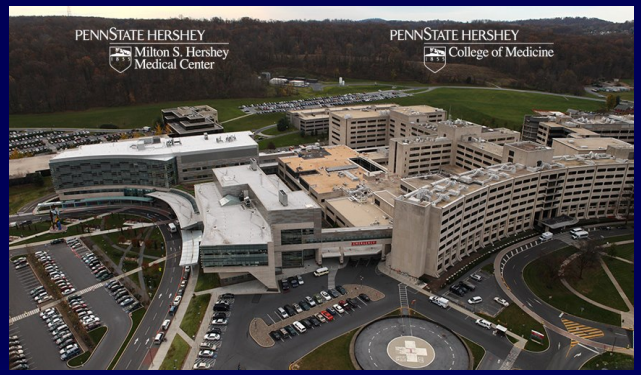
Recent Advances in Mechanical Ventilation for Anesthesiologist



Dr. Venugopal Reddy. MD, EDIC, FCARCSI

Associate professor of anesthesiology, and Perioperative Medicine

Hershey Medical Center, Penn state College of Medicine

Pennsylvania, USA

Advances in mechanical ventilation

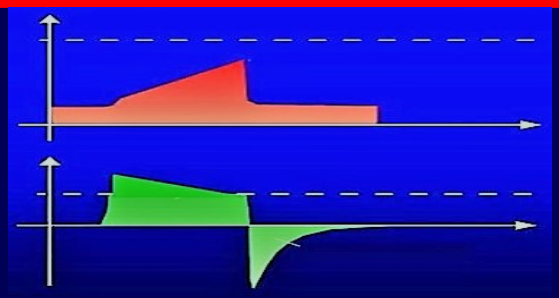
1. Pressure regulated volume control
2. Volume support ventilation
3. Airway Pressure release ventilation
4. Adaptive support ventilation
5. Neurally adjusted Ventilatory support
6. Mandatory Minute ventilation
7. Proportional assist ventilation
8. Knowledge based system

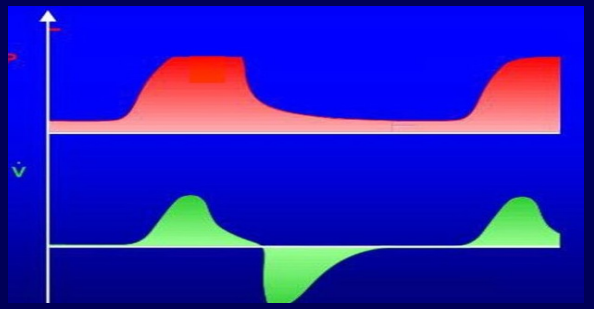
Auto-Flow or Pressure Regulated Volume Control (PRVC) Mode

Volume control ventilation

+

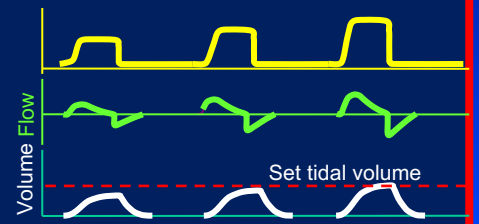
Pressure control ventilation





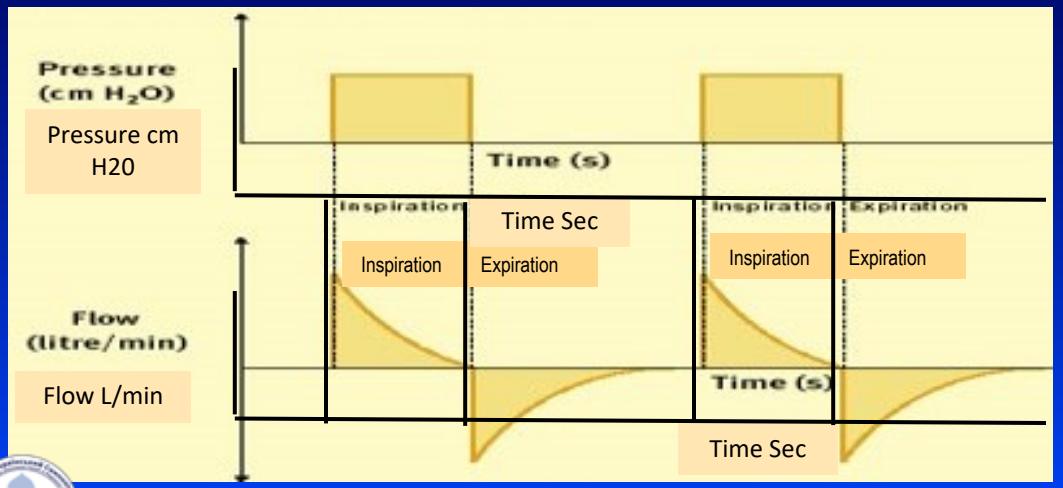
Auto Flow Dräger (Anesthesia/ICU)

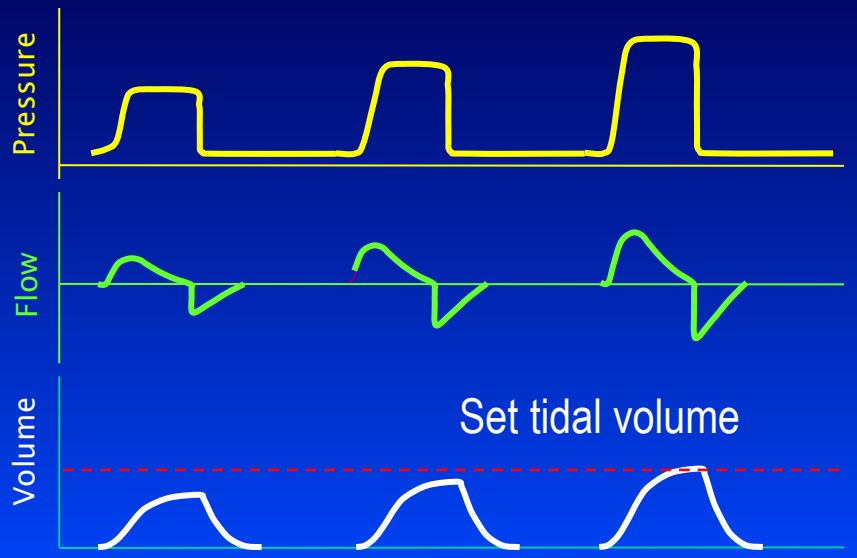
Pressure Regulated Volume Control (PRVC) :Maquet (ICU)



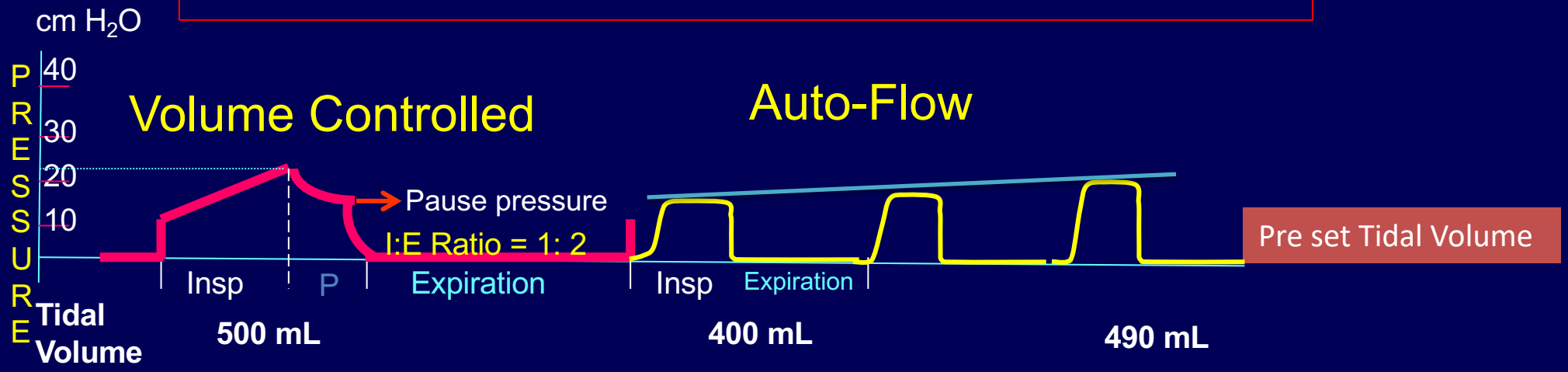
Pressure Control Mode vs Auto-flow

- PCV: With change in lung mechanics VT delivery is not guaranteed (airway obstruction, change in posture etc)
- Auto-Flow: PC breaths with **target tidal volume**
- Inspiratory pressure adjusted to deliver VT
- Like PCV – constant airway pressure, variable flow (flow as demanded by patient)





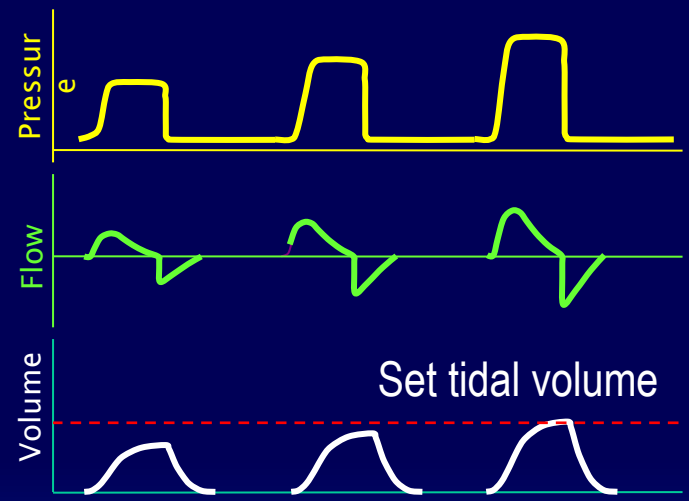
How does Auto-Flow work ?

