Unraveling the Mystique of Airway Pressure Release Ventilation

Recommendations & Revisions

Airway Pressure Release Ventilation (APRV) is a recruitment mode that provides a high mean airway pressure (MAP) by setting a prolonged inspiratory time, an adequate inspiratory pressure, and a short expiratory time.

If adequately set, the mode provides a good recruitment and maintains adequate lung protection.

The mode has been used initially to rescue patients with severe ARDS who fail on conventional modes of ventilation.

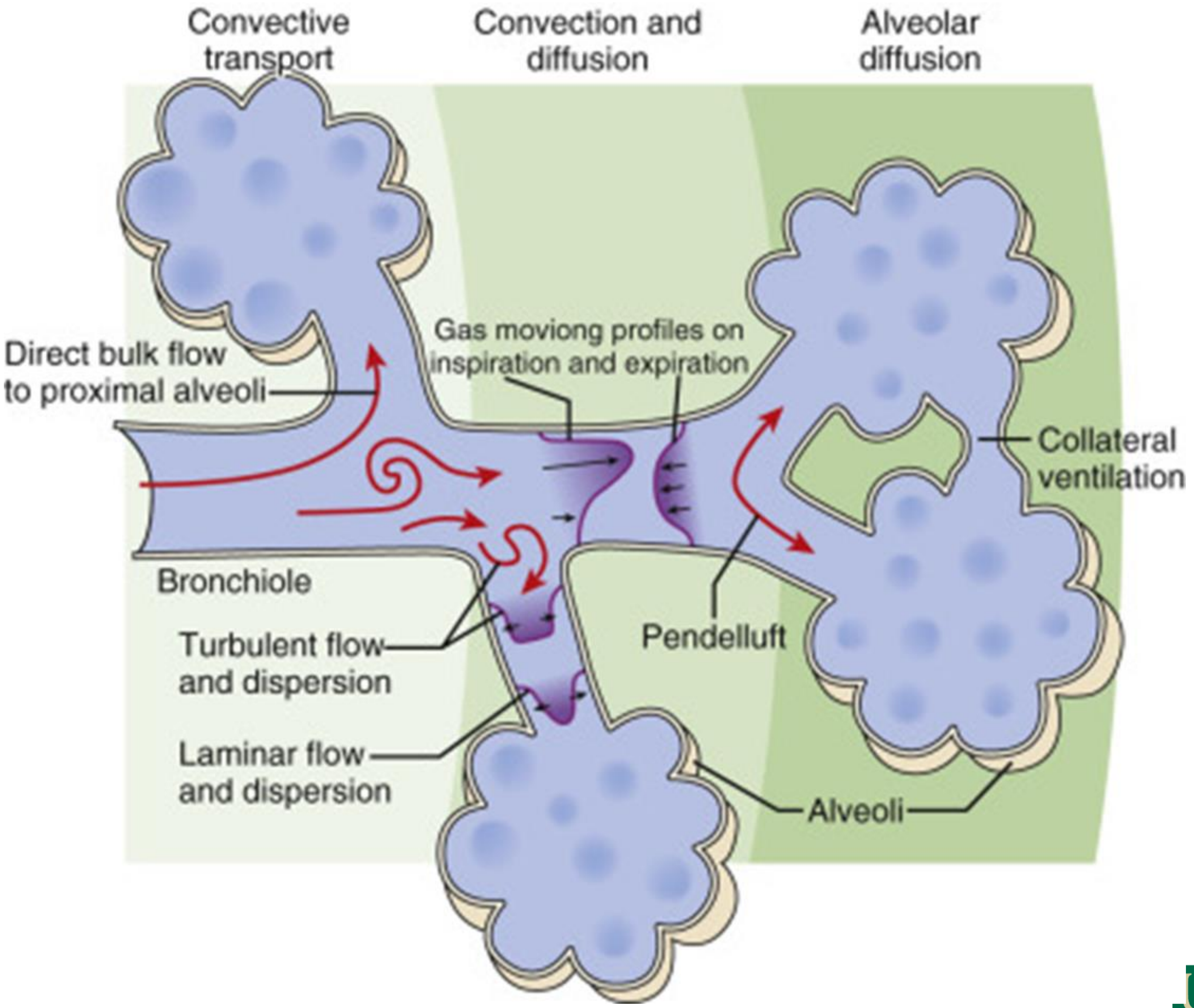
However, If started late, it may be difficult to recruit the lung, and ventilation is often a problem. This is why multiple studies have shown conflicting results.

This mode, if used, should be started early in the management of ARDS cases, as shown in a study published in the Intensive Care Medicine Journal by Zhou et al. The study included 138 patients who were randomized to APRV (71 patients) or low tidal ventilation (67 patients).

Despite some limitations in the study, it showed that there is no statistical difference in ICU mortality, but patients on APRV had more ventilator-free days, a higher rate of successful extubation, and a lower rate of tracheostomy. More studies are certainly needed to verify its benefits.

What is APRV?

- Airway pressure release ventilation (APRV) is a ventilator mode that utilizes a distending pressure along with a long inspiratory phase(> 4 seconds)
- Utilizes collateral alveolar ventilation to increase lung inflation
  - Popcorn in microwave effect
  - Required time to maximize lung inflation >2 hrs.



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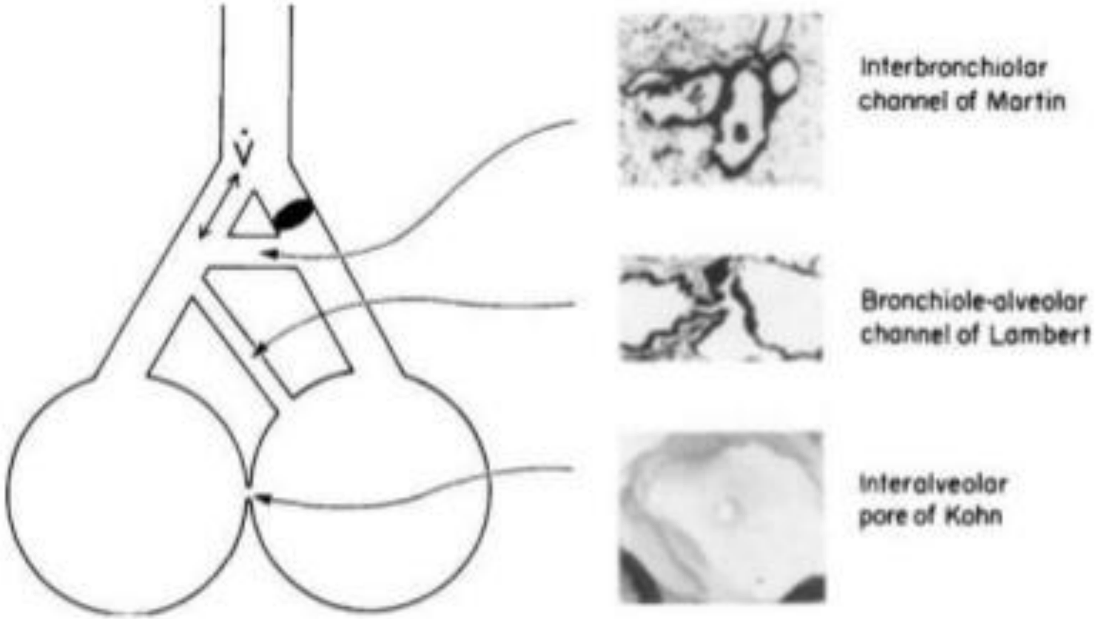
Definition :

"the ventilation of alveolar structures through passages or channels that bypass the normal airways"

And these are :

- Inter-bronchiolar
- Inter-alveolar
- Bronchiolo-alveolar.
- Interlobar " through fissues "



APRV takes advantage of the collateral channels of ventilation that are barely used at the FRC level in normal, healthy lungs

