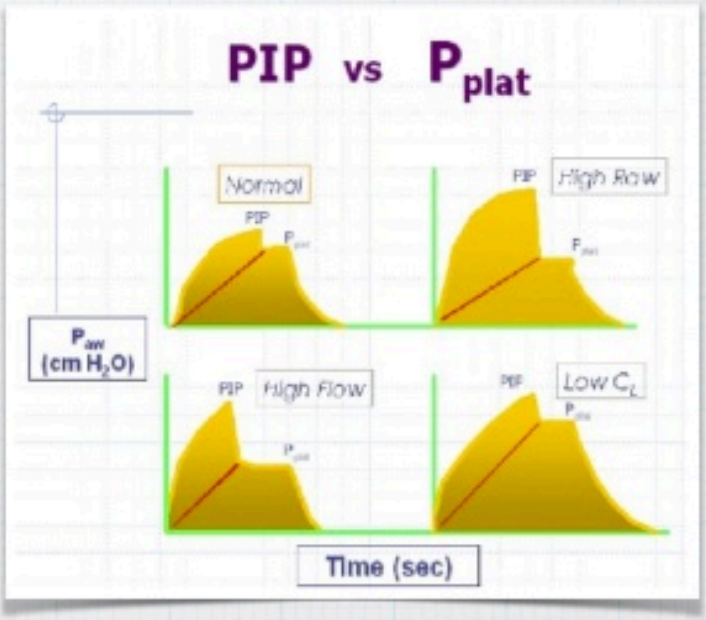
PIP and Pplat locate resistance

* High PIP +Normal Pplat= Increased resistance to flow [ETT obstruction or Bronchospasm]
* High PIP +High Pplat= Decreased lung compliance [Pneumonia,ARDS,Pulmonary Oedema,Abdominal distension]



Understanding airway pressures

The respiratory system can be thought of as a mechanical system consisting of resistive (airways +ET tube) and elastic (lungs and chest wall) elements in series

THUS P_{aw} = Flow X Resistance + Volume x 1/Compliance

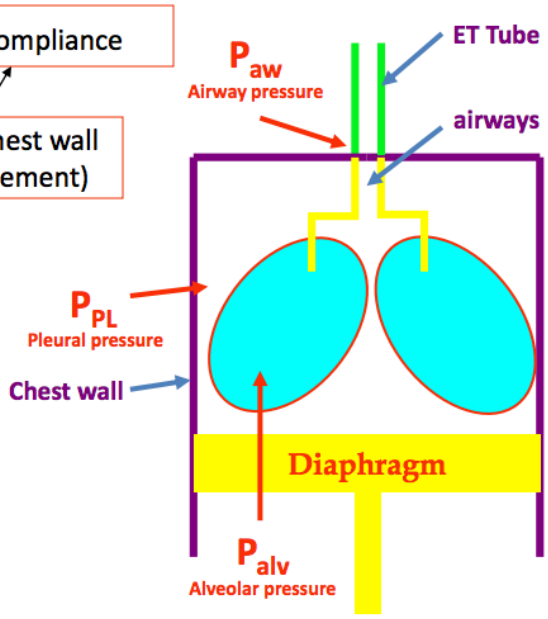
ET tube + Airways (resistive elements)

Lungs + Chest wall (elastic element)

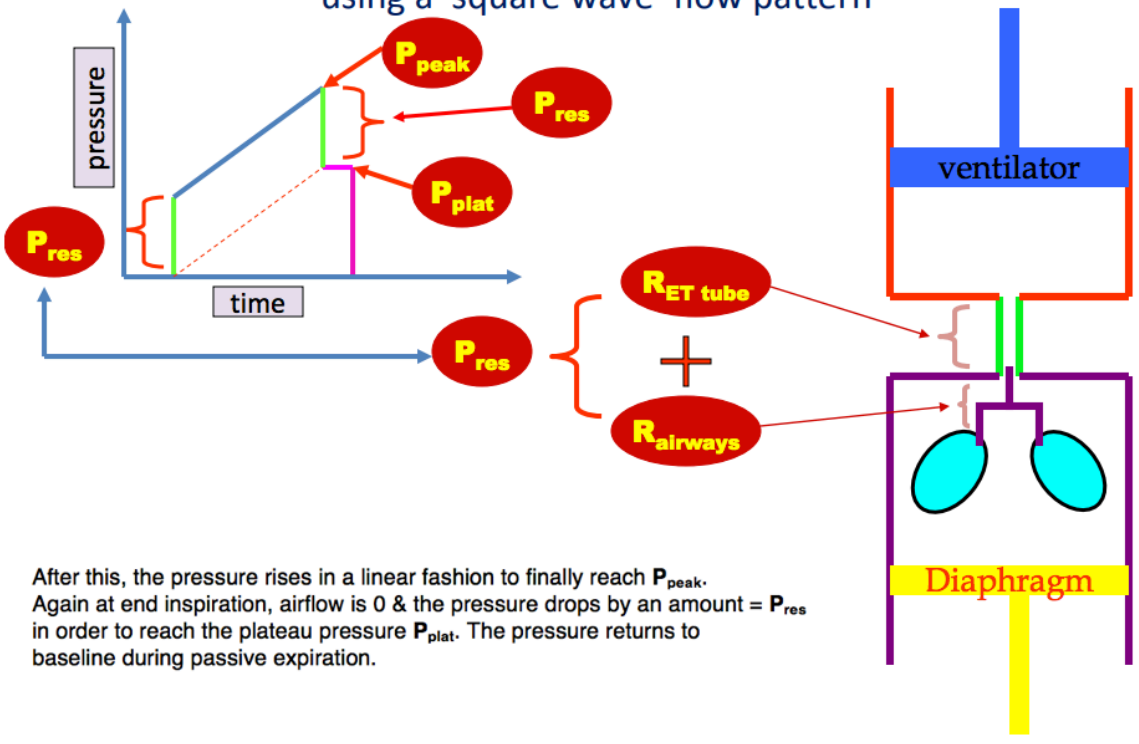
Resistive pressure varies with airflow & diameter of ETT & airways

The elastic pressure varies with volume & stiffness of lungs & chest wall.

