Advanced Ventilator Modes

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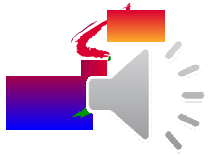
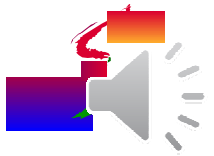


Advanced modes

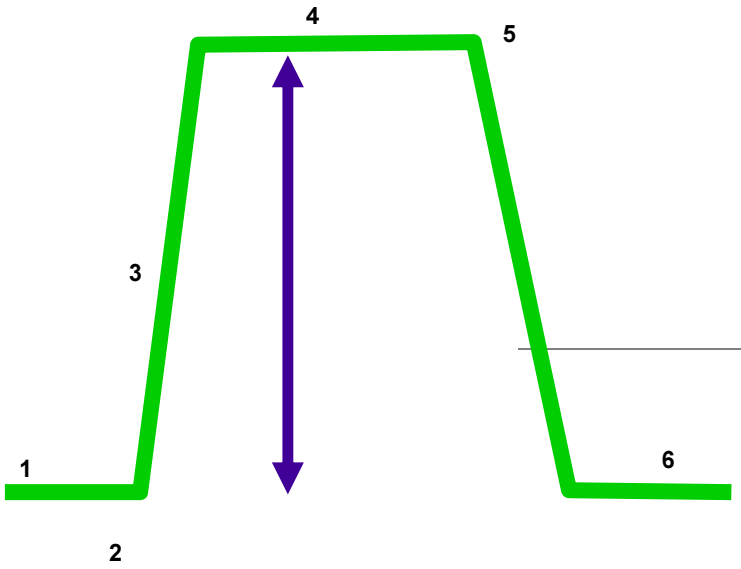
- Pressure-Regulated Volume Control
- Pressure-support ventilation (PSV)
  - Volume Support
  - Volume-Assured Pressure Support
  - Proportional Assist Ventilation (PAV)
  - Proportional Pressure Support (PPS)
  - SmartCare
- Airway Pressure Release Ventilation (APRV)

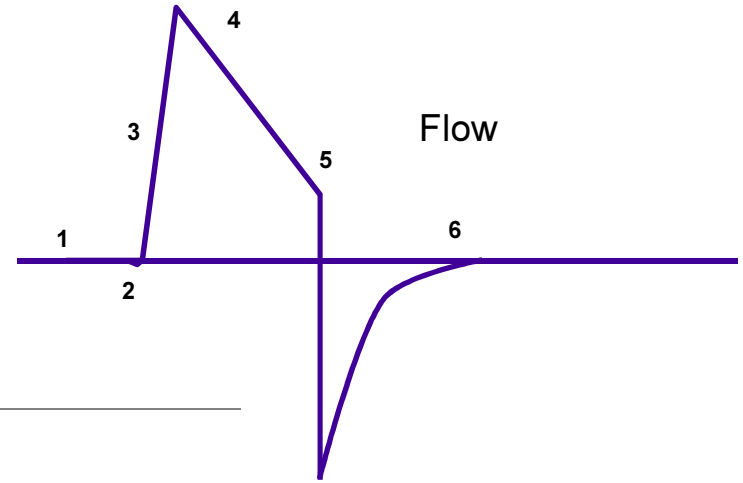
Description of breaths by 4 parameters

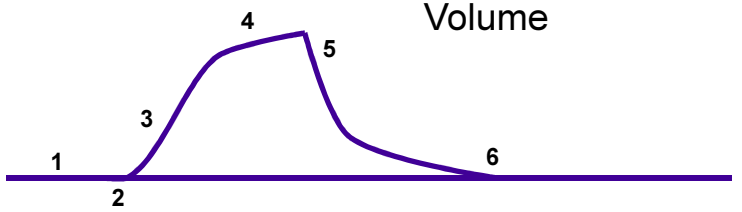
- Trigger
  - what starts the breath – pressure, flow, time
- Inspiratory limit/control variable
  - Pressure, flow, volume
- Cycling mechanism
  - what terminates the breath – pressure, volume, flow, time
- Baseline
- AND
- Other controls