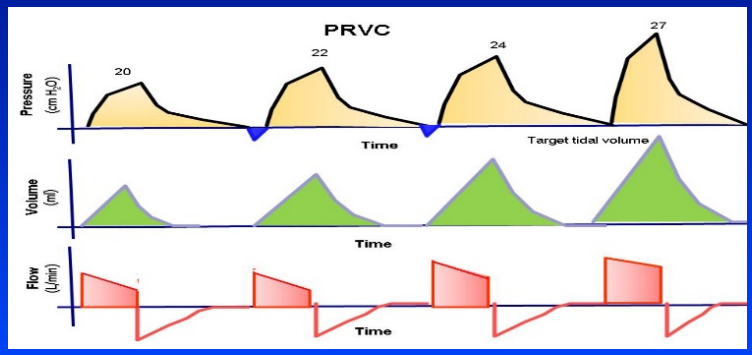


- First breath is a volume control breath
- The inspiratory pressure for the next breath is based on the plateau pressure of the first breath
- Then up to +/- 3 cm H20 changes per breath
- If the VT increases, the pressure support decreases by up to 3cm H_2O until the desired VT is reached

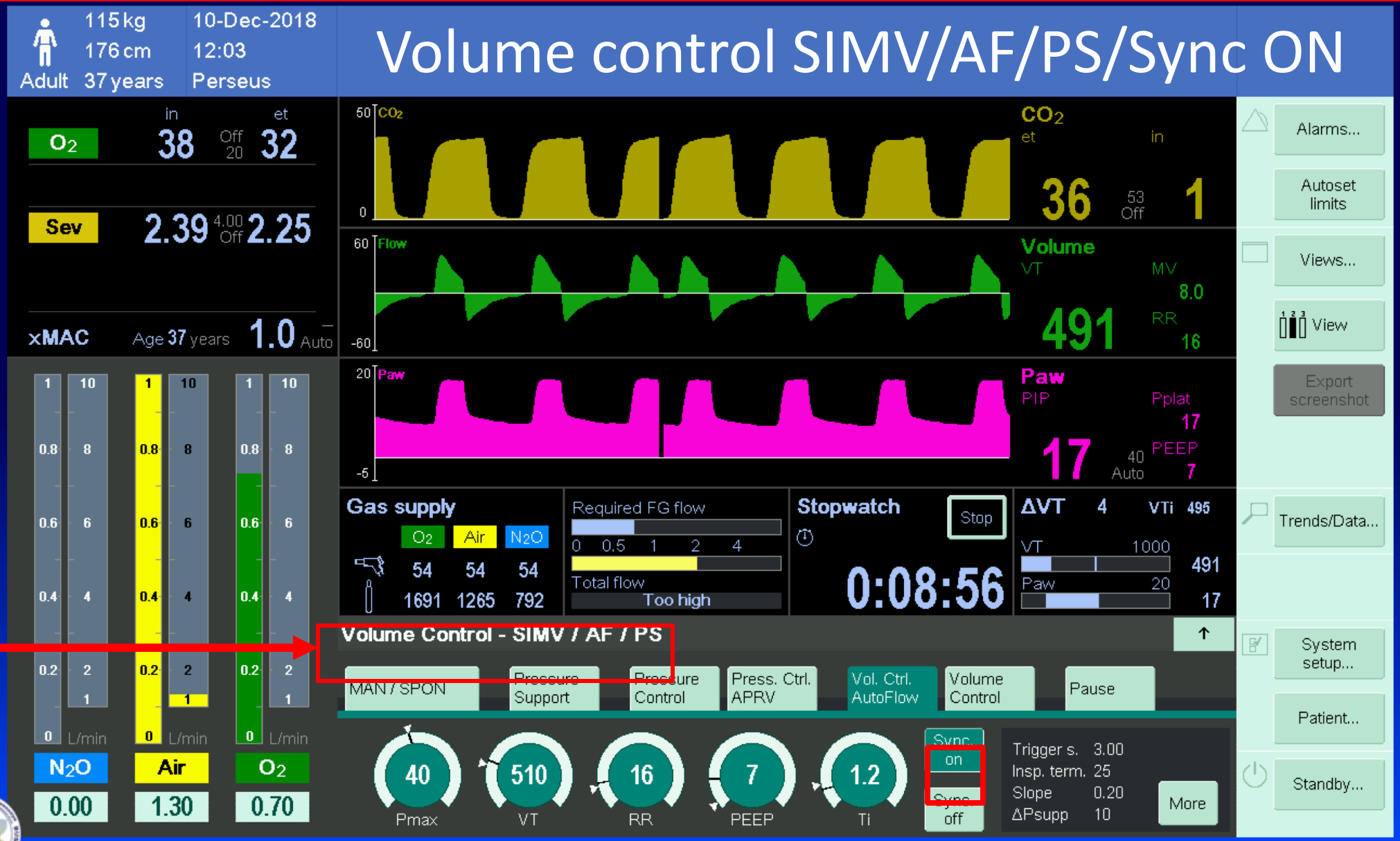
Auto Flow: Advantages

- Pressure adjusted for changes in compliance and resistance
- Maintains a minimum PIP
- Guaranteed V_T and V_E
- Allows patient control of respiratory rate and V_E
- Breath by breath analysis
- Limits volutrauma
- Prevents hypoventilation





Auto-flow (Dräger evita 4, XL)

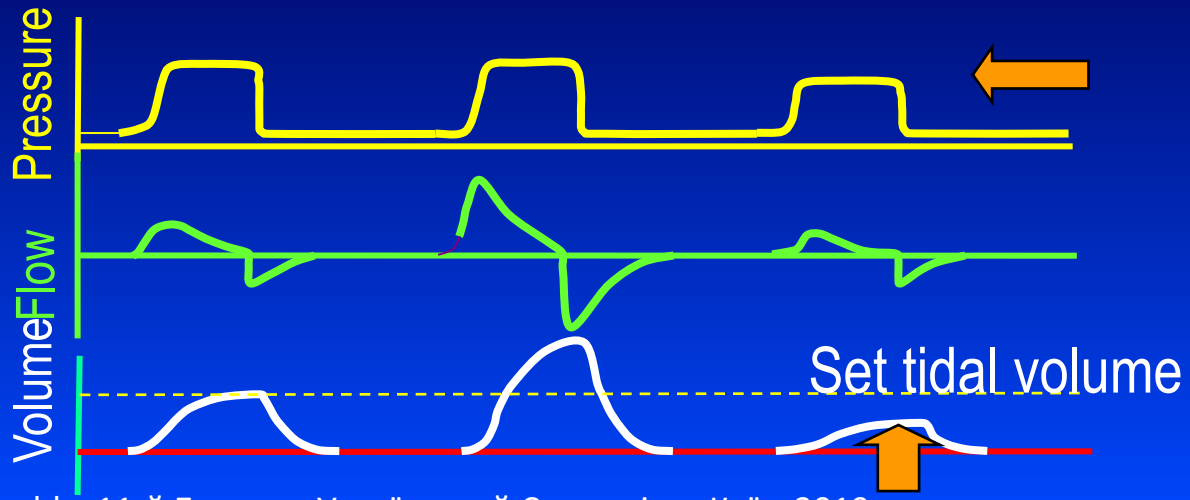


Auto Mode (PRVC): Indications

- Can be used routinely to take advantage of two modes in one (volume and pressure)
- Patient who require the lowest possible pressure and a guaranteed consistent V_T
- ALI/ARDS
- Patients requiring high and/or variable MV

PRVC: Disadvantages

- ✓ Pressure delivery is based on previous V_T and varies
- ✓ Intermittent patient effort ⇒ variable V_T
- ✓ Varying mean airway pressure
- ✓ Leaks are not compensated
- ✓ A sudden increase in respiratory rate and demand may result in a decrease in ventilator support



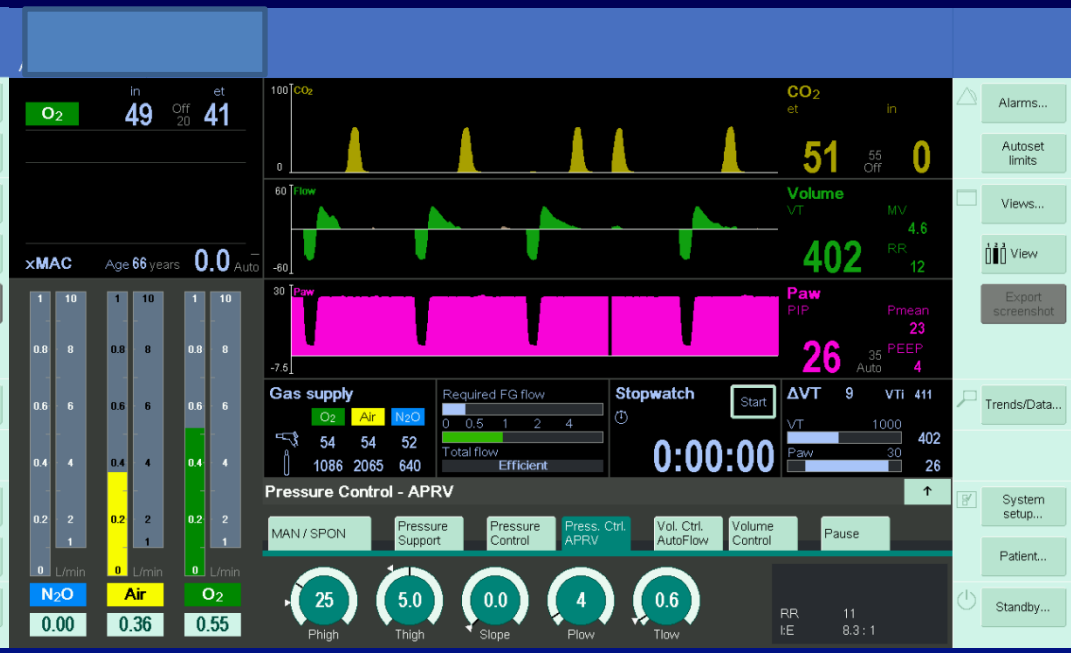
Pressure Controlled Ventilation

Pressure Controlled Inverse Ratio ventilation (PC-IRV)

