MECHANICAL VENTILATION

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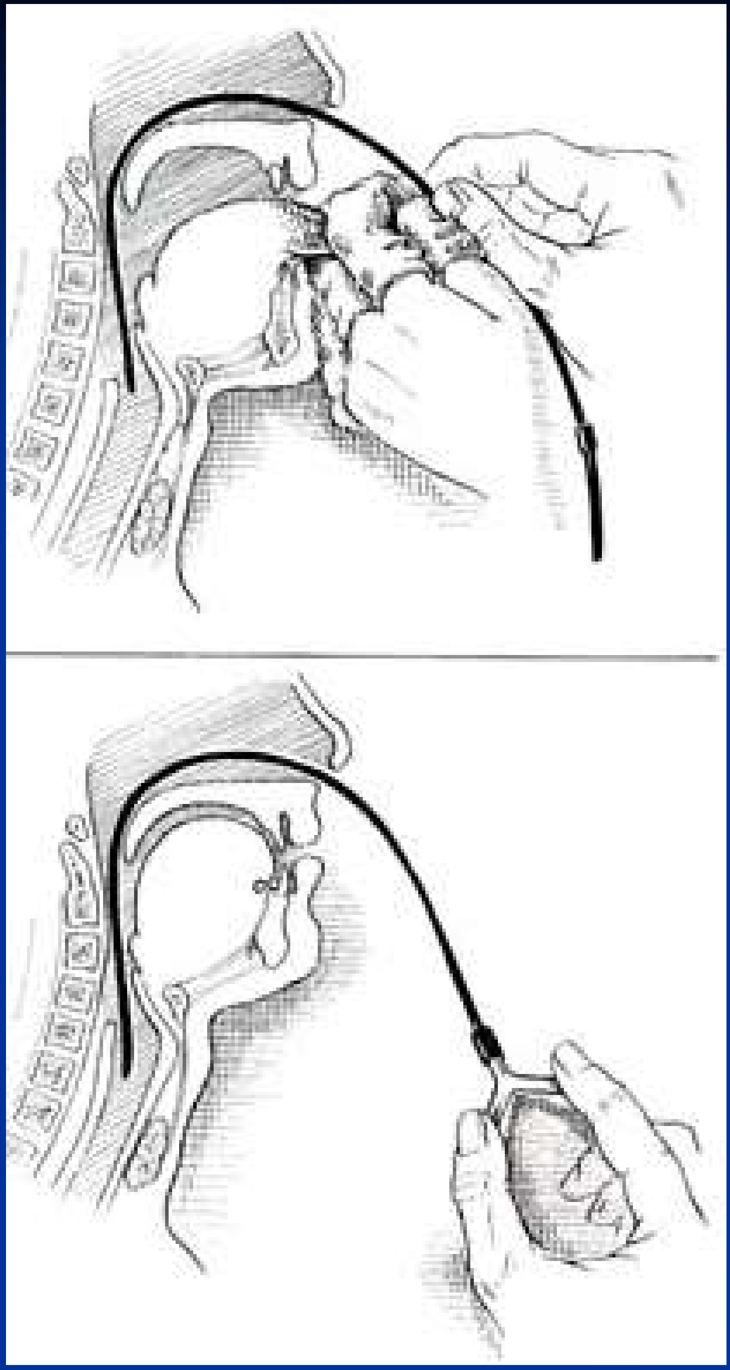
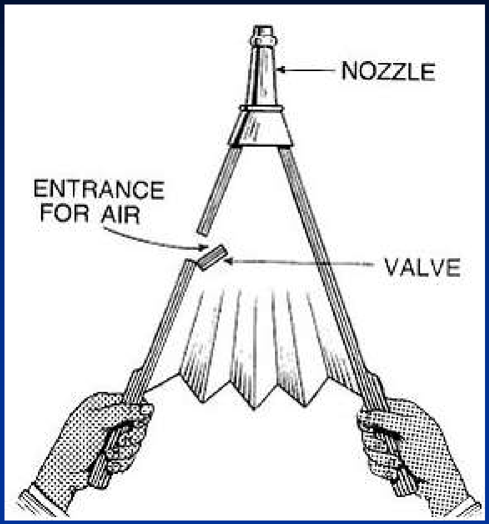
Mechanical Ventilation: Schedule

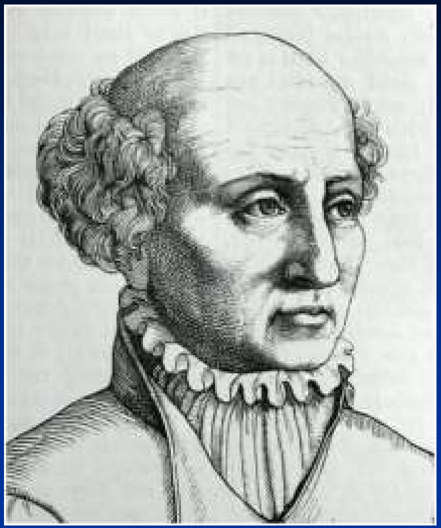
- History, Concepts and Basic Physiology – Nader
- Volume Control Ventilation (CMV, ACV) – Nader
- Intermittent Mandatory Ventilation (SIMV) – Nader
- Pressure Support Ventilation (PSV) – Nader
- Pressure Control Ventilation (PCV) – Junker
- Pressure Regulated Volume Control (PRVC) – Junker
- Airway Pressure Release Ventilation (APRV) – Junker
- Neurally Adjusted Ventilatory Assist (NAVA) – Nader