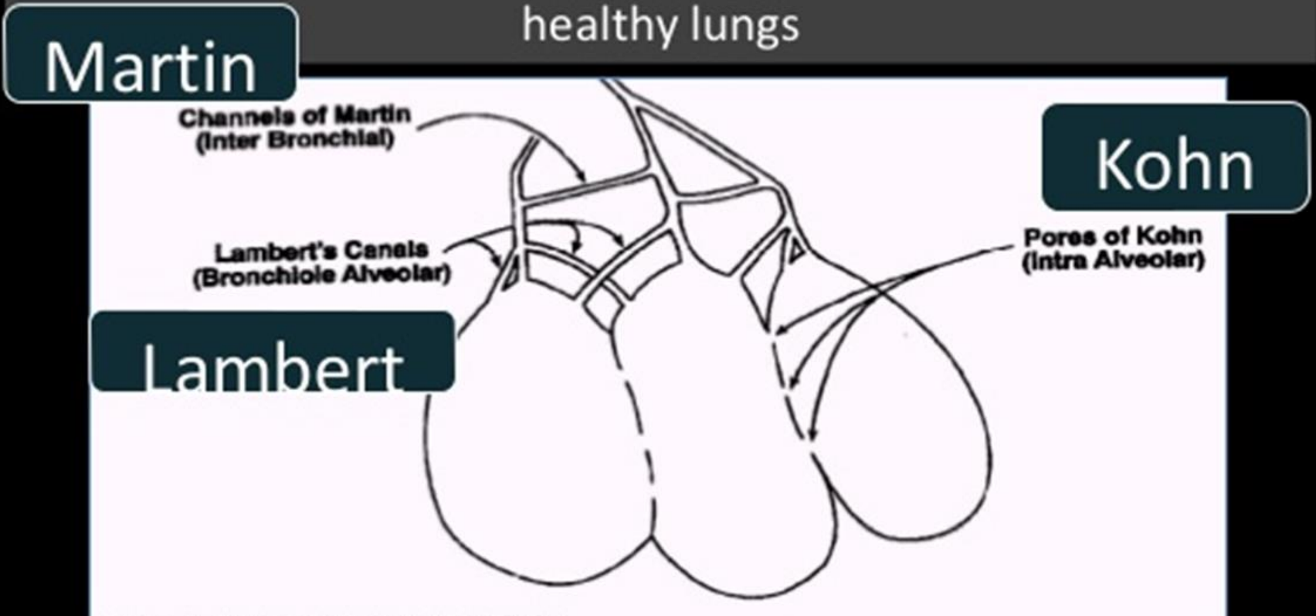
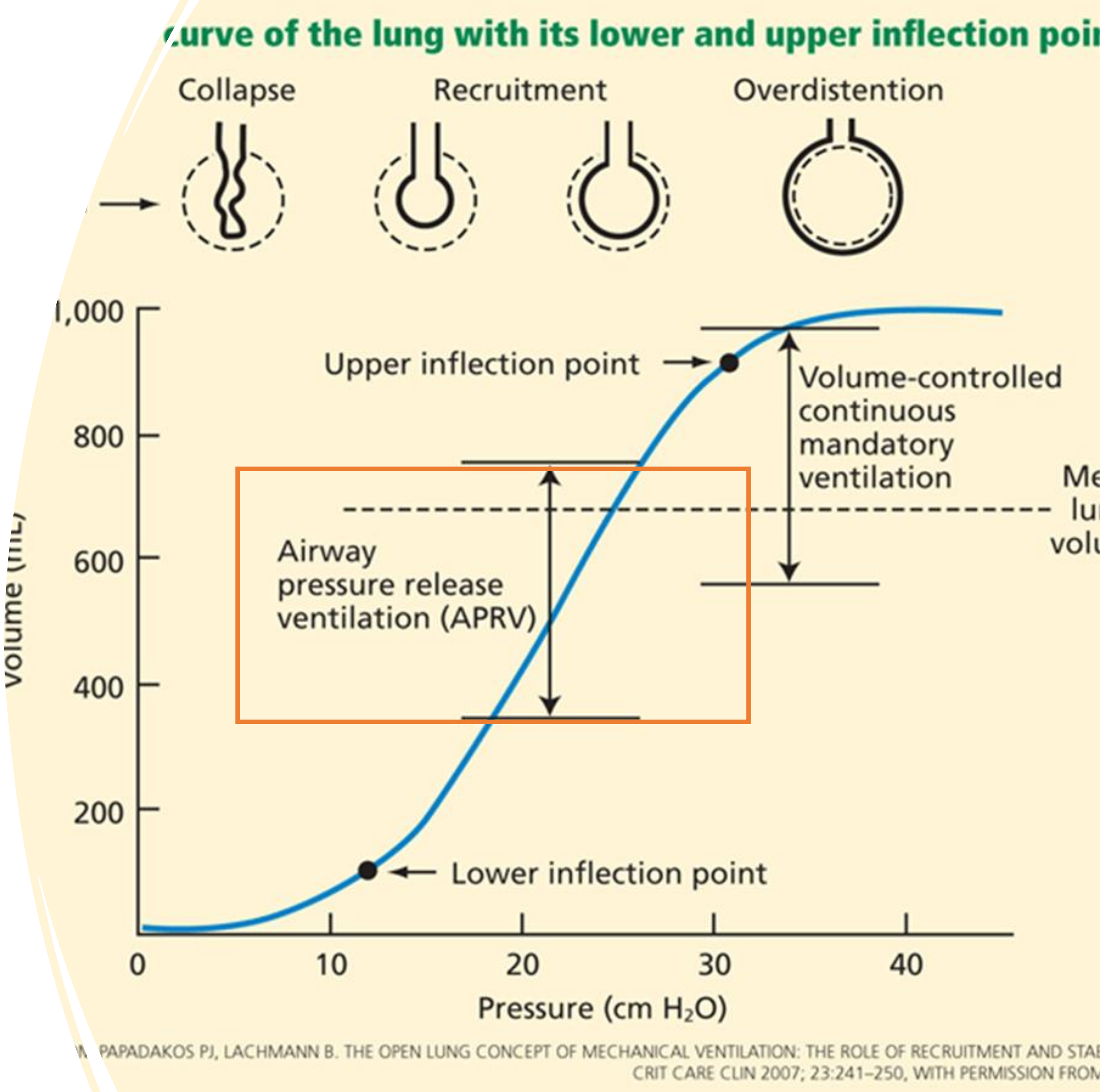


Figure 4. Collateral channels of ventilation

They become important In diseased states

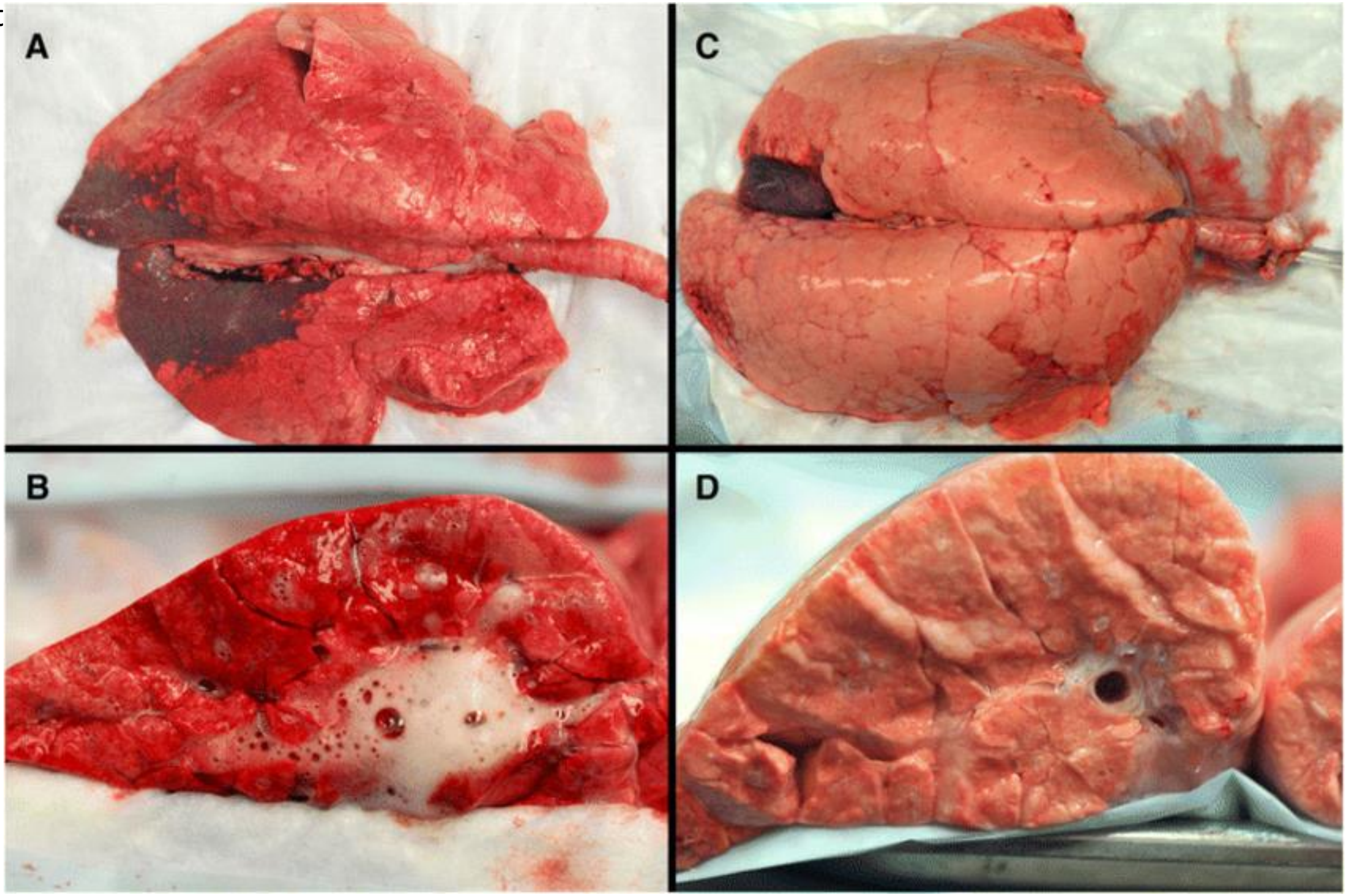
APRV=Open lung Concept



Conventional Mode

APRV

Animal surfactant wash out model



APRV Indications

- Refractory hypoxemia
  - **P/F<200 FIO2>70% and PEEP>10cm**
- ARDS
- Patients with high risk of respiratory deterioration – traumatic chest injury, aspiration, inhalation injury, pancreatitis
- Obesity BMI>35
- Bilateral atelectasis with increased oxygenation needs
- Unable to improve gas exchange via convention ventilation strategies

Airway Pressure Release (APRV) Parameters

- Two levels of Pressure
  - P_{high}
  - P_{low}
- Marked by a long inspiratory time and short expiratory time
  - T_{high}
  - T_{low}

APRV Settings

APRV SETTINGS

When starting APRV, the settings need to be maximized according to protective lung strategy. There are four main settings on APRV: P High, P Low, T High, and T Low. APRV is a pressure control mode.

Each individual breath is time-triggered, pressure-targeted, and time-cycled. Inspiration time (and thus cycling) is determined by setting the T-High. Expiration time is determined by setting the T Low. P High and T High levels help in lung recruitment and improve oxygenation.

P Low and T low help in maintaining lung recruitment in expiratory phase. The P Low is usually set at 0 cm H2O and lung recruitment is ensured by setting the end-expiratory flow rate at 50-75% of the peak expiratory flow (PEF) rate.

When the flow is cut by 50-75% of PEF, the lung will not completely empty and auto-PEEP will be build up, like the dynamic hyperinflation syndrome in asthmatic patients.

Lastly, spontaneous breaths must be preserved with APRV as they participate in a good percentage of minute ventilation.

Airway pressure Release ventilation

P_{High}

Set P_{High} 5 cm H_2O above mean airway pressure from previous conventional mode of ventilation. (may set it at the plateau pressure in volume-targeted modes or the pressure control in pressure-targeted modes).