Pressure-Regulated Volume Control

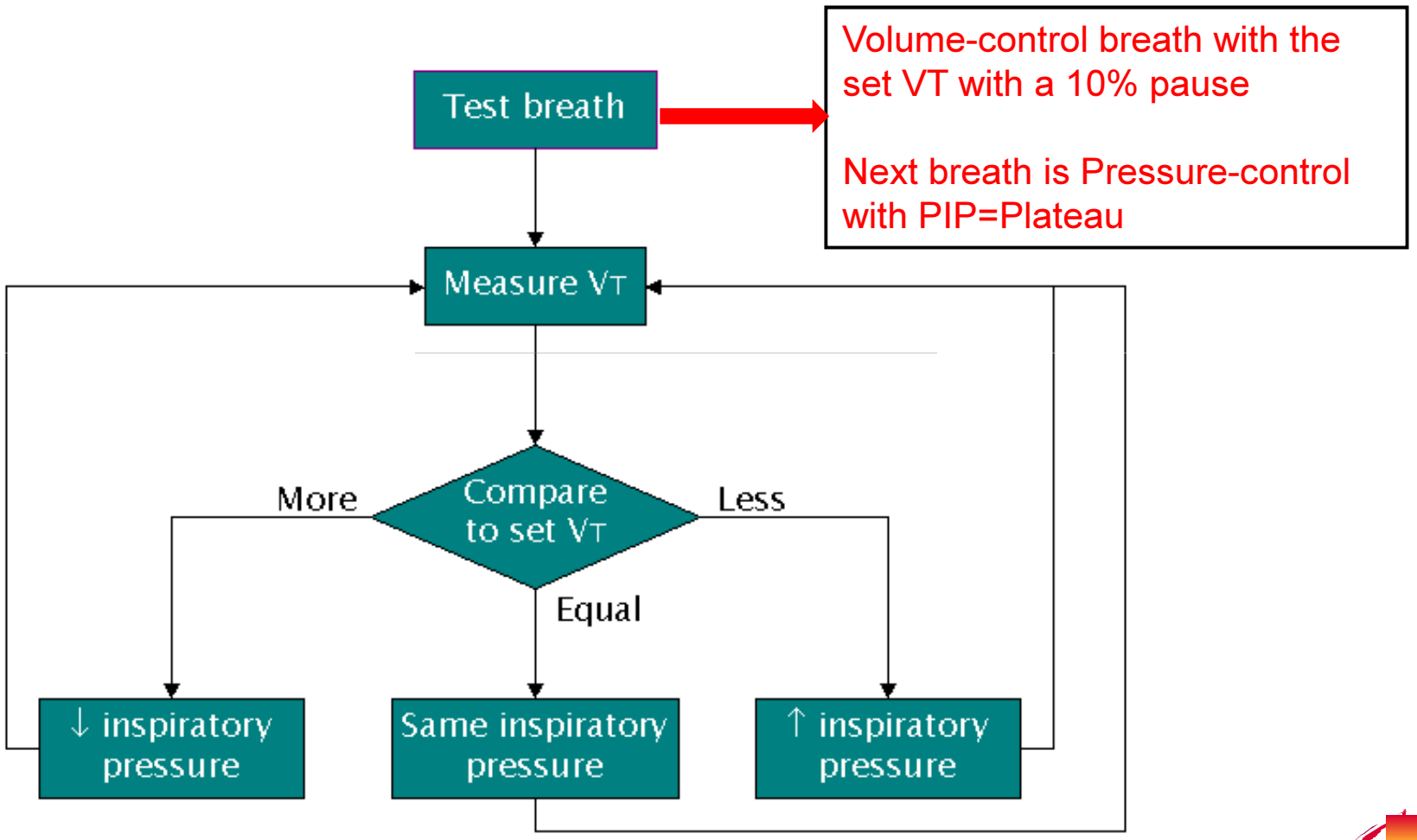




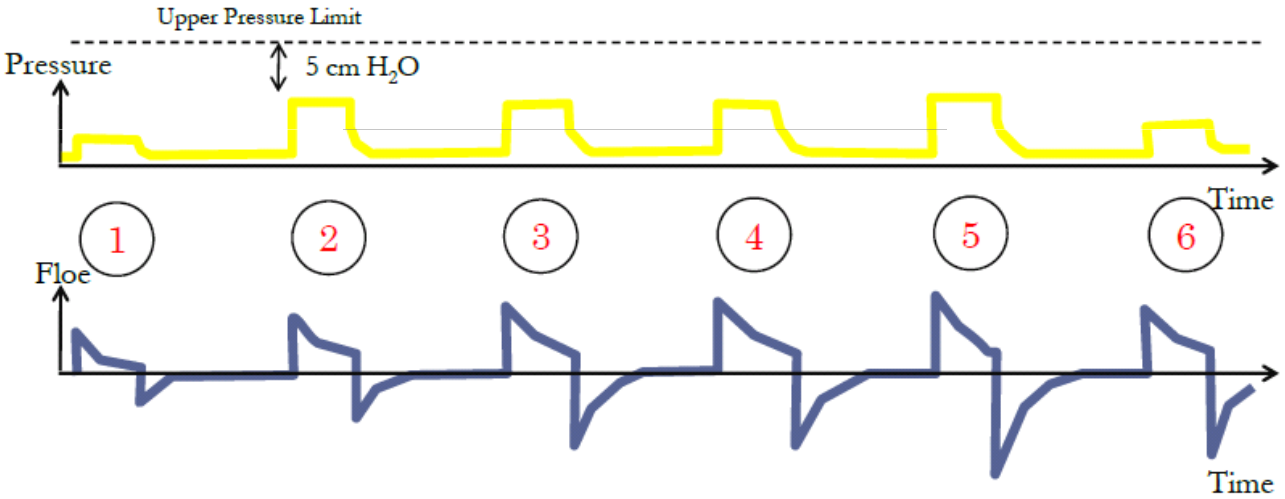


1. PEEP
2. Triggering
3. Rate of rise of pressure
4. Pressure support level
5. Termination of breath
6. PEEP

How it works

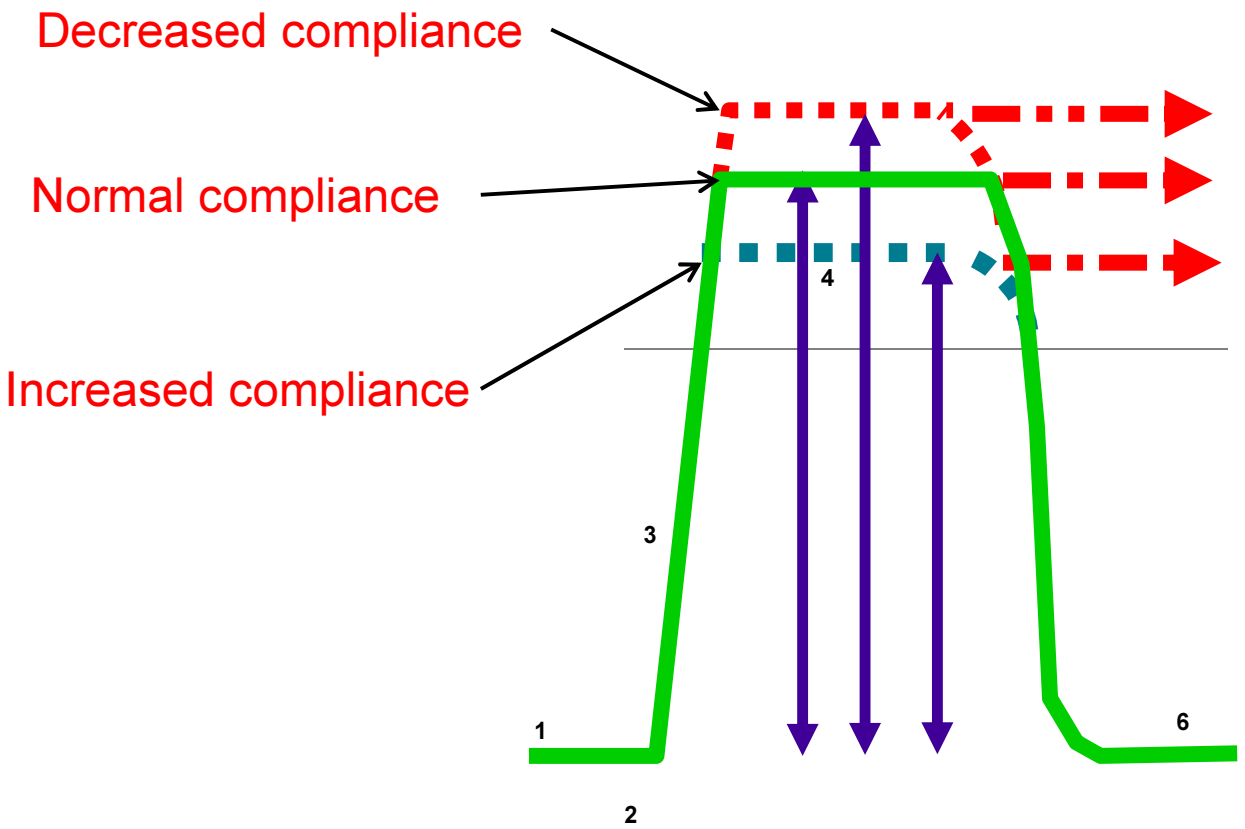

Test breath
Volume-control breath with the set VT with a 10% pause
Next breath is Pressure-control with PIP=Plateau
Measure VT
More
Compare to set VT
Less
Equal
↓ inspiratory pressure
Same inspiratory pressure
↑ inspiratory pressure

PRVC (Pressure Regulated Volume Control)



PRVC. (*1*), Test breath (5 cm H_2O); (*2*) pressure is increased to deliver set volume; (*3*), maximum available pressure; (*4*), breath delivered at preset $\dot{V}_E$, at preset *f*, and during preset T_I; (*5*), when V_T corresponds to set value, pressure remains constant; (*6*), if preset volume increases, pressure decreases; the ventilator continually monitors and adapts to the patient's needs