Fire Bellow

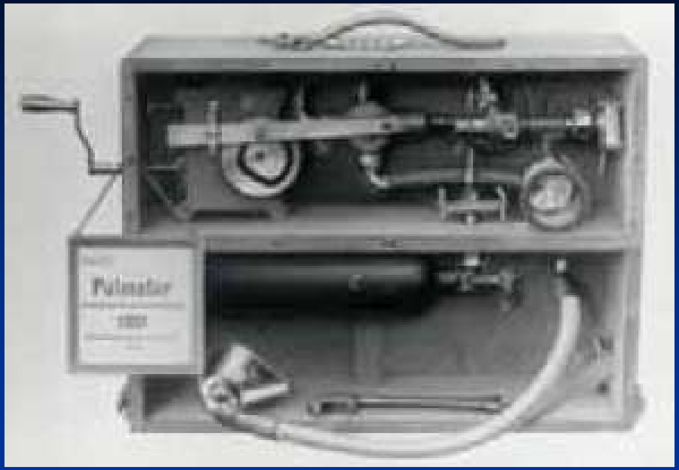


Paracelsus



Vesalius

Galen



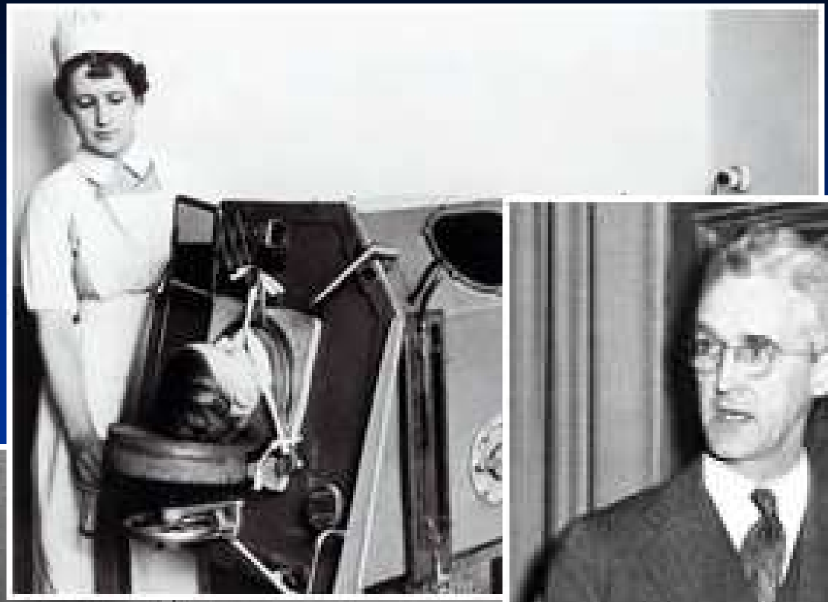
The Drager Pulmotor

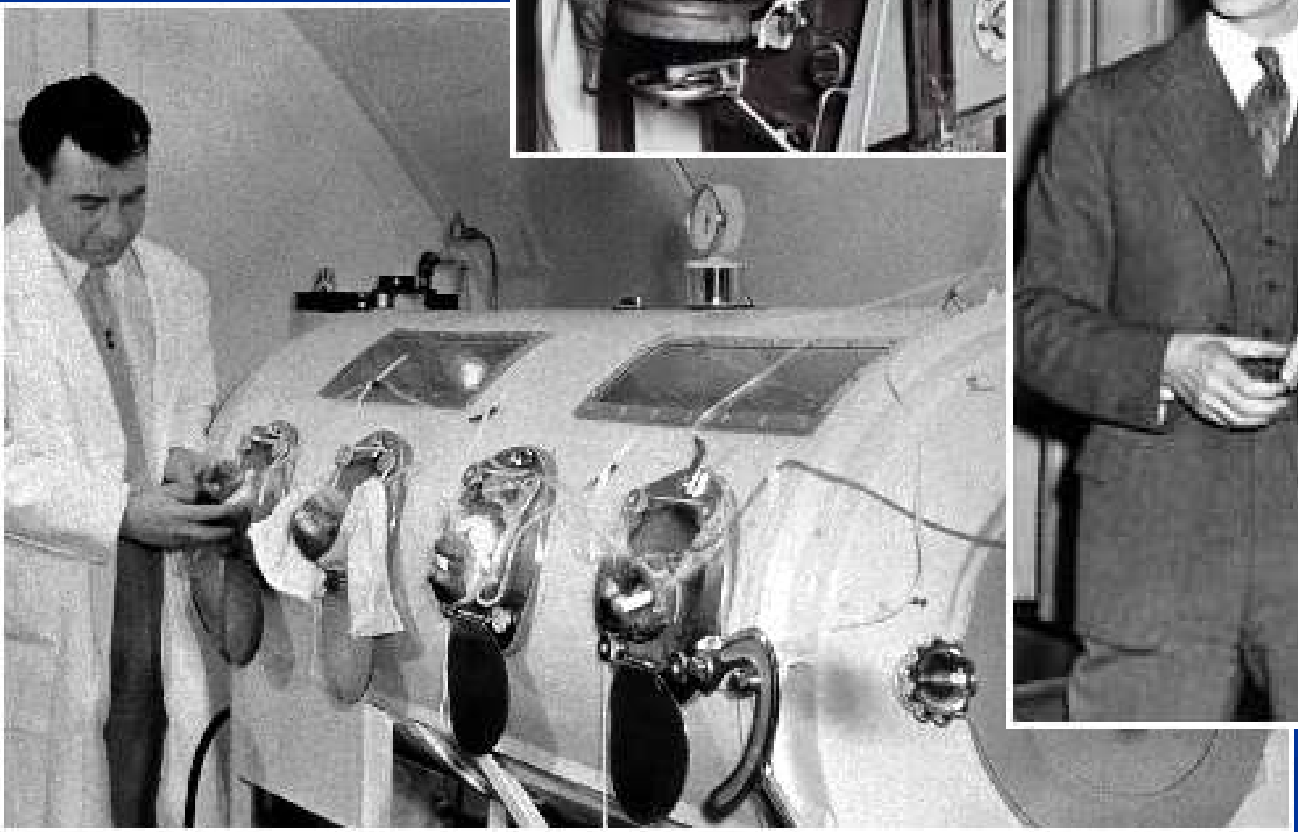
1911 *"Artificial Breathing Device"*

The Drager Pulmotor… *used by Fire and Police Units*

1900-1950

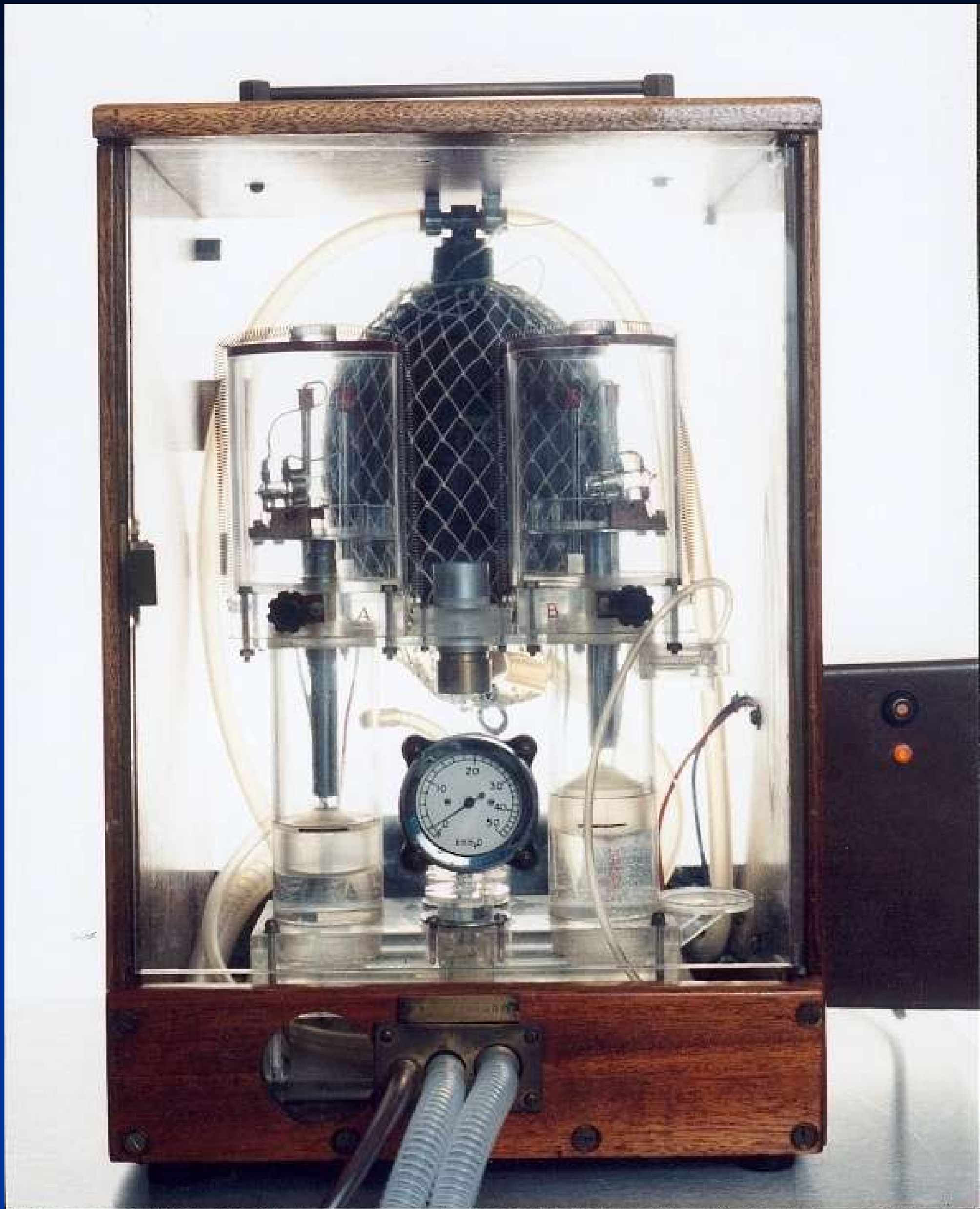
Iron Lung
1927

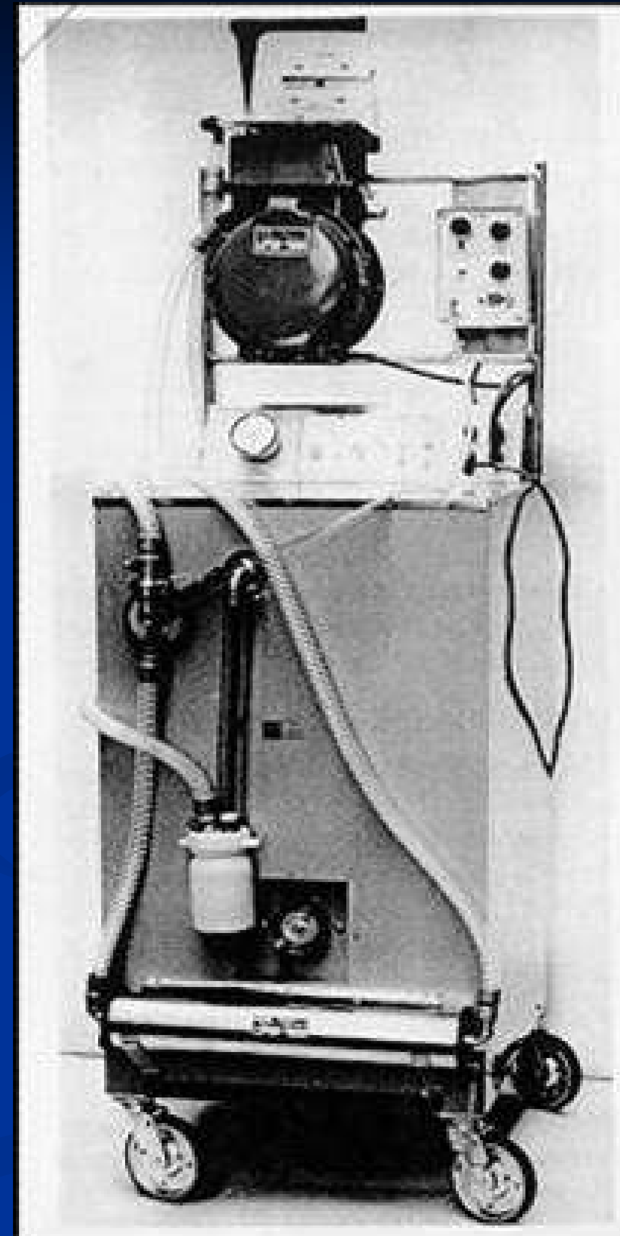




Philip Drinker

Rancho Los Amigos Hospital, 1953


A
B
10
20
30
40
50
0



Era of Respiratory Intensive Care

1950-1970

- *Bird Mark 7*
- *Bennet PR2*
- *Hamilton Standard*
- *Bear*

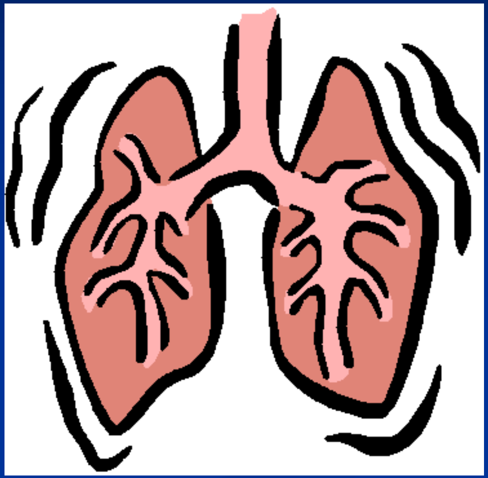


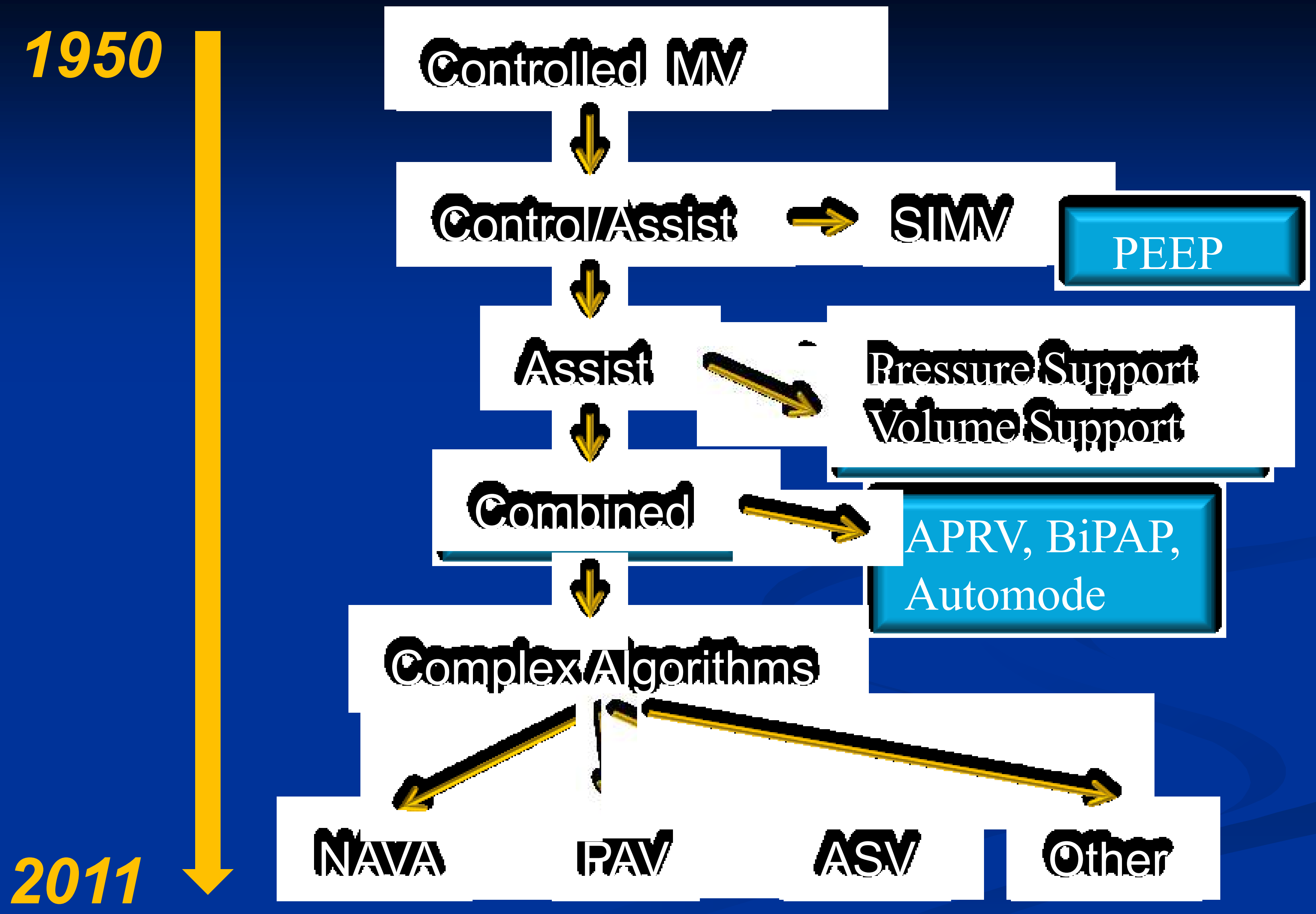


Then → Now

Role of Mechanical Ventilation:

- Provide oxygenation and ventilatory support during respiratory failure
- Improve gas exchange
- Unload respiratory muscles
- "Buy time" for healing and recovery





1950
2011
Controlled MV
Control/Assist
SIMV
PEEP
Assist
Pressure Support
Volume Support
Combined
APRV, BiPAP,
Automode
Complex Algorithms
NAVA
PAV
ASV
Other

Mechanical Ventilation:

Positive Pressure

Invasive

- CMV, AC
- SIMV
- PS / PC
- APRV / Bi-level
- PAV, ASV, NAVA

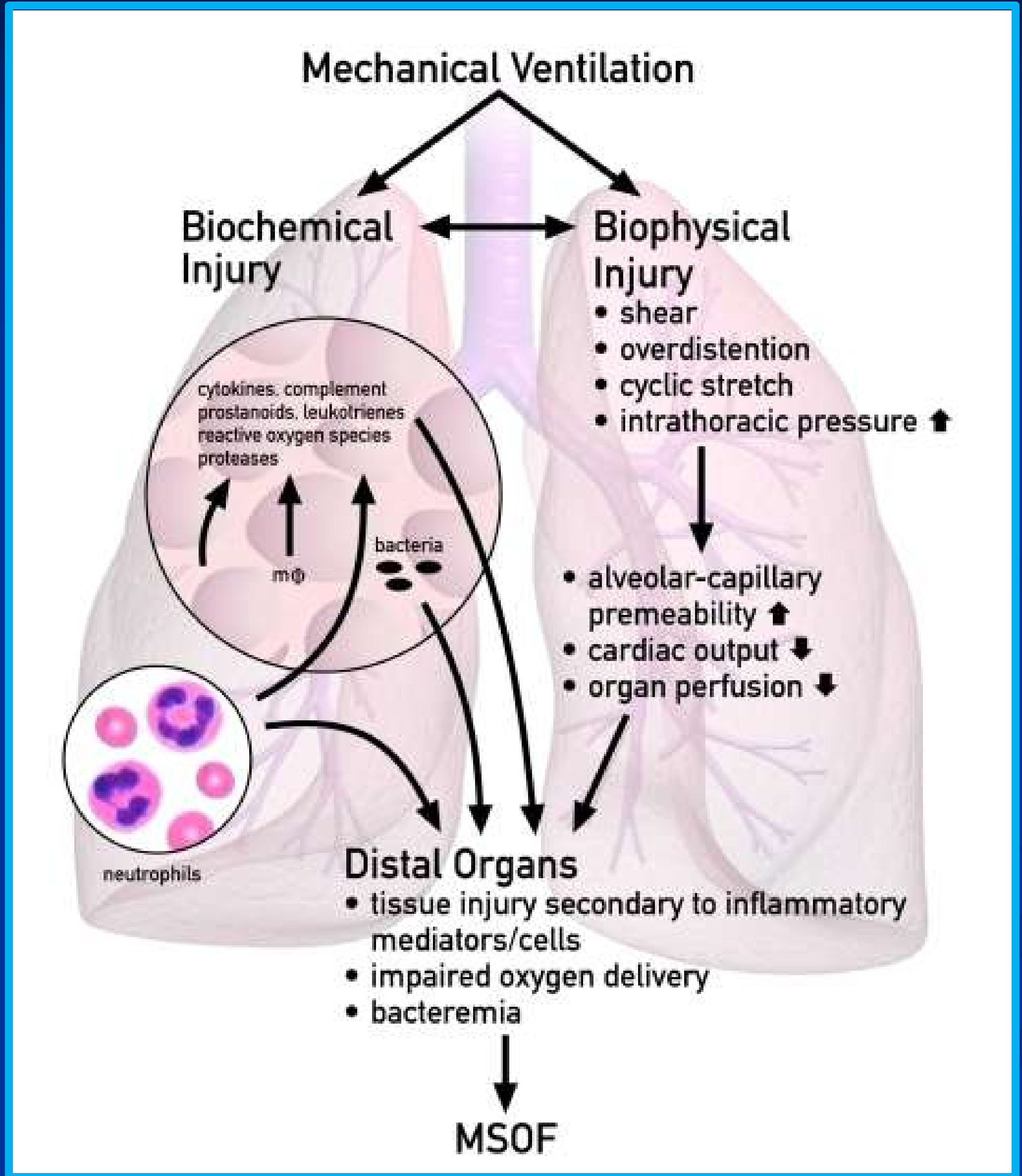
Non-Invasive

- BiPAP
- CPAP

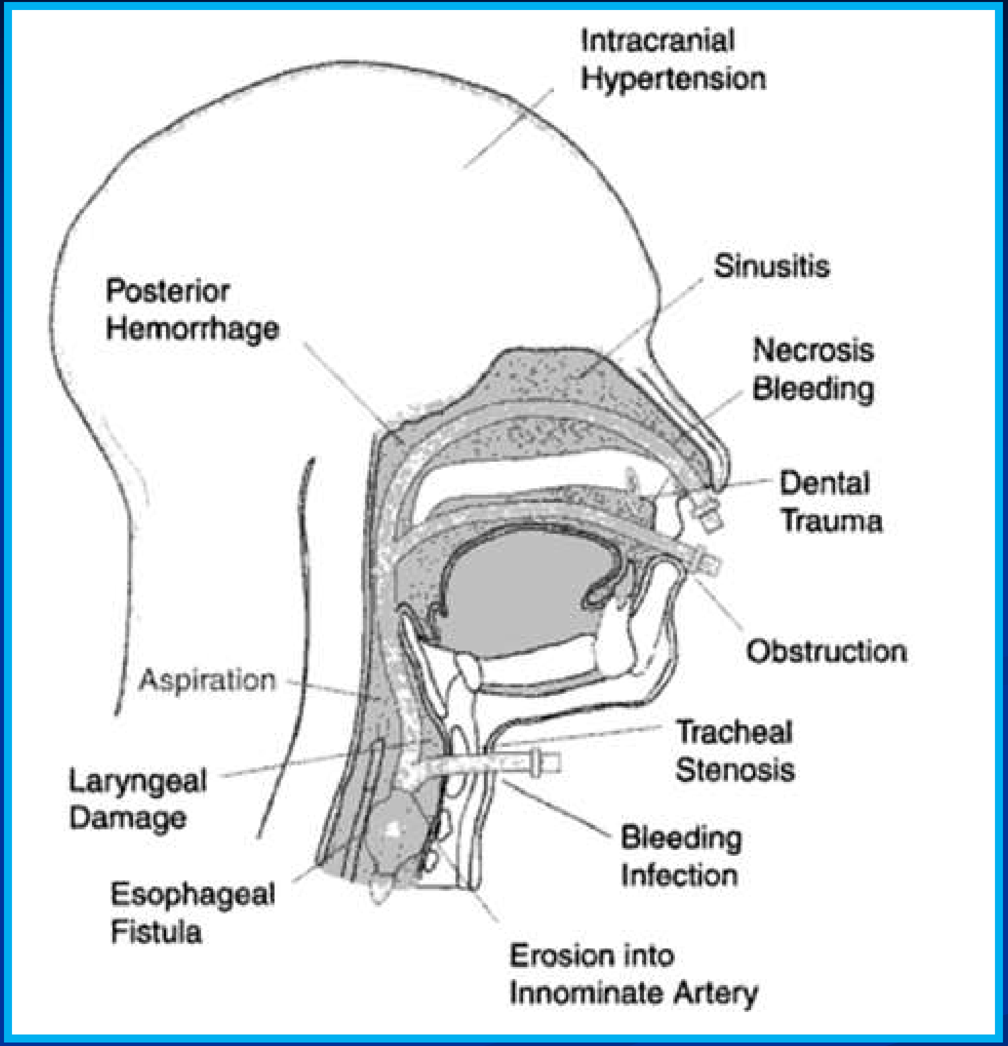
Negative Pressure

The Iron Lung

A Double-Edged Sword



- Hypotension post induction
- Hypertension due to agitation, pain, stimulation
- Hypercapnea → cerebral vasodilation
- Hypoxemia, Acidosis, PEEP



Complications of Endotracheal Intubation

CNS

↓

Phrenic nerve

↓

Diaphragm excitation

↓

Diaphragm contraction

↓

Chest wall, lung and esophageal response

↓

flow, pressure,volume changes

Ideal Technology

Ventilator

Current Technology

Breath characteristics

Trigger: what initiates a breath

- Timer (control) vs Effort (assist)

Gas delivery target: what governs gas flow

- Set flow vs Set insp pressure

Cycle: what terminates the breath

- Volume, Time, Flow, Pressure

MacIntyre, principles of mechanical ventilation, 2008

A ventilator breath that is patient triggered, pressure targeted, and time cycled is termed:

A) Volume Assist
B) Pressure Support
C) Pressure Control
D) Pressure Assist

MacIntyre, principles of mechanical ventilation, 2008

A ventilator breath that is patient triggered, pressure targeted, and time cycled is termed:

A) Volume Assist
B) Pressure Support
C) Pressure Control
D) Pressure Assist

A ventilator breath that is patient triggered, pressure targeted, and time cycled is termed:

A) Volume Assist (flow targeted, volume cycled)
B) Pressure Support (flow Cycled)
C) Pressure Control (machine triggered)
D) Pressure Assist (Pressure “Assist” Control)