Airway Pressure Release Ventilation

Pressure Control Inverse ratio Ventilation (PC-IRV)

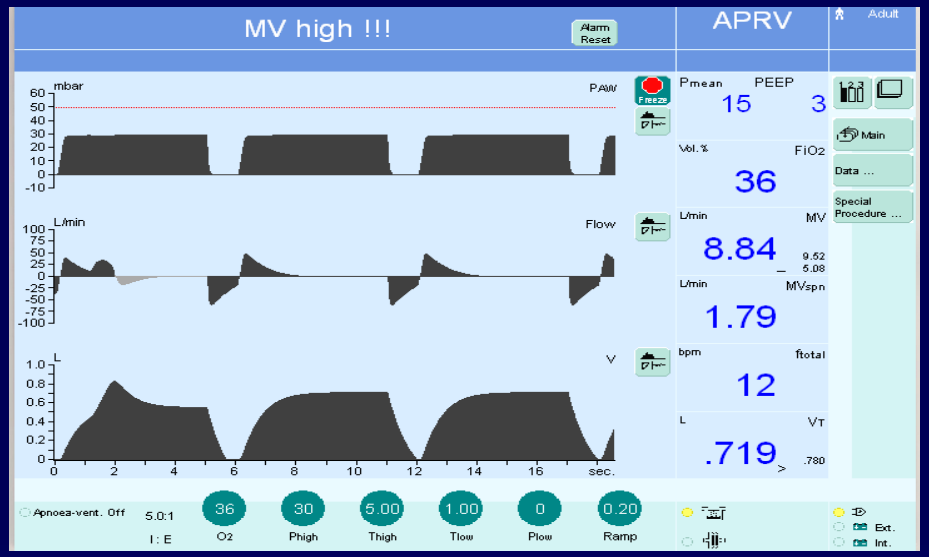
Airway Pressure release ventilation (APRV)

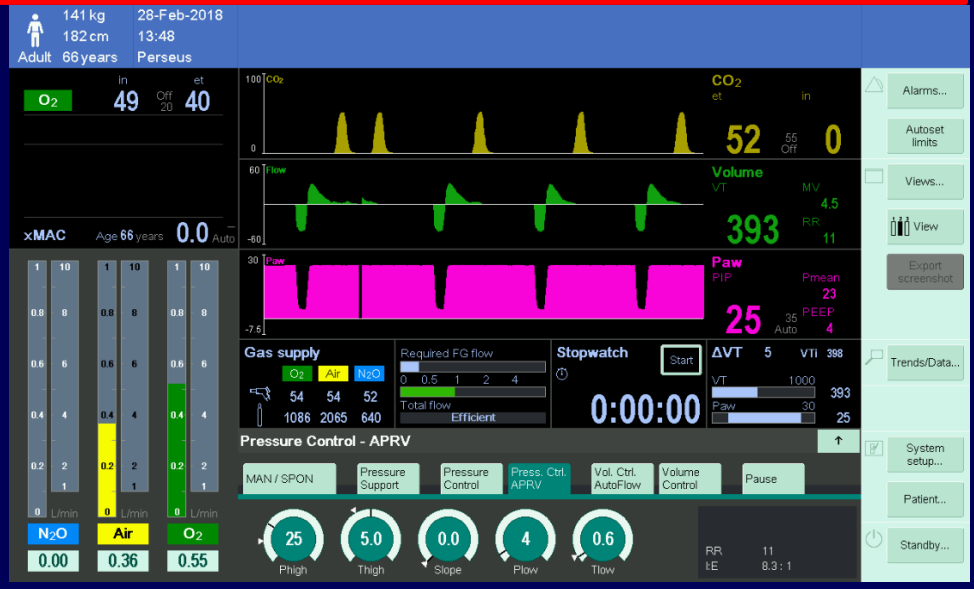


- ✓ I:E ratio is 4-5:1
- ✓ Spontaneous breath are not supported
- ✓ At times requires paralysis

- ✓ I:E can be even 5-15:1
- ✓ Spontaneous breath are fully supported
- ✓ No paralysis required
- ✓ Maintains MAP

Airway Pressure Release ventilation (APRV)

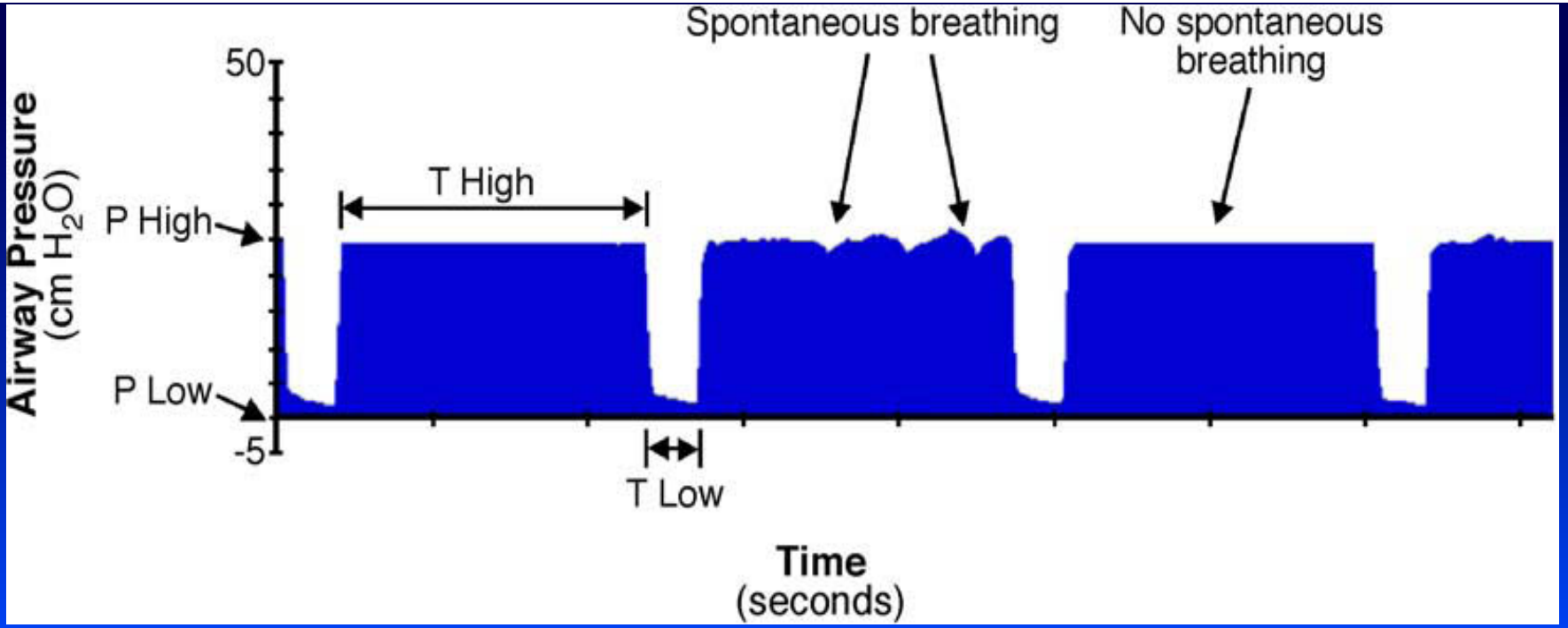




- Provides 2 levels of CPAP and allows spontaneous breathing at both levels
- CPAP released periodically for a brief period.
- Short release with spontaneous breathing promote CO_2 elimination
- Auto-PEEP is a possibility