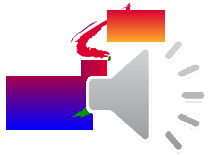
Pressure-Regulated Volume Control



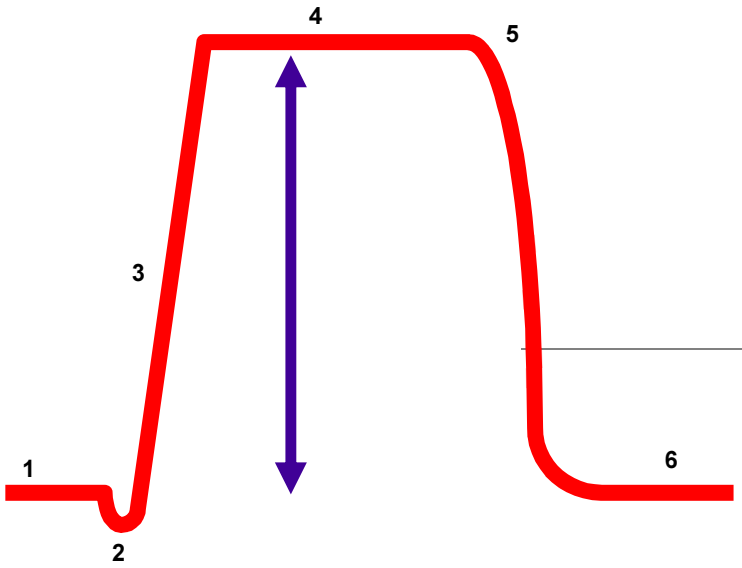
MAINTAIN DELIVERED TIDAL VOLUME

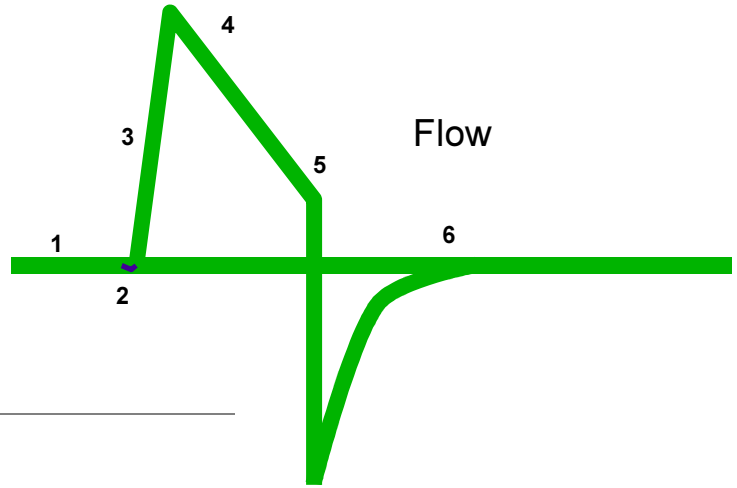
Indications for PRVC

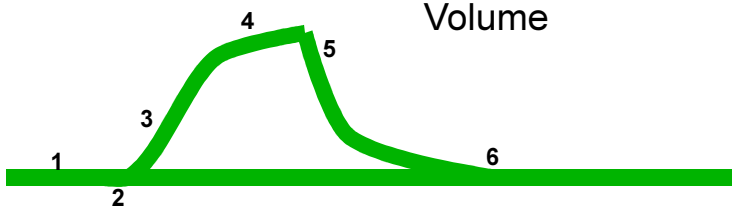
- Rapidly changing compliance
- Example
  - Neonate receiving surfactant
  - Patient with ARDS that is rapidly deteriorating
- When there is a need to maintain consistent tidal volume



Pressure-support ventilation







1. PEEP
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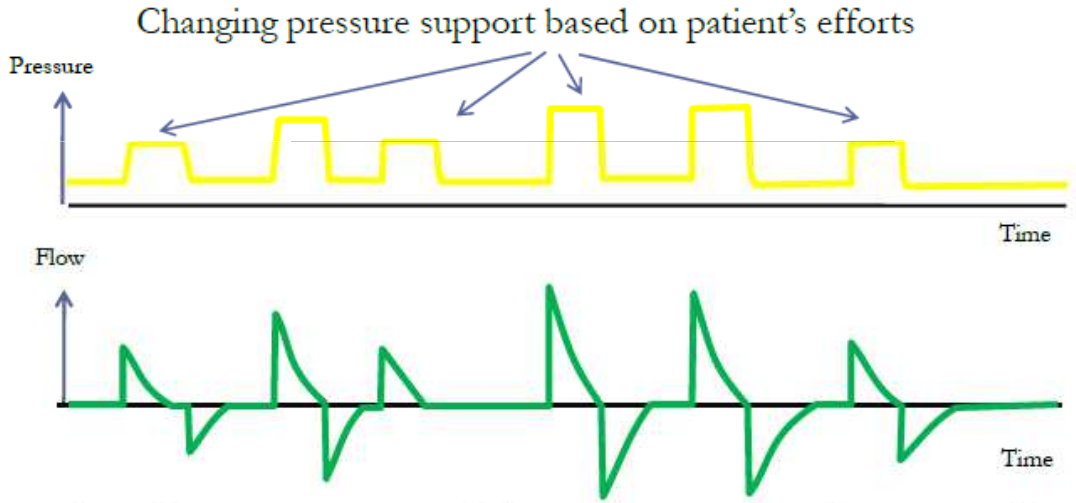
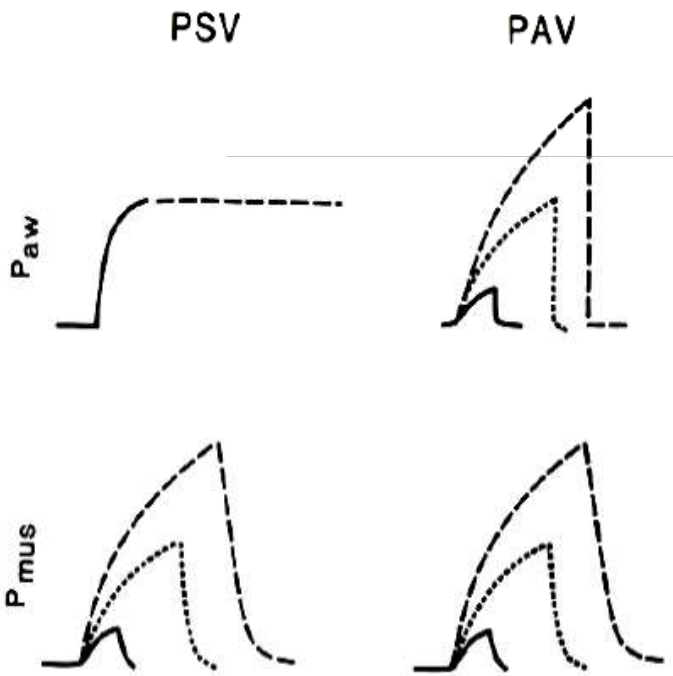
6. PEEP

Proportional Assist Ventilation (PAV)