Increase P_{High} gradually to improve oxygenation but do not exceed 30 cm H_2O (35 cm H_2O in severe obesity) to maintain lung protection.

Larger P_{High} causes large release volume, over-distention of the lung, excess driving pressure, and may impair hemodynamics.

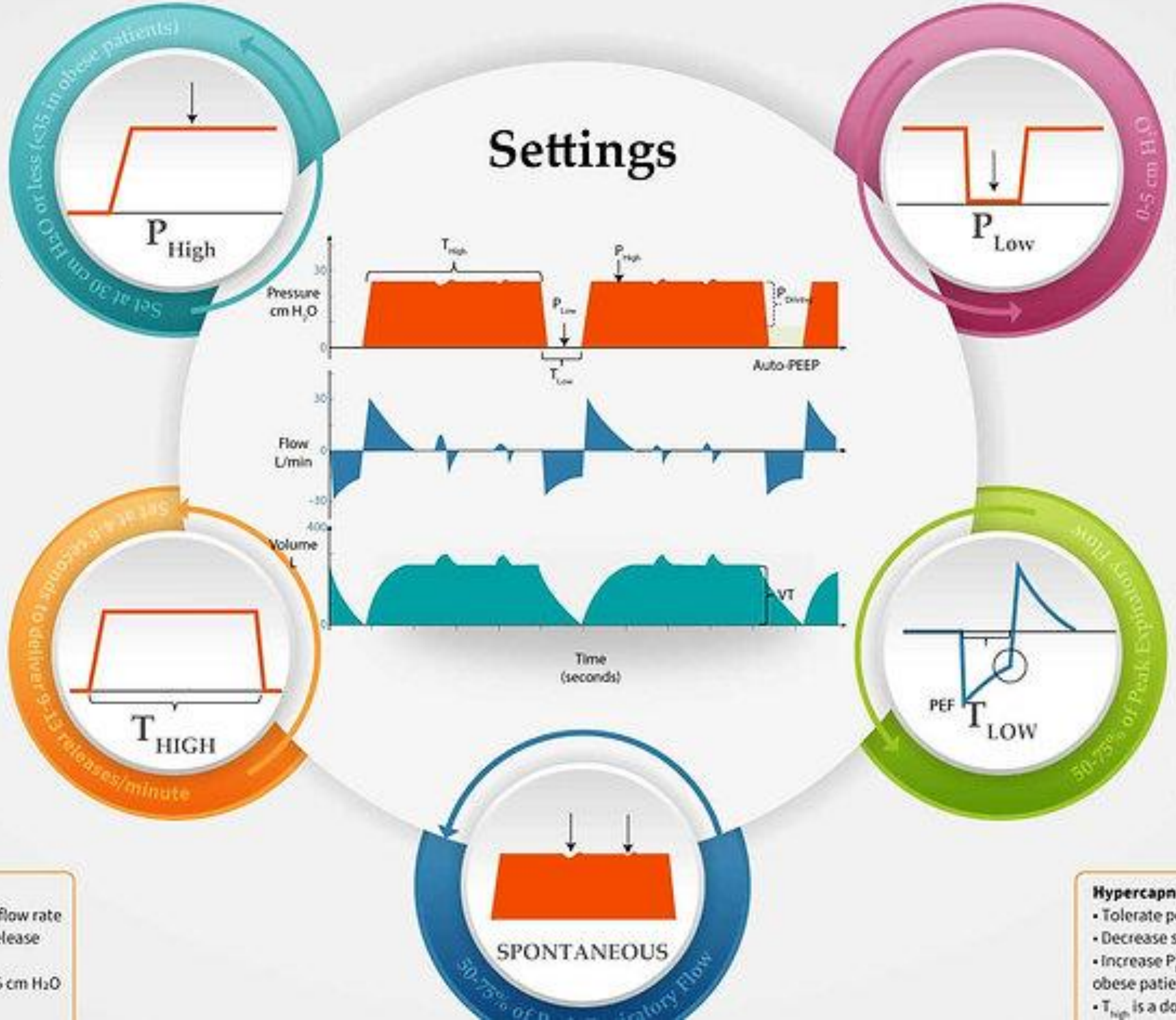
Inadequate P_{High} causes derecruitment, hypoxemia, low minute ventilation, and hypercapnia.

T_{HIGH}

T_{High}/T_{Low} determines release frequency per minute and affect ventilation.
Release frequency = 60 /(T_{High} + T_{Low}).

Set at 4-6 seconds to deliver 9-13 releases/minute.

Increase T_{High} gradually to improve oxygenation.
May decrease T_{High} to improve ventilation (but on the expense of oxygenation).



P_{Low}

In most protocols, P_{Low} is set at 0 cm H_2O

Advantages of P_{Low} above zero (5 cm H_2O): may provide more lung-protection (by avoiding atelectasis and wide fluctuations in airway pressure) and may allow for better oxygenation without increasing the P_{High} to dangerous levels.

Disadvantages of P_{Low} above zero: may reduce tidal volume and thereby promote hypercapnia, and will reduce driving pressure and expiratory flow velocity which may impair secretion clearances.

T_{Low}

Target 50-75% of Peak Expiratory Flow (PEF) to ensure adequate auto-PEEP, keep the lung recruited, and prevent collapse.

Setting T_{Low} at >75% of PEF causes small releases and ineffective ventilation.
Setting T_{Low} at <50% of PFE causes large releases, loss of auto-PEEP, and lung decruitment.
T_{High}/T_{Low} determines release frequency per minute and affect ventilation.
Requires attention and adjustment when lung compliance changes.

Hypoxemia?

- Reduce T_{Low} by 0.05-0.1 second if end-expiratory flow rate is <50% of the peak expiratory flow rate or if the release volume is >8 mL/kg of ideal body weight.
- Increase P_{High} by 1-2 cm H_2O if ≤30 cm H_2O (or ≤35 cm H_2O in morbid obese patients).

Hypercapnia?

- Tolerate permissive hypercapnia down to pH ~7.15.
- Decrease sedation to encourage spontaneous breathing.
- Increase P_{High} by 1-2 cm H_2O (up to ~30 cmH_2O or ~35 in obese patients).
- T_{High} is a double-edged sword: increasing T_{High} improves

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'AIRWAY PRESSURE RELEASE VENTILATION (APRV)

Evidence-Based Ventilator Mode

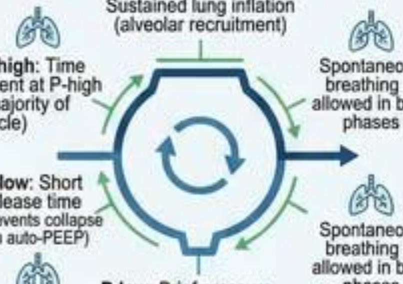
WHAT IS APRV?

Airway Pressure Release Ventilation (APRV) is an advanced invasive ventilator mode that:

- Maintains prolonged high airway pressure to keep alveoli open.
- Uses brief pressure releases for CO_2 elimination.
- Allows spontaneous breathing throughout the entire cycle.

Commonly used in **ARDS & severe hypoxemic respiratory failure**

HOW APRV WORKS



CLINICAL INDICATIONS

- ARDS / refractory hypoxemia
- Lung-protective ventilation strategies
- Post-operative atelectasis
- Patients difficult to sedate or paralyze
- Select trauma
- Select trauma & pediatric cases
- Requires trained clinicians and close monitoring

LIMITATIONS & CHALLENGES

- Steep learning curve
- Risk of hypercapnia or derecruitment
- Limited standardized protocols
- Difficult tidal volume monitoring
- Not ideal for COPD, asthma, or neuro patients
- Possible ↑ work of breathing without pressure support

KEY APRV SETTINGS

	Parameter	Purpose	Typical Range
1	P-high	Oxygenation & recruitment	20–30 cmH_2O
2	P-low	CO_2 release	0–5 cmH_2O
3	T-high	Sustained inflation	4–6 sec
4	T-low	Controlled release	0.2–0.8 sec

ADVANTAGES OF APRV

- Improved oxygenation
- Alveolar recruitment
- Reduced ventilator-induced lung injury (VILI)
- Less sedation & paralysis
- Better hemodynamic stability
- Efficient CO_2 elimination
- Improved patient-ventilator synchrony

APRV vs BiPAP

	APRV	BiPAP
1	Invasive	Non-invasive
2	Critically ill	Stable patients
3	Time-cycled	Patient-triggered
4	ARDS focus	COPD / OSA

APRV is also called **BiLevel Ventilation** (ventilator-dependent term)

KEY TAKEAWAY

APRV is a lung-protective strategy that:

- Keeps lungs open.
- Supports spontaneous breathing.
- Improves oxygenation.
- Reduces sedation needs.