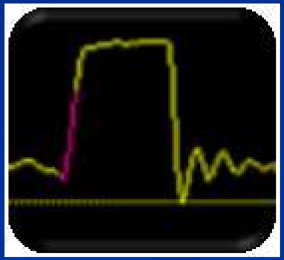
Breath characteristics Summary

	Trigger	Target / Limit	Cycle
Volume Control (VC)	Time	Flow	Volume
Volume Assist (VA)	Effort	Flow	Volume
Pressure Control (PC)	Time	Pressure	Time
Pressure Assist (PA)	Effort	Pressure	Time
Pressure Support (PS)	Effort	Pressure	Flow
Pressure Release (PR)	Time	Pressure	Time
Spontaneous (SP)	Effort	Pressure	Effort

Trigger

- Level of effort needed to start a ventilator breath

    - Pressure trigger - effort produces pressure drop in vent circuit



    - Flow trigger - effort draws gas out of a continuous flow through the vent circuit

MacIntyre, principles of mechanical ventilation, 2008

Trigger - Pressure

a) Effort

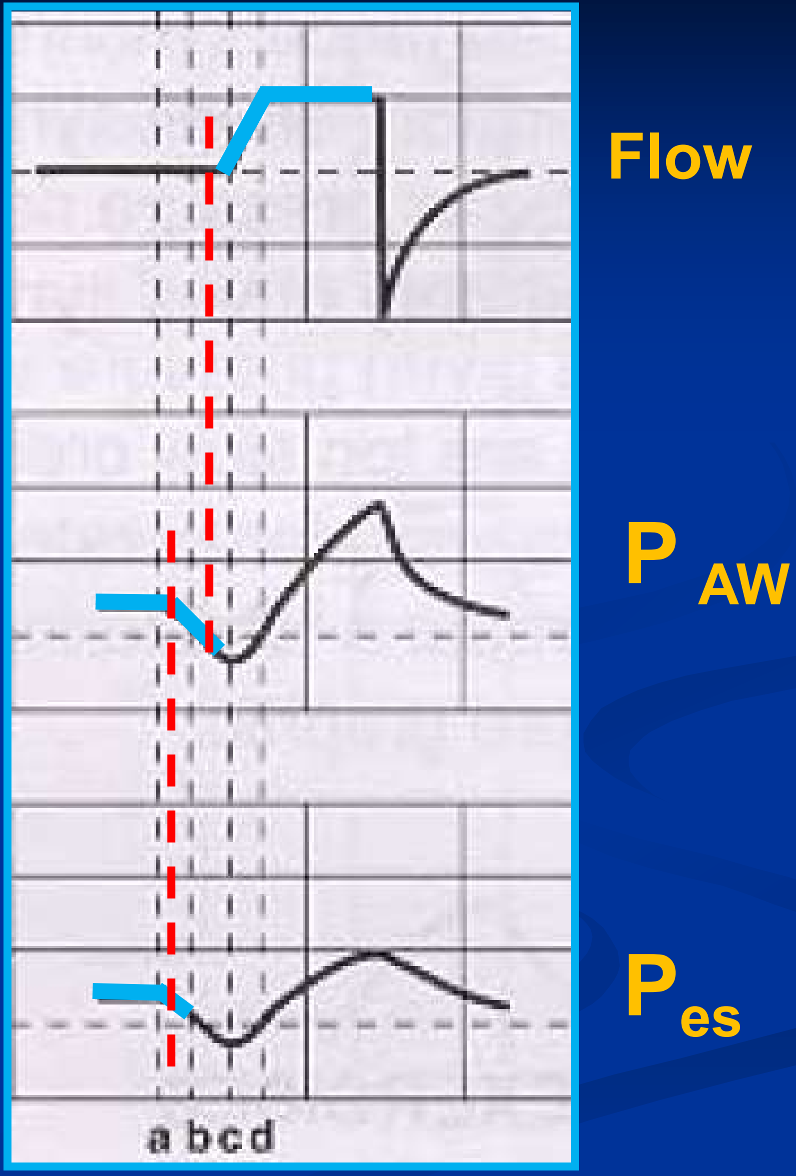
- Short Delay

b) Pressure drop sensed as effort

- Short Delay

c) Flow initiation by ventilator

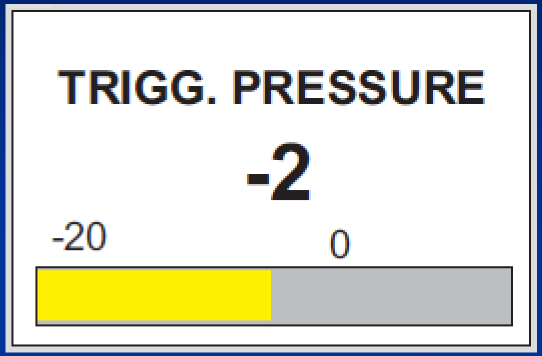
d) Target reached



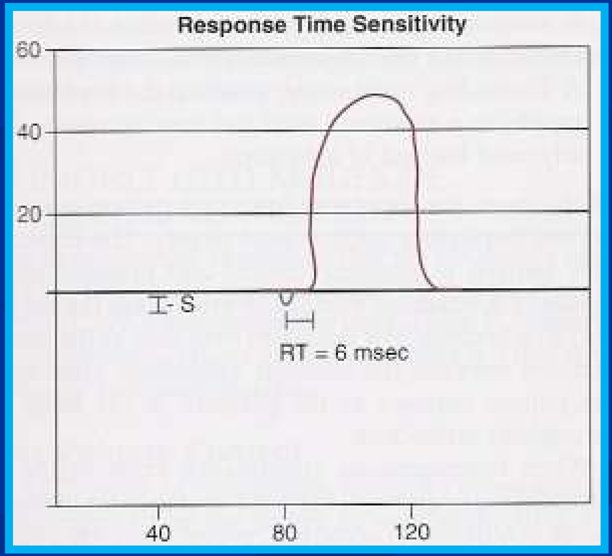
MacIntyre, principles of mechanical ventilation, 2008

Pressure Trigger:

Sensitivity determined by a set pressure drop



- *Too sensitive..*
  - Interference by motion, external stimulation, suctioning, air leaks in circuit or chest tubes, etc..

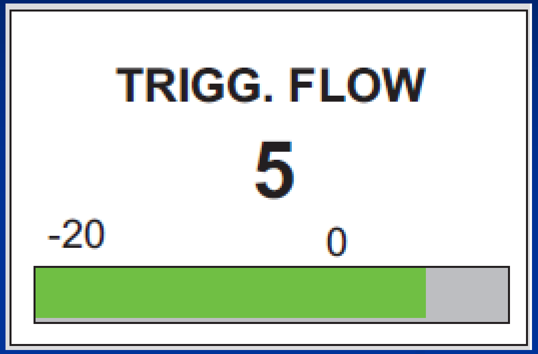


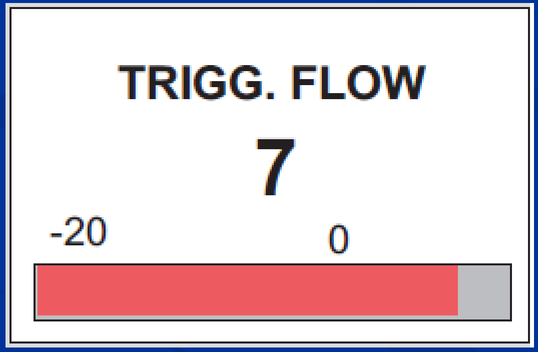
- *Too high..*
  - Increased work of breathing
  - Dyssynchrony, discomfort

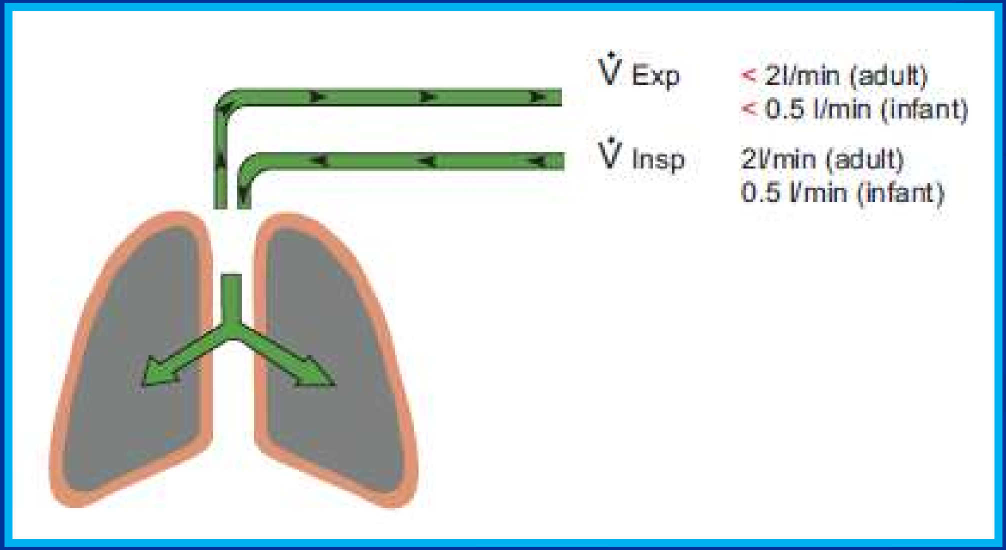
Flow Trigger:

- When the difference between insp and exp flow equals the preset flow trigger → New Inspiration

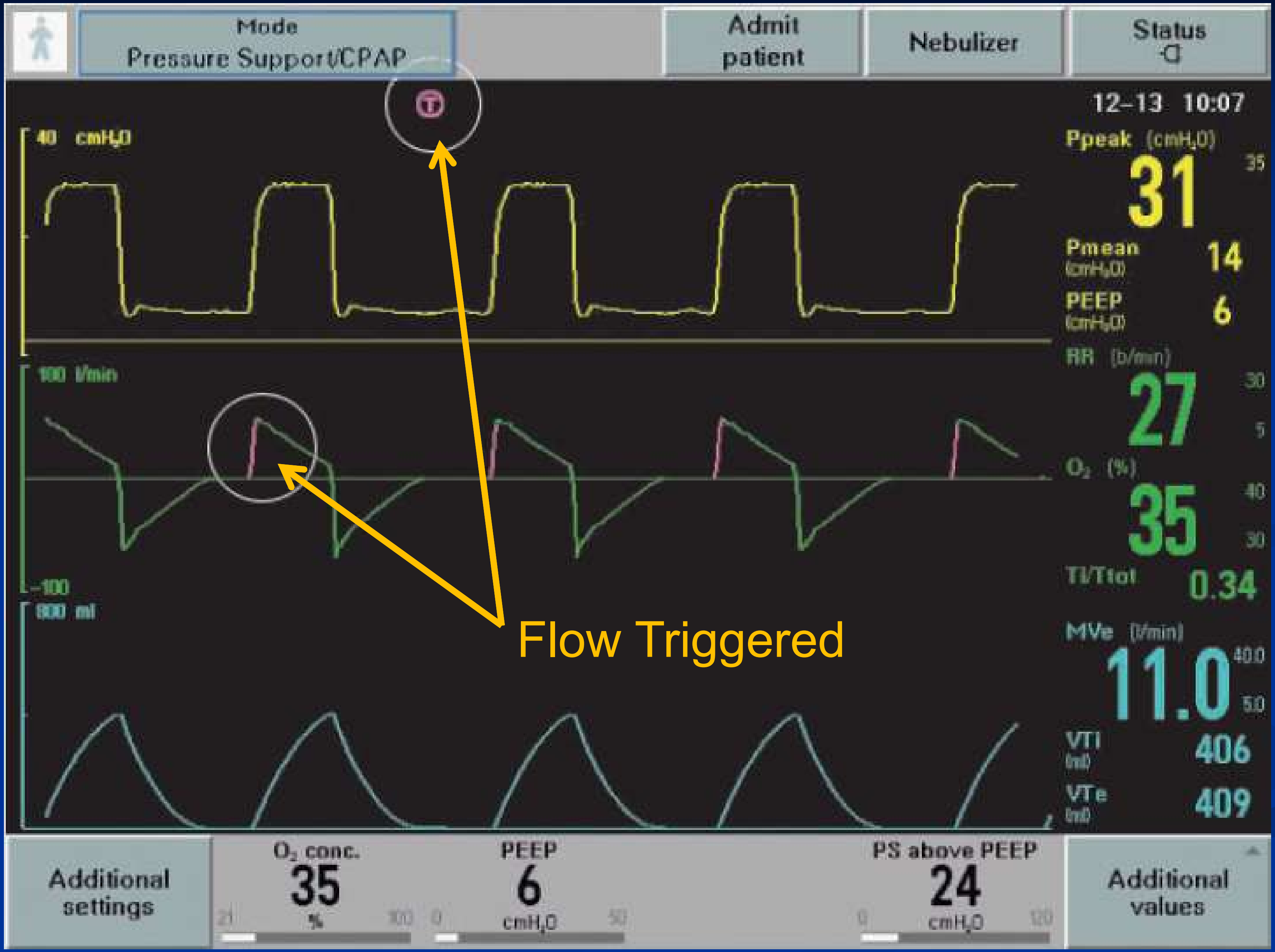
- Less delay in Response Time
- Decreased work of breathing







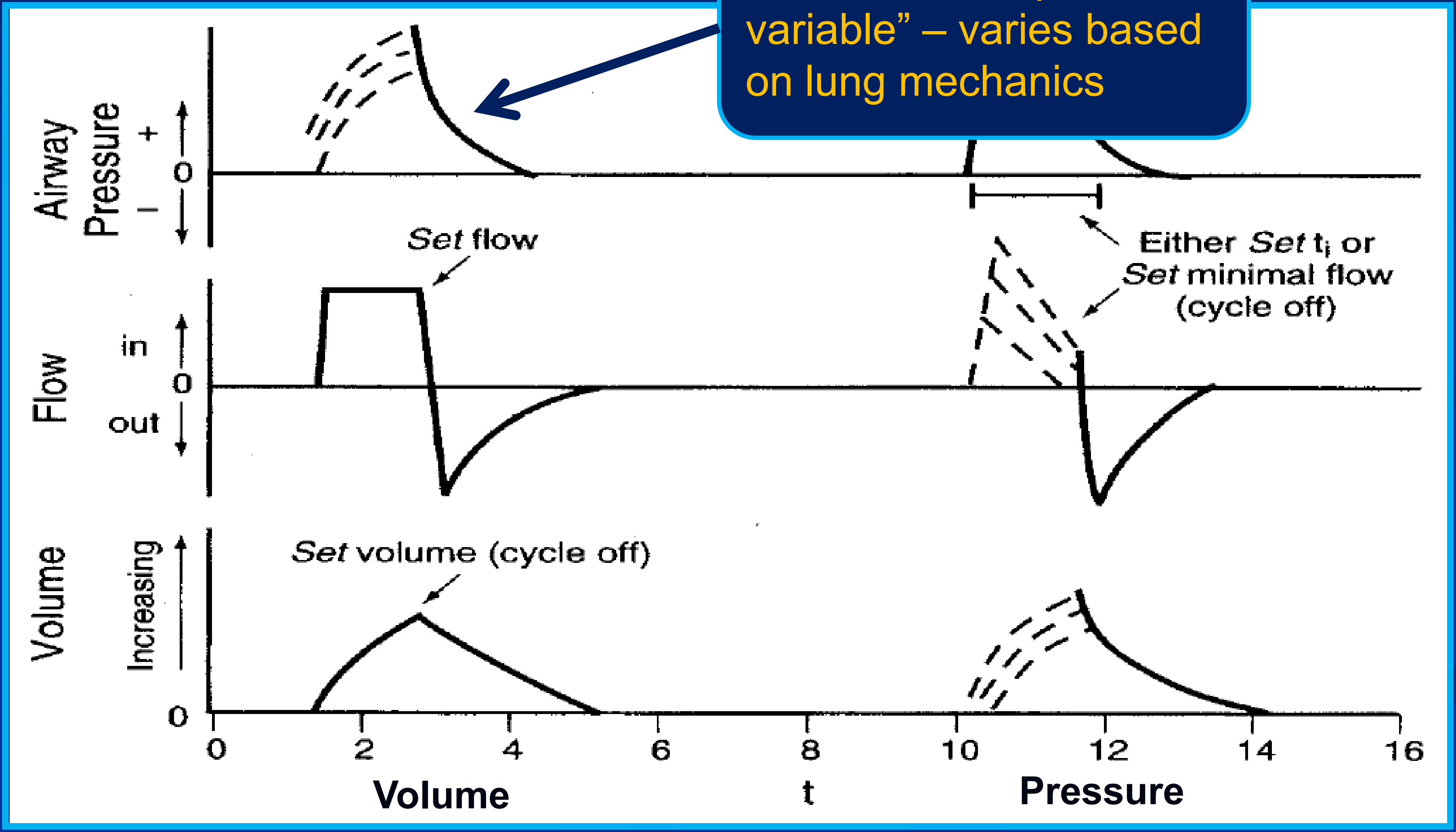
Maquet Pocket Guide, Modes of Ventilation , Servo-I