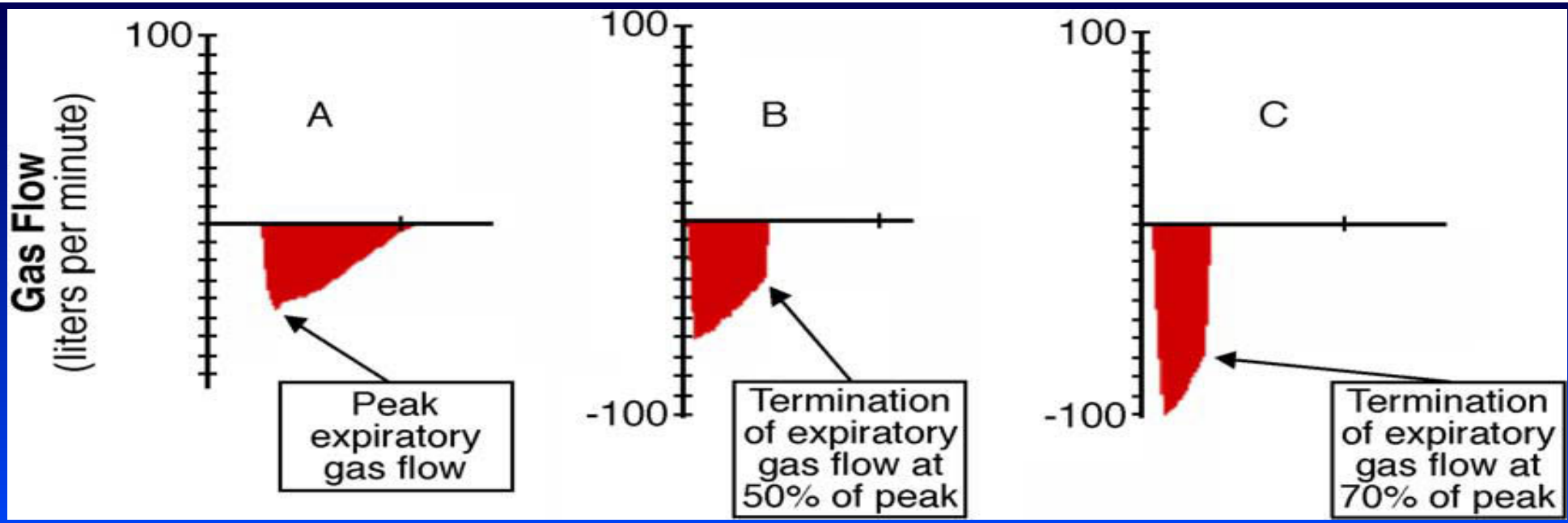
APRV: Terminology

P_{high}: Inspiratory pressure + Plow pressure (peak pressure)
P_{low}: Expiratory pressure (PEEP)
T_{high}: Time spent during inspiration (Insp time)
T_{low}: Time during deflation (Exp time)



Airway Pressure Release Ventilation

- do not let expiratory flow returning to zero
- Set Plow (PEEP) at 0 cm H_2O.
- Set T low so that expiratory flow from patient ends at about 50 to 75% of peak expiratory flow
- Avoid lung collapse during T_{low}.



Airway Pressure Release Ventilation (APRV)

- Advantages
  - Higher pressure: Alveolar recruitment, better oxygenation, maintenance of mean alveolar pressure
  - Lower pressure: alveolar ventilation and CO_2 removal
  - Recruitment of diseased lung
  - Allows spontaneous breathing and hence better gas distribution to the dependent lung regions
  - Decreased work of breathing
  - Constant recruitment including slow opening alveoli: Improved V/Q matching

Airway Pressure Release Ventilation (APRV)

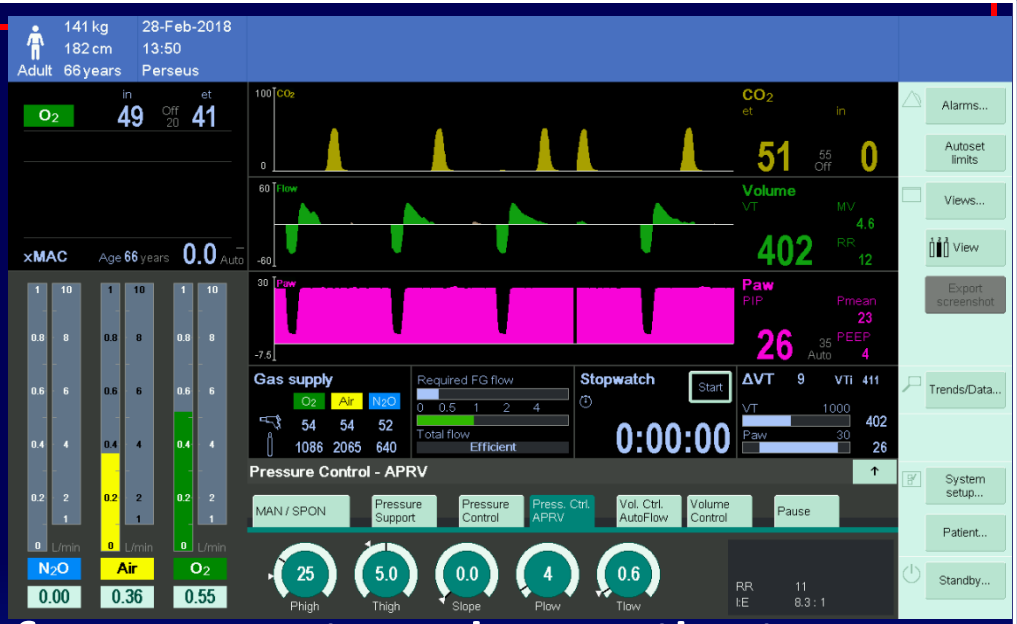
❑ Disadvantages

- Volume changes with alteration in lung compliance and resistance
- Could be harmful to patients with high expiratory resistance (i.e., COPD or asthma)
- Caution: in hemodynamically unstable patients Increase RV strain and after load, and PHT
- Spontaneous breath during T_{low}: Increase WOB
- Worsening of air-leak (BPF)
- Auto-PEEP is usually present

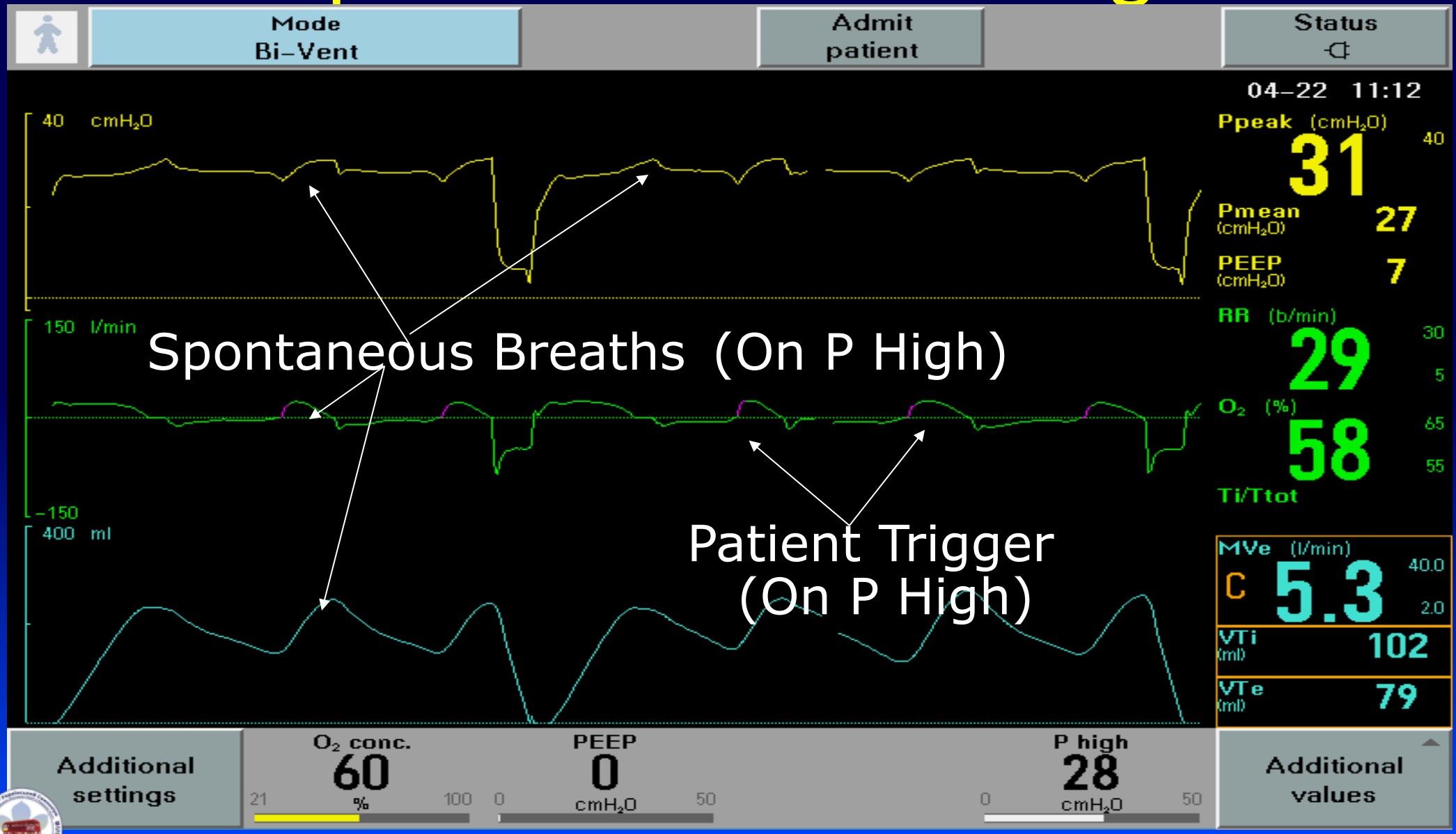
Airway Pressure Release Ventilation (APRV)

- Indication
  - ARDS
  - Hypoxemia
  - Atelectasis
  - Need for higher PEEP
- Settings
  - P_{high} plateau pressure of conventional ventilation
    - Use previous mean alveolar pressure/plateau pressure
  - T_{high} Inspiratory time (5.5-6.5 sec)
  - P_{low} 0 cm H_2O(PEEP) (intentional auto-PEEP)
  - T_{Low} 0.4-0.6 sec

