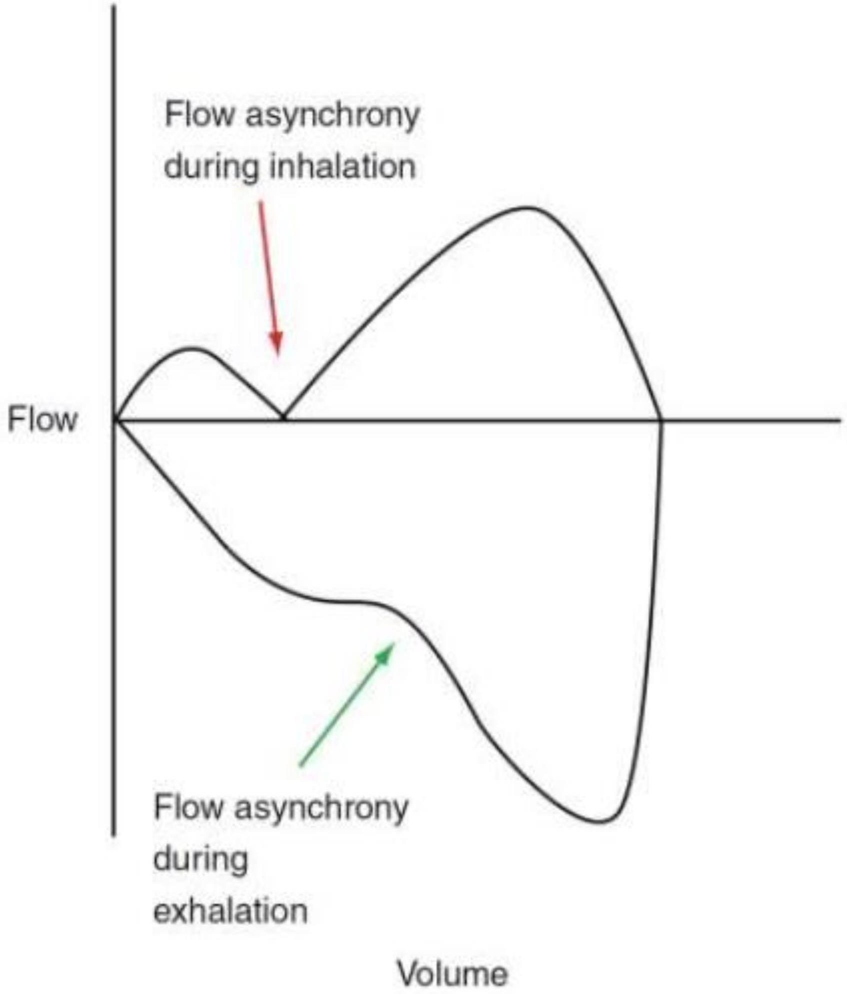


FIGURE 7-37 Pressure-volume loop and pressure-volume loop with either a deflection or a scooped-out pattern of the inspiratory limb indicating patient effort in the middle of the breath in an effort to match flow demands. Paw, airway pressure.

Trigger asynchrony | Cycle asynchrony | Flow asynchrony

insufficient flow | excessive flow



6. Correction:

- increase the insp flow or insp support.
- decrease Rise time.
- switch to PS or PC mode
- If patient effort is pathological (i.e. resulting in unnecessarily large tidal volumes and minute ventilation): Attempt to resolve the cause of increased respiratory drive, such as managing pain and distress, controlling fever, etc. If this cannot be achieved, increase sedation[2,3,9].

6. Rapid nots:

- Flow starvation generally occurs in patients with a vigorous respiratory drive and strong muscles of inspiration. For many clinicians, the picture of a tachypneic patient with obvious distress and bizarre ventilator waveforms will prompt an increase in sedation, with all the associated harms. If such patients can be made comfortable by ventilator adjustments alone, they can be kept awake and transitioned more rapidly towards extubation [9].

- Flow desynchrony is less common for pt on PC mode.
- Paradoxical motion of the chest and abdomen are common, and patients are often tachypneic and uncomfortable in appearance[9].

3- Pt-vent asynchrony..

3.3 (flow asynchrony).

3.3.2 (excessive flow).

1. **Definition:** exaggerated supply of inspiratory flow.
2. **Causes:**

- increase the assist pressure.
- short set rise time.

3. **Side effects:**

- Can affect cycling in PSV .
- turbulence flow, pt discomfort
- increase Pip.[1,9,10,11]

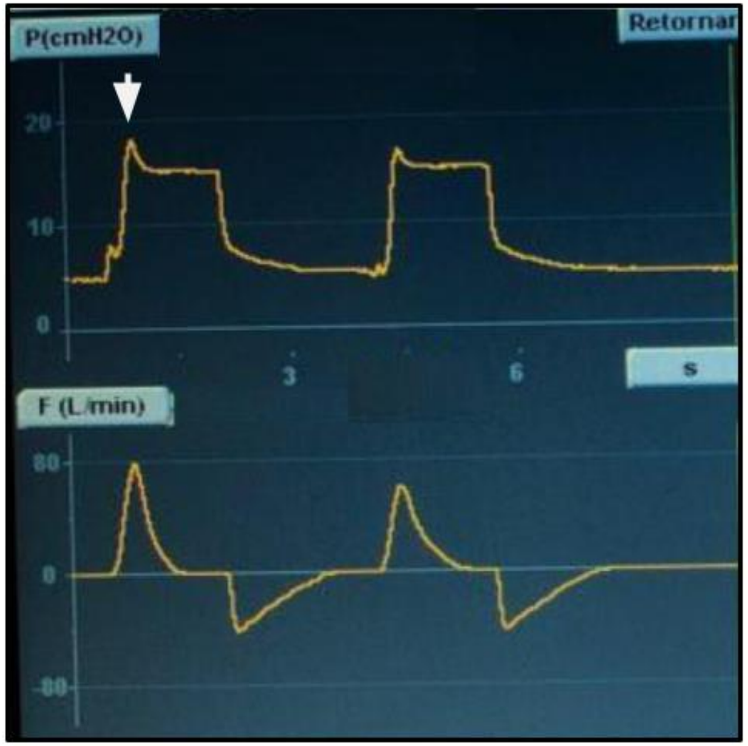
5. Determine by:

- pressure-time scalar.

6. Correction:

- decrease flow (VC).
- increase Rise time (PC, PSV mode).
- decrease IPAP (NIV)[1,9].