P_{el} = Volume x 1/Compliance



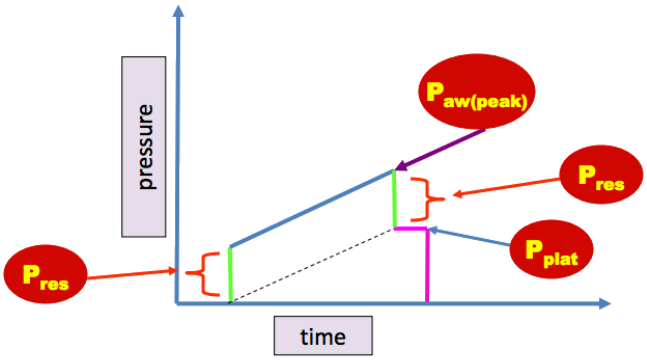
Understanding the pressure-time waveform using a 'square wave' flow pattern



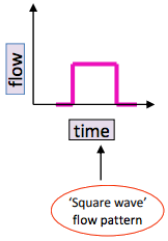
After this, the pressure rises in a linear fashion to finally reach P_{peak}. Again at end inspiration, airflow is 0 & the pressure drops by an amount = P_{res} in order to reach the plateau pressure P_{plat}. The pressure returns to baseline during passive expiration.

Pressure-time waveforms using a 'square wave' flow pattern

$P_{aw(peak)}$ = Flow x Resistance + Volume x 1/ Compliance

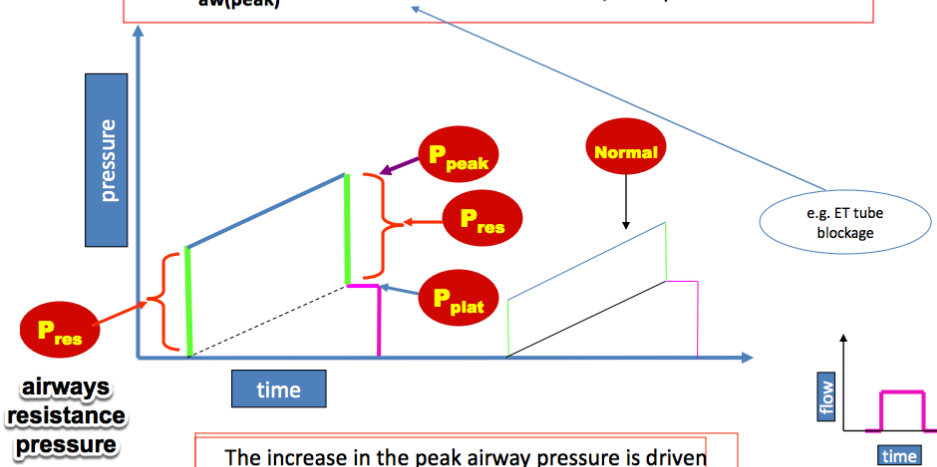


This is a **normal** pressure-time waveform
With normal peak pressures (P_{peak}) ;
plateau pressures (P_{plat})and
airway resistance pressures (P_{res})

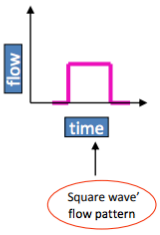


Waveform showing high airways resistance

$P_{aw(peak)}$ = Flow x Resistance + Volume x 1/ Compliance + PEEP



The increase in the peak airway pressure is driven entirely by an **increase** in the airways resistance pressure. Note the **normal** plateau pressure.



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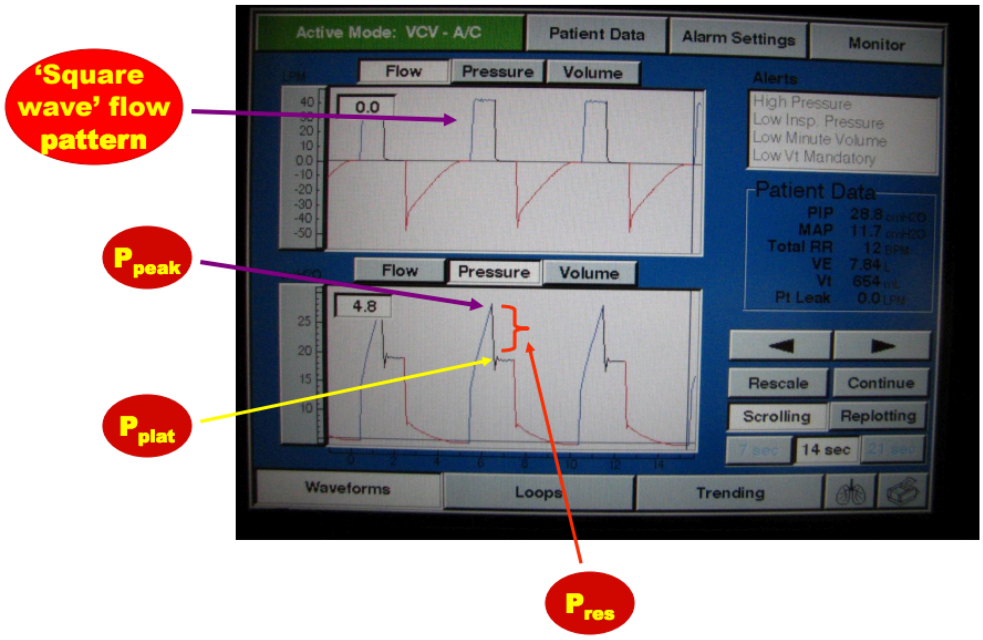
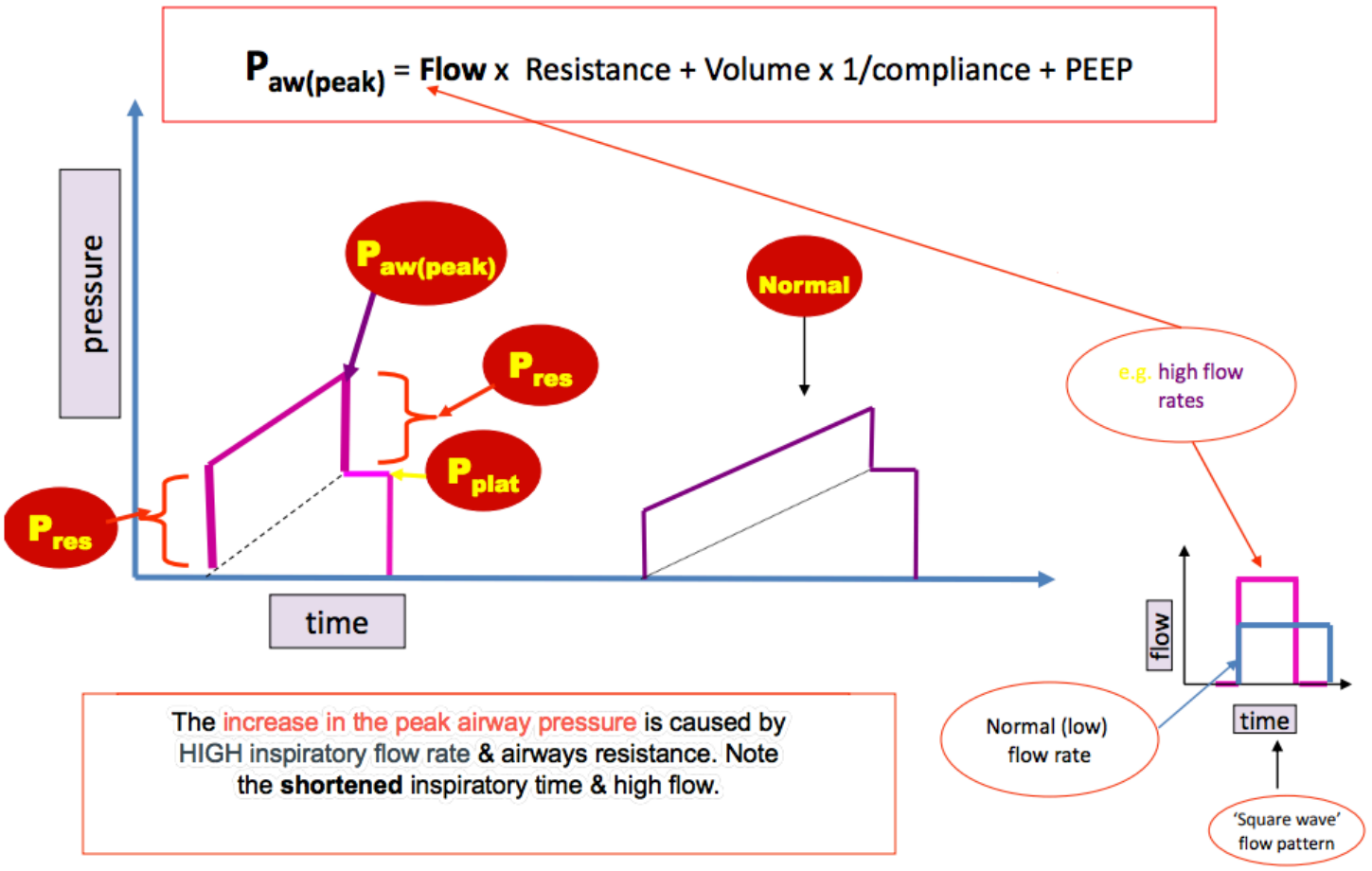
Waveform showing increased airways resistance