T_{Low} should be equal to 40%-50% of peak expiratory flow



Spontaneous Breathing



Airway Pressure Release Ventilation (APRV)

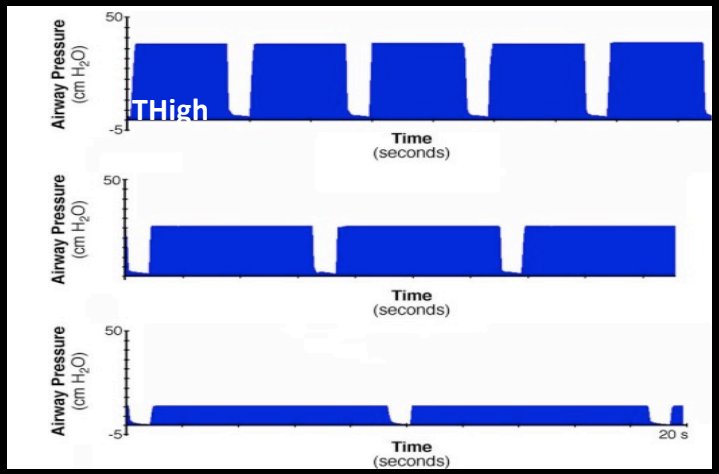
- **Hypoxia**
  - Prolong T_{high} by 0.5 to 1 sec
  - Increase p_{High} by 2-5 cm H_2O
- **Hypercapnia**
  - Tolerate permissive hypercapnia
  - Decrease T_{high} by 0.5-1 sec
  - Shorter T_{High} means more release/min.

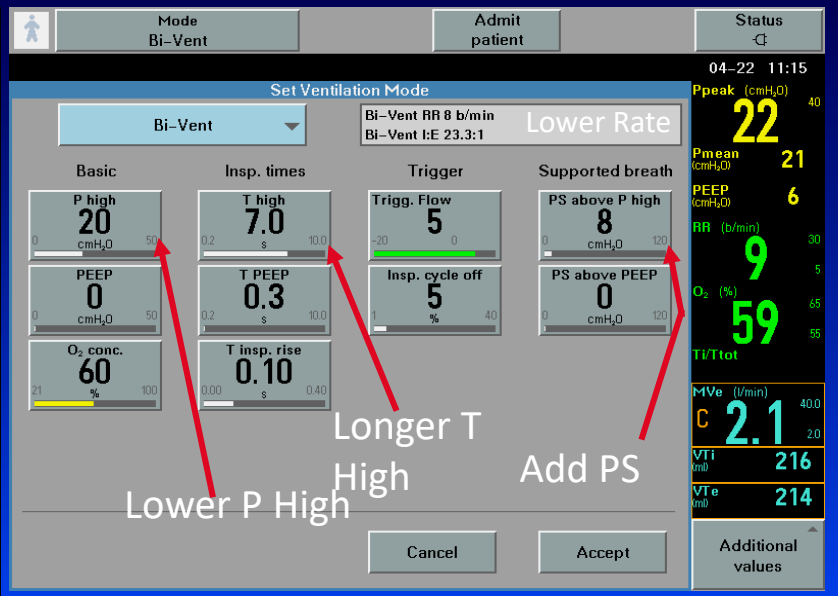
Example: T_{High} 5 sec. = 12 releases/min

T_{High} 4 sec = 15 releases/min

APRV: Weaning

1. Decrease FIO_2
2. Reduce P_{High}, by 2 cmH_20
3. Increase T_{High}
4. P_{high} 15 cm H_20 and T high 15 sec - CPAP



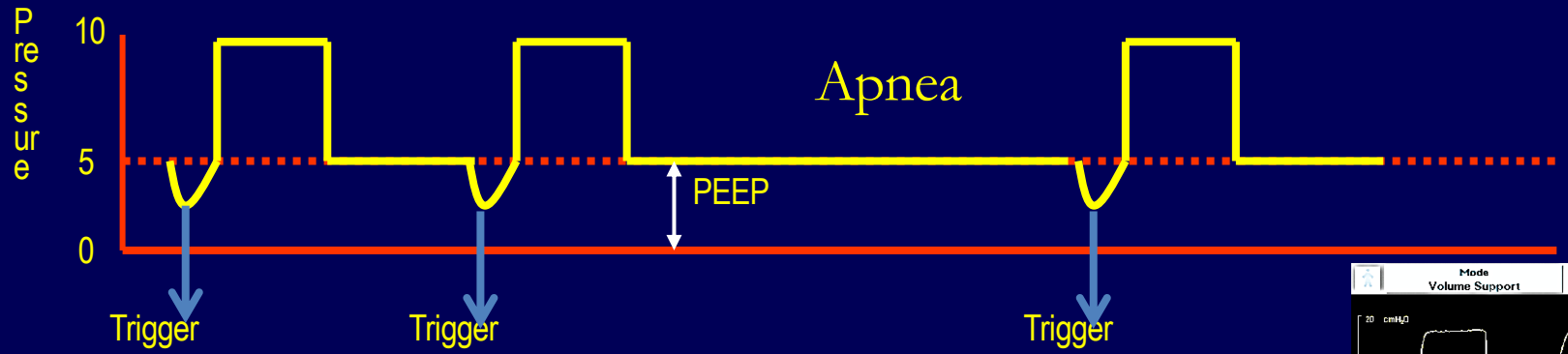


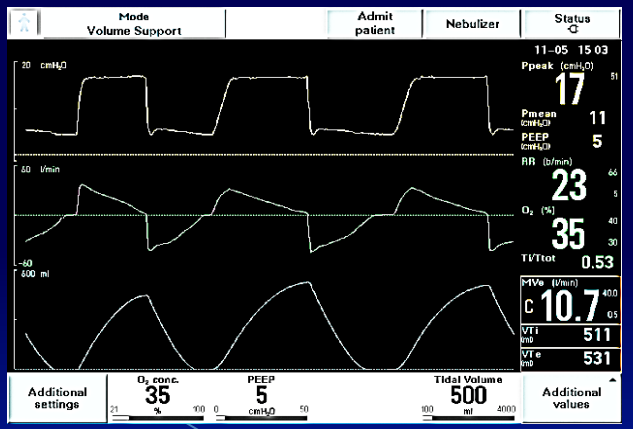
SIMV

Pressure Support

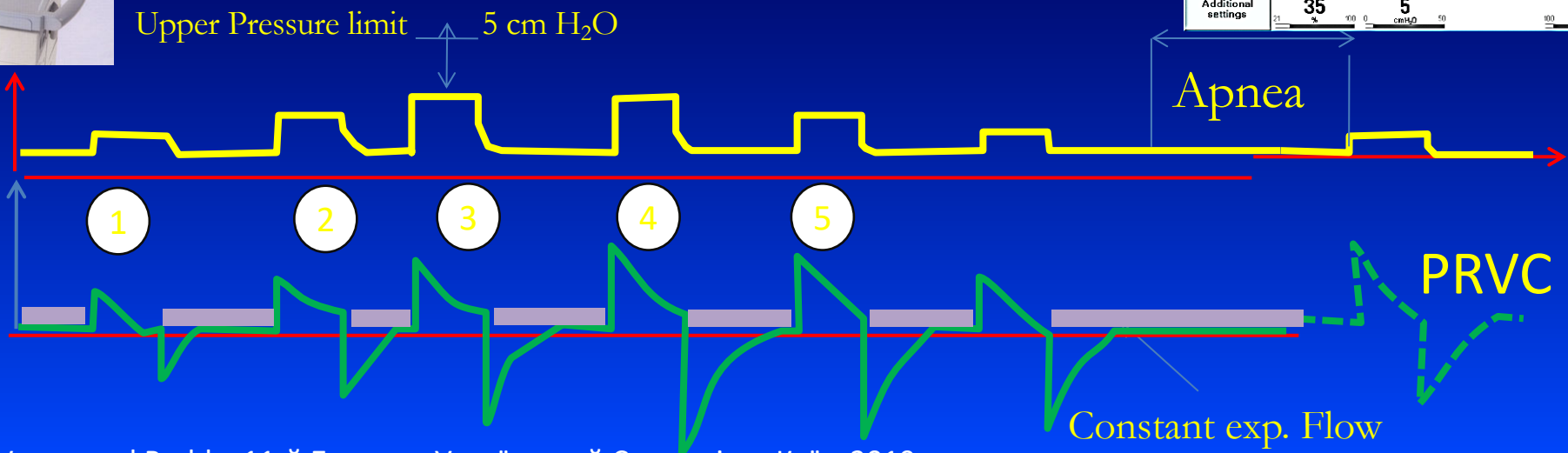
Volume Support

Pressure support

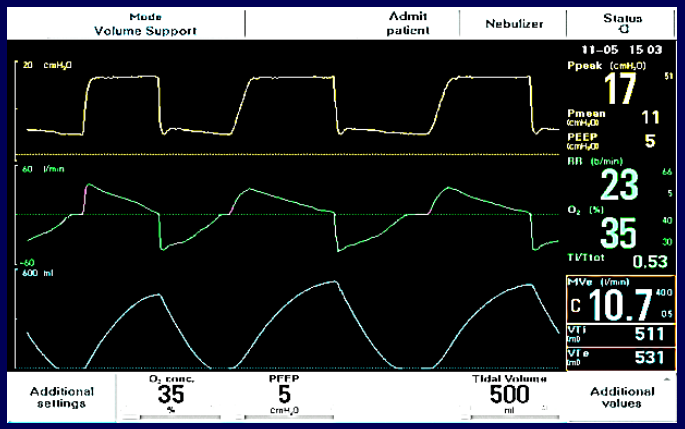




Volume support ventilation

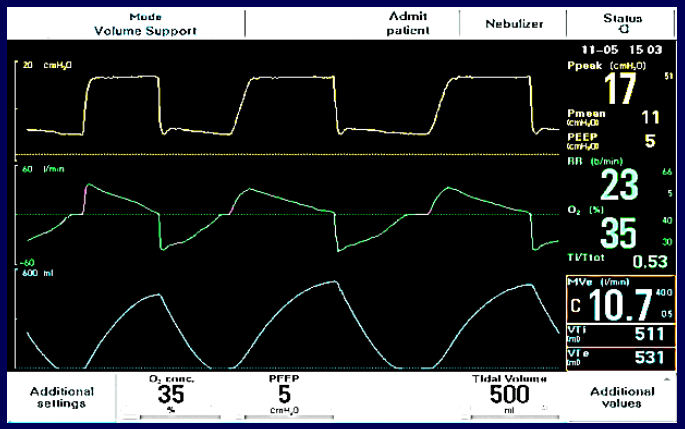


Volume support (Servo)