Excessive flow



Trigger asynchrony | Cycle asynchrony | Flow asynchrony

insufficient flow | excessive flow

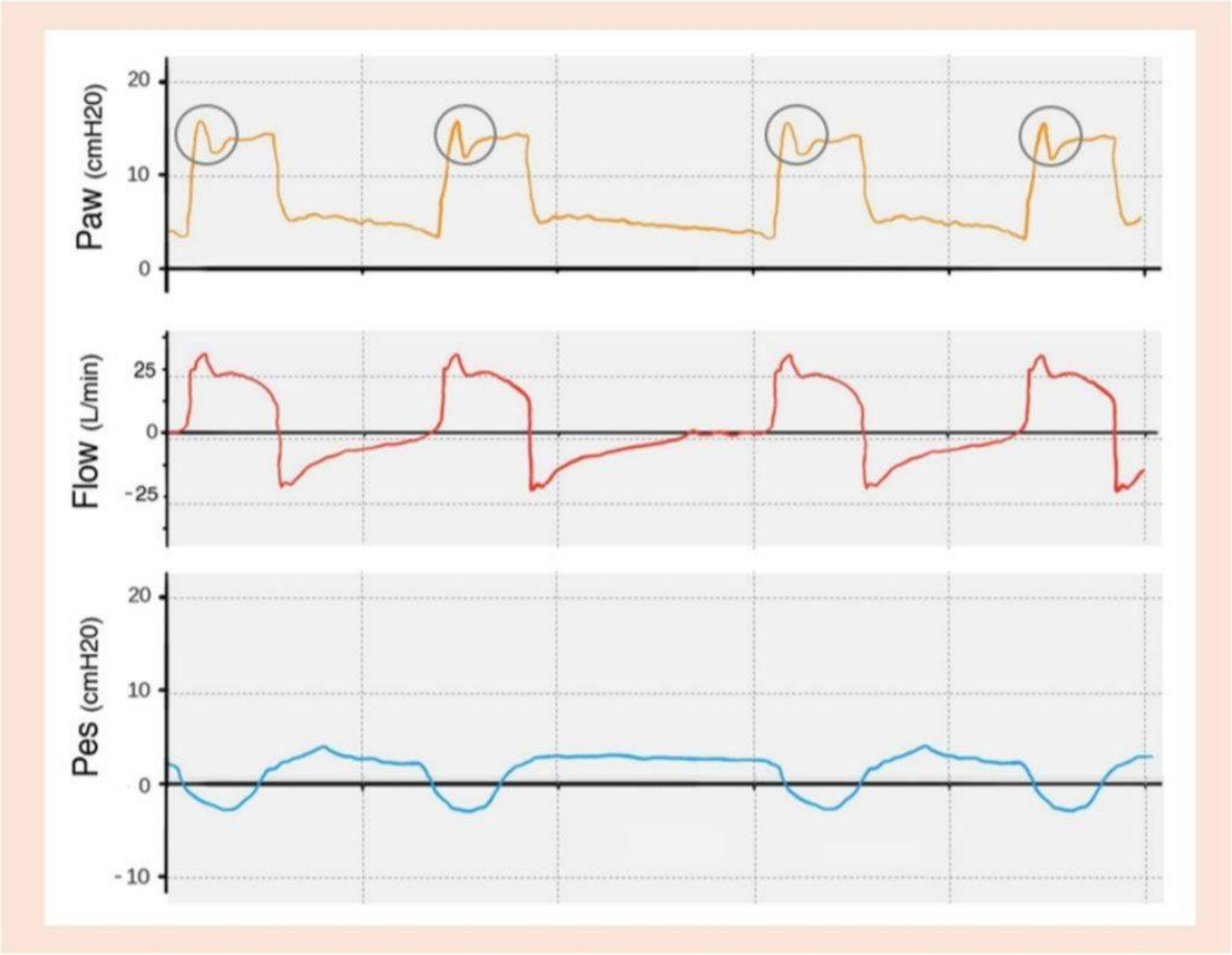


Figure 8. Flow overshoot—The excessive inspiratory flow creates a steep initial peak in the airway pressure waveform (circled areas), and the inspiratory phase may be shortened.

Trigger asynchrony | Cycle asynchrony | **Flow asynchrony**

insufficient flow | **excessive flow**

-Increased Inspiratory flow ≈ decrease Rise time.

-Decrease Inspiratory flow ≈ increase Rise time.

-VC: set the insp flow.

-PC: set the Rise time.

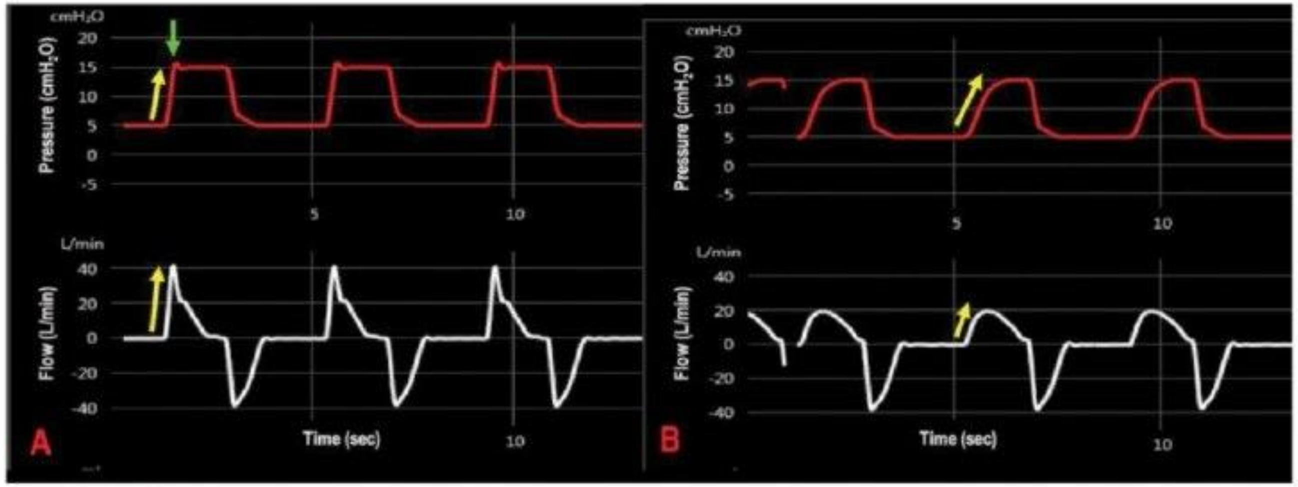


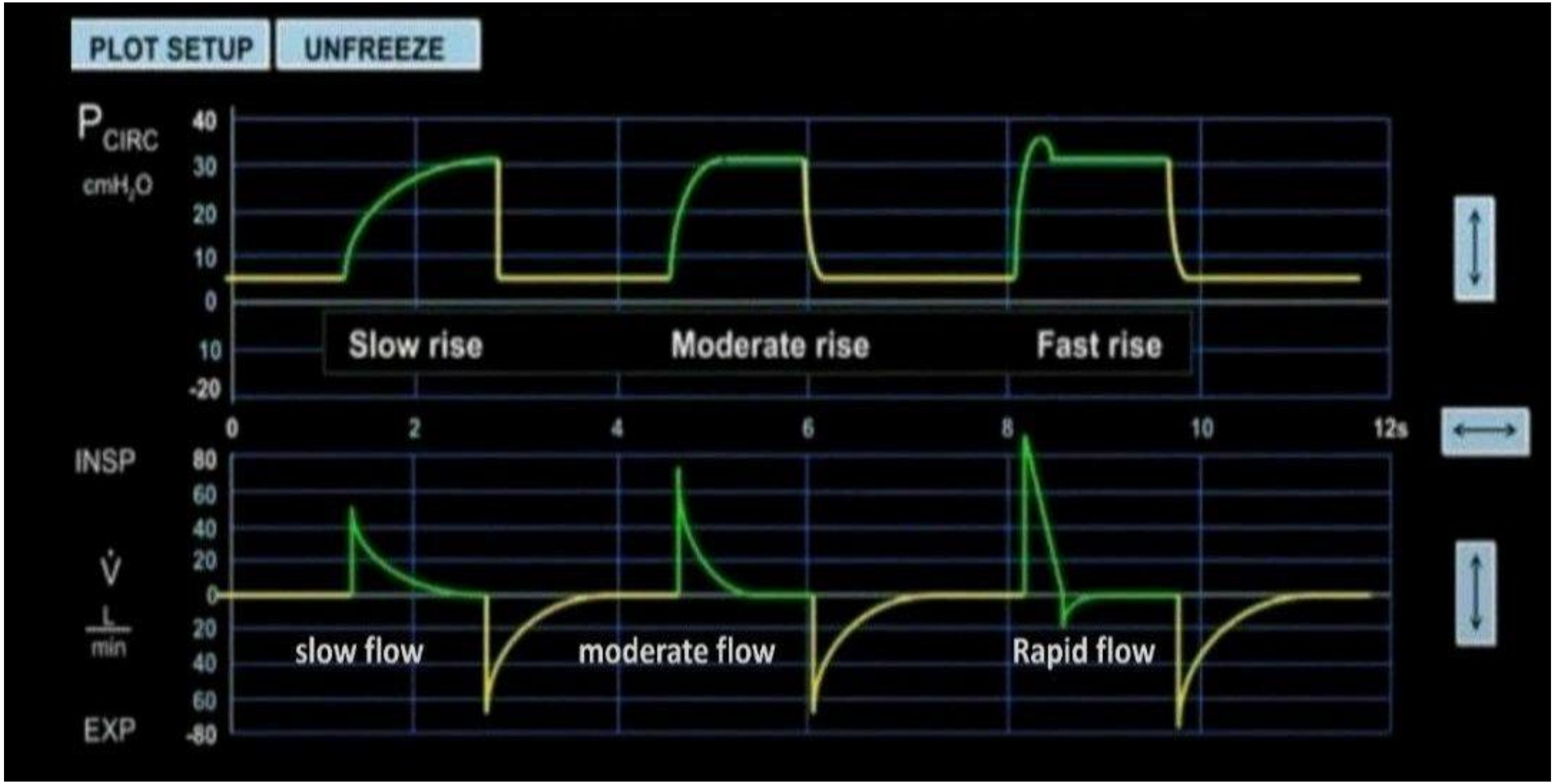
FIGURE 7-6 Flow-time scalar indicating a fast rise time. A sharp rise to peak inspiratory flow rate (PIFR) and airway pressure (yellow arrow) is observed. (**A**) A rapid rise time causes an increase in airway pressure indicated by a "bump" (green arrow). (**B**) A flow-time scalar indicates a slow rise time that delays initial flow delivery, thus slowing the pressure rise to the preset level (yellow arrow).