✔ Most effective when used by experienced clinicians

✖ Not suitable for all patients

Goals of APRV

Goals:

- Reduction of Volume Induced Lung Injury [VILI] by preventing the shearing forces brought on by the repetitive opening and closing of compliant and non-compliant airways.
- Providing alveolar stability
- Recruitment of alveoli by maintaining a higher mean airway pressure
- Minimizing de-recruitment.
- Prevention of VILI will allow further reduction in decreased airway pressures
- Stable mean airway pressure and thus hemodynamics

Patients Who May Not Do Well on APRV

- Obstructive diseases
  - COPD/Asthma
  - Mucus plugging
- Hemodynamically marginal
  - Increase in mean airway pressure
- High minute ventilation requirements to maintain acid-base balance
  - Lose the effect of a increase I-time and collateral gas distribution

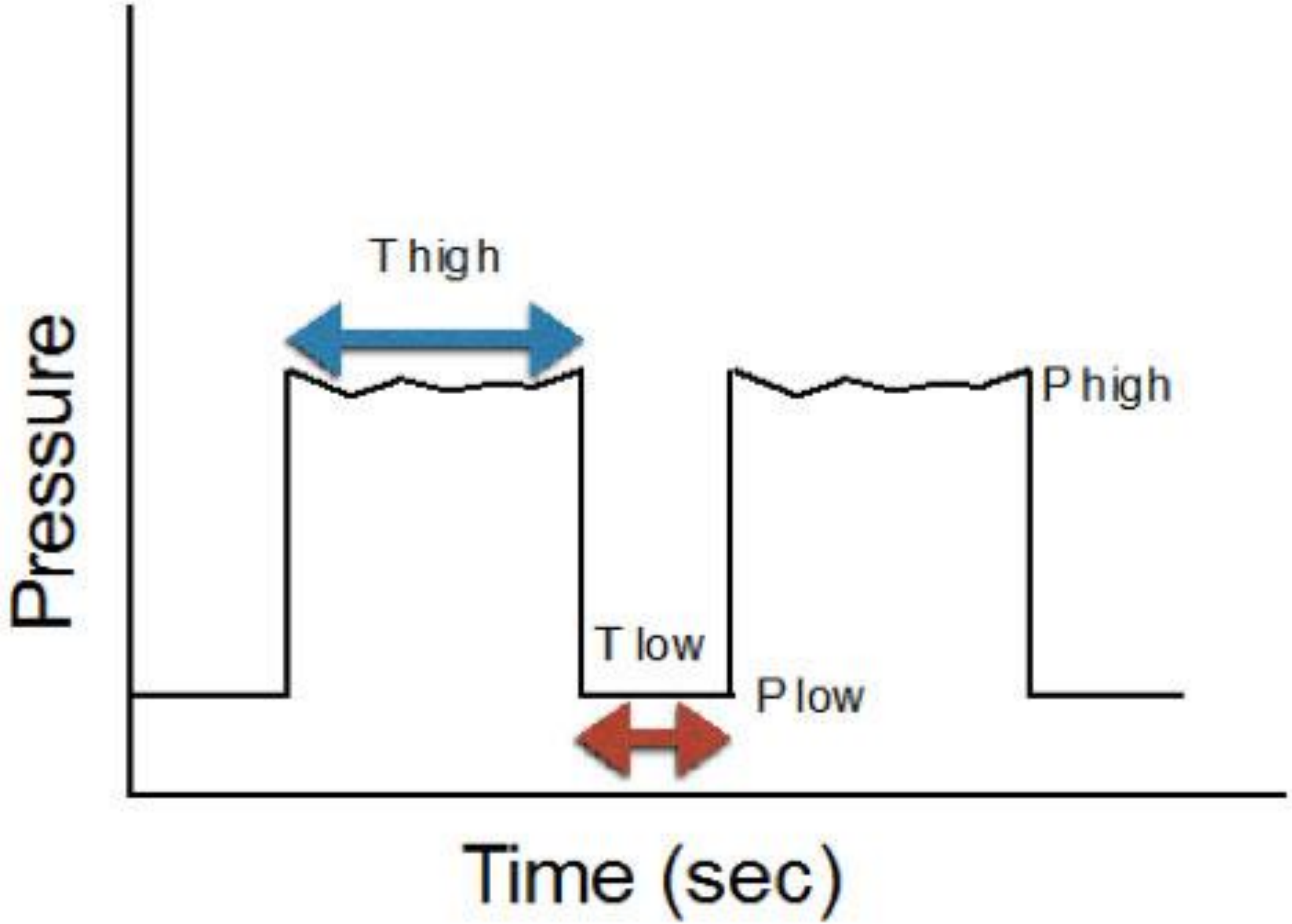
Clinician Controlled Parameters

P High
T High

Recruitment/Oxygenation

P Low
T Low

Release Phase/Ventilation


Thigh
Phigh
Tlow
Plow
Pressure
Time (sec)

SET UP

- P high (plateau pressure (conv vent.) +2 cm H2O (usually 30 – 35 cm H20)
- P low (0 cm H20) *
- Thigh >5 seconds
- T low (maintain exp. flow 33%-66%)

* Allow for greatest CO2 clearance in the shortest duration

P High

Selecting the best P High is vital in APRV. P High increases the mean airway pressure on APRV, helps to recruit the lung, and improves oxygenation. It also helps in ventilation as more alveoli are available to participate in gas exchange when the lung is recruited.

If the patient is already on the conventional mode of ventilation, **P High is set at 5 cm H2O higher than the mean airway pressure on the conventional mode of ventilation**. For example, if the MAP was 19 on CMV, the P High should be set at 24 cm H2O.

Alternatively, you can set the P High at the plateau pressure in volume-targeted modes or the pressure control in pressure-targeted modes.

P High can be gradually increased to improve oxygenation but should not exceed 30 cm H2O (35 cm H2O in severe obesity) to stay within the limitation of protective lung strategy. **A larger P High causes large release volume, overdistention of the lung, excess driving pressure, and possible impairment of hemodynamics.**

On the other hand, an inadequate P High causes derecruitment of the lung, hypoxemia, low minute ventilation, and hypercapnia.

P Low

In most protocols, P Low is set at 0 cm H_2O. However, some prefer to set it at value of no more than 5 cm H_2O.

The advantages of P Low above zero are to provide more lung-protection by avoiding atelectasis and wide fluctuations in airway pressure in the expiratory phase.

In this way, P Low helps to improve oxygenation without increasing the P High to dangerous levels.

On the other hand, P Low above zero may reduce the tidal volume and thereby promote hypercapnia and elevation of CO_2.

It may also reduce driving pressure and expiratory flow velocity which could impair secretion clearances.

T High

Inspiratory time is determined by setting the T High.
The longer the T High, the higher the MAP and thus the better the lung recruitment and oxygenation. The ratio between T High and T Low determines the release frequency per minute which affects ventilation and CO2 removal. The release frequency is calculated with this formula:

Release frequency = 60 /(THigh + TLow)

T High is usually set at 4 seconds and gradually increased to improve oxygenation. It is important to pay attention to the number of releases, as a higher T High will decrease the release frequency per minute and thus decrease ventilation and CO2 removal.

Depending on the T High and T low, the release frequency may vary between 8-14 releases/minute.

A longer T High may improve ventilation as more recruited alveoli participate in gas exchange.

However, if the releases are decreased significantly, ventilation and CO2 removal is decreased. In many situations, the outcome must be assessed. Eventually, it may be necessary to decrease the T High to improve ventilation at the expense of oxygenation.

T Low

T low is set to target 50-75% of Peak Expiratory Flow (PEF) to ensure adequate auto-PEEP.

Auto-PEEP is responsible for keeping the lung recruited during expiration and preventing collapse. Setting T Low at >75% of PEF may cause small releases and ineffective ventilation. On the other hand, setting T Low at <50% of PFE may cause large releases, loss of auto-PEEP, and lung decruitment.

T Low is the most critical setting on APRV as it needs to be adjusted according to changes in lung physiology. T Low may be optimal for a certain lung compliance. However, if the lung compliance is worsened, the lung will be emptied faster as the Time Constant is now shorter. Thus, the same setting of the T Low will cut the expiratory flow at a lower value and cause derecruitment of the lung.

On the other hand, improvement in lung compliance causes a longer Time Constant and will cut the expiratory flow at a higher value, causing worsening in the auto-PEEP and possible ventilation.

The ratio between T High and T Low determines release frequency per minute and affects ventilation and CO_2 removal, as mentioned above.

Recruit Phase P High & T High

- Regulates: end inspiratory volume

  Determines mean airway pressure

- Maintenance of increased surface area for maximum gas exchange

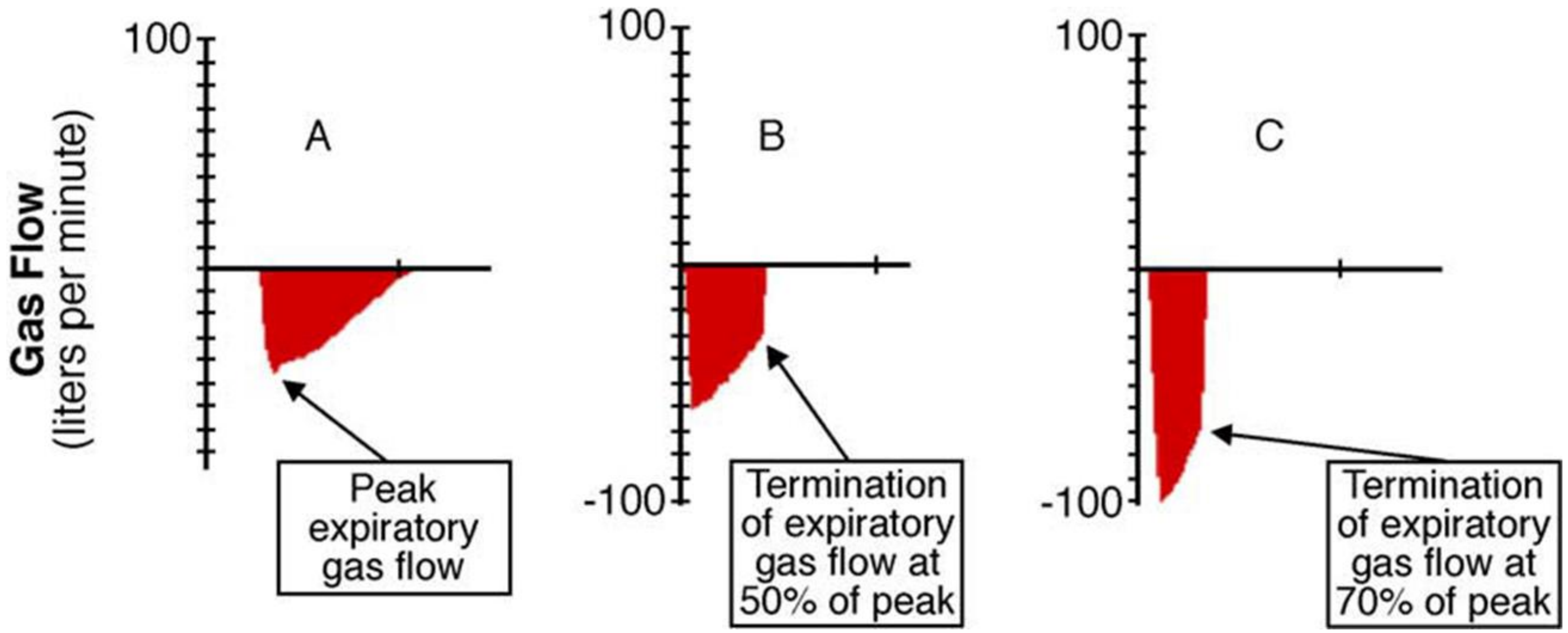
Release Phase (T Low & P Low)