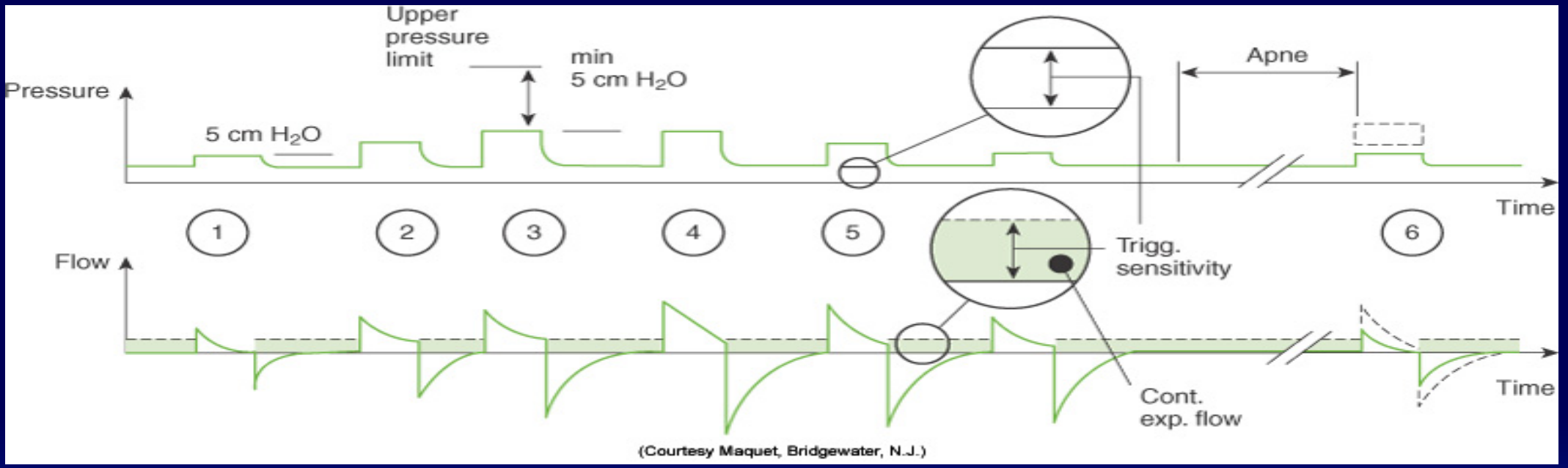
- All breaths are patient triggered, pressure limited, and flow-cycled.
- In this mode the pressure is automatically adjusted by the ventilator to meet the minimal set tidal volume.
- Pressure support changes with each breath, depending on the patients activity to achieve the target VT.
- Patient controls the I:E and the total inspiratory time
- This improves the ventilator-patient synchrony.

Volume support (Servo)



- As the patient breaths deeper, the ventilator gives less pressure
- If the patients generates little pressure, the ventilator gives more support
- Back up (if rate is too low or apnea) is PRVC or VC
- Allows the respiratory muscles to take on work of breathing.

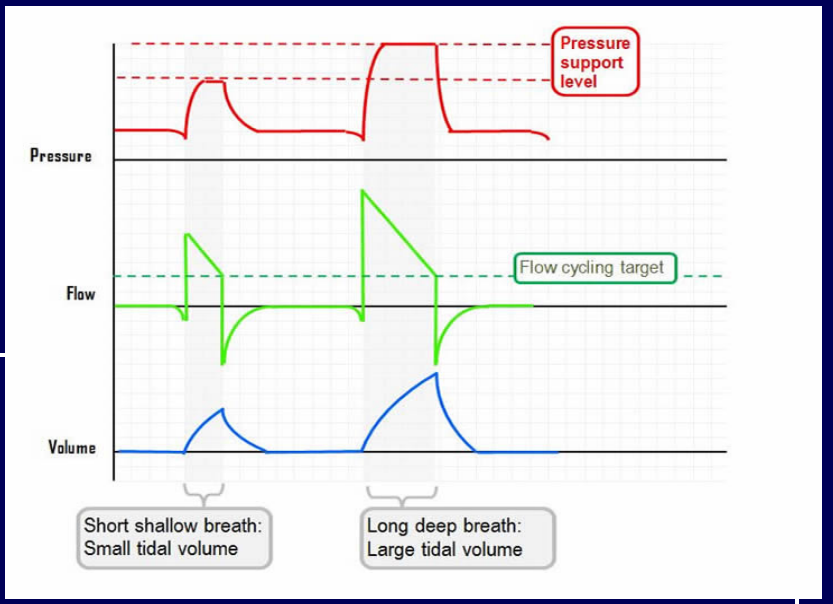
Volume Support



(Courtesy Maquet, Bridgewater, N.J.)

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
4. VT higher than set VT delivered results in lower pressure
5. patient can trigger breath
6. Apnea: Ventilator switches to PRVC (auto-mode)

Volume support (VS)



❑ Advantages

- Guaranteed VT and VE
- PS breaths using the lowest required pressure
- ↓ patient's spontaneous respiratory rate
- ↓ patient WOB
- Allows patient control of I:E time
- Breath by breath analysis
- Variable inspiratory flow to meet the demand

Volume support (VS)

❑ Disadvantages

- Spontaneous ventilation required
- V_T selected may be too large or small for patient
- Varying mean airway pressure
- Auto-PEEP may affect proper functioning
- A sudden increase in respiratory rate and demand may result in a decrease in ventilator support

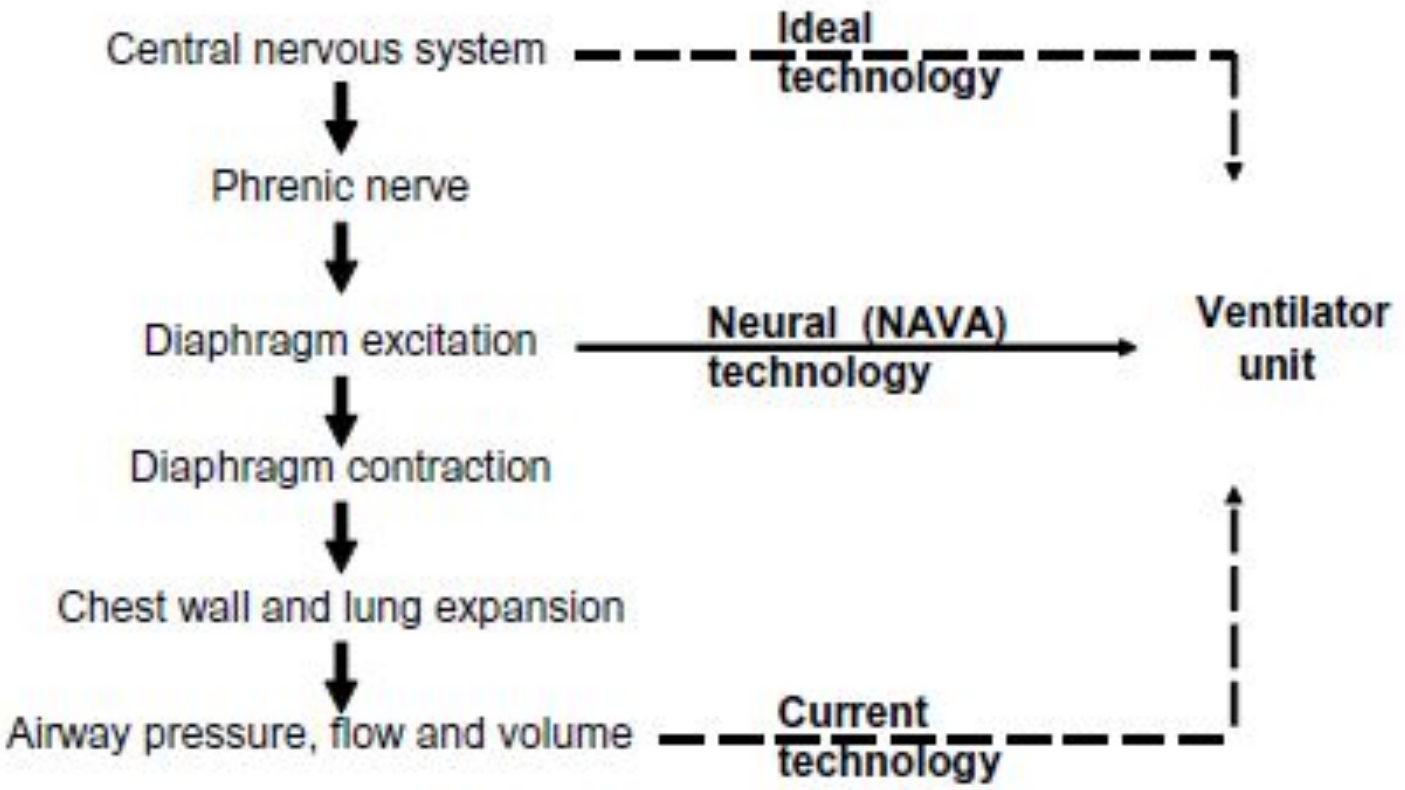
Volume Support (VS)

Indications

- Spontaneous breathing patient who require minimum V_E
- Patients who have inspiratory effort who need adaptive support
- Patients who are asynchronous with the ventilator
- Used for patient who are ready to wean

Neurally adjusted Ventilatory support

Steps necessary to transform central respiratory drive into an inspiration at which technology able to control a ventilator could be implemented.