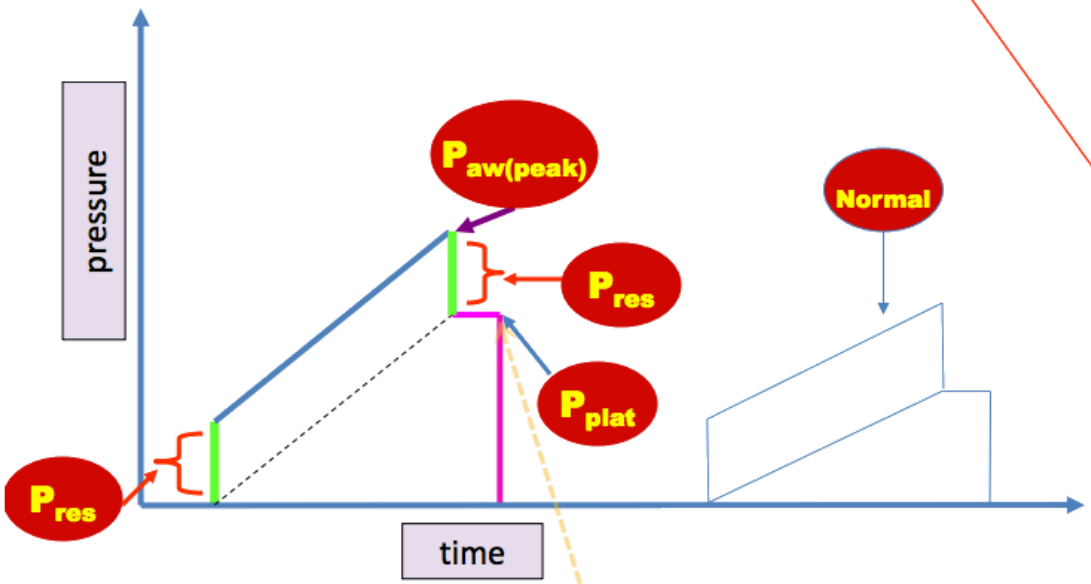


Waveform showing high inspiratory flow rates



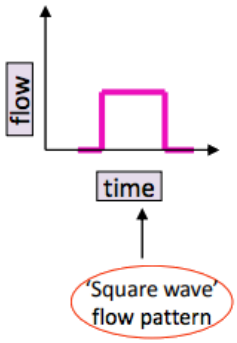
Waveform showing decreased lung compliance

$P_{aw(peak)}$ = Flow x Resistance + Volume x 1/ Compliance + PEEP

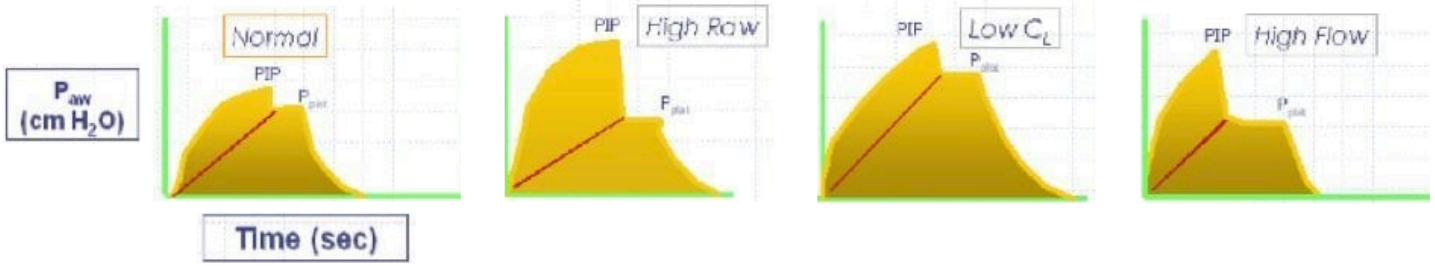


e.g. ARDS

The increase in the peak airway pressure is driven by the DECREASE in *lung compliance*. Increased airways resistance is often also a part of this scenario. Plateau Pressure is INCREASED!