Description

ATTENTION PLEASE!

Trigger asynchrony | Cycle asynchrony | **Flow asynchrony**

insufficient flow | excessive flow



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Cycling and flow asynchronies
Mechanisms, risks and possible solutions

	Cycling		Flow	
Variants	*Premature cycling*	*Late cycling*	*Insufficient flow*	*Excessive flow*
Mechanisms	Mechanical ventilator inspiratory time < patient neural inspiratory time	Mechanical ventilator inspiratory time > patient neural inspiratory time	Flow rate < patient ventilatory demand	Flow rate > patient ventilatory demand
Risks	Respiratory discomfort Dyspnea	Respiratory discomfort Dyspnea Hyperinflation	Dyspnea Increased respiratory drive and work of breathing	Airway pressure overshoot
Possible solutions	Increase ventilator inspiratory time	Decrease ventilator inspiratory time	Flow increase (VCV) Use PCV or PSV modes	Reduce flow or increase rise time in PCV or PSV modes

4. the leak on vent waveform..

the leak on vent waveform

1. Definition: the set TV > Pt TV.

2. Causes:

- misplaced nasogastric tube.
- the ETT out or small size.
- cuff rupture or not inflated.
- the close suction still open.
- leak from the HME or humidifier, loose connections.
- chest tube, BP fistula.
- ventilator malfunction or faulty flow sensor[10,11,12,13,14].

the leak on vent waveform

3. Side effects:

- auto-PEEP trigger.
- co2 retention.
- low Mv, PEEP and TVe[11,12,14].

4. Determine by:

- **Volume scalar:**
  - Inspiratory leak: set TV > pt TV.
  - Expiratory leak: the volume doesn't return to the baseline during exhalation[10,14].

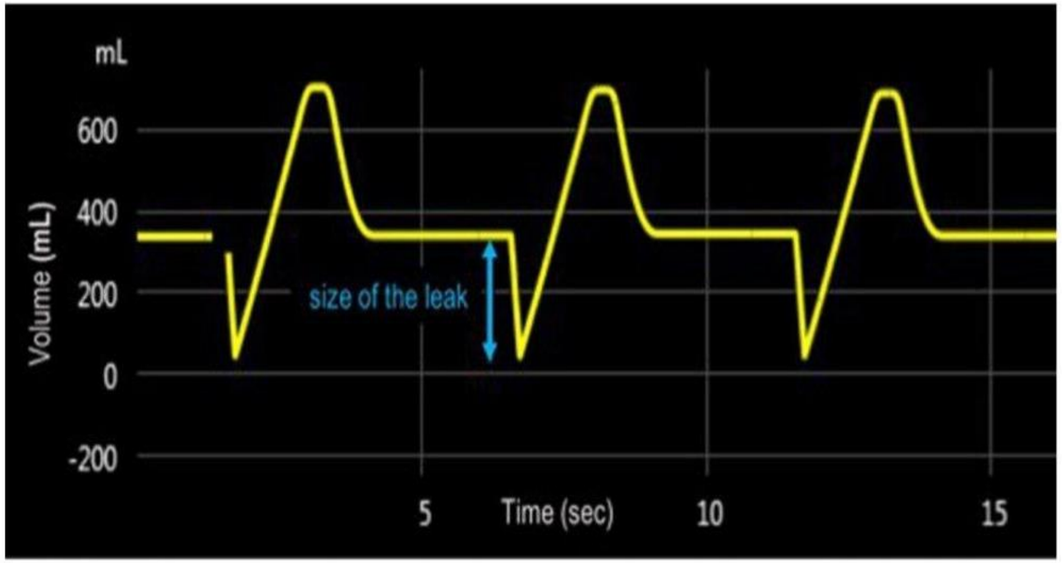

FIGURE 7-10 Volume-time waveform showing the presence of an air leak. The expiratory tracing does not reach baseline (zero) and provides the appearance of a check mark. The volume of the leak can be estimated by measuring the distance from the plateau to the end of the expiratory tracing (arrow).

the leak on vent waveform

- **P-V loop:** failure to close the loop[10].

- **F-V loop:** failure to close the loop[10].

- **P-T scalar:** decrease the PIP and difficult trigger[12,14].

- **F-T scalar:**
  - the expiratory flow waves have decreased volumes expired after the leak develops.
  - decreased the PEFR[12,14].

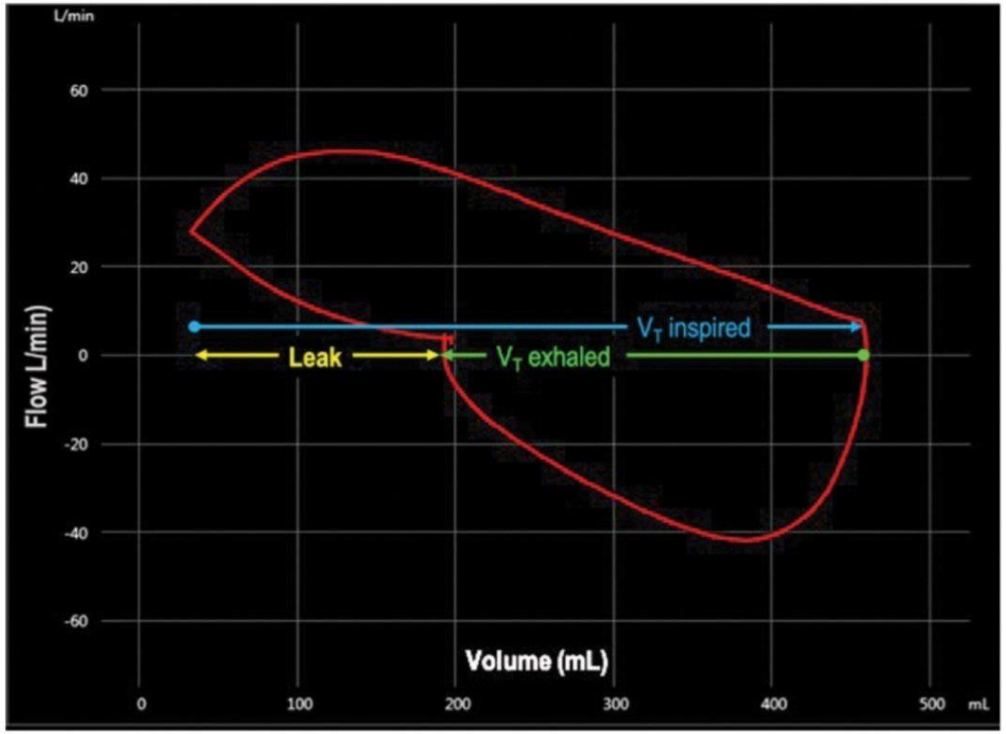

FIGURE 7-23 Flow-volume loop displaying an expired limb of the waveform not fully returning to zero. The gap indicates the magnitude (in mL) of the leak.