Maquet Pocket Guide, Modes of Ventilation , Servo-I

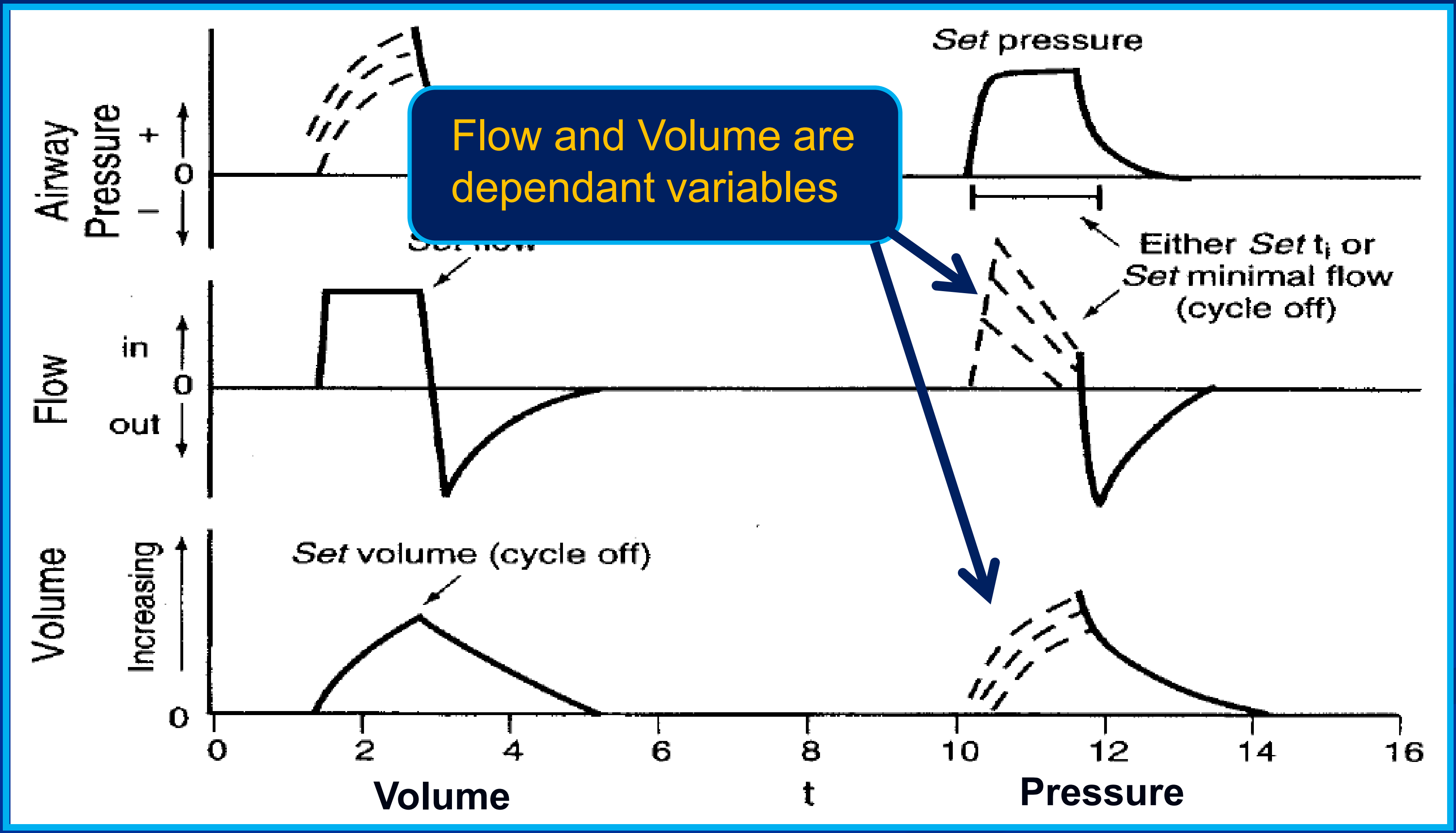
Gas Delivery

Pressure is “dependant variable” – varies based on lung mechanics



MacIntyre, principles of mechanical ventilation, 2008

Gas Delivery



MacIntyre, principles of mechanical ventilation, 2008

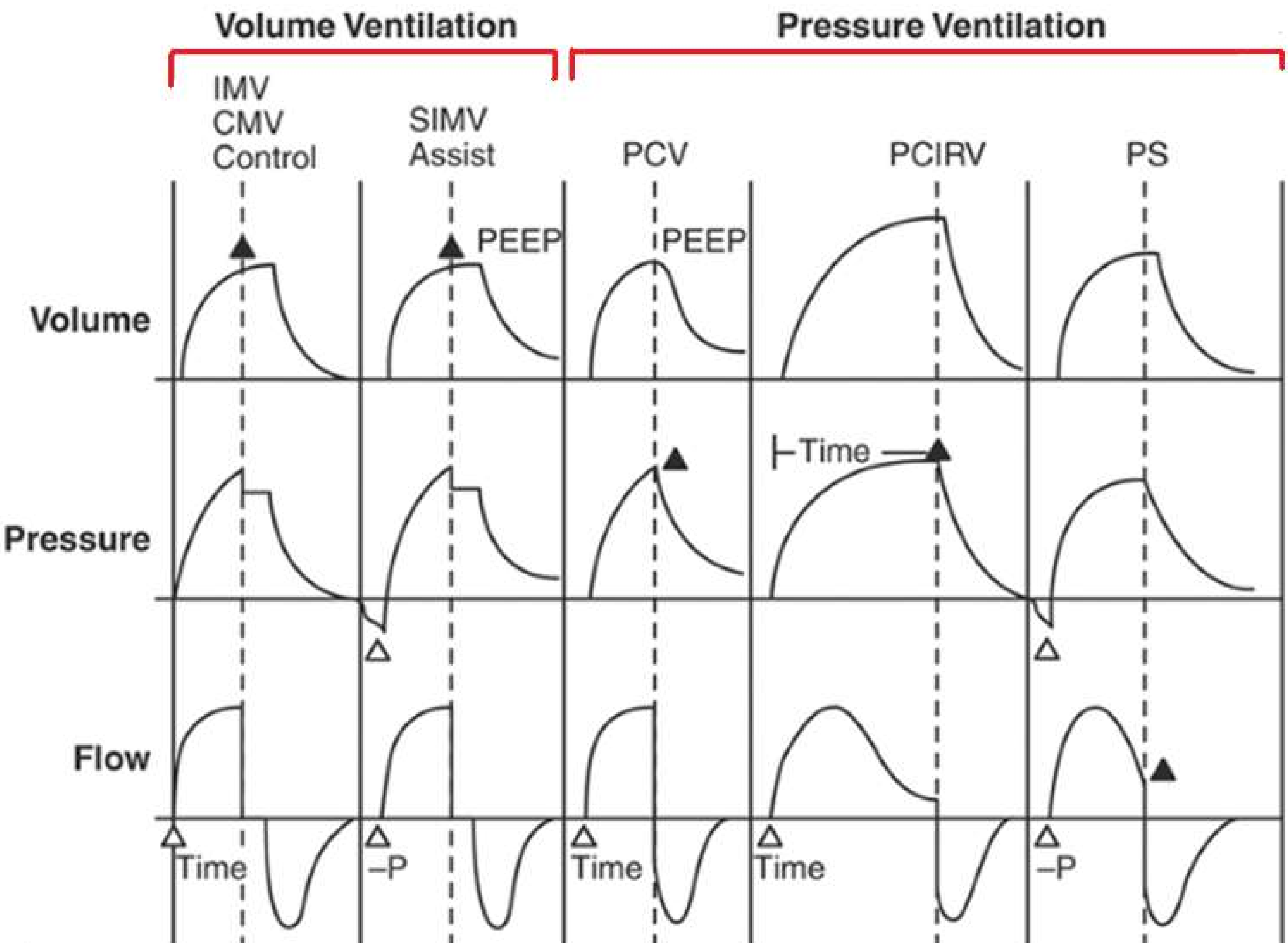
Cycle …*what terminates the breath*

Cycling occurs in response to:

- Delivered Volume
- Elapsed Time
- Predetermined decrement in Flow Rate

After cycling occurs, exhalation valves open, inspiration ends, and passive exhalation occurs

MacIntyre, principles of mechanical ventilation, 2008

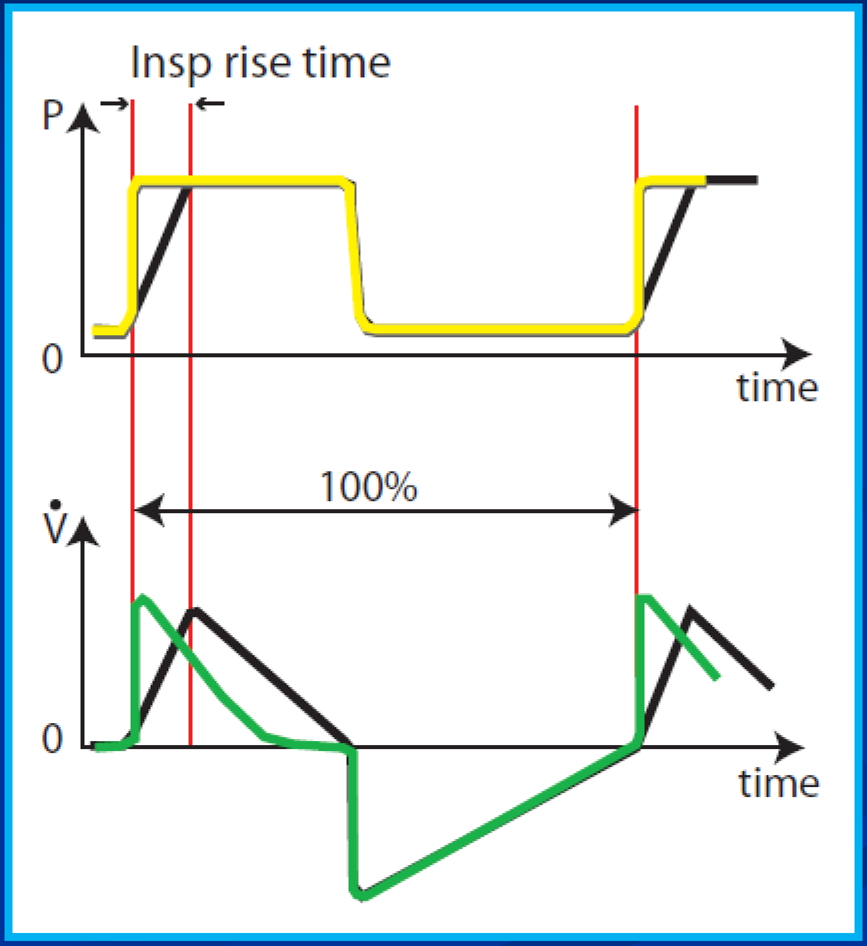


Cycle △	Time	Breath	Time	Time	Breath
Limit ▲	Volume	Volume	Pressure	Pressure-Time	Flow

Inspiratory rise time:

- Time taken to reach inspiratory flow or pressure at the start of each breath

- % of cycle time in controlled modes
- Time (seconds) in PS/CPAP, or VS



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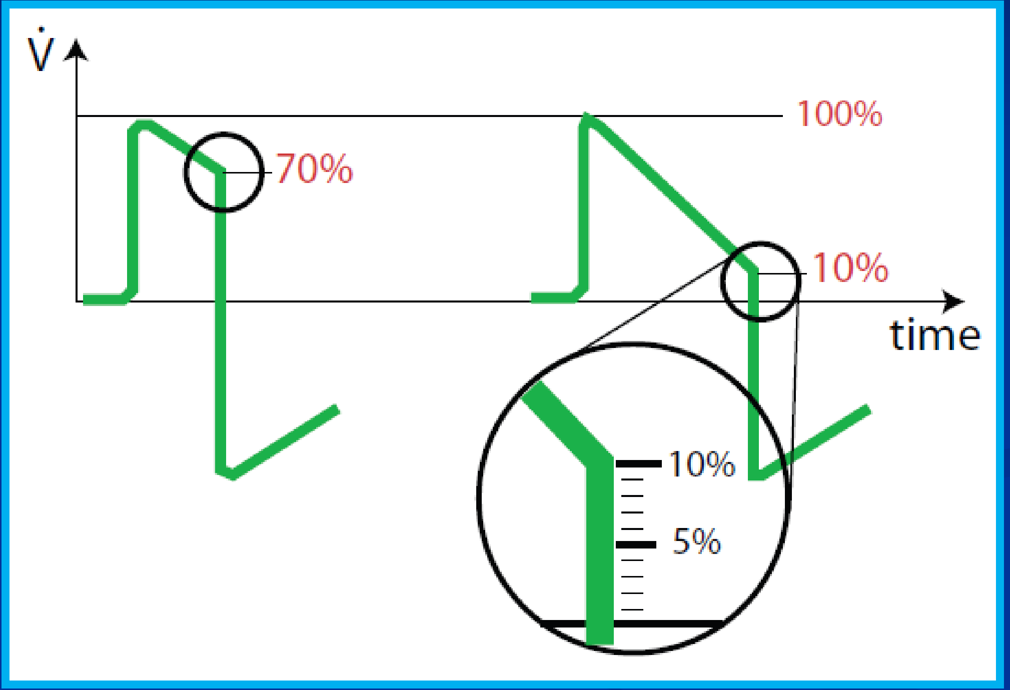
Inspiratory cycle off:

- Point at which inspiration changes to expiration

  (Spontaneous and Supported modes)