PEAK INSPIRATORY PRESSURE (PIP) vs Plateau Pressure (P_{plat})



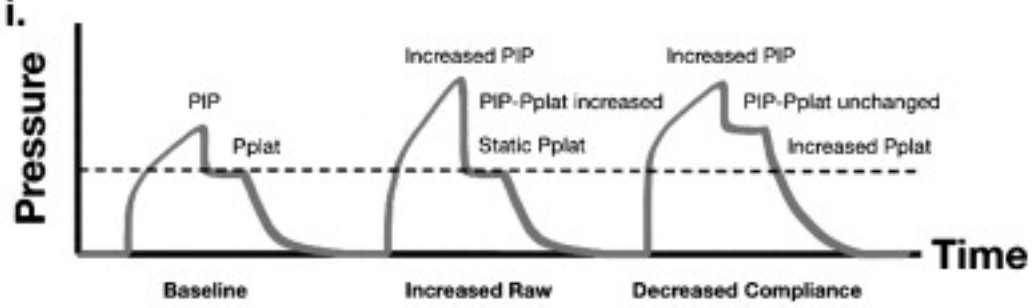
Normal:
Normal PIP: < 40
Normal Pplat: < 30

Hi airway resistance:
Hi PIP, normal Pplat

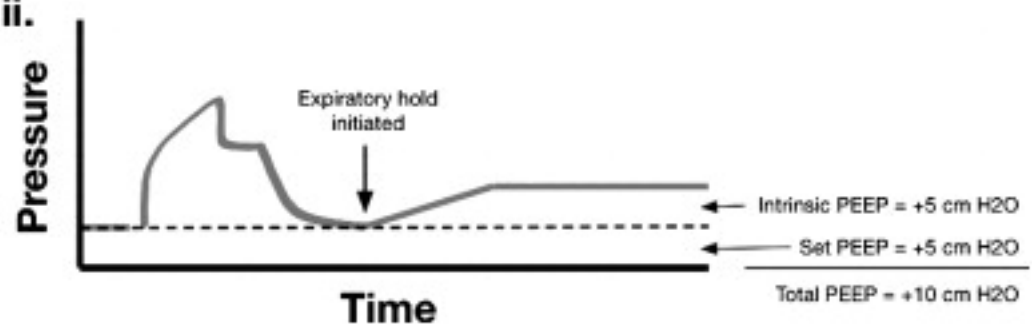
Low Lung Compliance:
Hi PIP, Hi Pplat

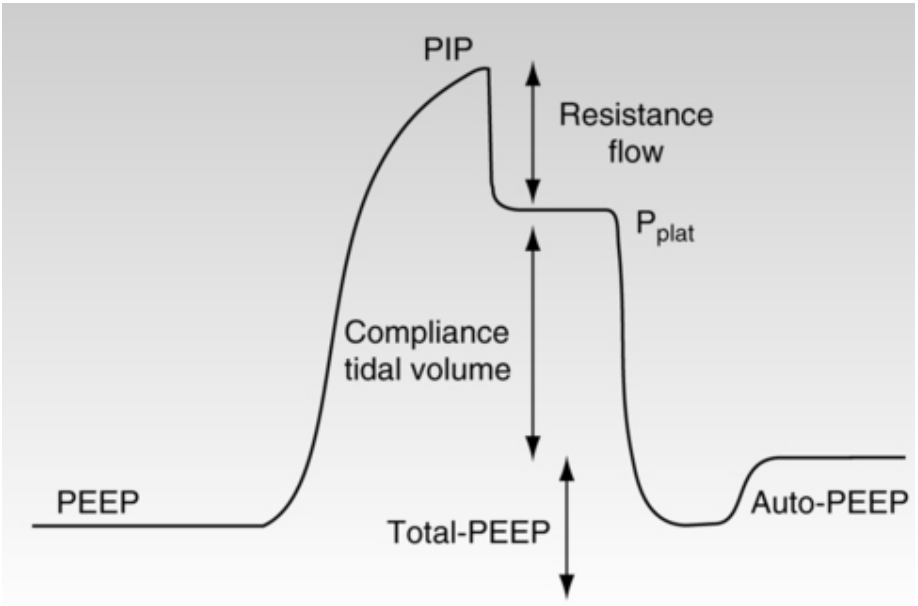
Hi Flow Rate:
Increases PIP !
Inspiratory time is SHORTER than normal.
Hi PIP, normal Pplat

i.

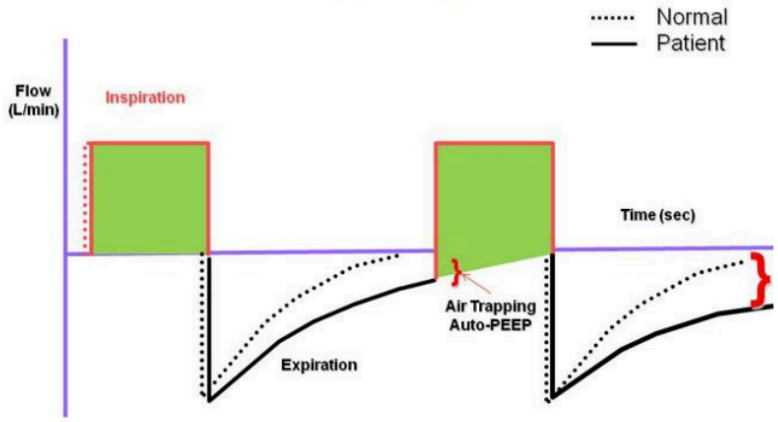

Pressure
PIP
Pplat
Increased PIP
PIP-Pplat increased
Static Pplat
Increased PIP
PIP-Pplat unchanged
Increased Pplat
Time
Baseline
Increased Raw
Decreased Compliance

ii.