the leak on vent waveform

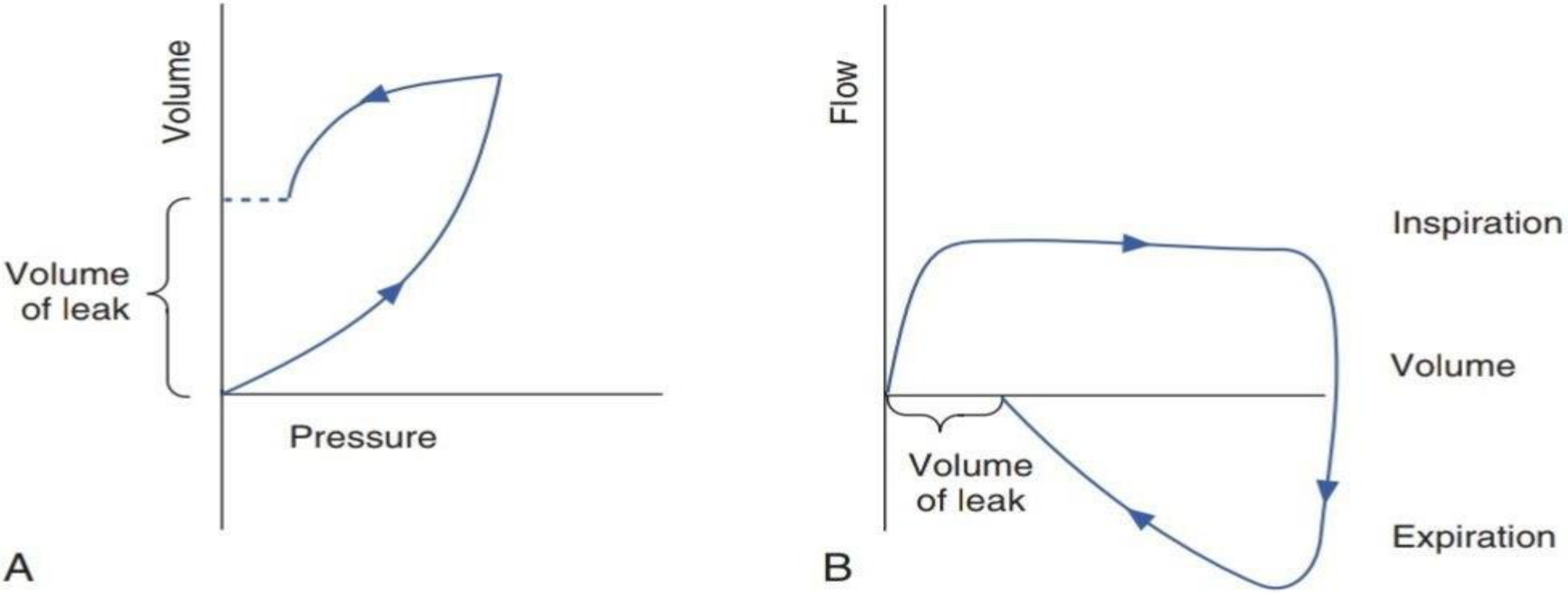

Fig. 18-6 Pressure-volume loop **(A)** and flow-volume loop **(B)** indicating an air leak.

the leak on vent waveform

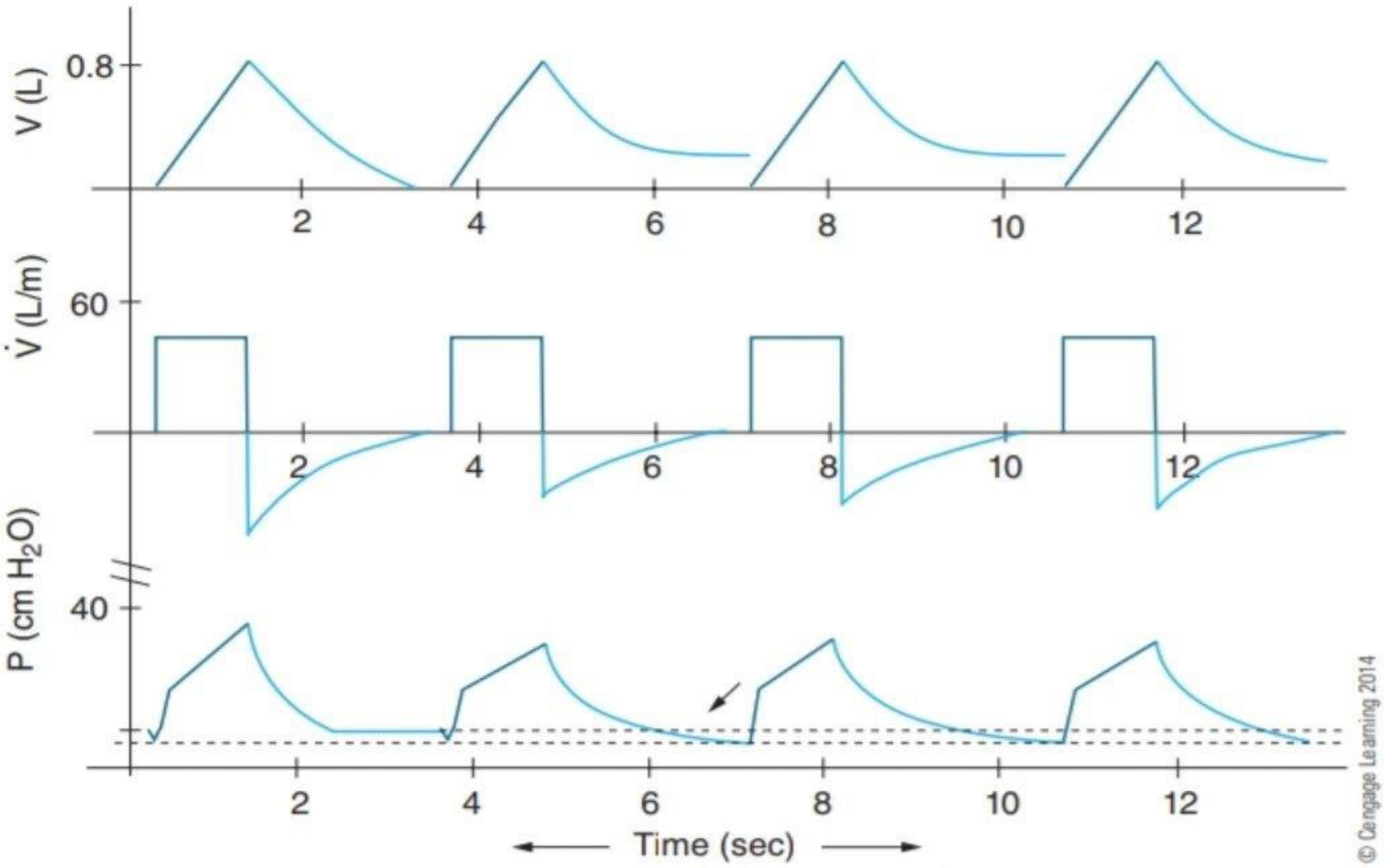

FIGURE 11-37 Changes to the volume-, flow-, and pressure-time waveforms demonstrate the effect of an air leak when PEEP is used. A reduced circuit pressure (due to air leak) is sufficient to drop the sensitivity level below the PEEP level, causing autotriggering and fast mechanical frequency.