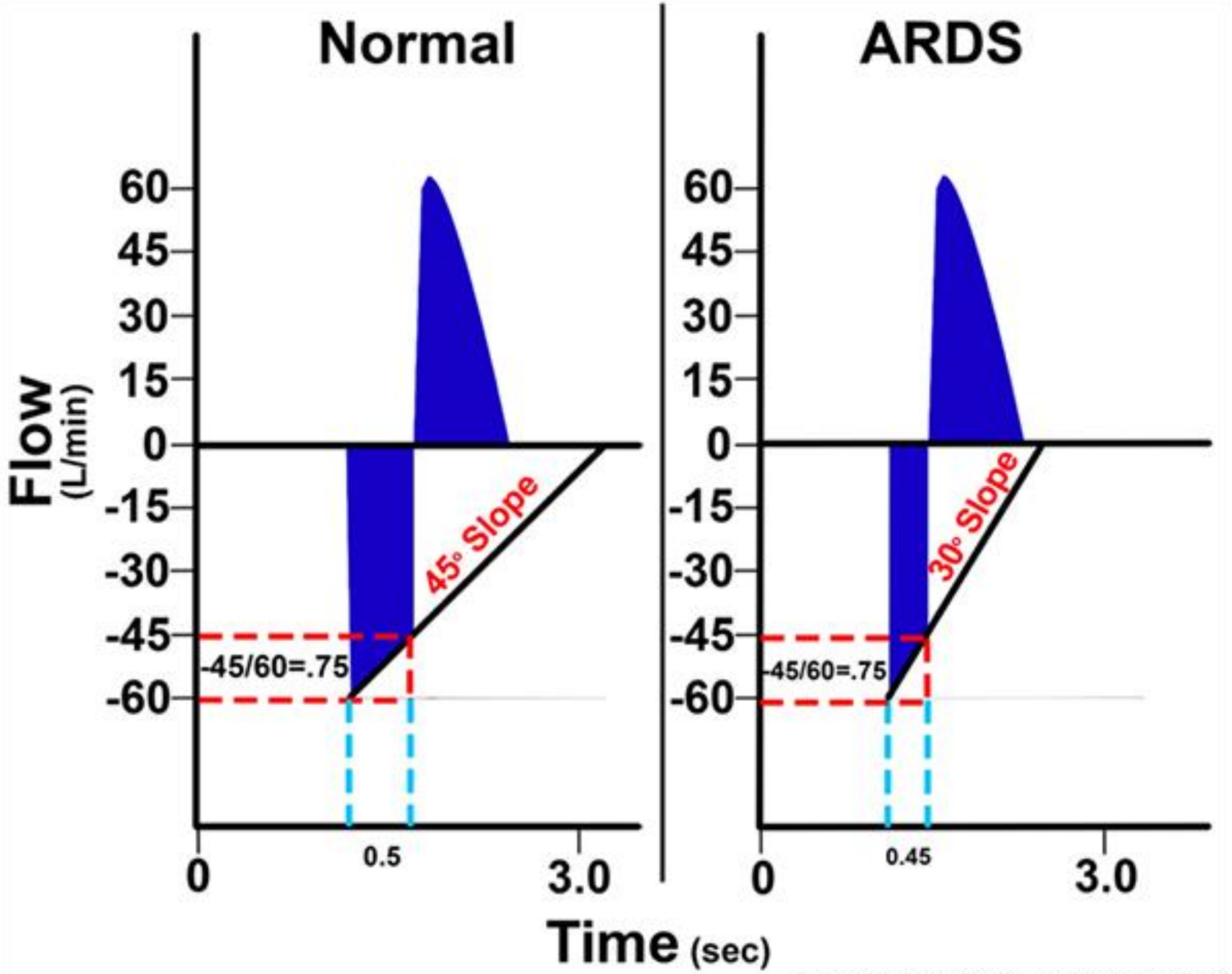
- T Low is brief (0.4 – 1.2) should not allow de-recruitment (depends on elastic recoil)
- T Low phase requires the assessment of the expiratory flows, (maintain 50-75% of PEF)
  - T Low that is too short may cause breath stacking on apneic patients or those who occasionally “ride the vent”(Exp flow waveform resembles the “tomb stone”).
  - T Low that is too long will cause the lung to de-recruit (exp flow > 50 % waveform returning close to baseline).

Tlow Recommendations

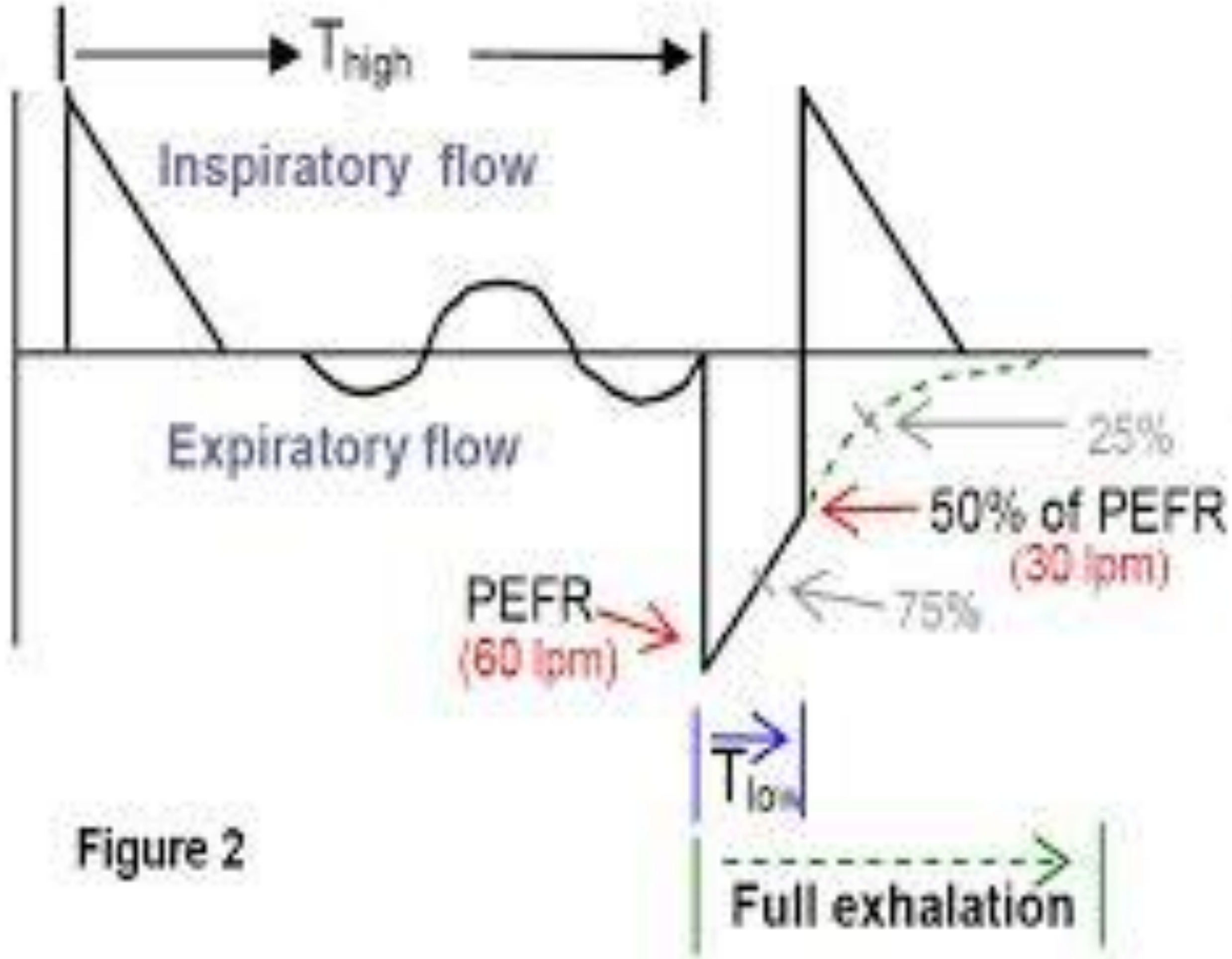
- At least 25% gas released but not more than 50%
- Fpe 60 lpm=at least 15 lpm but not more 30 lpm
  - 60 lpm x .75=45 lpm 60 lpm x .5 =30 lpm (end expiratory flow between 30-45 lpm)
- ARDS recommendations
  - Mild .4-.6 sec
  - Moderate .3-.5 sec
  - Severe .2-.4 sec

Expiratory Flow





Jain SV et al. 2016 PMID 27207149



T high
Inspiratory flow
Expiratory flow
25%
50% of PEFR
(30 lpm)
75%
PEFR
(60 lpm)
T low
Full exhalation

Figure 2

Spontaneous Breathing

Spontaneous breathing plays a major role in maintaining adequate ventilation in APRV. Most of the reasons for failing APRV are due to inadequate ventilation and CO2 removal.