Pressure
Expiratory hold initiated
Intrinsic PEEP = +5 cm H2O
Set PEEP = +5 cm H2O
Total PEEP = +10 cm H2O
Time


PIP
Resistance flow
Pplat
Compliance tidal volume
PEEP
Total-PEEP
Auto-PEEP

Air Trapping

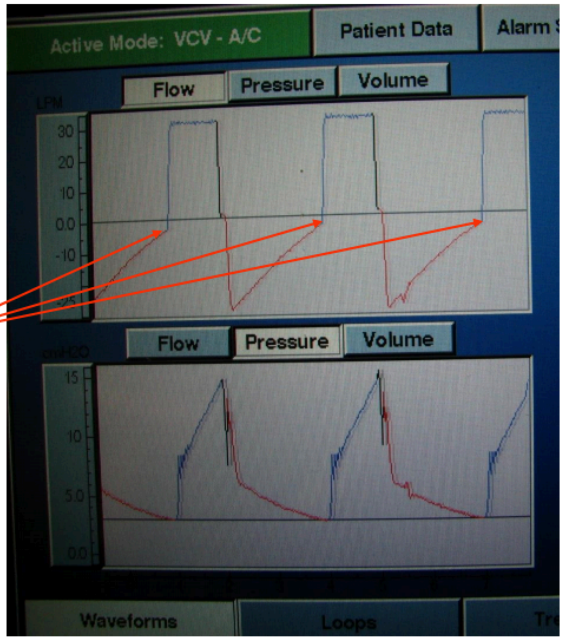


Expiratory flow continues and fails to return to the baseline prior to the new inspiratory cycle

Detecting Auto-PEEP

Recognize Auto-PEEP when

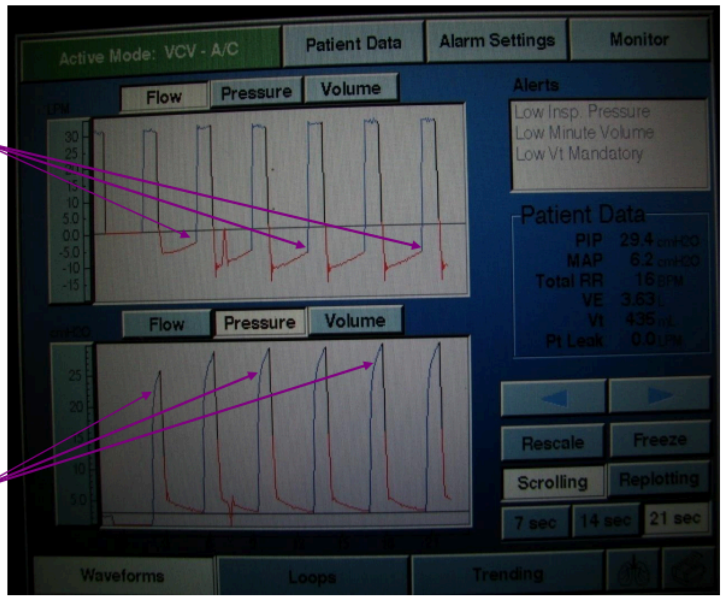
Expiratory flow continues and fails to return to the baseline prior to the new inspiratory cycle



The development of auto- PEEP over several breaths in a simulation

Notice how the expiratory flow fails to return to the baseline indicating air trapping (AutoPEEP)

Also notice how air trapping causes an increase in airway pressure due to increasing end expiratory pressure and end inspiratory lung volume.



Understanding how flow rates affect I/E ratios and the development of auto PEEP

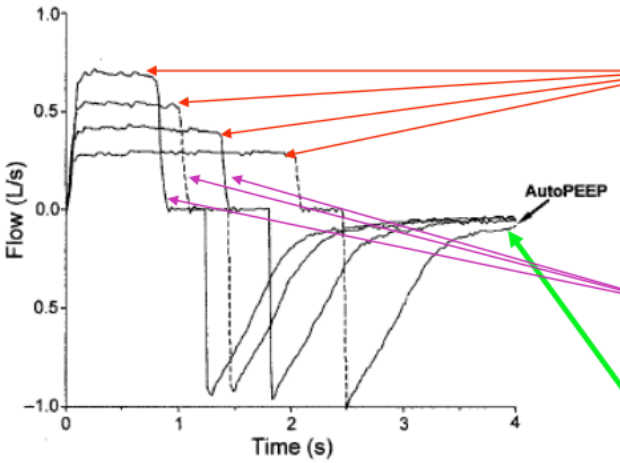


Fig. 1. Flow waveform showing air trapping by decreasing flow at equal tidal volume. Progressive reduction in expiratory time generates auto-PEEP when the expiratory time is not long enough to exhale all of the preceding tidal volume.

Decreasing the flow rate

Increase the inspiratory time and consequently decrease the expiratory time (decreased I/E ratio)

Thus allowing incomplete emptying of the lung and the development of air trapping and auto-PEEP

Lluis Blanch MD, PhD et al: Respiratory Care Jan 2005 Vol 50 No 1

Recognizing prolonged expiration (air trapping)

Recognize **airway obstruction** when

Expiratory flow quickly tapers off and then enters a prolonged low-flow state without returning to baseline (auto- PEEP)

This is classic for the flow limitation and decreased lung elastance characteristic of COPD or status asthmaticus

Common problems that can be diagnosed by analyzing Ventilator waveforms

Abnormal ventilatory Parameters/ lung mechanics
E.g.. Overdistension, Auto PEEP COPD

Patient-ventilator Interactions
E.g. flow starvation, Double triggering, Wasted efforts Active expiration