the leak on vent waveform

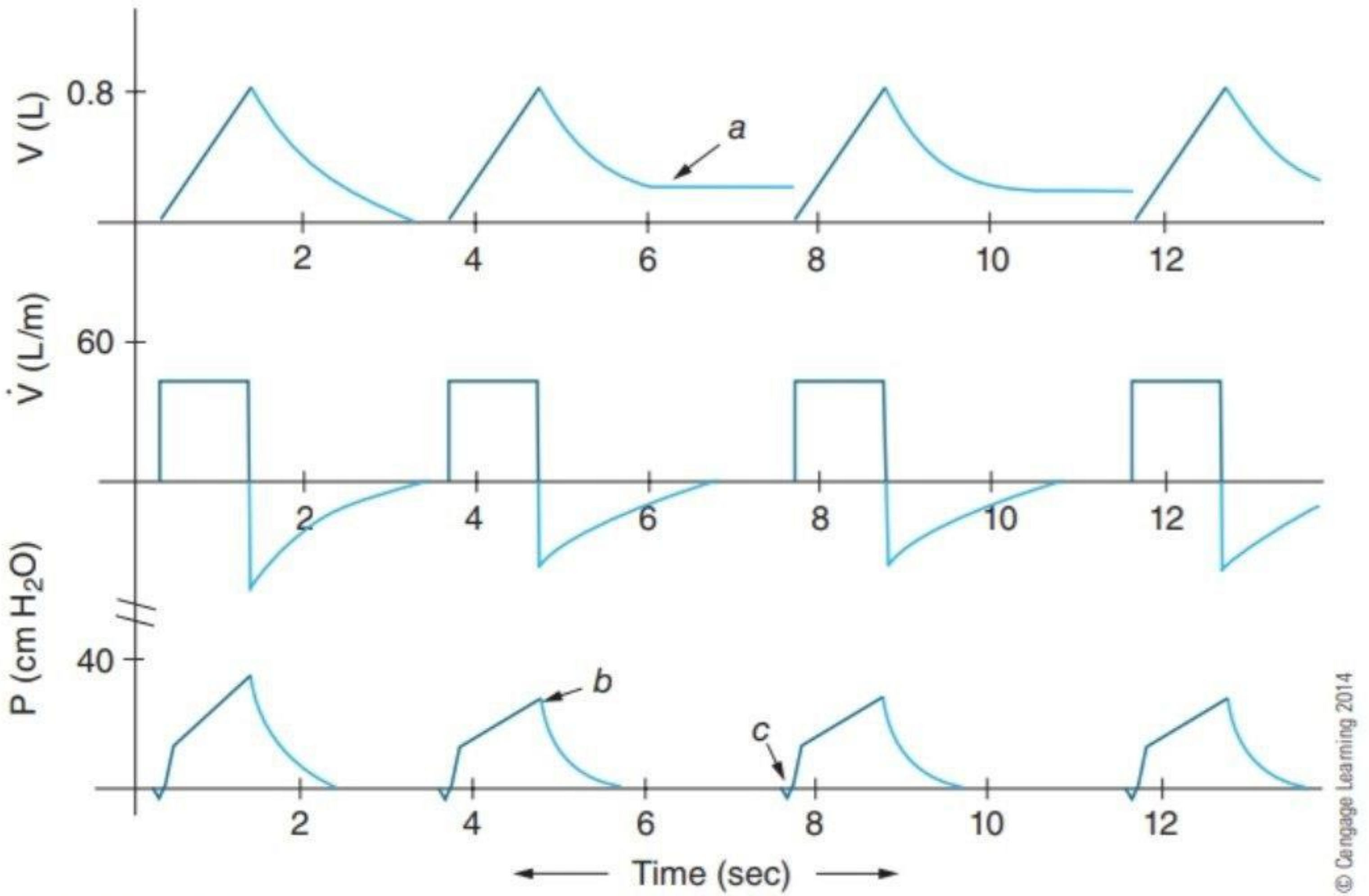

FIGURE 11-36 Changes to the volume-, flow-, and pressure-time waveforms demonstrate the development of an air leak. Note that the expiratory volume starting from the second breath (*a*) does not return to baseline. The peak inspiratory pressure starting from the second breath (*b*) is reduced from the previous level.

the leak on vent waveform

5. Correction:

- large size ETT.
- the cuff inflated between 25-35.
- no any rupture for the cuff.
- Reposition the tie or the Ett.
- check from all the connections.
- insure from the close suction not open.
- if the pt has BP fistula or chest tube > treat the cause[12,13,11].

5. Appendix..

1- the most important points on F-V and P-V loop.
2- C-stat VS C-dyn.

P-V loop

1/Lower inflection point on the inspiratory limb (LIPi or Pflex):

-represent: the opening up of the majority of collapsed alveoli.

-the benefit: used to set the appropriate PEEP level (about 2 cm H2o above LIPi) also can detect if the pt have increase inspiratory resistance or not.

Most important point (V-P Loop): UIPi, LIPi, UIPe..

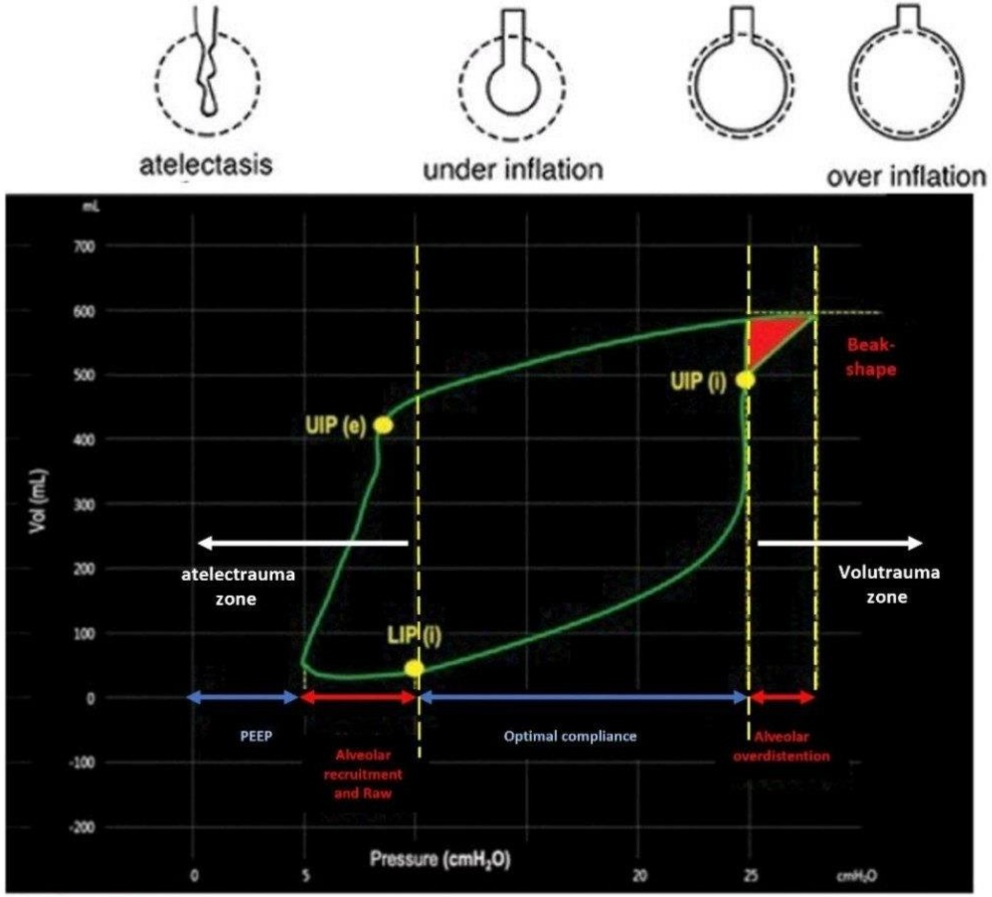

FIGURE 7-17 Pressure-volume loop (PVL) showing inflection points (IPs). The lower inflection point (LIP) represents the opening pressure, whereas the upper inflection points (UIPs) represent either the presence of alveolar overdistention [UIP (i)] or lung recoil and airway resistance characteristics [UIP (e)]. The beak-shaped part of the PVL at end of inspiration (red-shadowed area) is the region of pressure where rising pressure does not lead to increasing volume and indicates the presence of alveolar overdistention. PEEP, positive end-expiratory pressure; Raw, airway resistance.

P-V loop

2/Upper inflection point on the inspiratory limb (UIPi):

-represent: the end of alveolar recruitment and the beginning of pulmonary over-distension.

-the benefit: determine the beginning of the alveolar distention and detect the appropriate PC.

Most important point (V-P Loop):
UIPi, LIPi, UIPe..