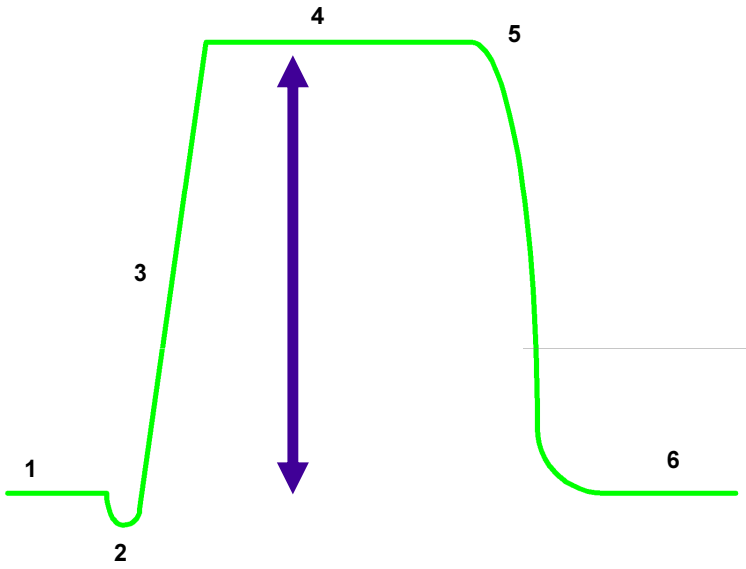
Rregulates the pressure output of the ventilator moment by moment in accord with the patient's demands for flow and volume.
Thus, when the patient wants more, (s)he gets more help; when less, (s)he gets less. The timing and power synchrony are therefore nearly optimal—at least in concept.

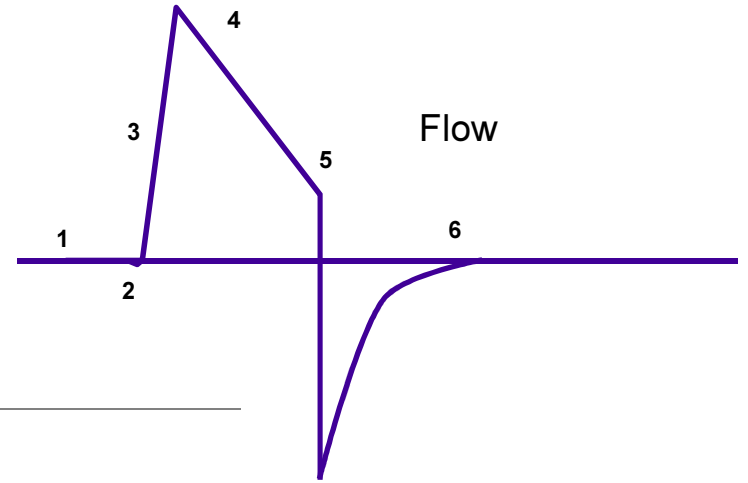
Proportional Assist Amplifies Muscular Effort

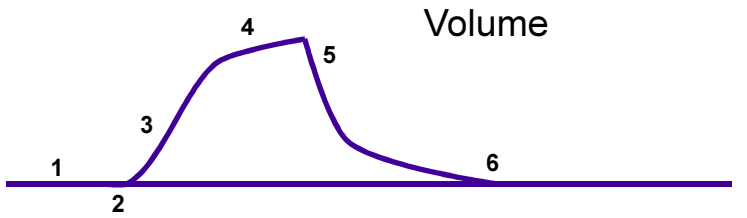


Muscular effort (P_{mus}) and airway pressure assistance (P_{aw}) are better matched for Proportional Assist (PAV) than for Pressure Support (PSV).

Volume-support ventilation



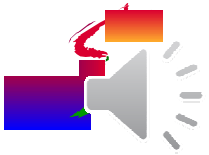




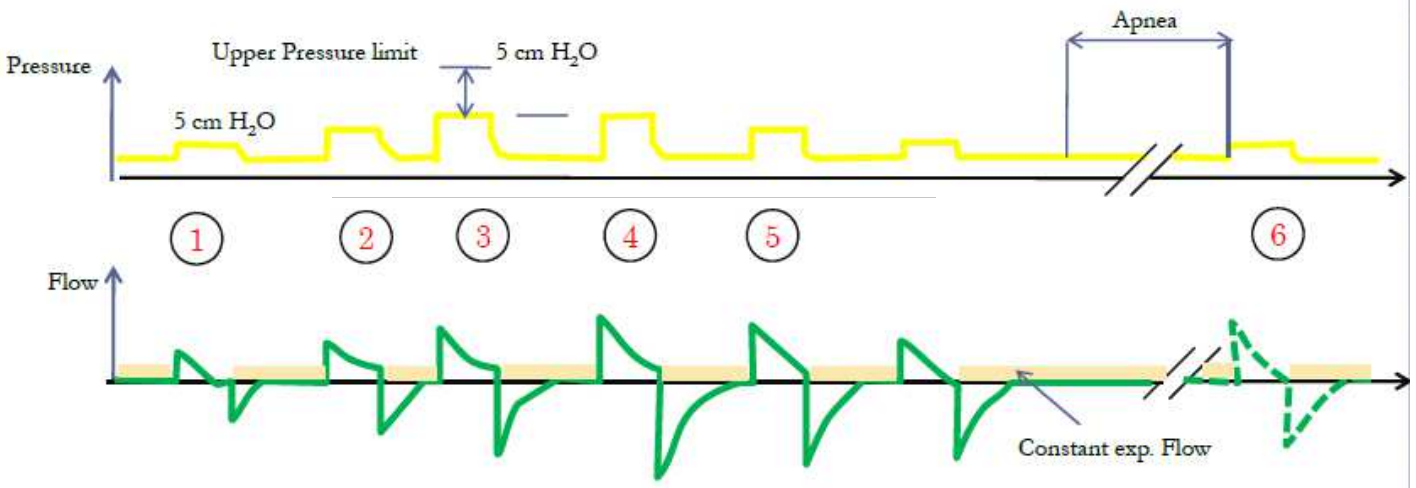
1. PEEP
2. Triggering
3. Rate of rise of pressure
4. Pressure support level
5. Termination of breath
6. PEEP

Volume-support

- Dual control breath-to-breath
- Closed-loop control of Pressure-Support ventilation
  - **Uses tidal volume as the feedback control for continuously adjusting the pressure support level**
- Trigger
  - **Flow or pressure**
- Inspiratory limit variable
  - **Pressure and volume**
- Cycling
  - **Flow cycling**
- Baseline is PEEP