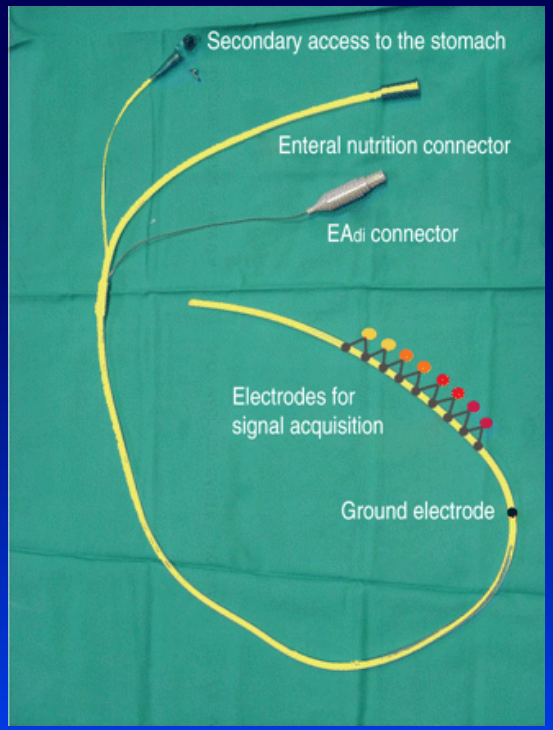


Neurally adjusted ventilatory assist (NAVA)

- Normal: Initiation of inspiration: flow or pressure but there could be delay in providing the support

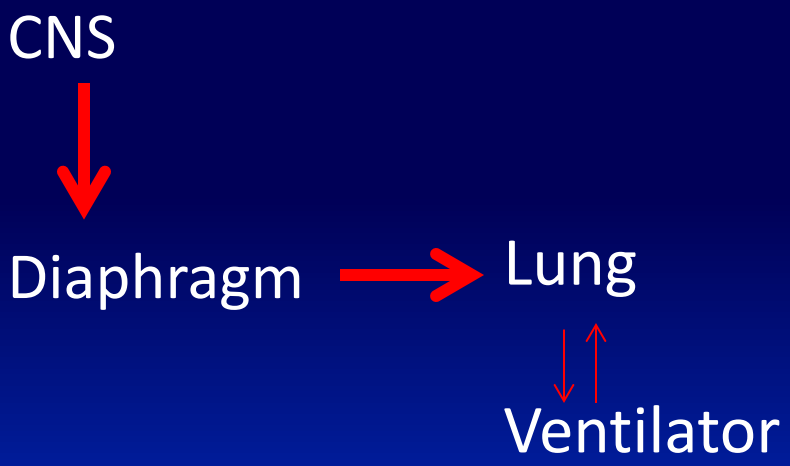
NAVA:

- Triggering achieved through electrical activity of the diaphragm (EAdi)
- Ventilator delivers an inspiratory pressure proportional to the electrical activity of the diaphragm (EAdi)
- EAdi includes both frequency and intensity
- Recording done by esophageal catheter
- Patient controls inspiratory time
- No signal: PS ventilation and apnea PC mode