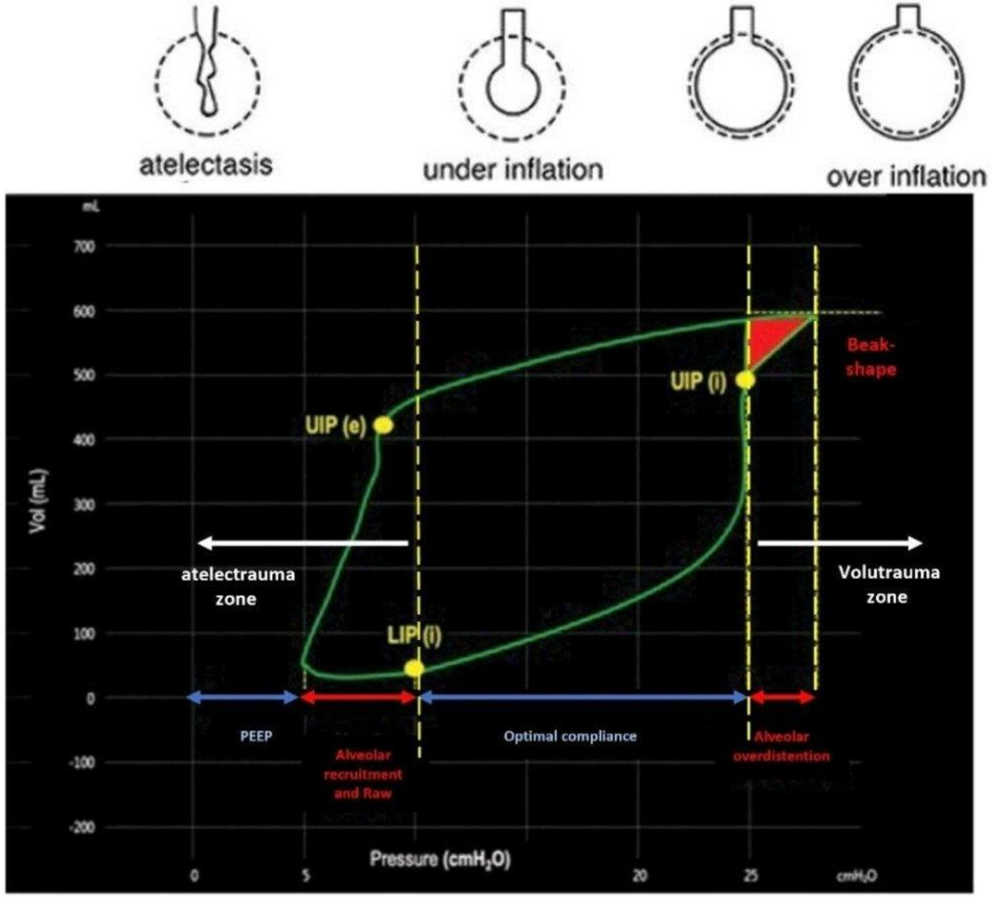

FIGURE 7-17 Pressure-volume loop (PVL) showing inflection points (IPs). The lower inflection point (LIP) represents the opening pressure, whereas the upper inflection points (UIPs) represent either the presence of alveolar overdistention [UIP (i)] or lung recoil and airway resistance characteristics [UIP (e)]. The beak-shaped part of the PVL at end of inspiration (red-shadowed area) is the region of pressure where rising pressure does not lead to increasing volume and indicates the presence of alveolar overdistention. PEEP, positive end-expiratory pressure; Raw, airway resistance.

P-V loop

3/ the slope between LIPi-UIPi:

-Represent: respiratory system compliance.

-the benefit: determine if the pt have low or high or normal lung compliance.

Most important point (V-P Loop): PEEP, TV, PIP.

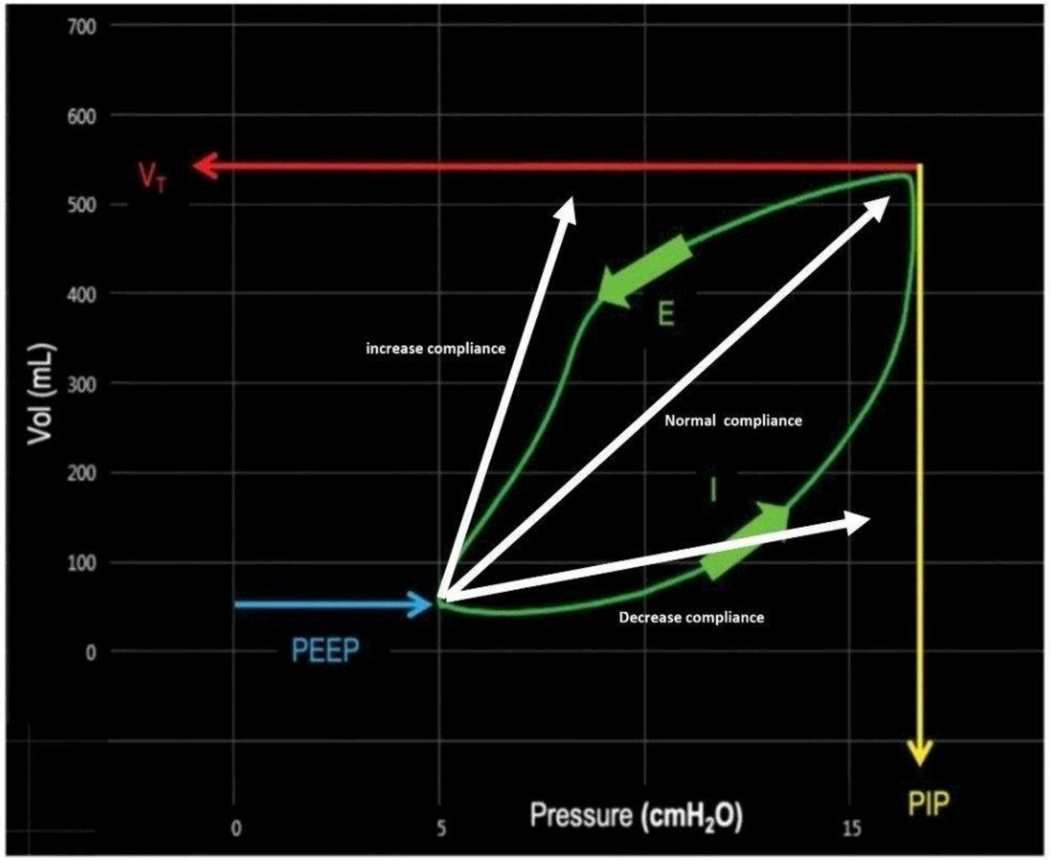

FIGURE 7-16 This pressure-volume loop shows a mechanical breath that occurs in a counterclockwise fashion. Inspiration (I) starts at a preset level of positive end-expiratory pressure (PEEP) (blue arrow) and exhalation (E) begins after either a preset peak inspiratory pressure (PIP) (yellow arrow) or VT (red arrow) has been reached.

P-V loop

4/ Upper platue portion of the inspiratory loop (beak-shaped or penguin-like shape):

-Represent: the alveolar overdistention (increase the pressure while small change in lung volume).

-The benefit: in ARDS pt determine if the set TV is high or not (volutruma).

Most important point (V-P Loop):
UIPi, LIPi, UIPe..