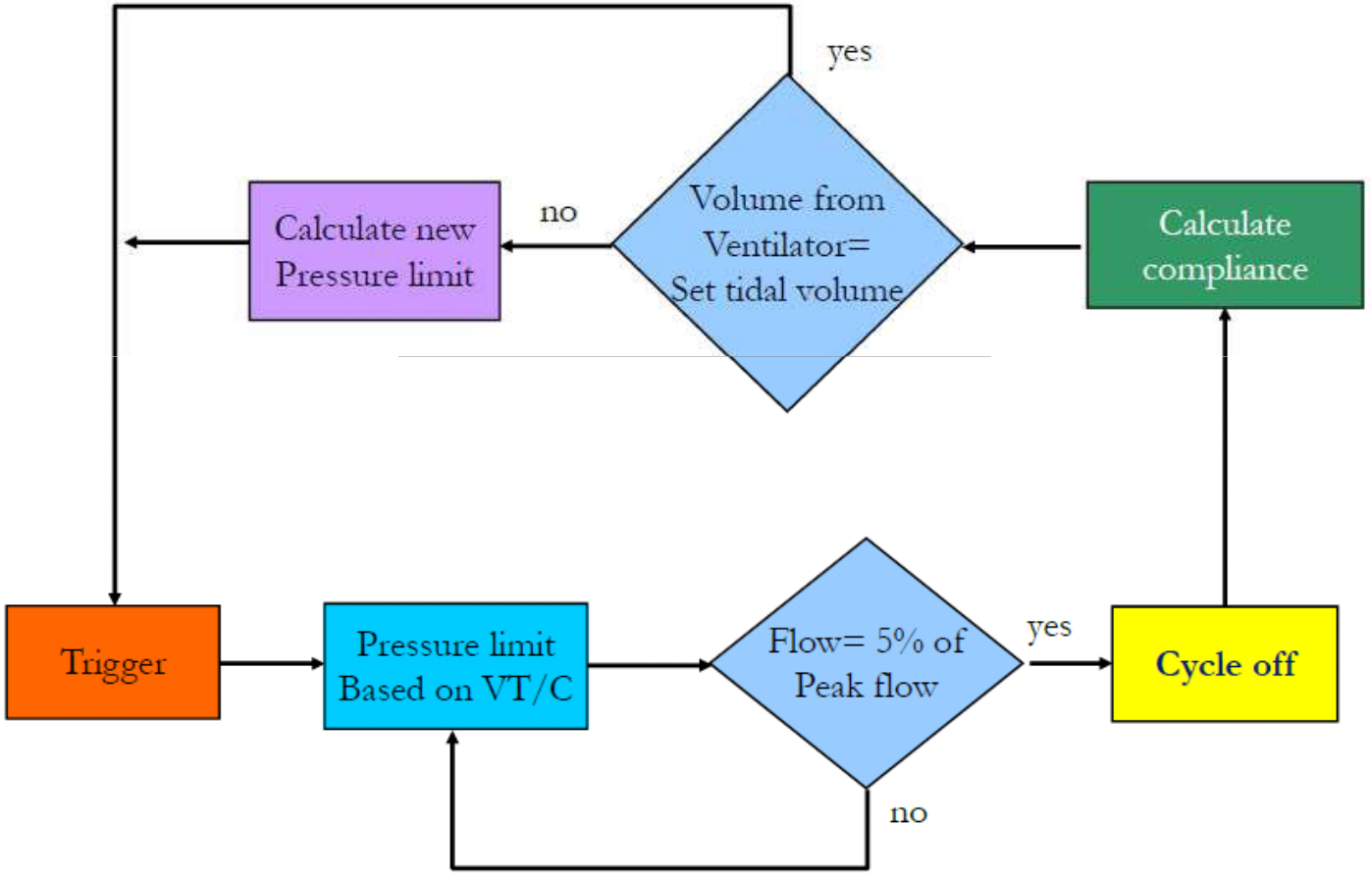


VS (Volume Support)



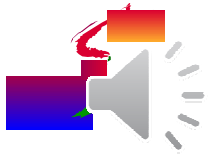
(*1*), VS test breath (5 cm H2O); (*2*), pressure is increased slowly until target volume is achieved; (*3*), maximum available pressure is 5 cm H2O below upper pressure limit; (*4*), VT higher than set VT delivered results in lower pressure; (*5*), patient can trigger breath; (*6*) if apnea alarm is detected, ventilator switches to PRVC

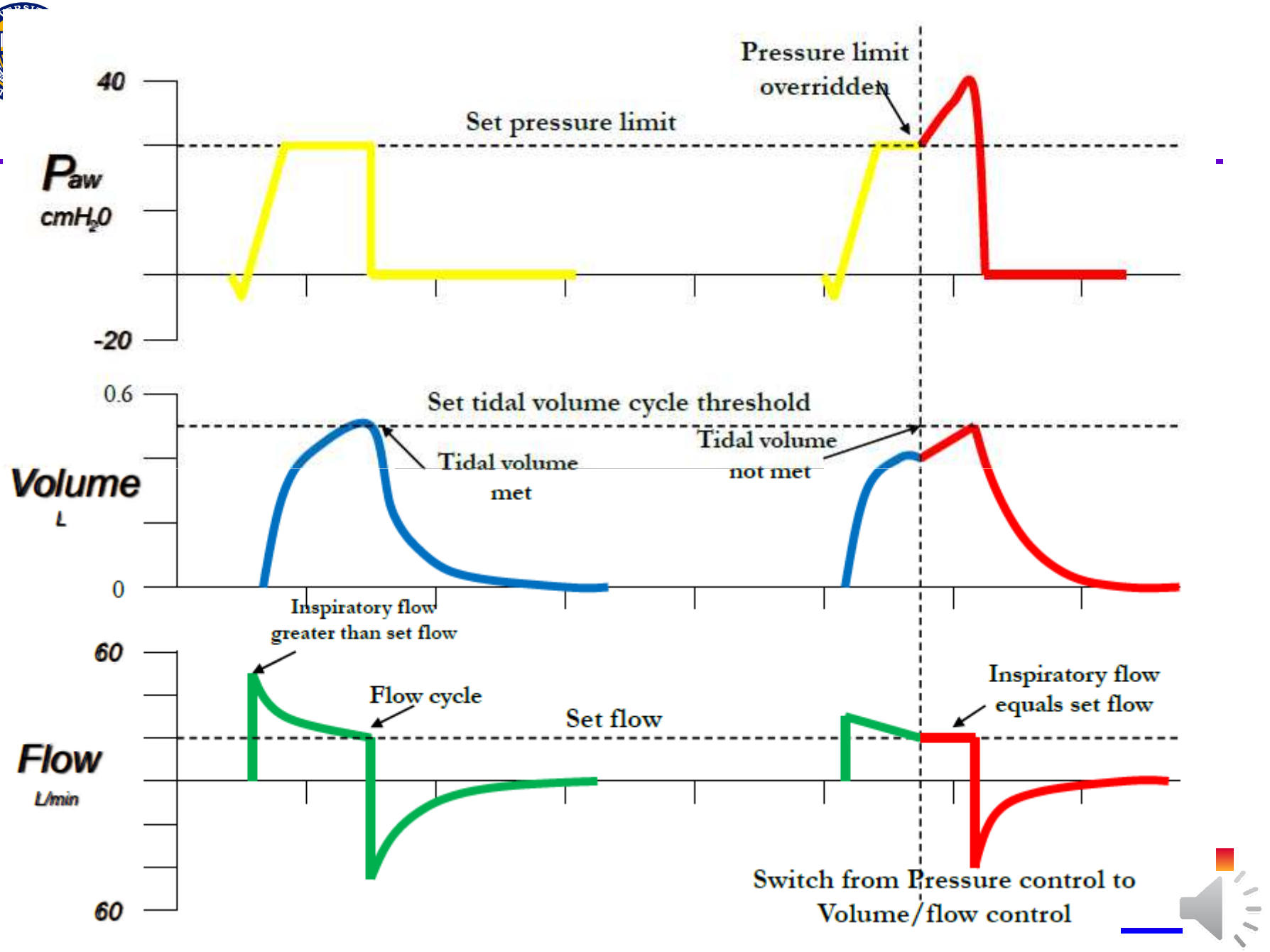
Logic for Volume Support



Volume-Assured Pressure Support

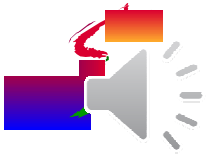
- Dual control within a breath
- Called VAPS (Bird 8400Sti and TBird)
- Called Pressure Augmentation (Bear 1000)
- Amato et al (Chest 1992) Haas et al (Respir Care 1995)
  - **VAPS reduced work of breathing by 50% over volume-control ventilation**
  - **Improved dynamic compliance**
  - **Reduced Auto-PEEP**