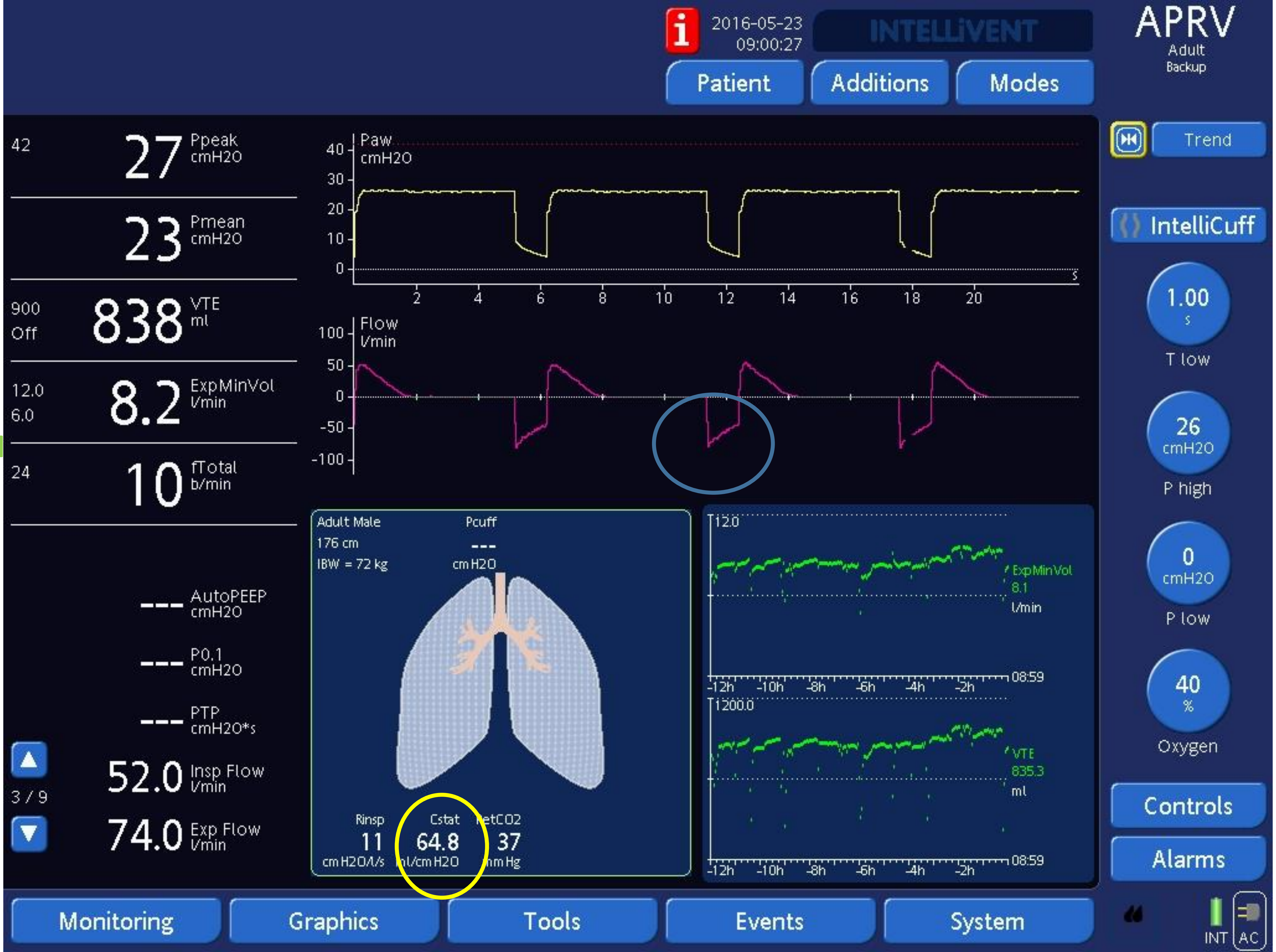
Contrary to the belief that patients may not tolerate APRV and should be kept heavily sedated, those patients can do very well and maintain adequate spontaneous ventilation on APRV with the appropriate level of sedation.

In general, spontaneous breathing should provide ~10-30% of minute ventilation in severe ARDS and ~30-60% of minute ventilation in mid to moderate ARDS without dyspnea. In addition, spontaneous breathing improves alveolar recruitment to the dorsal caudal regions of the lungs.

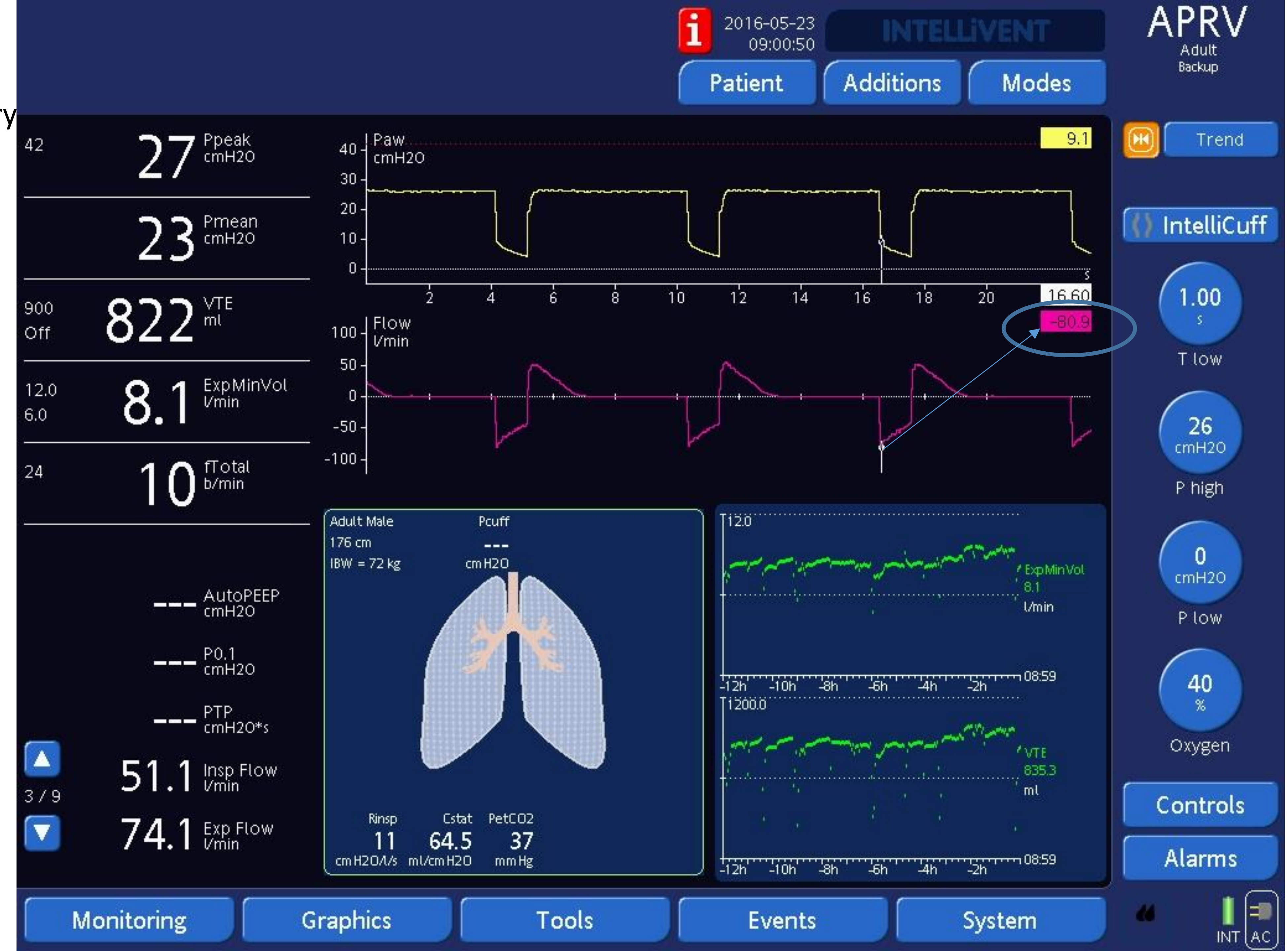
APRV settings correct based on expiratory flow and lung inflation

Note:

Tlow set at 1.00 based on exp. flow 50% (see next 2 slides) and CLT optimized



Peak expiratory
Flow=80 lpm

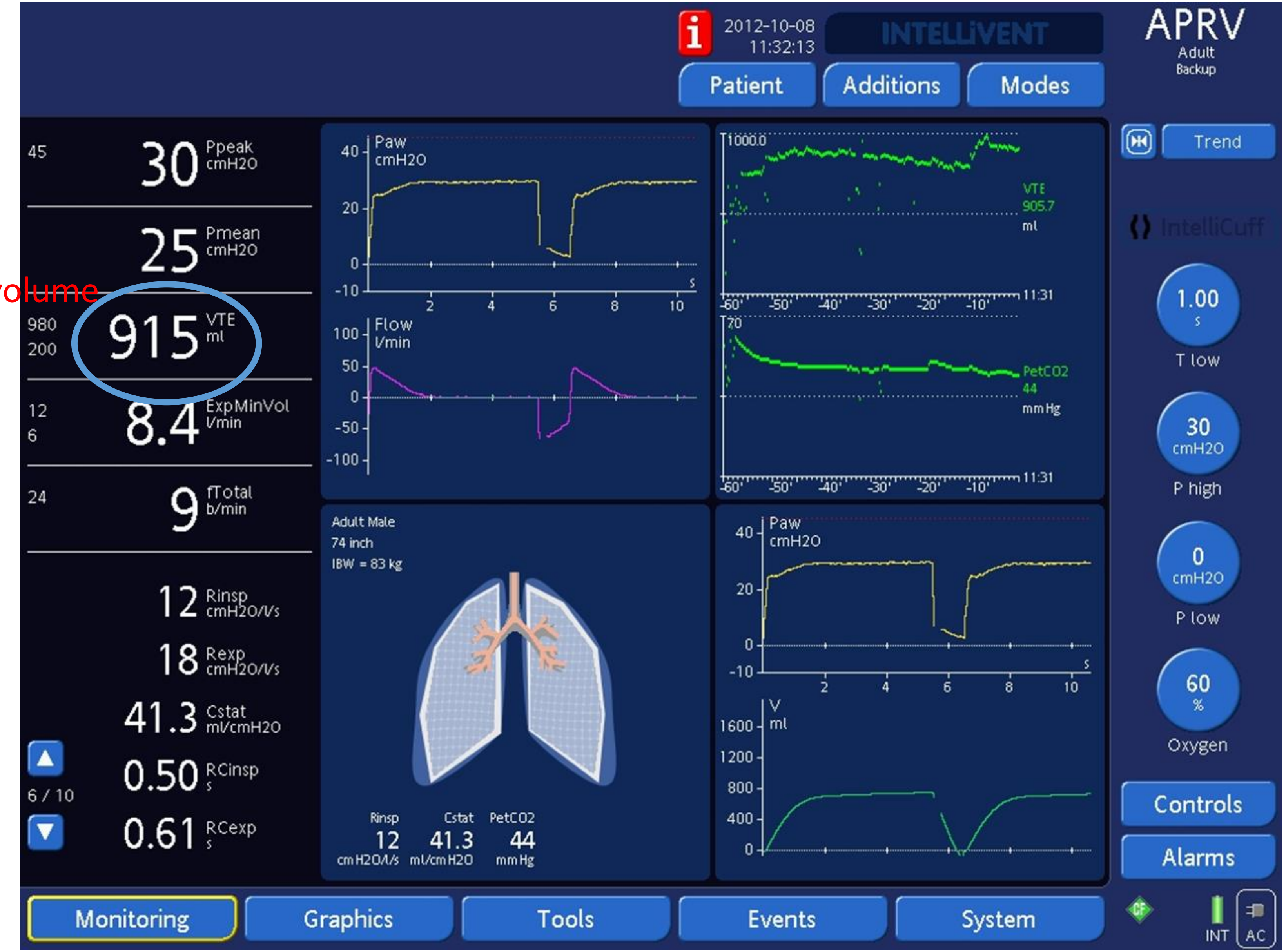


End expiratory Flow=41 liters
80-41=39 lpm
change in expiratory flow
Change in flow = 39/80
expiratory flow change of 48.5%
Goal:
To maintain exp. flow change between 33%-66%

Release Volume

- Release volume will reflect the patient's FRC volume and is not a cyclic tidal volume
- Volumes can exceed 1.0 liter
- In ARDS pts. target 6-8cc/kg/IBW

Release volume



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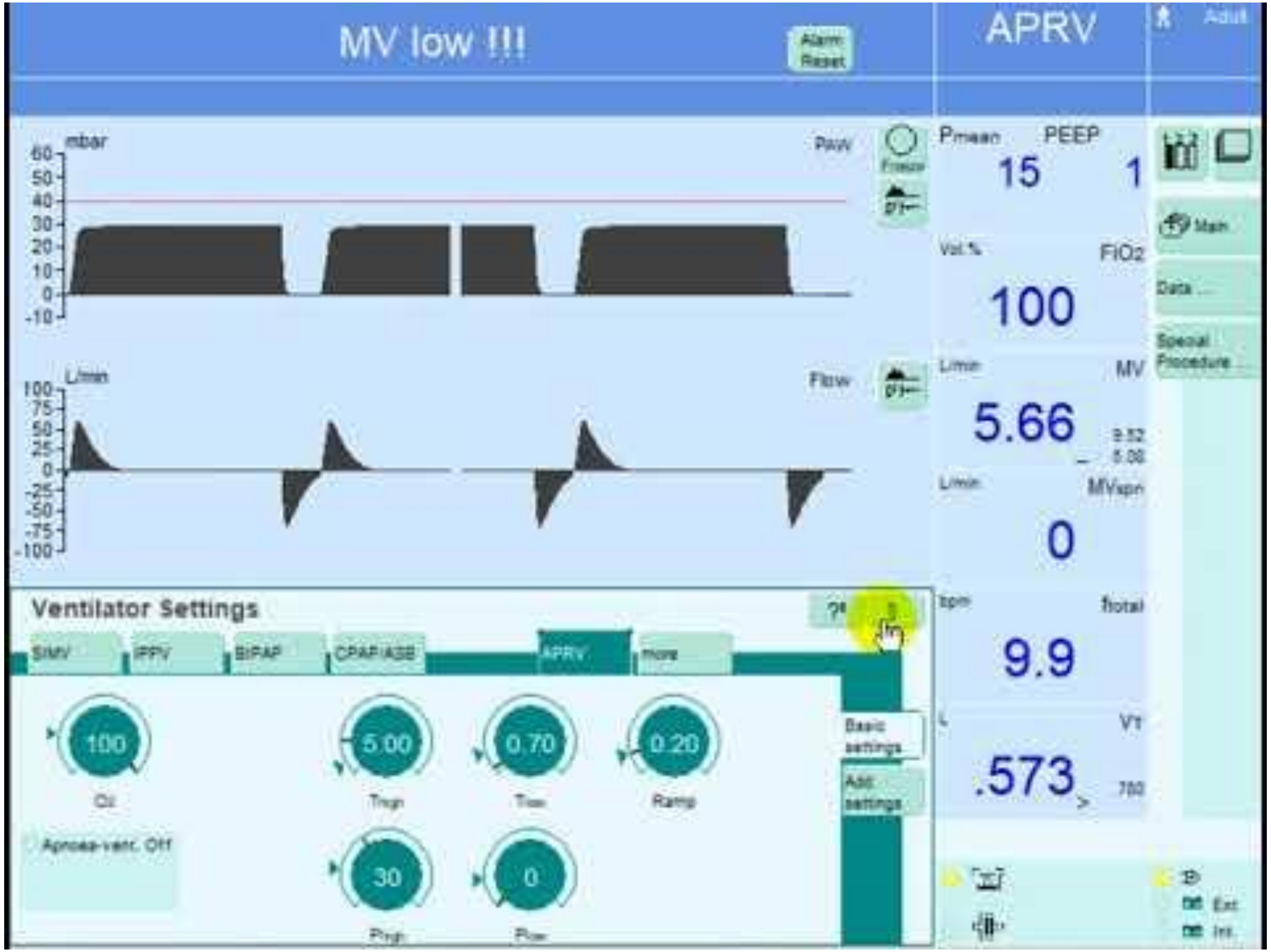
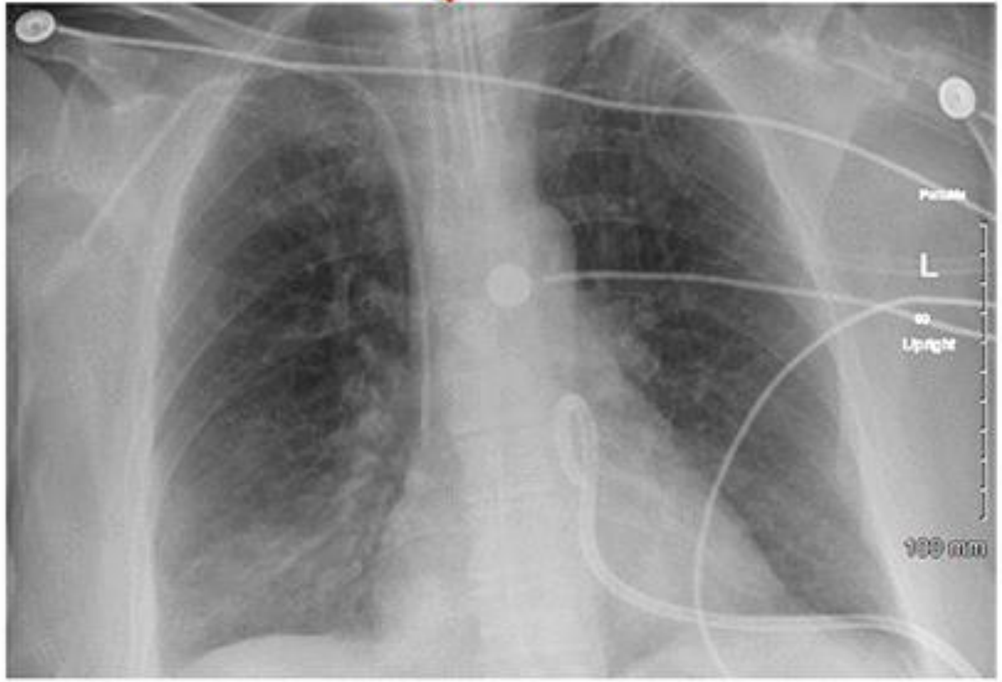

MV low !!!
Alarm Reset
APRV
Adult
mbar
Paw
Freeze
L/min
Flow
Pmean
PEEP
15
1
Vol.%
FIO2
100
Main
Data ...
Special Procedure ...
L/min
MV
5.66
L/min
MVspn
0
bpm
ftotal
9.9
VT
.573
Ventilator Settings
SIMV
IPPV
BIPAP
CPAP/ASB
APRV
more
100
5.00
0.70
0.20
30
0
Ramp
Apnoea-vent. Off
Basic settings
Add. settings
Ext.
Int.