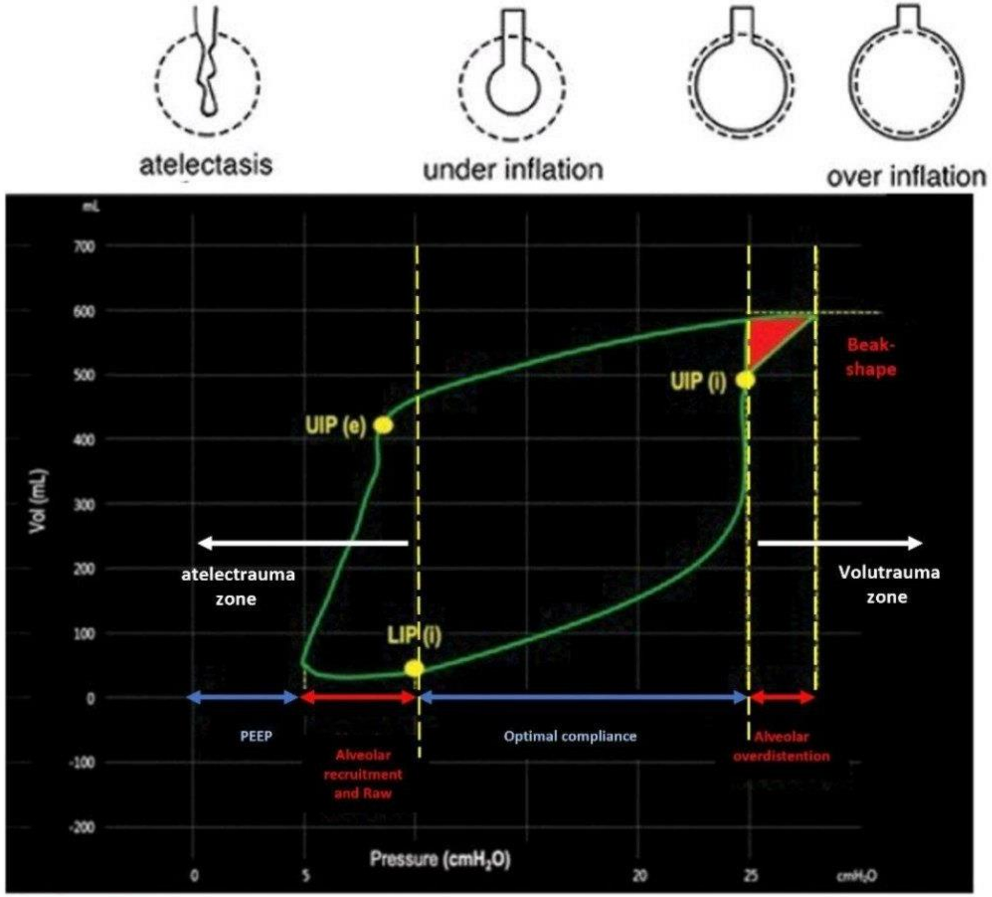

FIGURE 7-17 Pressure-volume loop (PVL) showing inflection points (IPs). The lower inflection point (LIP) represents the opening pressure, whereas the upper inflection points (UIPs) represent either the presence of alveolar overdistention [UIP (i)] or lung recoil and airway resistance characteristics [UIP (e)]. The beak-shaped part of the PVL at end of inspiration (red-shadowed area) is the region of pressure where rising pressure does not lead to increasing volume and indicates the presence of alveolar overdistention. PEEP, positive end-expiratory pressure; Raw, airway resistance.

P-V loop

5/ Upper inflection point on the deflation portion of the curve (UIPd, deflection point, deflation point):

-represent: lung recoil and airway resistance.

-the benefit: determine the appropriate level of peep and the airway resistance (detect if the pt have expiratory airway resistance or not).

-changes in respiratory compliance are best seen in P-V loops.

Most important point (V-P Loop):
UIPi, LIPi, UIPe..

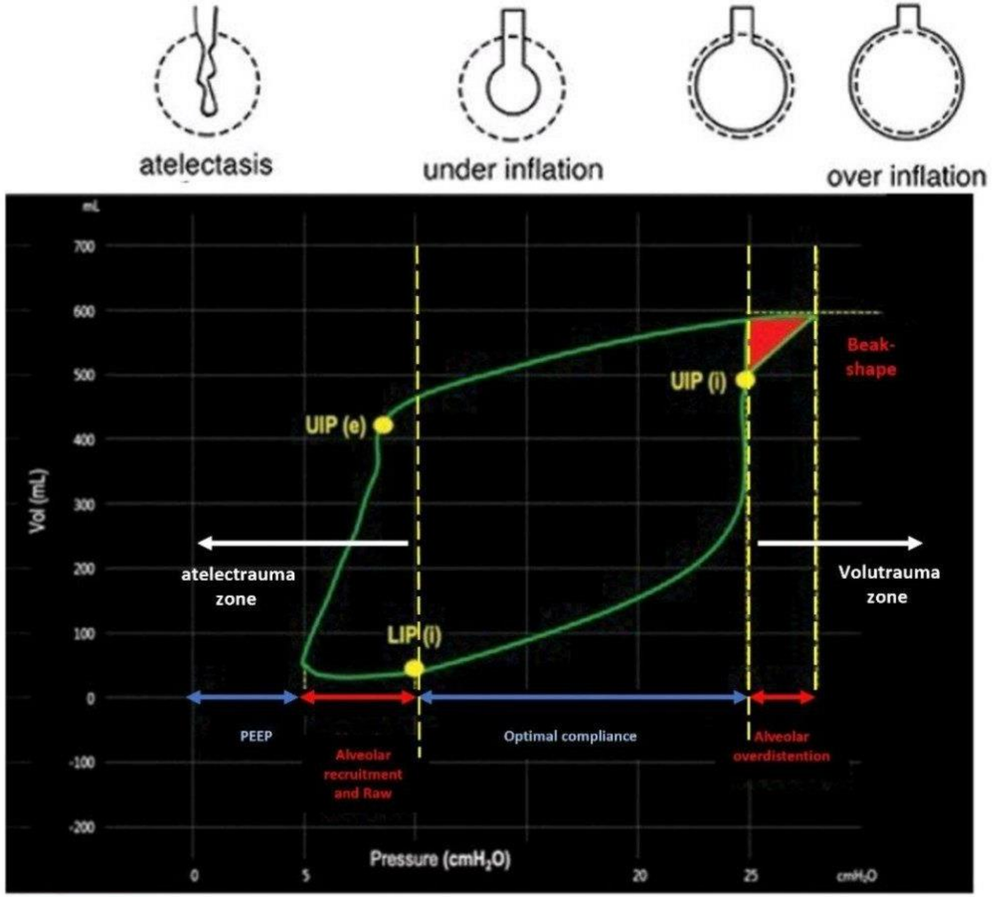

FIGURE 7-17 Pressure-volume loop (PVL) showing inflection points (IPs). The lower inflection point (LIP) represents the opening pressure, whereas the upper inflection points (UIPs) represent either the presence of alveolar overdistention [UIP (i)] or lung recoil and airway resistance characteristics [UIP (e)]. The beak-shaped part of the PVL at end of inspiration (red-shadowed area) is the region of pressure where rising pressure does not lead to increasing volume and indicates the presence of alveolar overdistention. PEEP, positive end-expiratory pressure; Raw, airway resistance.

F-V loop

1/ peak Inspiratory flow rate:

-represent: reflect the flow pattern set on ventilator, witch is a constant flow rate or square wave.

-the benefit: determine if the pt have inspiratory resistance or not.

Most important point (F-V Loop):
PIFR, PEFR, TV...

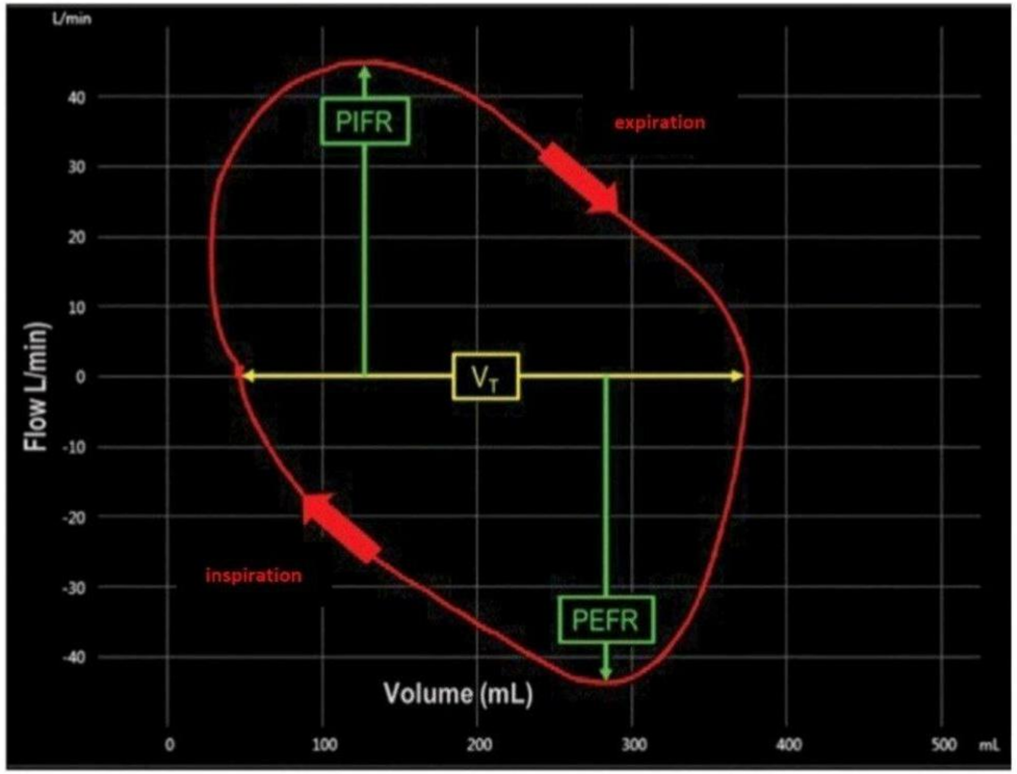

FIGURE 7-22 Waveform showing a typical configuration of the flow-volume loop. Peak inspiratory flow rate (PIFR), peak expiratory flow rate (PEFR), and VT are labeled.