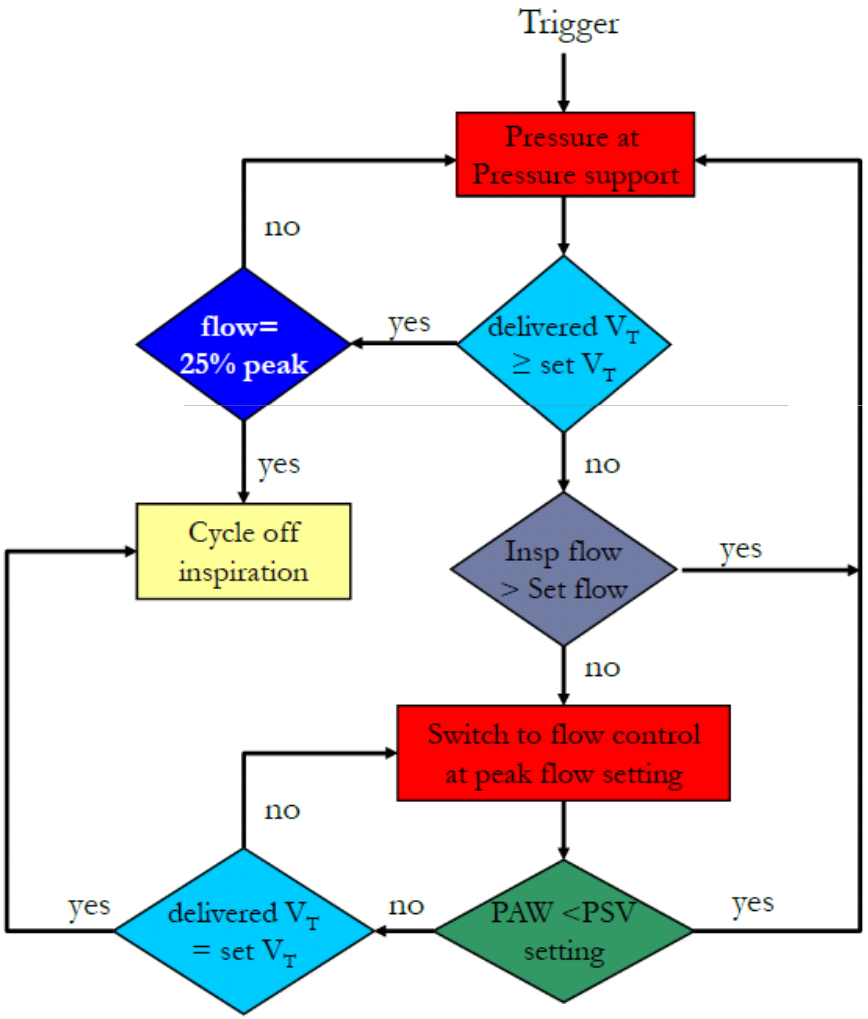



Pressure limit overridden
Set pressure limit
40
Paw
cmH2O
-20
0.6
Set tidal volume cycle threshold
Tidal volume not met
Tidal volume met
Volume
L
0
Inspiratory flow greater than set flow
60
Flow cycle
Set flow
Inspiratory flow equals set flow
Flow
L/min
60
Switch from Pressure control to Volume/flow control

Volume-assured Pressure Support

- Combines desired aspects of volume and pressure-targeted ventilation
- Trigger
  - **Pressure or flow**
- Inspiratory limit variable
  - **Dual control within a breath**
  - **At first, it is pressure-limited (IT IS PRESSURE-SUPPORT)**
  - **If the computer senses that the desired tidal volume will not be delivered, it switches to constant-flow volume control**
  - **The flow and duration is determined by the remaining tidal volume to be delivered**
- Cycling
  - **Flow-cycling or time-cycled**
- Baseline is PEEP





Control logic for volume-assured pressure-support mode

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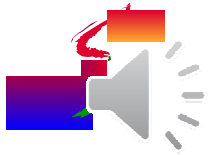
Airway pressure release ventilation

M. CHRISTINE STOCK, MD; JOHN B. DOWNS, MD; DEBORAH A. FROLICHER, BS

Ideal ventilatory support in ALI/ARDS

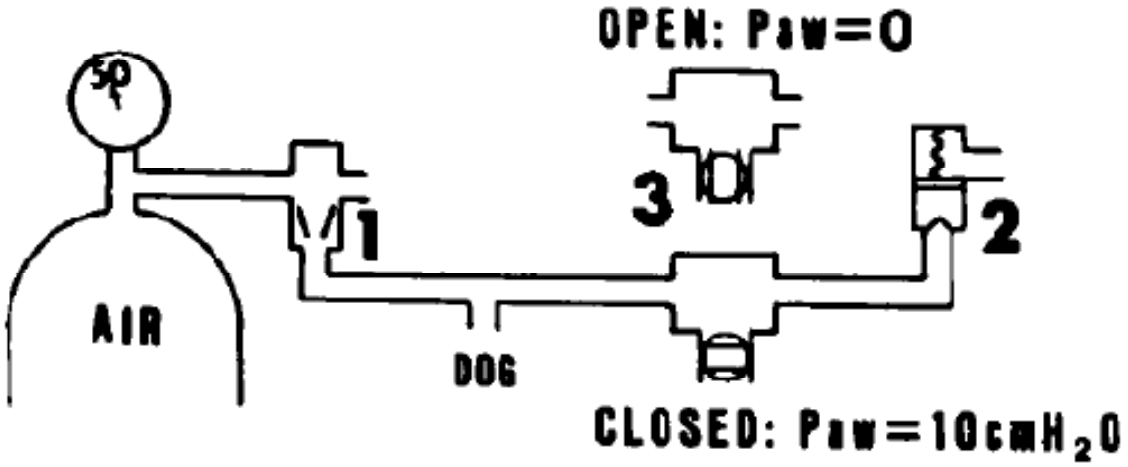
- Keep lungs open with sufficient CPAP without depressing caridac output
- Deliver mechanical breaths without increasing Paw excessively
- Allow unrestricted spontaneous ventilation