Only *one day* of treatment between these two films

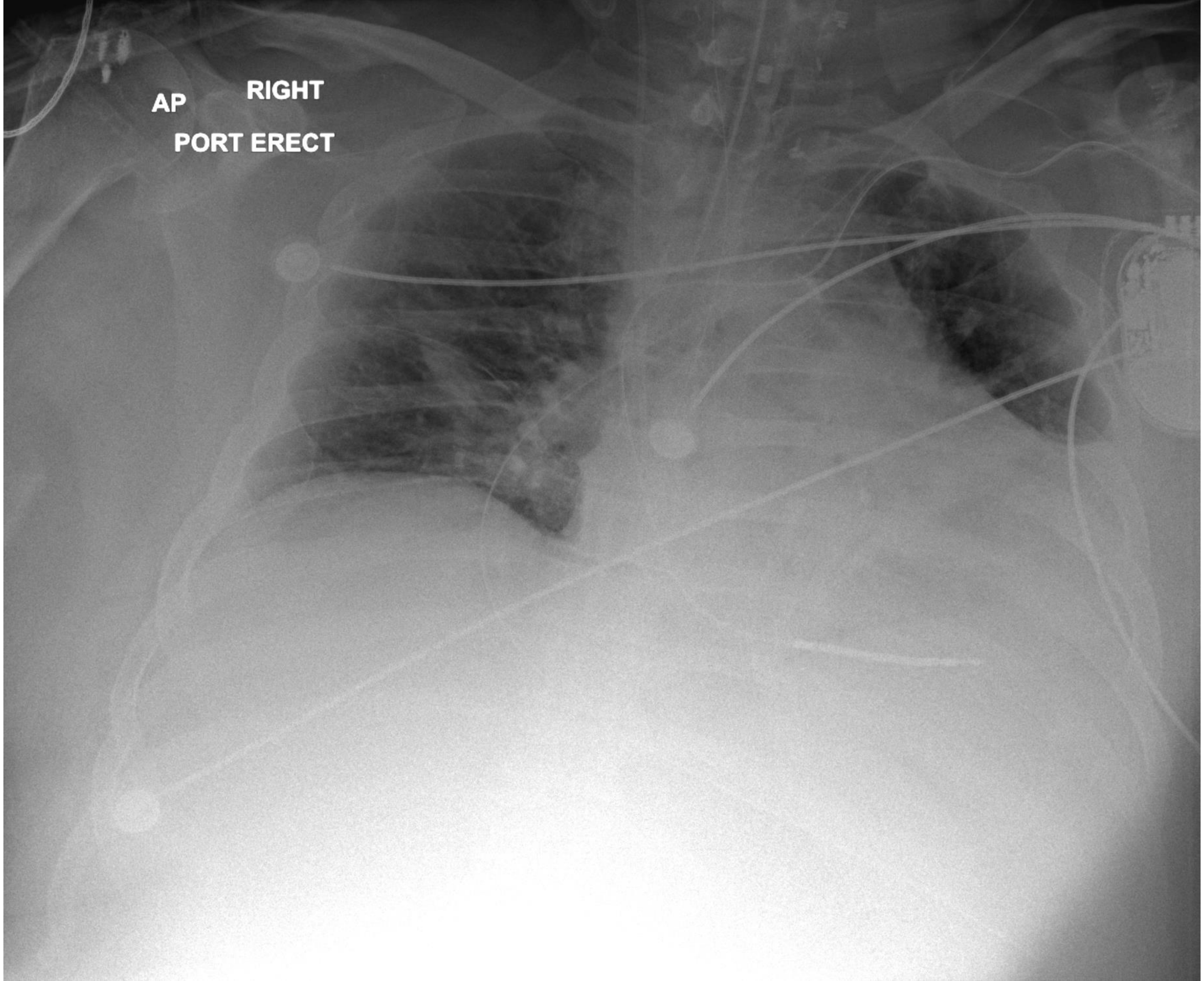


De-resuscitative APRV: This man was transferred to Genius General Hospital after receiving 14 liters of crystalloid

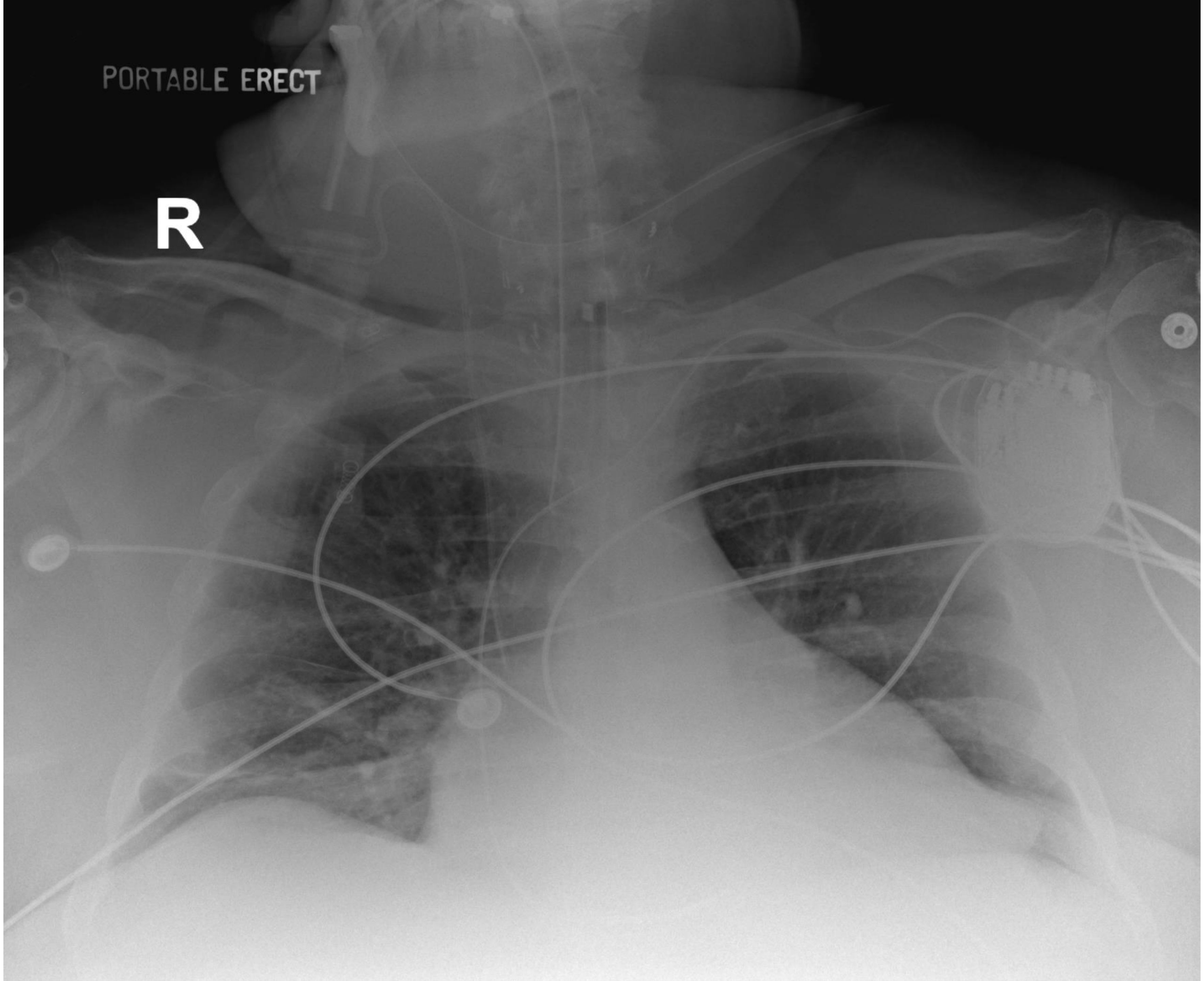
PRE APRV on CMV with 14cm PEEP

Post APRV 34/0 12 hrs.

Pre APRV



Post APRV 4 hrs



ADJUSTMENTS After the initial settings of APRV, oxygenation and ventilation can be assessed through arterial blood gases and adjustments can be made, as necessary.

What If the patient has Hypercapnia?

First, the level of permissive hypercapnia must be determined. Most patients can tolerate permissive hypercapnia with a pH of ~7.15 if they are hemodynamically stable.

Adequate spontaneous breathing must also be ensured. It may be necessary to decrease sedation to encourage spontaneous breathing. Adjustments on APRV to improve ventilation include the following:

•Increase P High by 1-2 cm H2O (up to ~30 cmH2O or ~35 in obese patients).

•Increase T High by 0.5-1 second to improve lung recruitment and thereby improve CO2 clearance (if the patient is derecruited). On the other hand, reducing T High increases the frequency of releases, thereby increasing the minute ventilation and improving CO2 clearance.

•Decrease P Low by 1.2 cm H2O (if positive) to increase the release volumes.

•Last resort: may increase T Low by 0.05-0.1 second if end-expiratory flow rate is >50% of the PEF to allow more time for the release volume..

What if the patient is still hypoxemic?

Remember that APRV improves oxygenation by providing a higher mean airway pressure (area under the pressure-time curve). Therefore, if the patient is still hypoxemic, the following adjustments can be made:

Reduce T Low by 0.05-0.1 second if end-expiratory flow rate is <50% of the peak expiratory flow rate or if the release volume is >8 mL/kg of ideal body weight. This will provide a higher auto-PEEP and thus better oxygenation.

Increase P High by 1-2 cm H2O but you need to remain within the limitation of protective lung strategy with a P High ≤30 cm H2O (or ≤35 cm H2O in morbid obese patients).

Increase T High by 0.5-1 second.

Last resort: Increase P Low by 1.2 cm H2O.

What if the patient has hypocapnia?

If the patient is hypocapnic, you need to decrease minute ventilation by decreasing the release volume frequency or the volume of the releases. This can be done by the following interventions:

Decrease P High if able from oxygenation standpoint.

Increase T High.

Decrease T Low.

Weaning the APRV Patient

- Reduce P_{high} and Increase T_{high}
- Allow Patient to perform more spontaneous breathing (add PSV)
- **"Drop and Stretch"** concept
- Drop Phigh by 2-4cm and extend Thigh by .5-.6 seconds
- Switch to conventional ventilation when Phigh is<22cm

APRV Key Points

- The patient spontaneous breathing should contribute to 30% of minute ventilation during implementation
- The Tlow should not be increased solely to improve exhale volume or improve CO2 elimination
    - Can lead to RACE(shear trauma)
    - Maintain between 50-75% of Fpe
- Plow should not be set above 0
    - Alters the expiratory flow slope
    - Decreases expiratory flow
    - Reduces secretion removal
- No PSV should be used above the Phigh
    - Can cause lung strain
    - Changes the flow dynamic from sinusoidal flow pattern to decelerating pattern
- Monitoring of APRV waveforms should be assessed a minimum of every 4 hrs.
    - Any change in pulmonary physiology will necessitate changing the Tlow

Conclusion

- APRV is indicated for treatment of reduced oxygenation secondary to loss of lung volume or fluid congestion
- May take a few hours for maximized results
- APRV is best utilized early in the disease process
- APRV may reduce mean arterial blood pressure
- APRV is not indicated for acid-base disturbances


THANK
YOU!