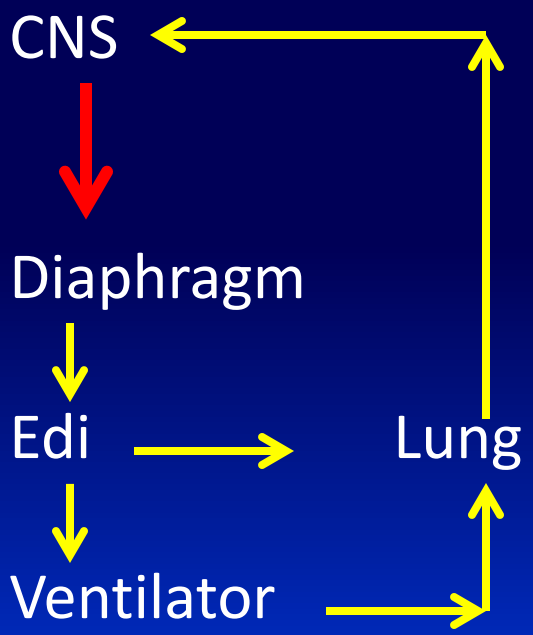


Neurally Adjusted Ventilatory Support

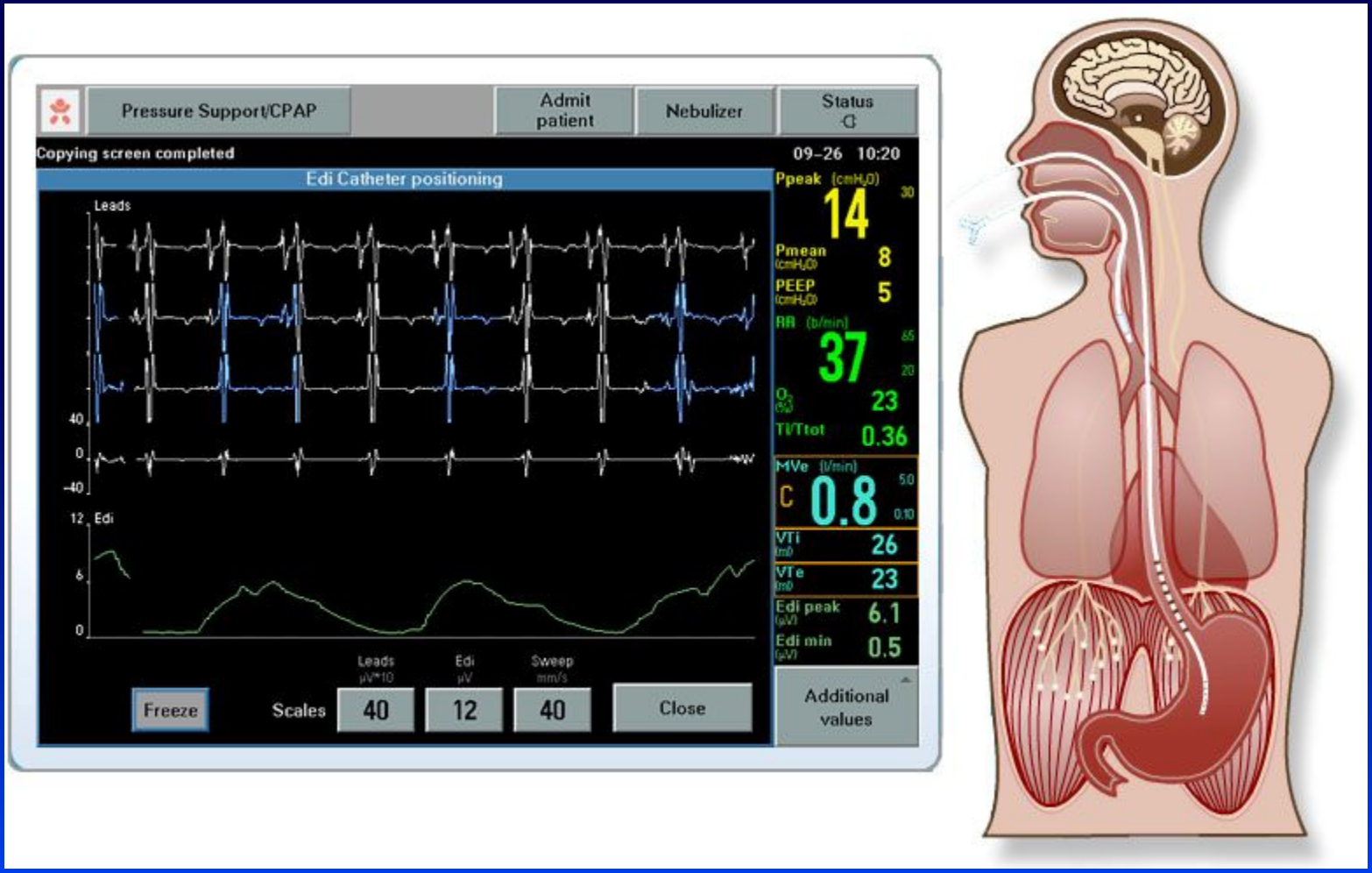
Pneumatic Trigger



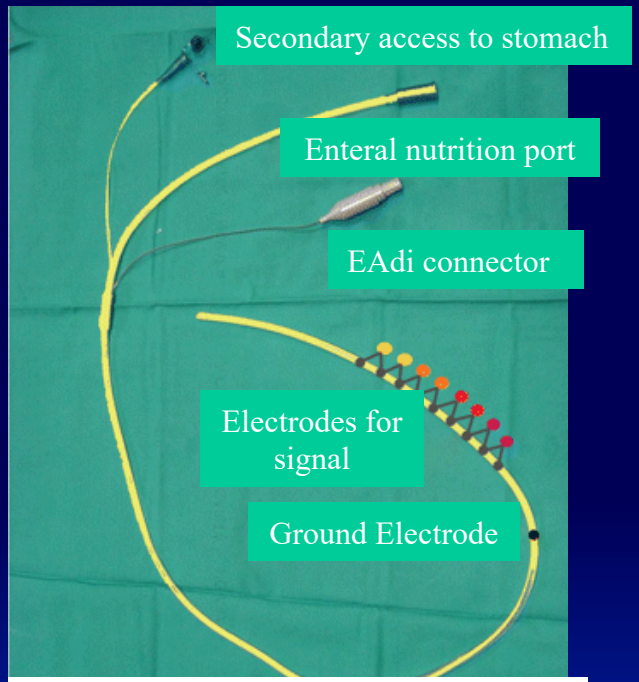
NAVA Trigger

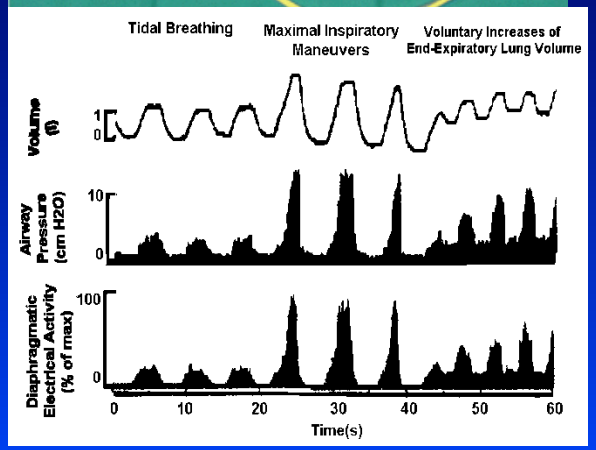


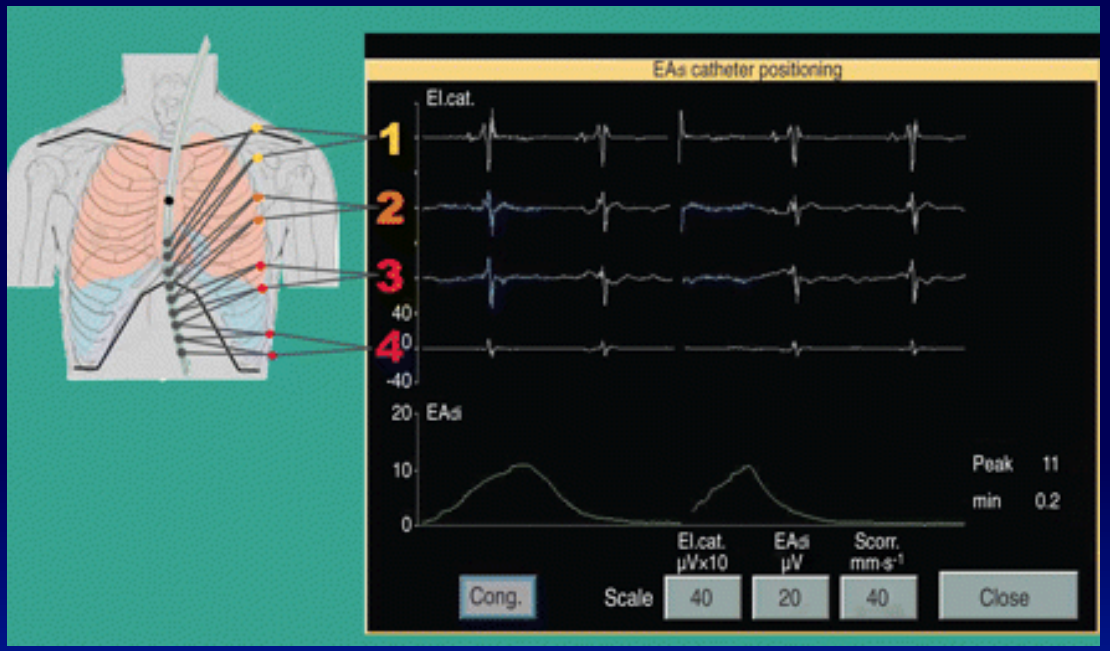
Neurally adjusted ventilatory mode



Neurally adjusted ventilatory assistance







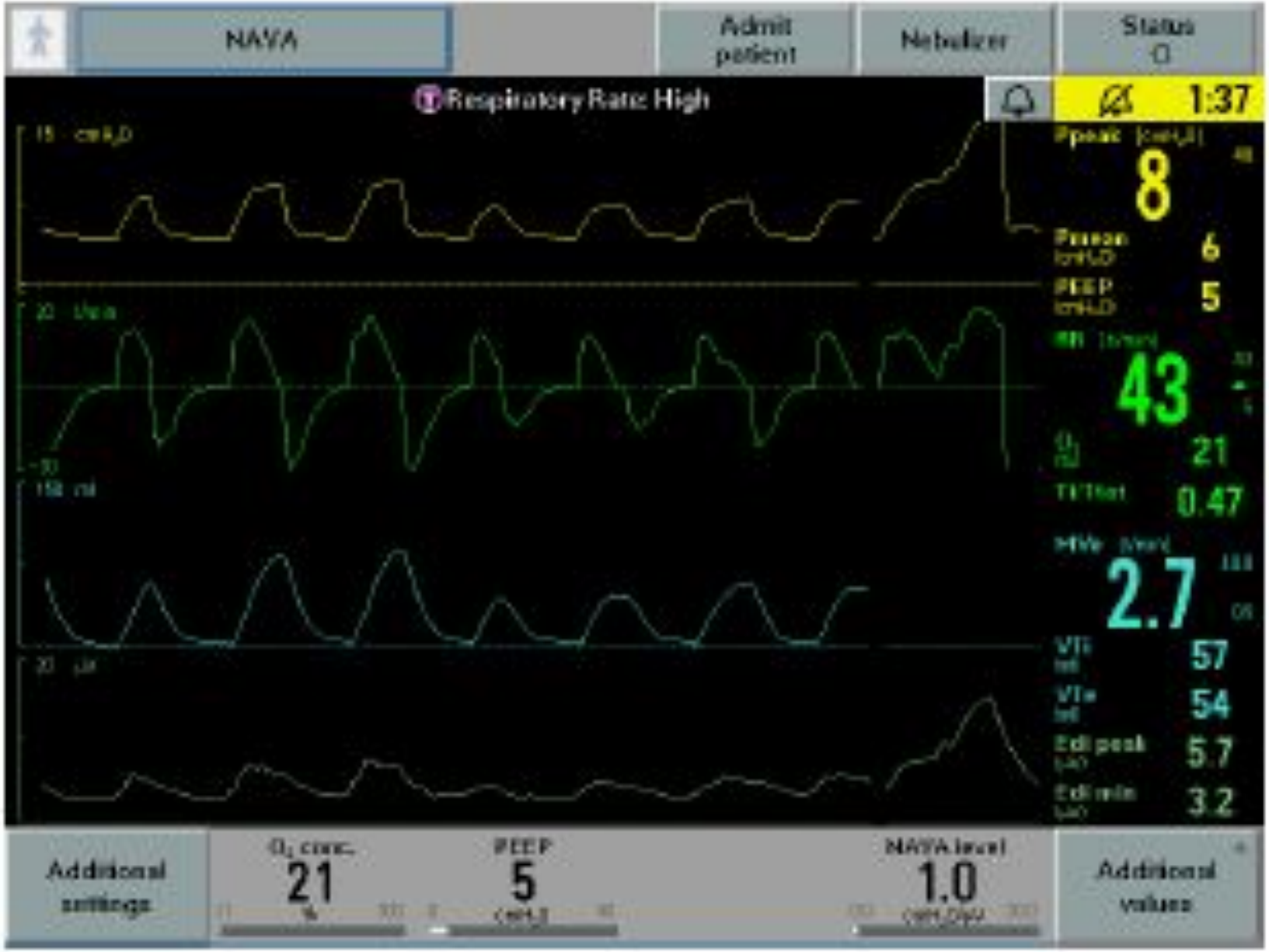
EMG tracings: 4, obtained from 8 differential electrodes electrical activity of the diaphragm (EAdi)

EMG signal from the closest pair to the diaphragm, is transformed into a waveform

NAVA: ventilator setting

Inspiratory PS	VT 6–8 ml/kg
Flow-trigger	lowest possible
Expiratory trigger	30% of the peak inspiratory flow
Level of assistance	PSV-100 and ⇧ or ⇩
PEEP and FiO2	

- Too low NAVA level:
  - rapid shallow breathing and Neural output shows high EAdi signal
  - Increase NAVA support EAdi signal decrease until plateau and patient is comfortable


NAVA
Admit patient
Nebulizer
Status
Respiratory Rate High
1:37
8
6
5
43
21
0.47
2.7
57
54
5.7
3.2
Additional settings
21
5
1.0
Additional values

?