Original circuit for APRV

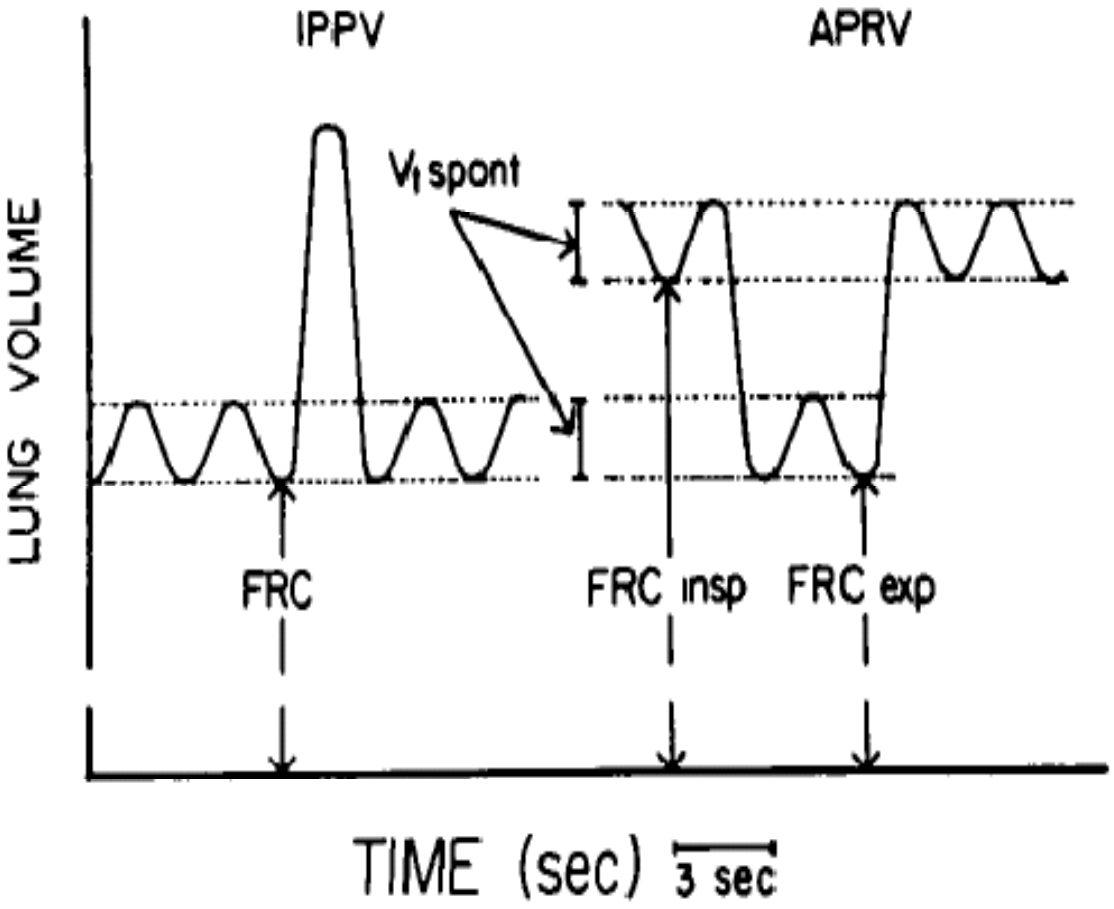
When timing switch is ***open*** Paw, gas escapes to atmosphere to a predetermined lower level of CPAP

1. Venturi valve
2. Exiratory valve
3. Timing switch



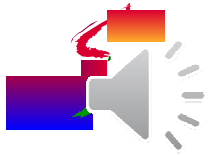
When timing switch is ***closed*** Paw is equal to the pressure generated by the expiratory valve

Lung volumes during IPPV vs APRV



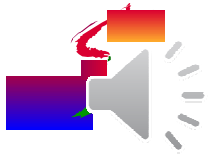
John Down's Editorial

- To provide APRV, continuous positive airway pressure (CPAP) is maintained so that the patient can breathe spontaneously without significant airway pressure fluctuation
  - High flow
  - Unrestricted spontaneous breathing



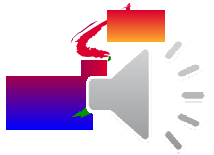
John Down's Editorial

- Select the appropriate level of CPAP
  - Approximately a few cms above the mean airway pressure seen with conventional ventilatory mode
  - Respiratory effort
  - Respiratory rate
  - PaO2
  - Compliance



John Down's Editorial

- Next question – Is additional ventilation required?
  - PaCO2 is normal or low – Answer is NO
  - PaCO2 high ~~– Answer is YES~~
  - Institute APRV



John Downs

- APRV is proposed as a unique way to augment alveolar ventilation without intermittently increasing Paw above the CPAP level when delivering a mechanical breath

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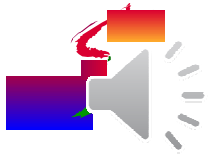
Airway pressure release ventilation during acute lung injury: A prospective multicenter trial

JUKKA RÄSÄNEN, MD; ROY D. CANE, MD, FCCM; JOHN B. DOWNS, MD, FCCM; JAMES M. HURST, MD; IRMA T. JOUSELA, MD; ROBERT R. KIRBY, MD; HERBERT J. ROGOVE, DO, FCCM; M. CHRISTINE STOCK, MD