F-V loop

2/ peak expiratory flow rate:

-represent: the volume of air expeld from the lung at faster rate.

-the benefit: influence by any thing that can cause airway obstruction, so that we can detect if the bronchodilator has good effect or not on the pt by this point, also the EPFR decrease as compliance increase.

Most important point (F-V Loop):
PIFR, PEFR, TV...

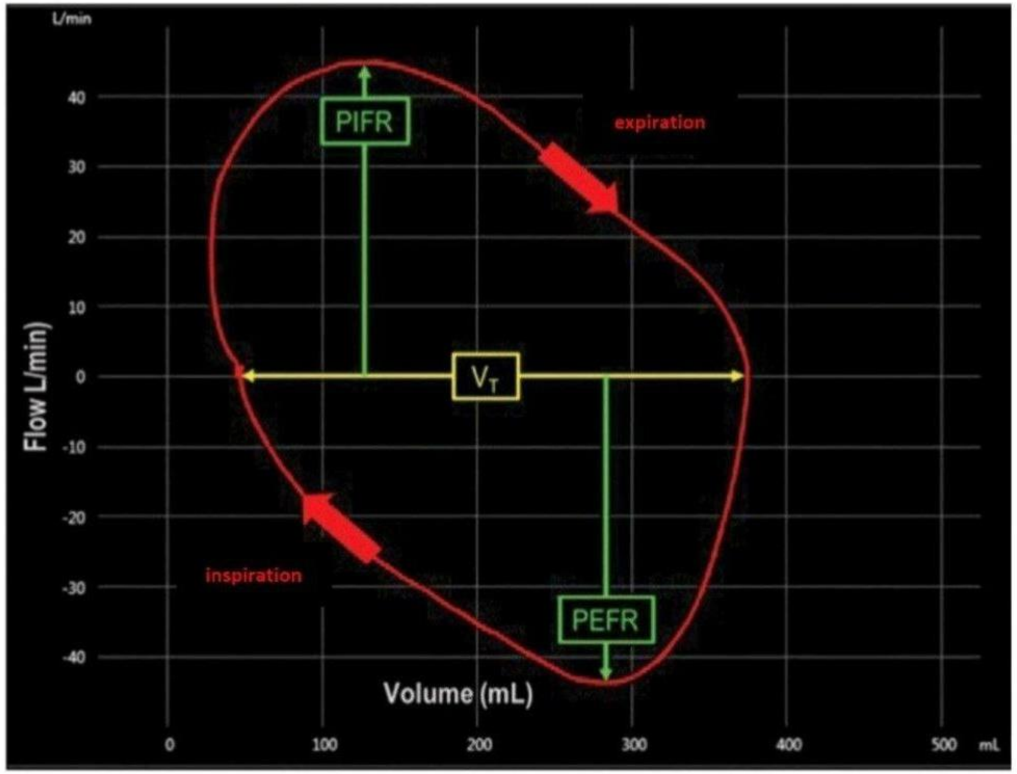

FIGURE 7-22 Waveform showing a typical configuration of the flow-volume loop. Peak inspiratory flow rate (PIFR), peak expiratory flow rate (PEFR), and VT are labeled.

F-V loop

3/ mid expiratory flow:

-the benefit: determine if the bronchodilator has good effect on pt or not.

4/ TV.

-the effects of bronchodilator are best appreciated in the F-V loop.

Most important point (F-V Loop): PIFR, PEFR, TV...

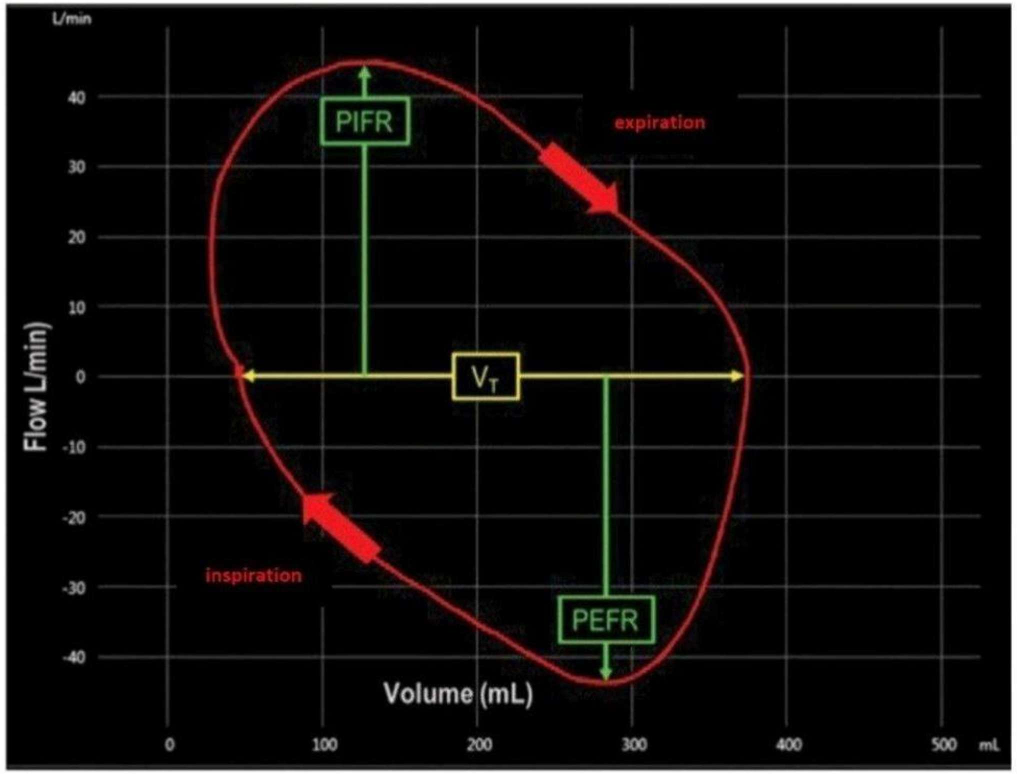

FIGURE 7-22 Waveform showing a typical configuration of the flow-volume loop. Peak inspiratory flow rate (PIFR), peak expiratory flow rate (PEFR), and VT are labeled.

static compliance loop

-Definition: the pressure required to overcome the elastic forces of the respiratory system for a given tidal volume, and under a zero flow (static) condition [1].
-reflect: the elastic resistance of the lung and chest wall [12].
-taken during: end inspiratory pause where gas movement is absent.
-normal range: 70-100 mL/cm H2O, if the pt on mv the normal range 40-60 mL/cm H2O (If the static compliance less than 25mL/cm H2O WOB very high) [11,23].
-equation: TV/Plat-PEEP.
-decrease: ARDS, atelactisis, tension pneumothorax, obesity, retained secretion.

dynamic compliance loop

-Definition: the compliance of the lung at any given time during actual movement of air [24].
-reflect: airway resistance and elastic properties of the lung and chest wall [12].
-taken during: mechanical breath with gas movment (airflow is present) [1].
-normal range: 50-80 mL/cm H2O [24]. for critically ill (30 - 40 mL/cm H2O) Cdyn.
-equation: TV/PIP-PEEP.
-decrease by: bronchospasm, kink Ett, airway obstruction or secretion, water in the vent circuit, mucosal edema.

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Thank you!