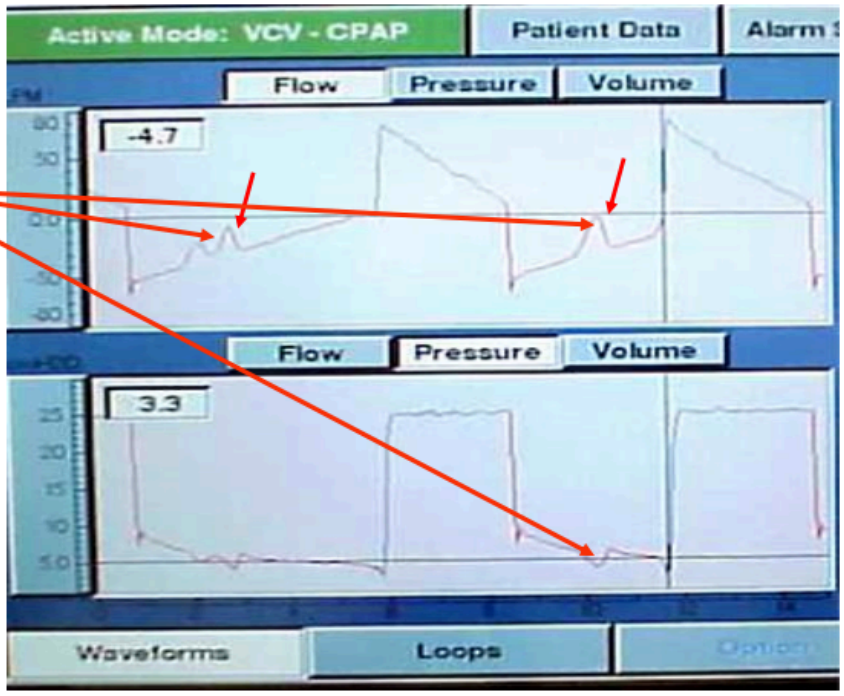
Ventilatory circuit related problems
E.g. auto cycling and Secretion build up in the Ventilatory circuit

Recognizing ineffective/wasted patient effort

Patient inspiratory effort fails to trigger vent resulting in a wasted effort

Results in fatigue, tachycardia, increased metabolic needs, fever etc

Causes: High AutoPEEP, respiratory muscle weakness, inappropriate sensitivity settings



Recognizing flow starvation

Look at the pressure-time waveform

If you see this kind of scooping or distortion instead of a smooth rise in the pressure curve....

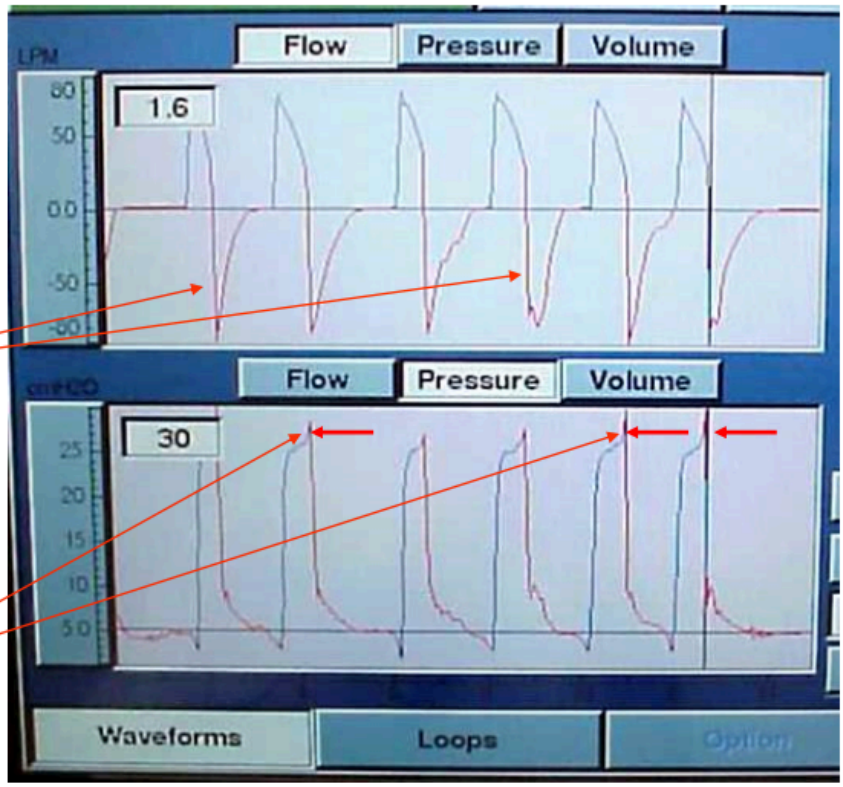
Diagnose flow starvation in the setting of patient discomfort, fatigue, dyspnea, etc on the vent

Recognizing active expiration

Look at the flow-time & pressure-time waveform

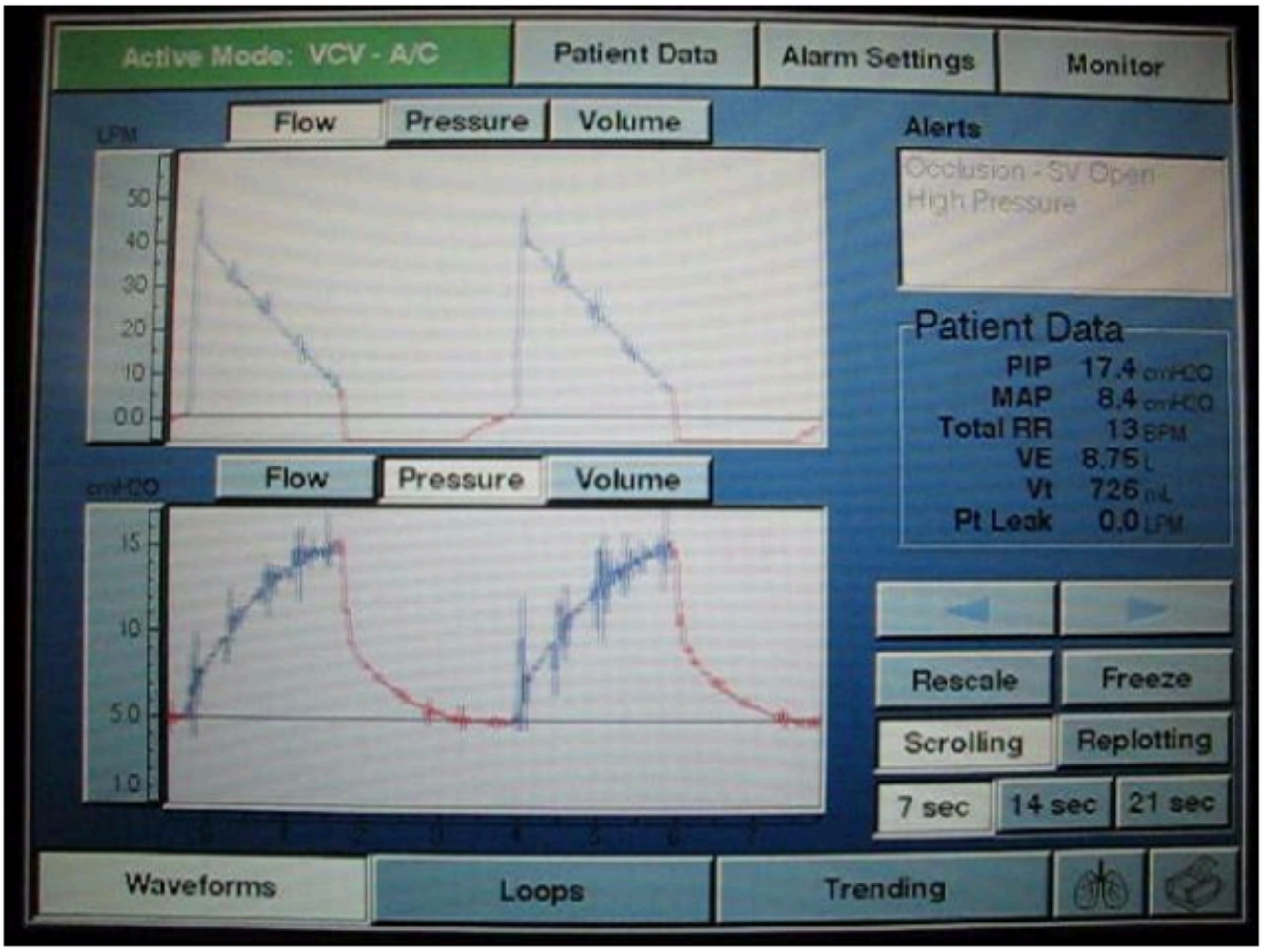
Notice the high and variable expiratory flow rates due to varying expiratory muscle effort