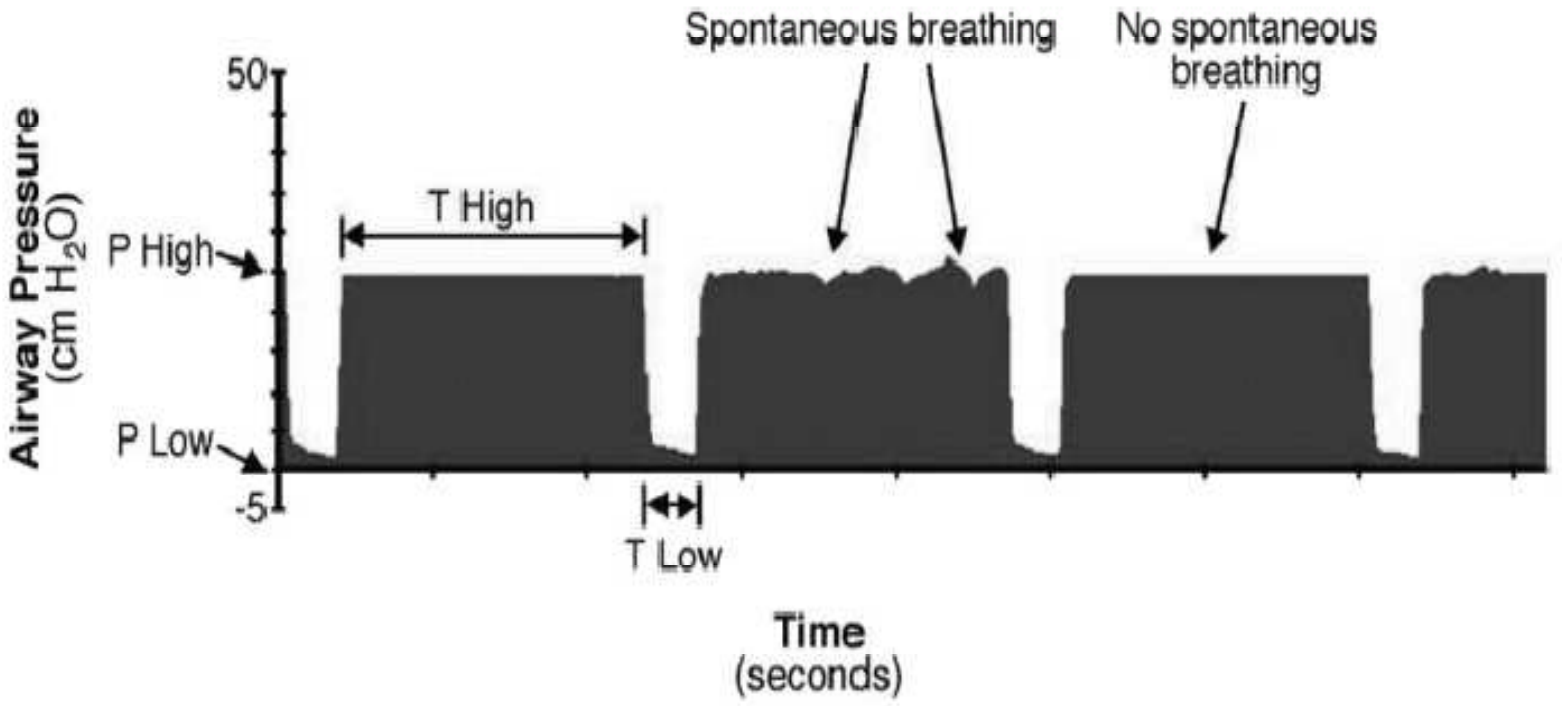
Ventilator settings

	Conventional Ventilation	APRV	*p* Value
F_{IO_2}	0.43 ± 0.09	0.44 ± 0.10	
CPAP (cm H_2O)	13 ± 3	21 ± 9	<.0001
Peak airway pressure (cm H_2O)	49 ± 14	21 ± 9	<.0001
Mean airway pressure (cm H_2O)	15 ± 4	17 ± 8	<.05
Release pressure (cm H_2O)	—	6 ± 5	NS
Ventilatory rate (cycles/min)	8 ± 4	10 ± 4	<.0001
Mechanical tidal volume (mL/kg)	12 ± 3	9 ± 3	<.001
Spontaneous respiratory rate (cycles/min)	20 ± 14	19 ± 14	NS
Minute ventilation (L/min)	12.4 ± 4.8	11.5 ± 4.3	NS

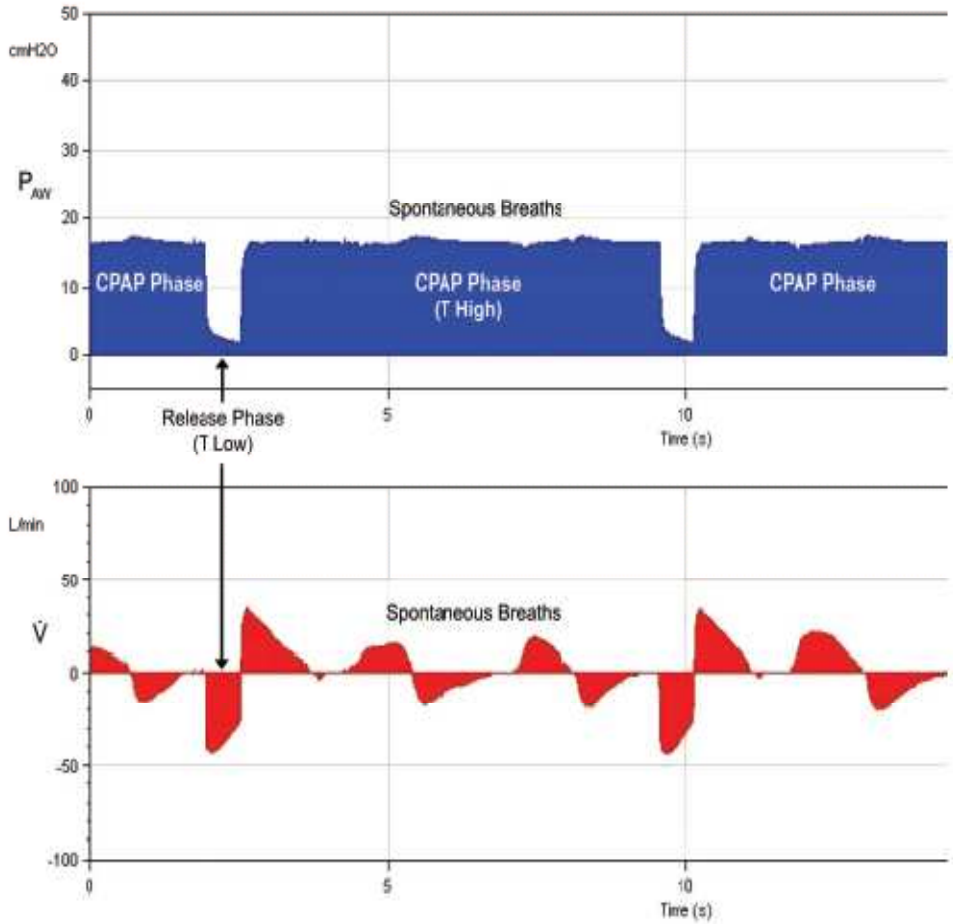
Physiologic parameters

Pao_2 (torr)	97 ± 35	101 ± 42	NS
(kPa)	13.0 ± 4.7	13.5 ± 5.6	NS
$Paco_2$ (torr)	43 ± 8	42 ± 8	NS
(kPa)	5.8 ± 1.1	5.6 ± 1.1	NS
pHa	7.38 ± 0.07	7.39 ± 0.07	NS
Heart rate (beats/min)	104 ± 23	105 ± 22	NS
Mean BP (mm Hg)	88 ± 9	89 ± 12	NS

APRV with and without spontaneous breathing

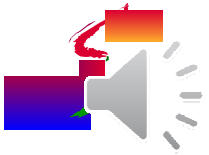


APRV


cmH2O
50
40
30
20
10
0
P_{Aw}
Spontaneous Breaths
CPAP Phase
CPAP Phase
(T High)
CPAP Phase
Release Phase
(T Low)
0
5
10
Time (s)
L/min
100
50
0
-50
-100
$\dot{V}$
Spontaneous Breaths
0
5
10
Time (s)

How to set the parameters?

- P_{high}
  - Above the mean airway pressure on conventional mechanical ventilation
  - Below the pause pressure (alveolar pressure)
- P_{low}
  - Should be set at a level
    - Does not allow alveolar collapse
    - Does not produce auto-PEEP
- T_{high}
  - No specific recommendations
  - Start with an I:E 1.5-2:1 and then increase if tolerated and necessary
- T_{low}
  - No specifc recommendations
  - Should not be so low that it produces auto-PEEP
  - Should not be set too high that it encourages alveolar collapse



Things to monitor

- Respiratory
  - Work of breathing
  - RR
  - Comfort of breathing
  - Asynchrony/Dyssynchrony
  - Gas exchange
    - Oxygenation
    - Ventilation
- Cardiovascular
  - HR
  - BP
  - Perfusion
  - CVP