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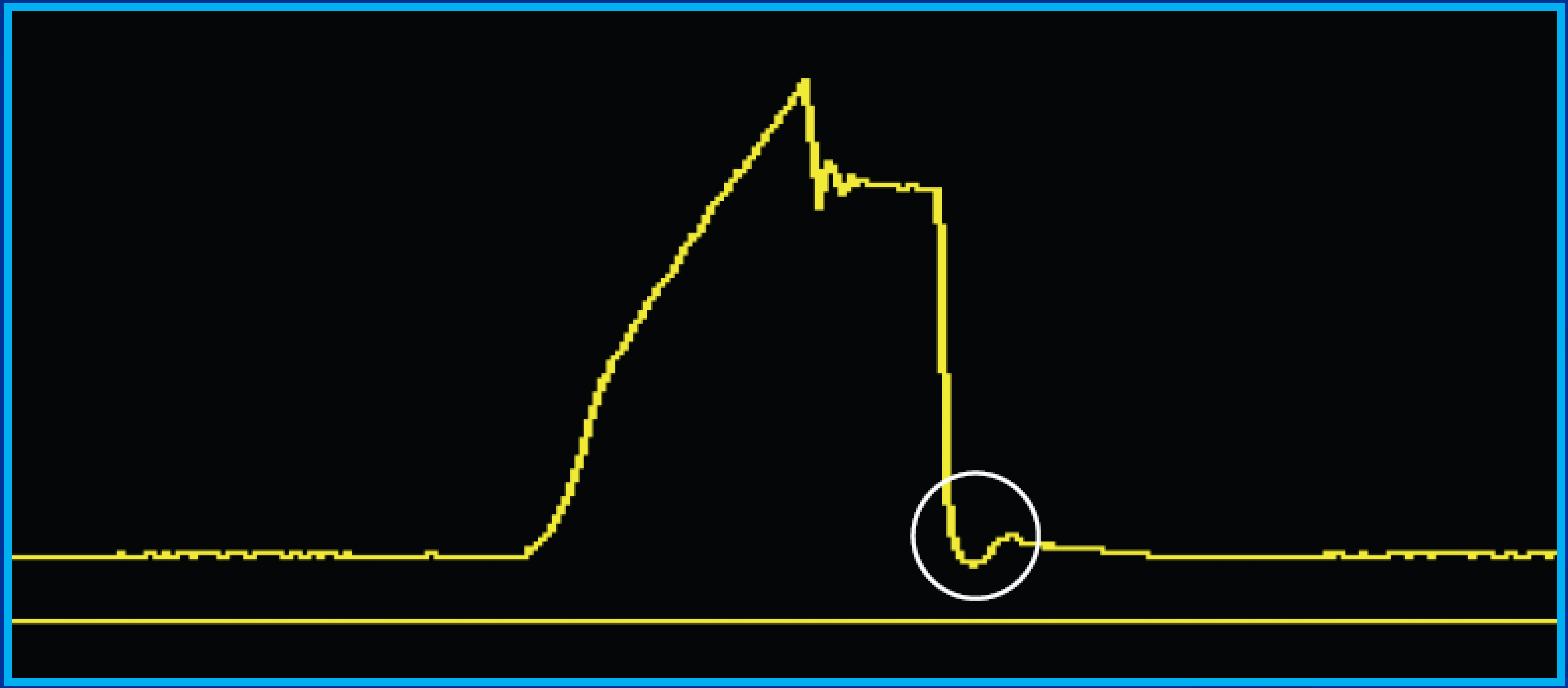
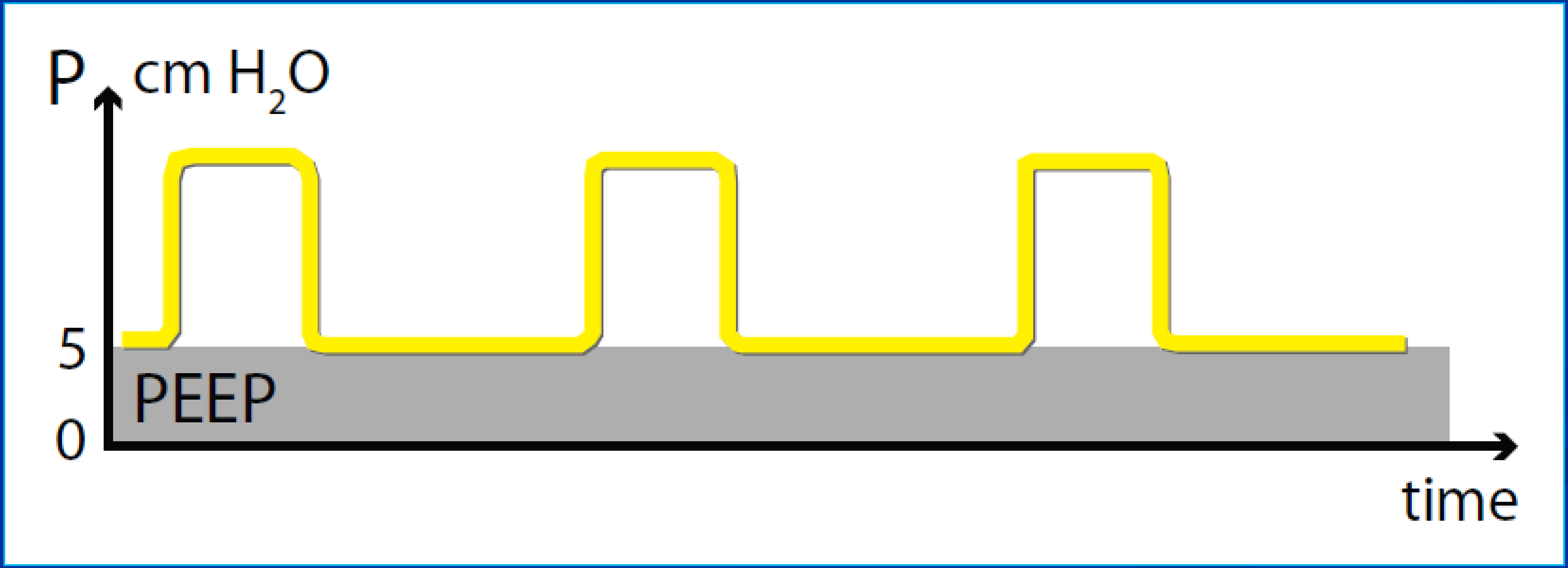
Time Constant Valve Controller



Maquet Pocket Guide, Modes of Ventilation , Servo-I

PEEP: Positive End Expiratory Pressure

- 0 – 50 cmH2O (usually <12)
- Pressure to prevent collapse of the alveoli, small airways, and maintain FRC



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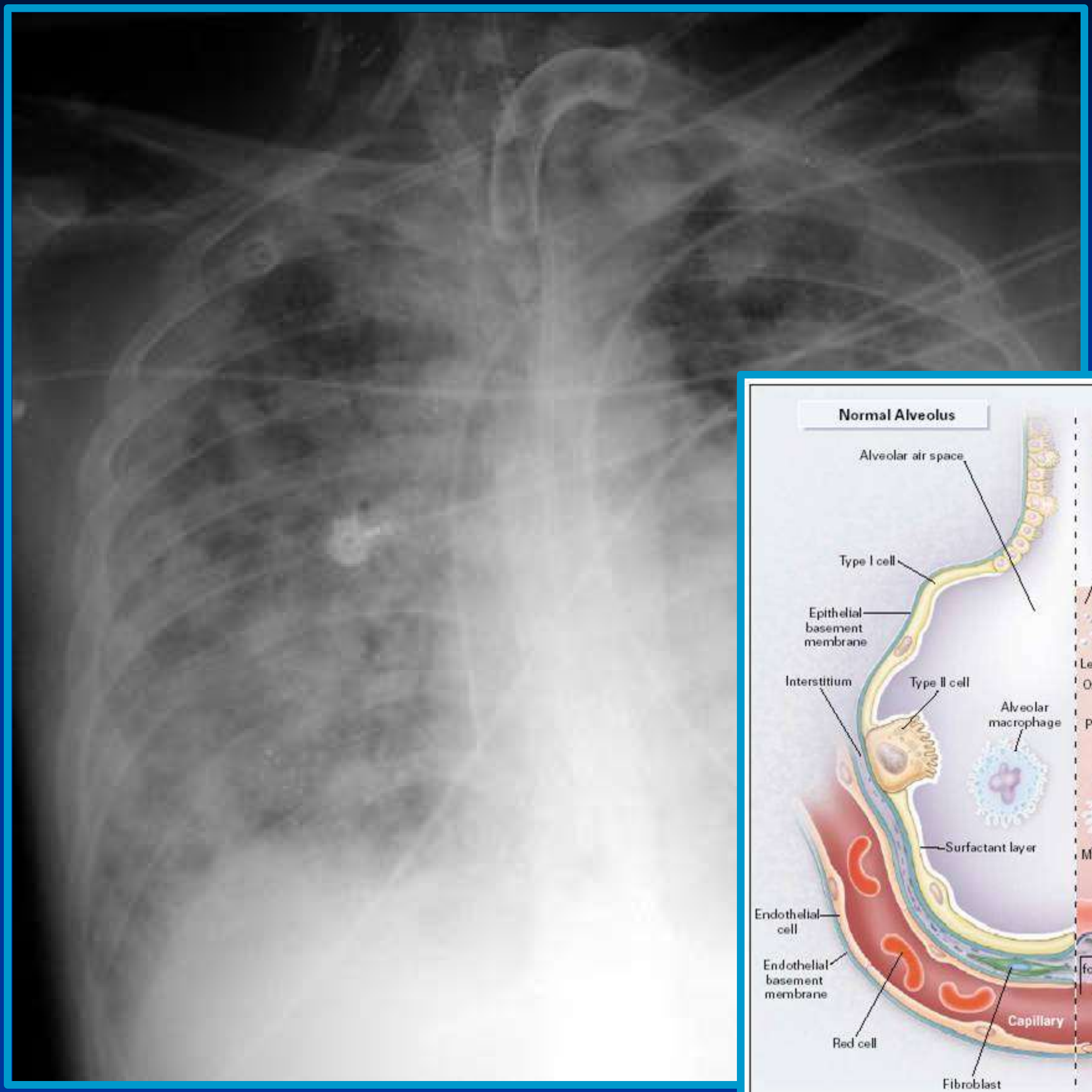
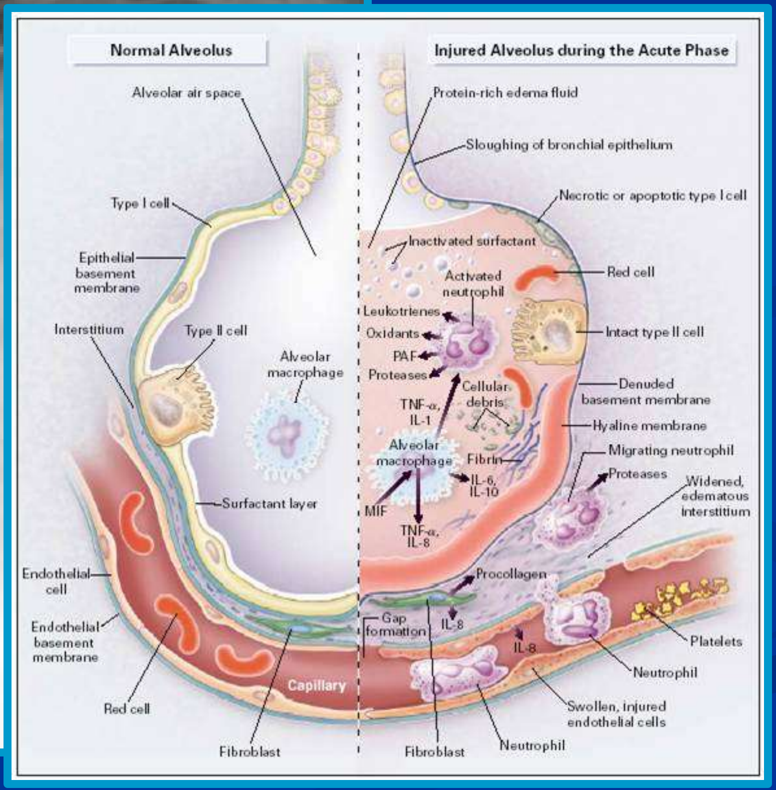
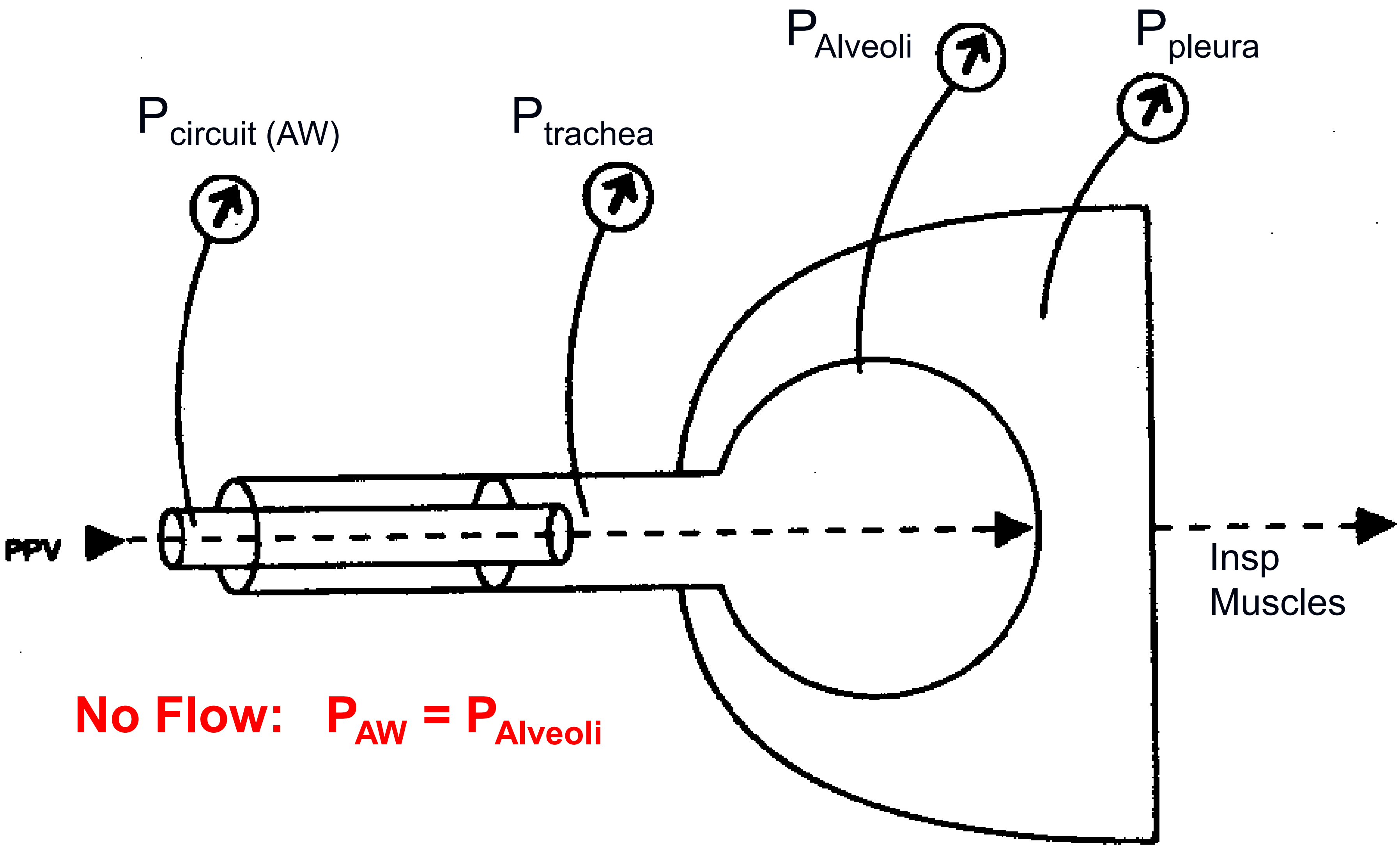


ALI / ARDS



Normal Alveolus
Injured Alveolus during the Acute Phase
Alveolar air space
Type I cell
Epithelial basement membrane
Interstitium
Type II cell
Alveolar macrophage
Surfactant layer
Endothelial cell
Endothelial basement membrane
Red cell
Capillary
Fibroblast
Protein-rich edema fluid
Sloughing of bronchial epithelium
Necrotic or apoptotic type I cell
Inactivated surfactant
Activated neutrophil
Red cell
Leukotrienes
Oxidants
PAF
Proteases
Intact type II cell
TNF-α, IL-1
Cellular debris
Denuded basement membrane
Hyaline membrane
Alveolar macrophage
Fibrin
Migrating neutrophil
Proteases
IL-6, IL-10
Widened, edematous interstitium
MIF
TNF-α, IL-8
Procollagen
Gap formation
IL-8
IL-8
Platelets
Neutrophil
Swollen, injured endothelial cells
Fibroblast
Neutrophil