The patient's active expiratory efforts during the inspiratory phase causes a pressure spike.

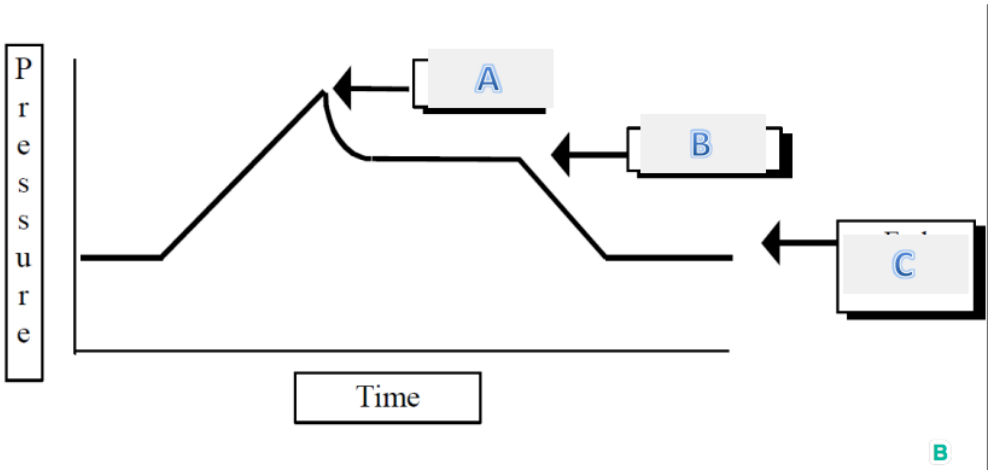


PEARL: This is a high drive state where increased sedation/paralysis and mode change may be appropriate for lung protection.

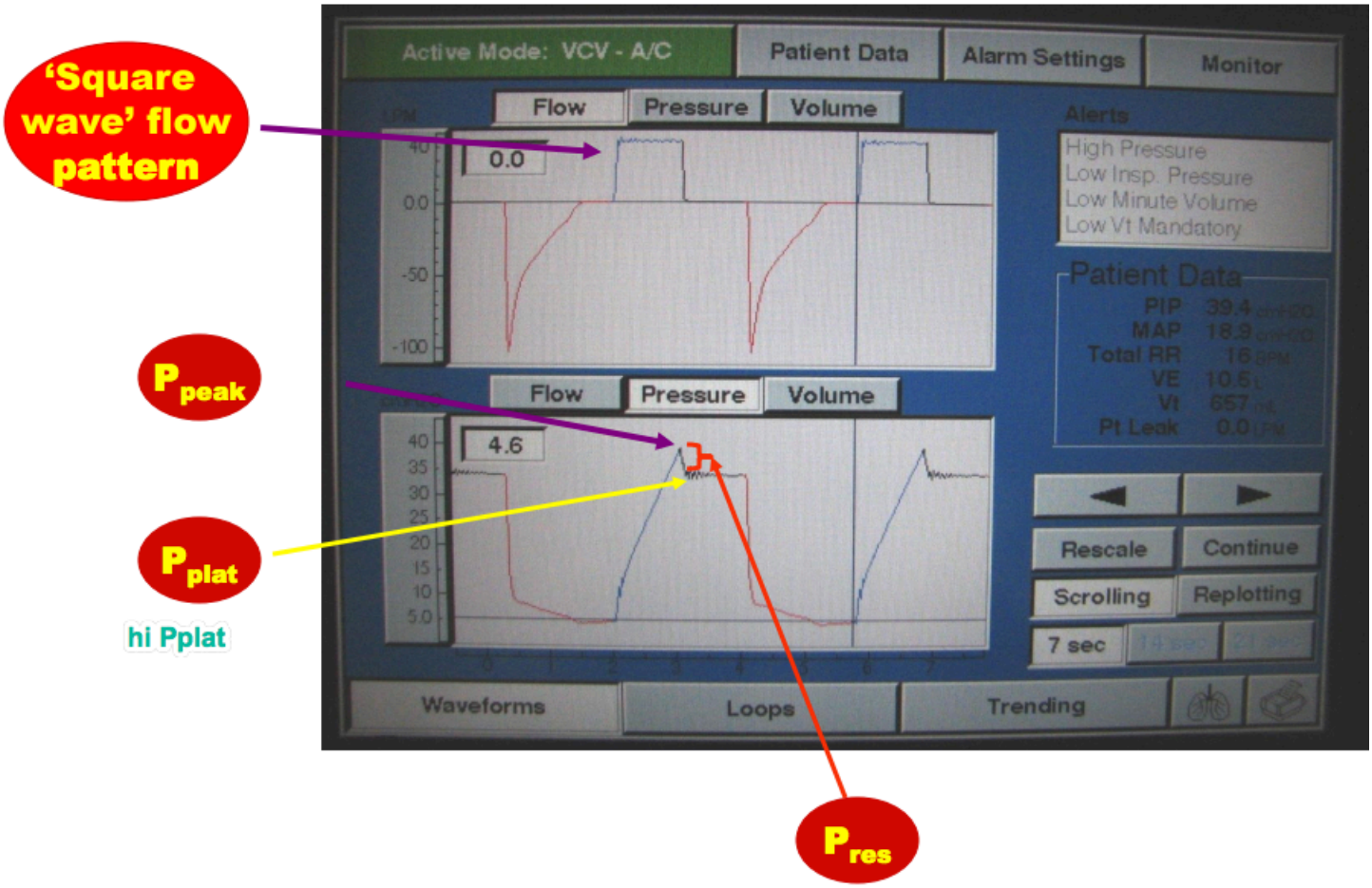
Characteristic scalars due to secretion build up in the tubing circuit



Where is the plateau pressure?

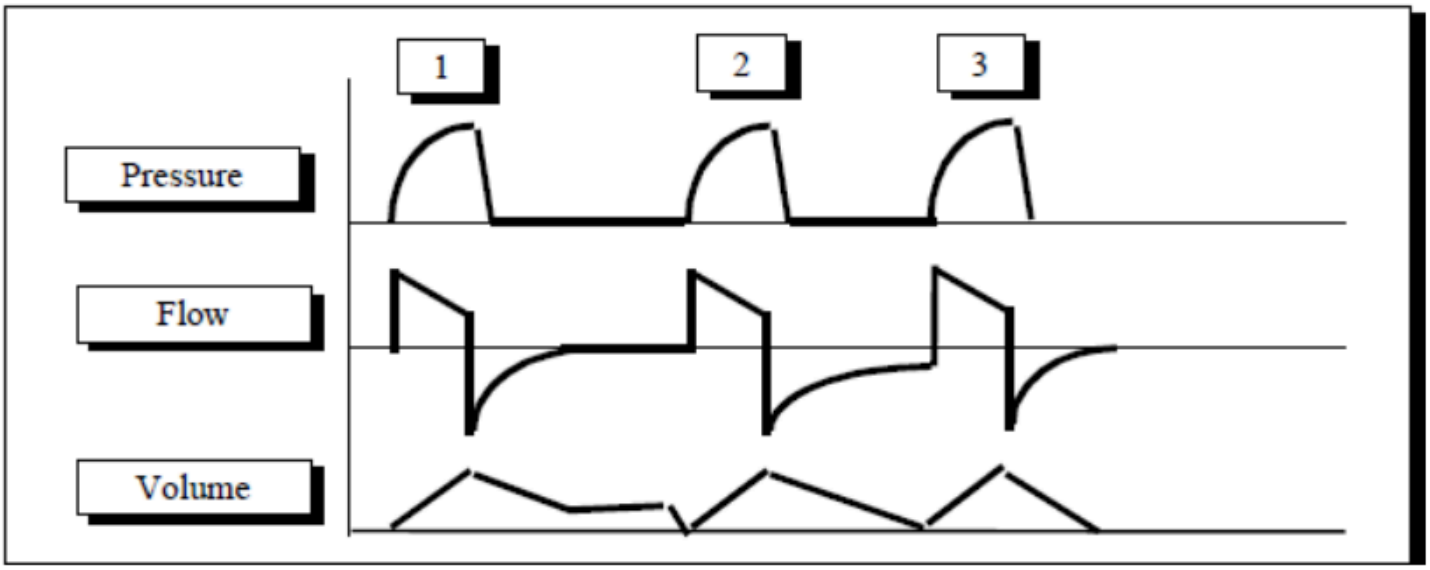


Waveform showing decreased lung compliance



Which waveform shows autopeep?

2



What is shown by the Red Arrow

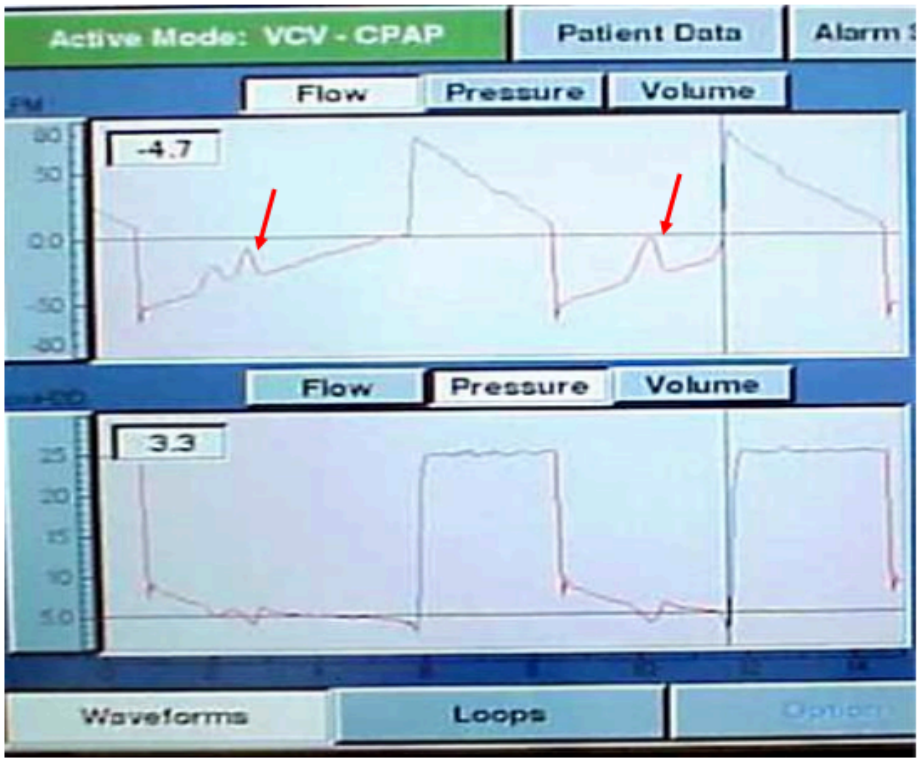
A. Auto Peep

B. Retained Secretions

C. Ineffective Patient Effort

D. Double Triggering

C



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