Respiratory System Mechanics



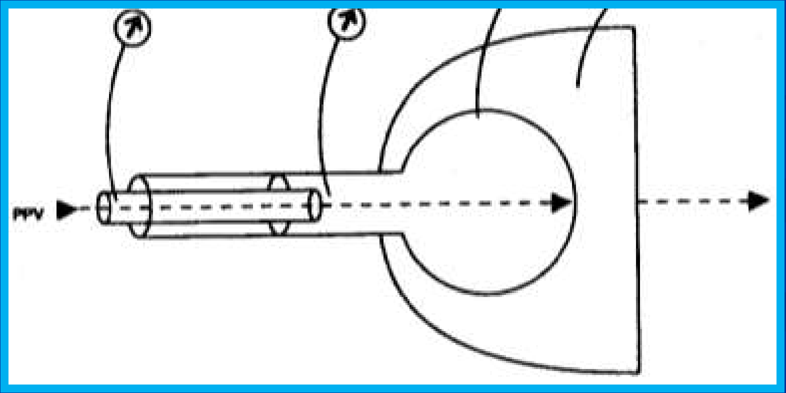
No Flow: $P_{AW} = P_{Alveoli}$

MacIntyre, principles of mechanical ventilation, 2008

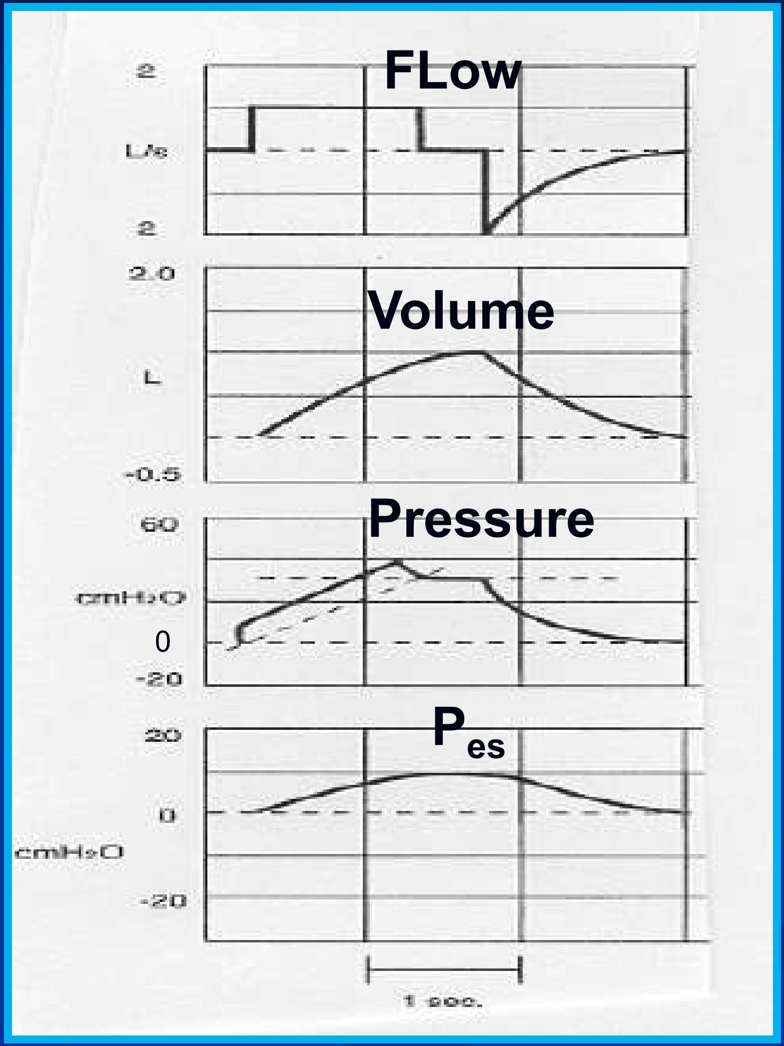
Under "No Flow" conditions (static)

- Only distending pressure in Alveoli measured
- End-Inspiratory Pressure = P_A = $P_{plateau}$
- End-Expiratory Pressure = P_A = $PEEP_i$

During "Flow Conditions", airway pressures are affected by both distending pressures as well as flow-related pressures



- Insp flow = 1 L/sec
- Exp flow (peak) = 2 L/sec
- V_T = 1 Liter
- P_{peak} = 40 cm H2O
- $P_{plateau}$ = 30 cm H2O
- Base $_P$ (PEEP) = 0 cm H2O
- Peak $_{Pes}$ = 10 cm H2O
- Base $_{Pes}$ = 0 cm H2O



MacIntyre, principles of mechanical ventilation, 2008

Flow Pressures:

P_{peak} - $P_{plateau}$ = Pressure for Flow

40 - 30 = 10 cm H2O

Distending Pressures:

$P_{plateau}$ - $P_{base(PEEP)}$ = Pressure to distend resp system (lung+cw)

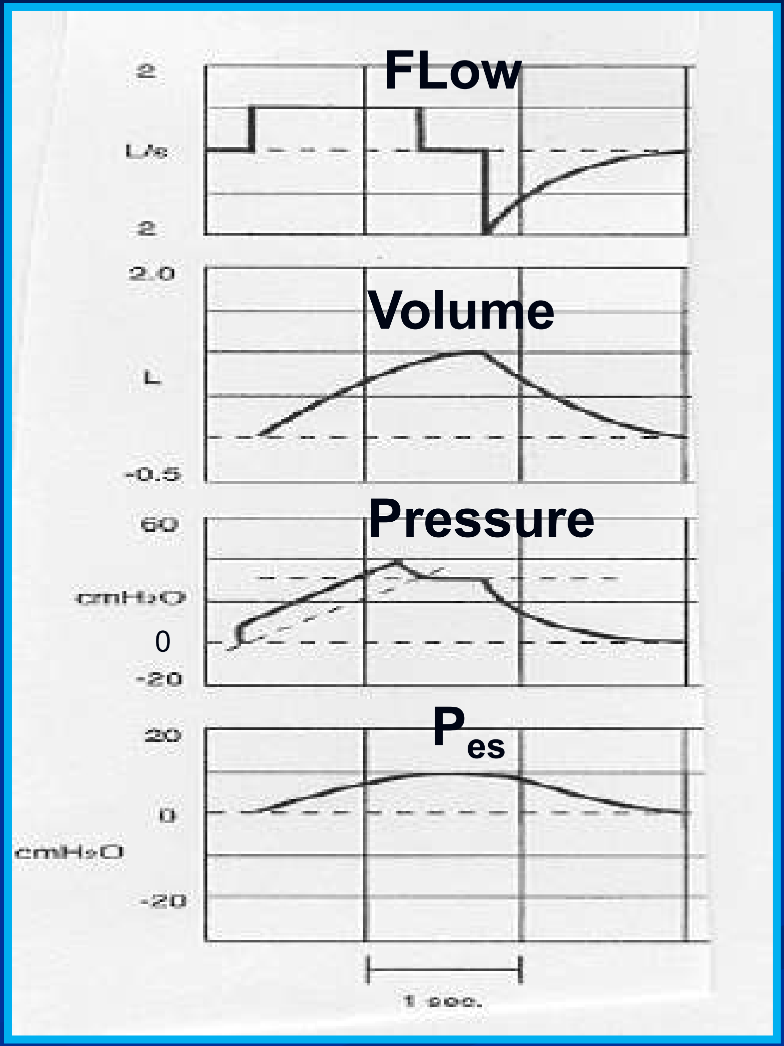
30 - 0 = 30

Peak $_{Pes}$ – Base $_{Pes}$ = Pressure to distend chest wall (P_{CW})

10 - 0 = 10

$P_{\text{Resp system}}$ - $P_{\text{Chest wall}}$ =

Pressure to distend lungs = **20**



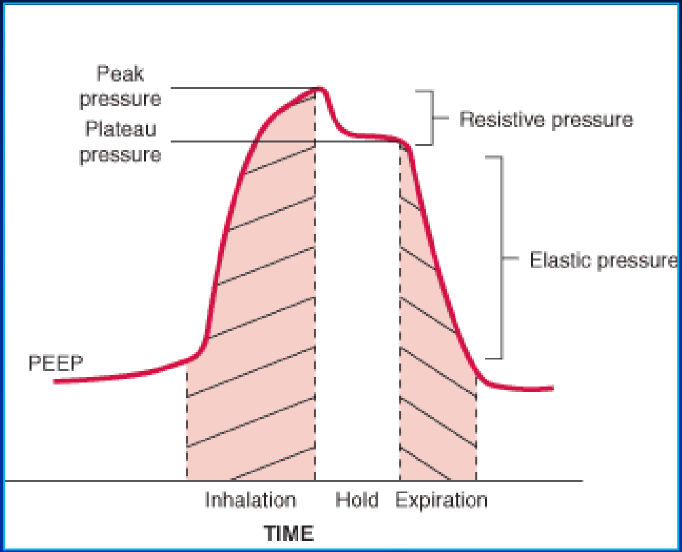
MacIntyre, principles of mechanical ventilation, 2008

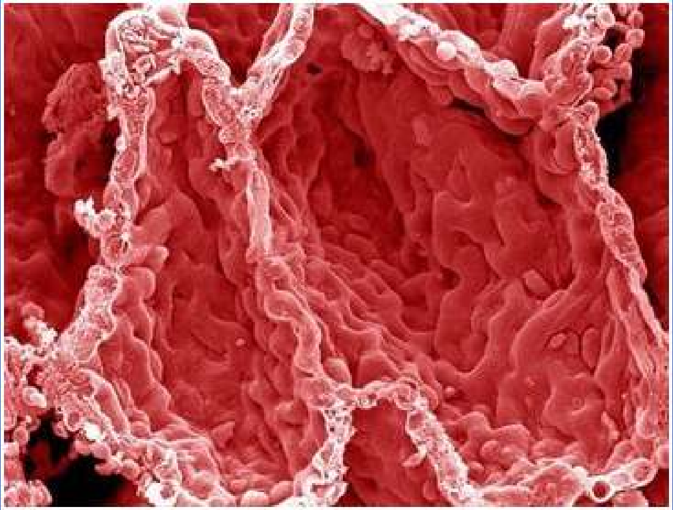
Compliance

- The inverse of lung elastance
- The pressure required to expand the lung and change the lung volume

  C = V/P

- C_{static} - no air movement
- $C_{dynamic}$ - during active inspiration





Compliance

$C_{rs} = V_T / (P_{plateau} - PEEP)$

$= 1/(30-0) = .0333$ L/cm H2O

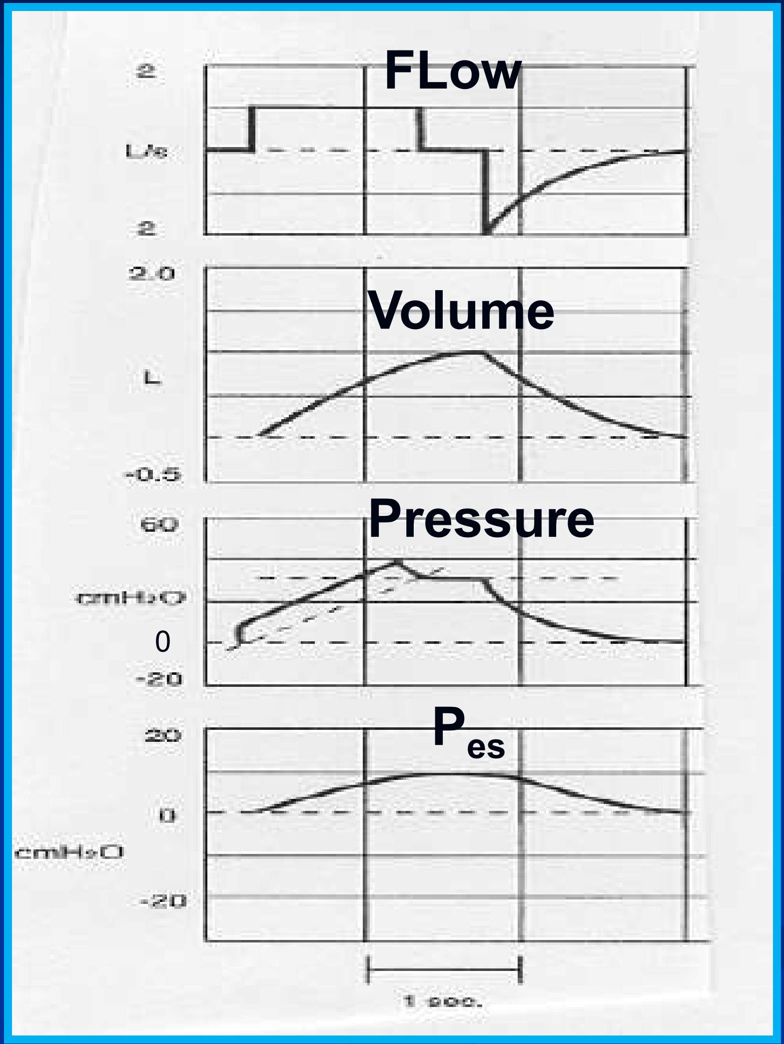
$C_{cw} = V_T / Peak_{Pes} - Base_{Pes}$

$= 1/(10-0) = .100$ L/cm H2O

$C_L = V_T / C_{rs} - C_{cw}$

$C_L = V_T/(P_{plateau} - PEEP - Peak_{Pes} - Base_{Pes}) = 1/(30-0-10-0)$

$= .05$ L/cm H2O = 50 ml/cm H2O



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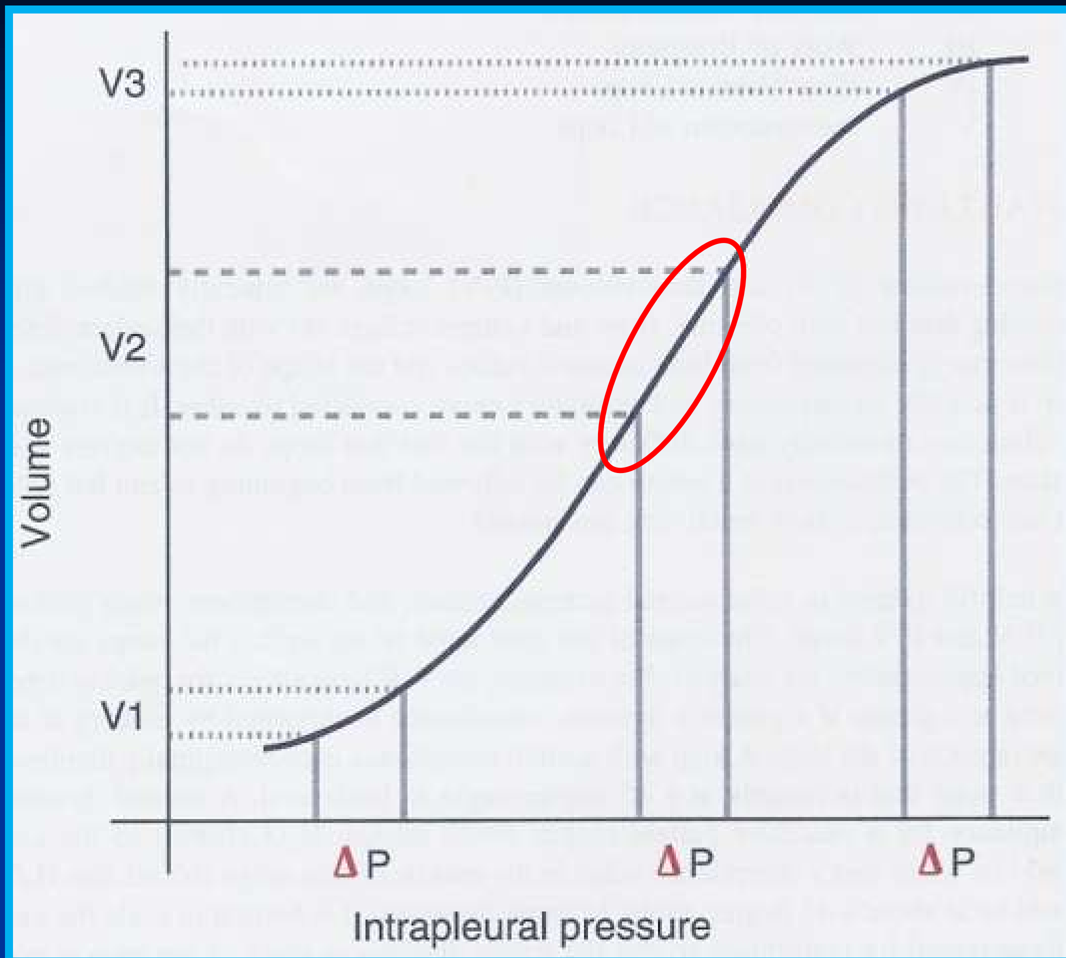
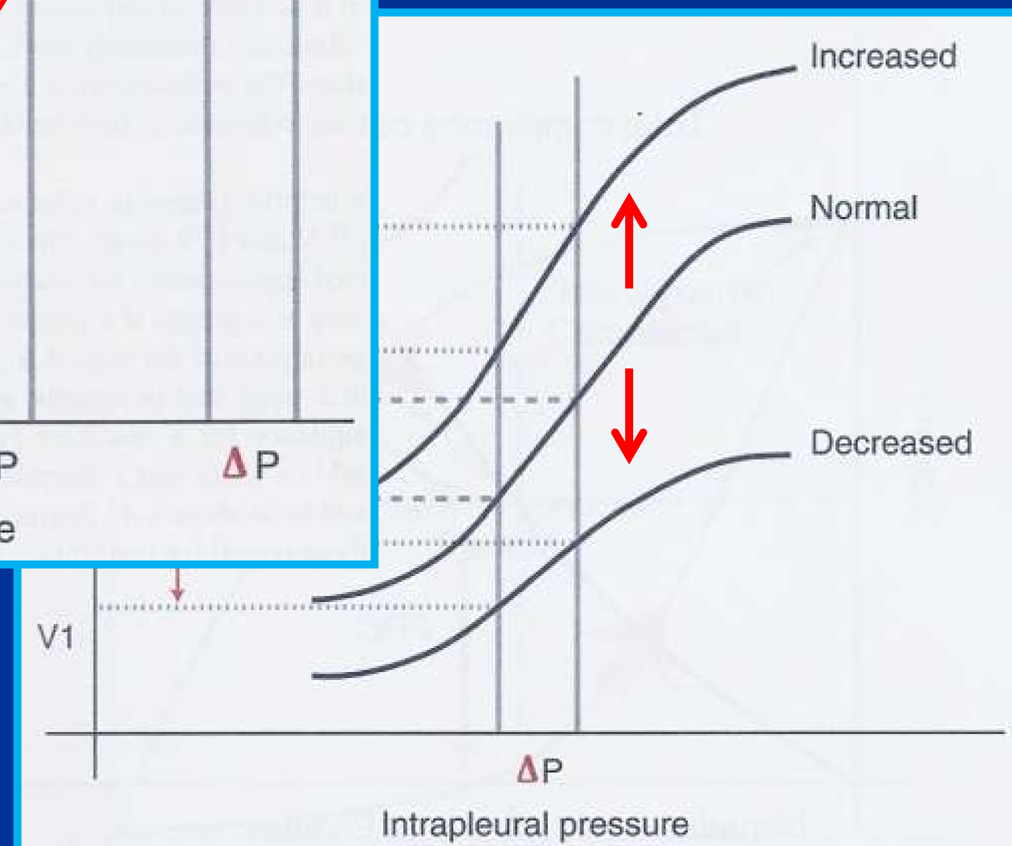
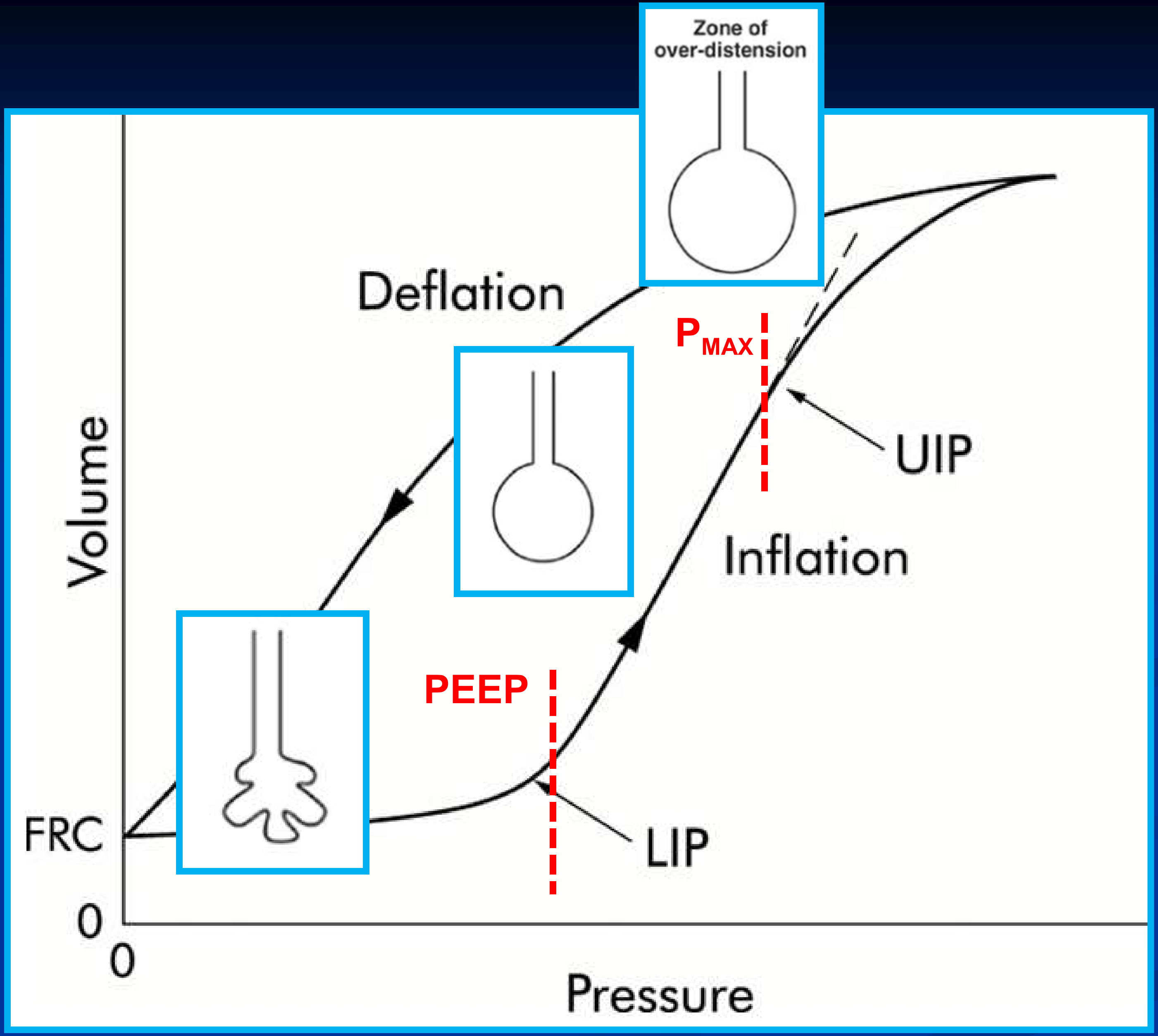

V3
V2
V1
Volume
ΔP
ΔP
ΔP
Intrapleural pressure


Increased
Normal
Decreased
V1
ΔP
Intrapleural pressure


Zone of
over-distension
Deflation
PMAX
UIP
Inflation
PEEP
LIP
FRC
Volume
0
0
Pressure

Resistance and Compliance

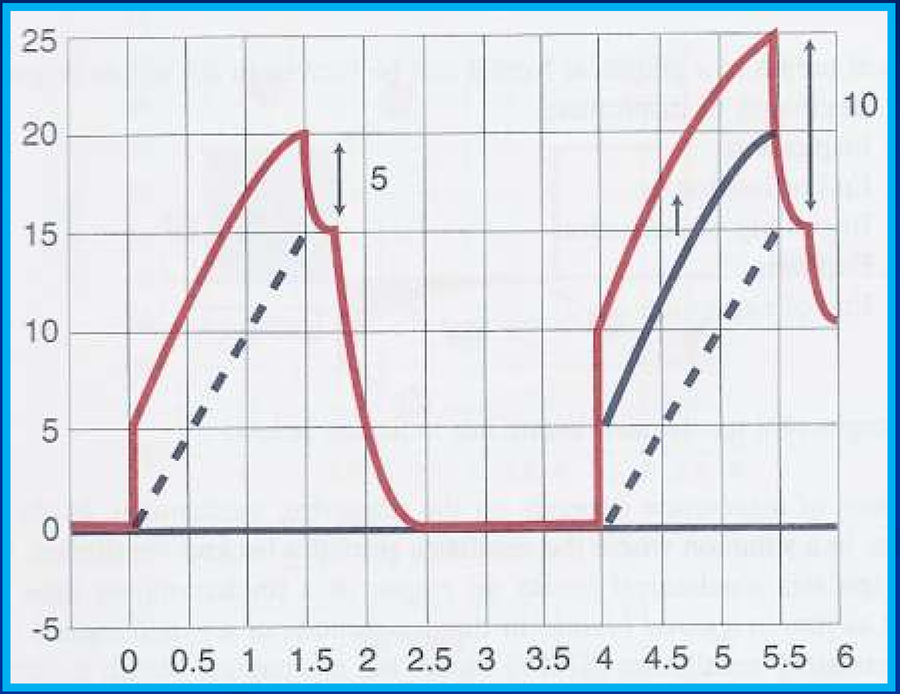
Transairway Pressure (P_{TA})

The pressure required to overcome R_{AW} as gas flows through the airways.

P_{TA} = flow rate x R_{AW}

Alveolar Pressure (P_A):

Pressure required to deliver a tidal volume against the recoil force of the alveoli



The effect of increased airways resistance on the pressure waveform

$P_A = P_{plateau} = P_{static}$

$PIP = P_{TA} + P_{plateau}$

Resistance and Compliance

As lung compliance decreases the static or plateau pressure increases resulting in increased peak pressure

Example:

V_T = 750 mL

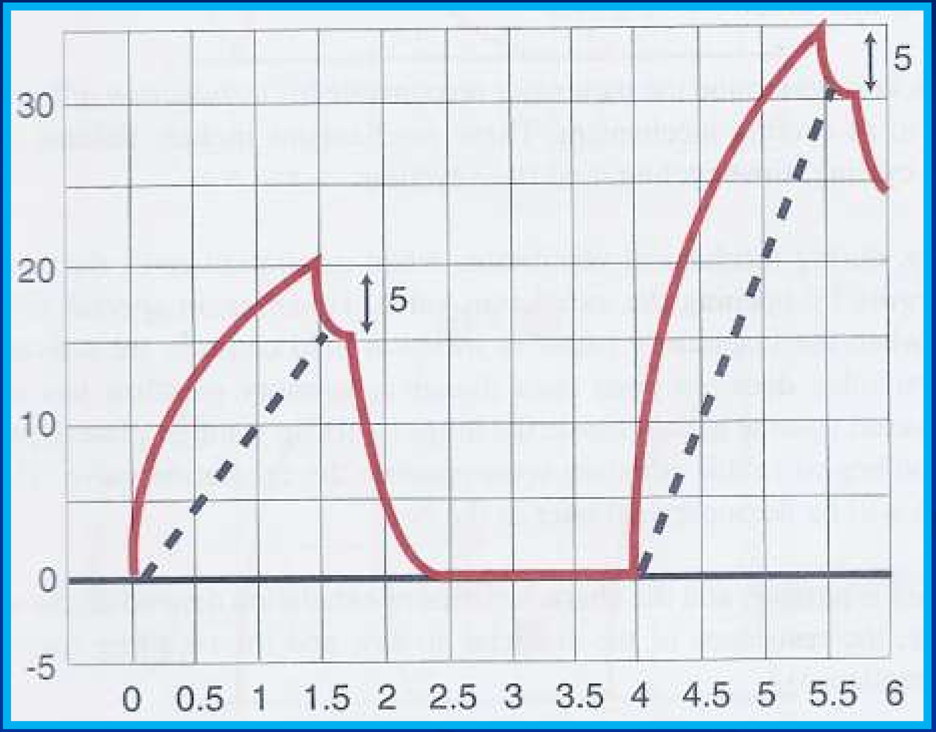
Flow = 5 cm H2O

C_{RS} = 50 mL/cm H2O

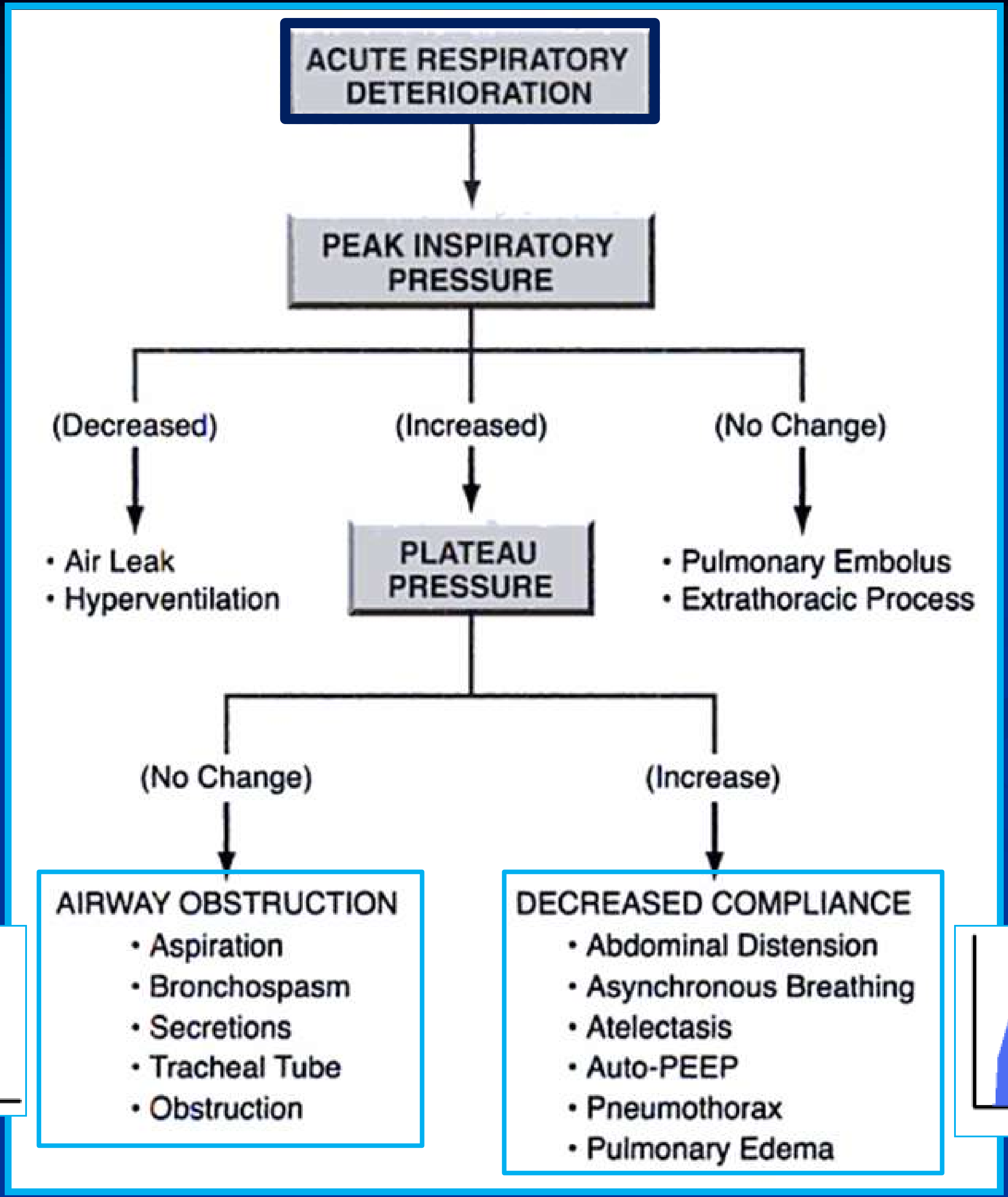
$P_{plateau}$ = 15 cm H2O

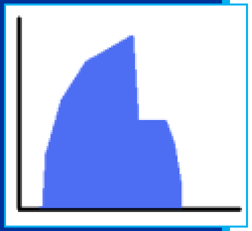
P_{TA} = flow x R_{AW}

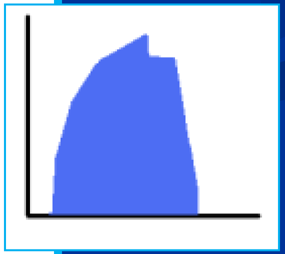
PIP = P_{TA} + $P_{plateau}$



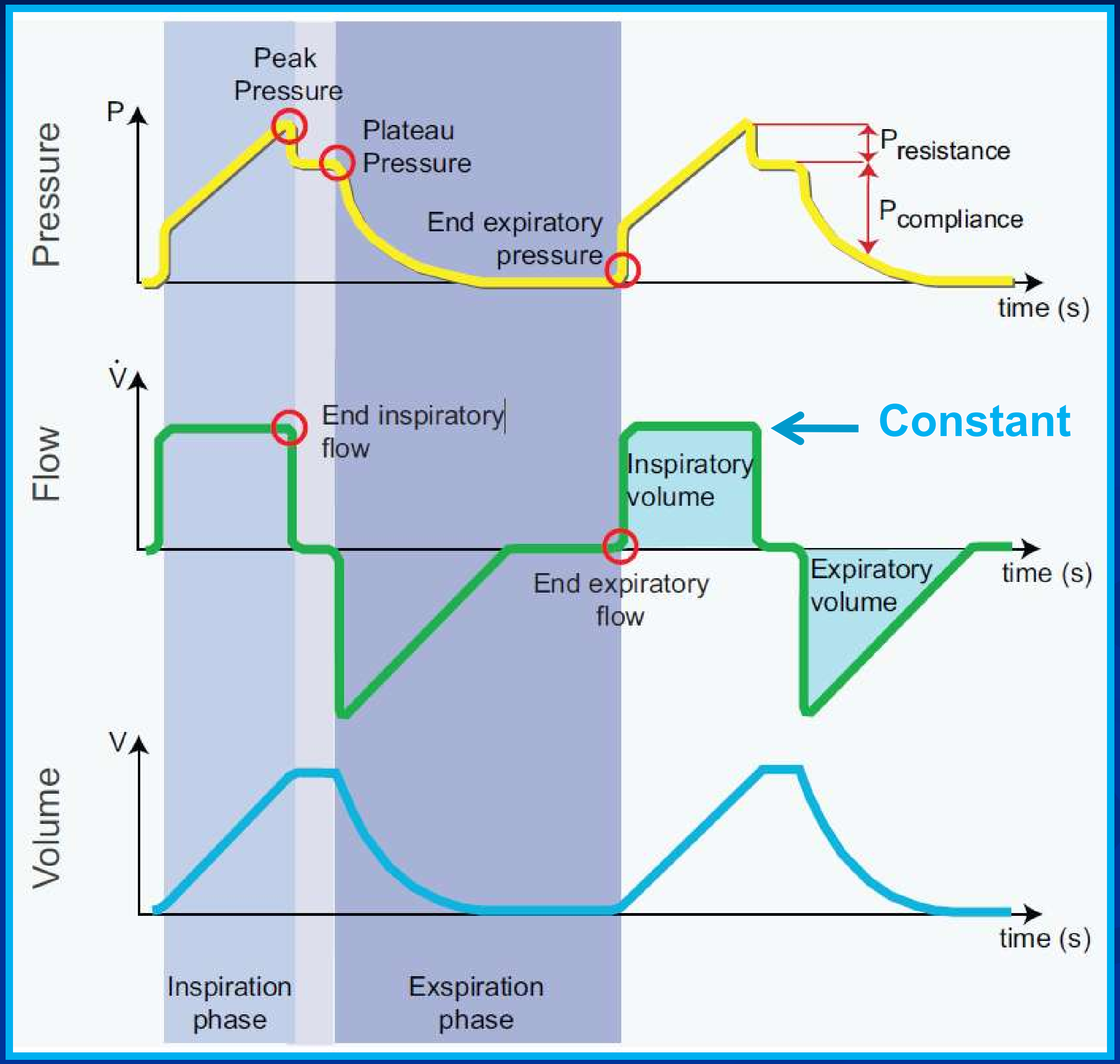
Marino, The ICU Book, 2007





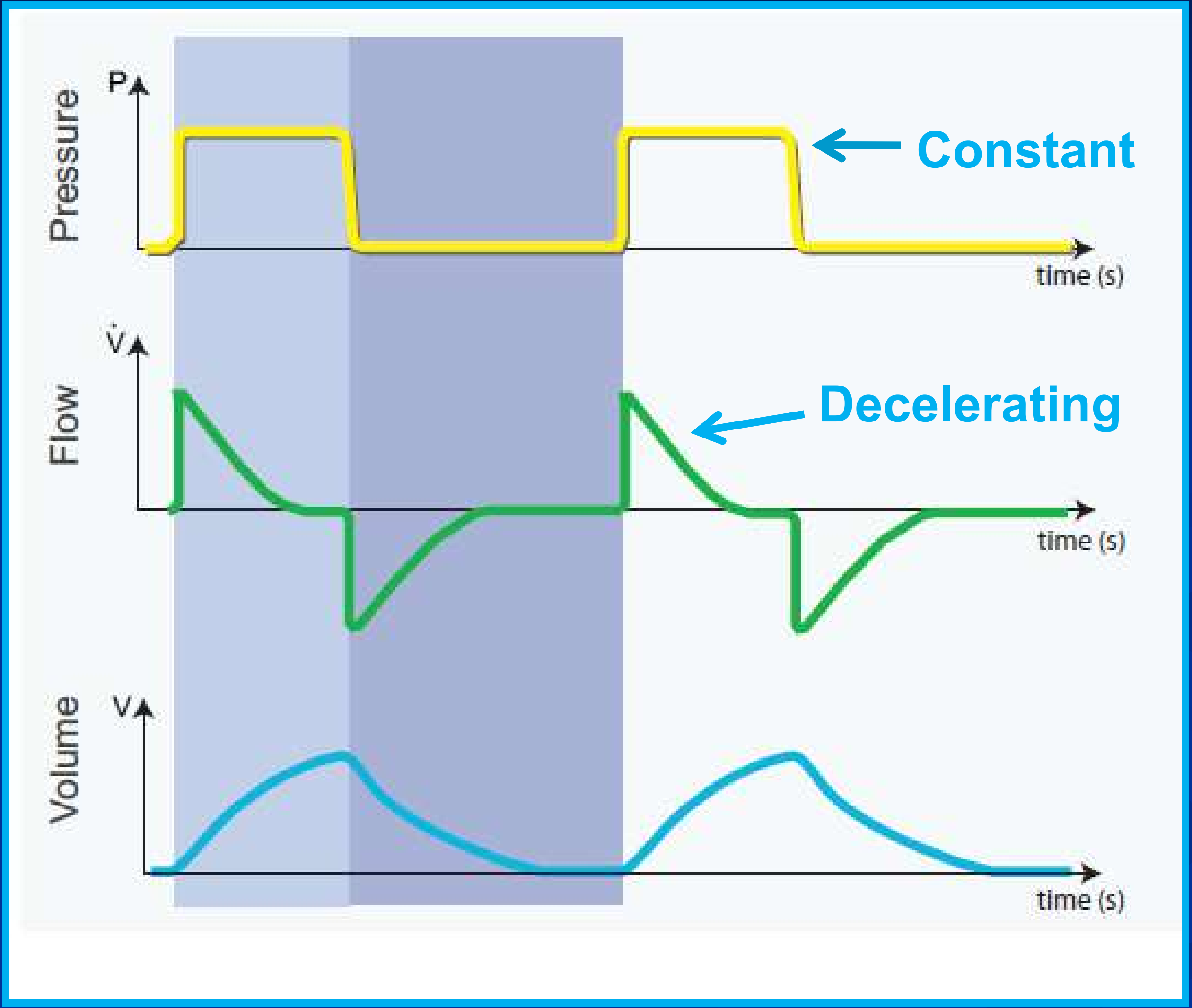


Flow Pattern: Volume Control Ventilation



Maquet Pocket Guide, Modes of Ventilation , Servo-I

Flow Pattern: Pressure Control Ventilation

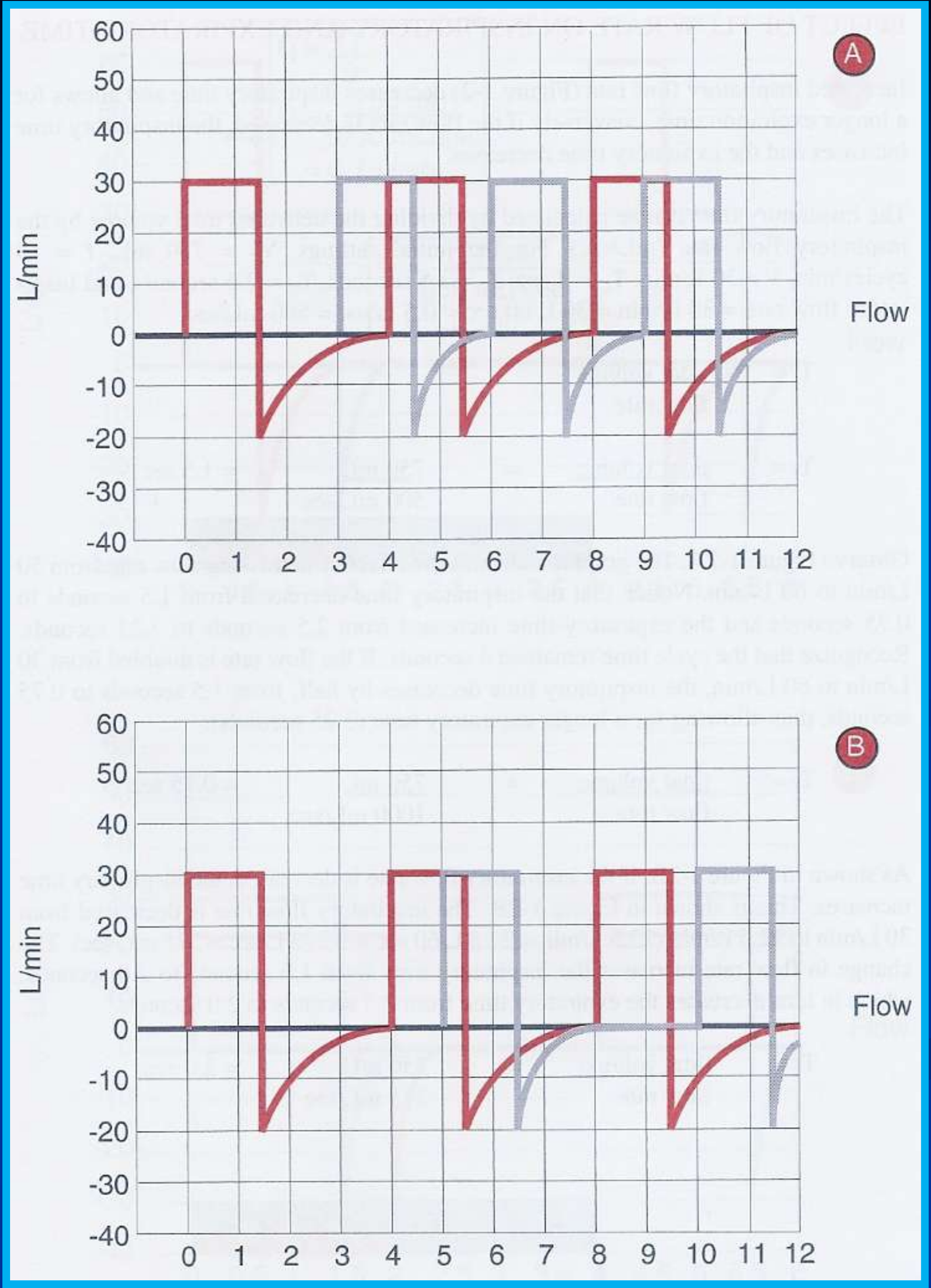


Examples: PC, PRVC, PS, VS, SIMV (PRVC, PC) + PS

Effect of changing Respiratory Frequency (f) on Cycle Time (T_C)

(A) RR increased to 20, cycle time decreases to 3 sec and expiratory time decreases to 1.5 sec

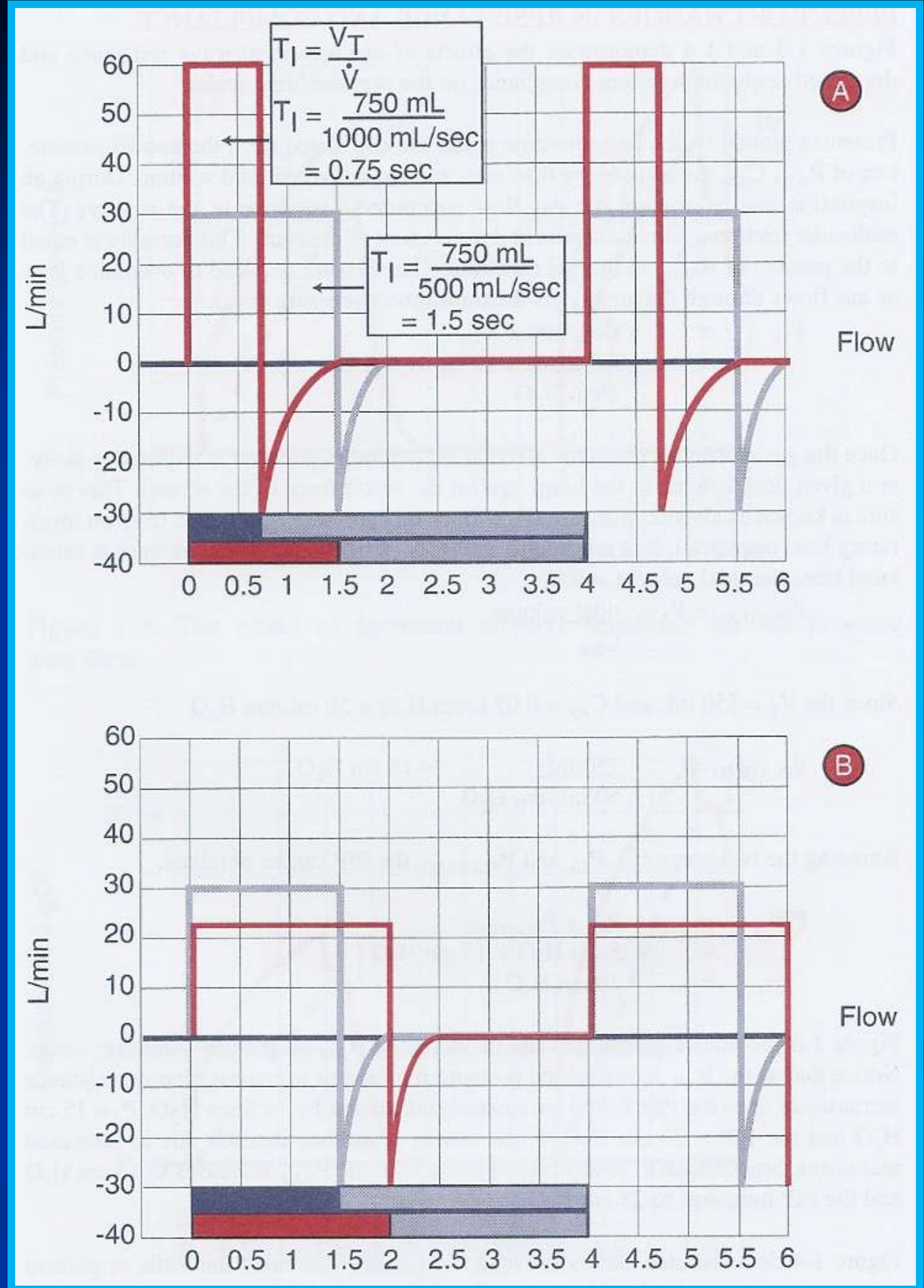
(B) RR decreased to 12, cycle time increases to 5 sec, since the inspiratory time remains unchanged, expiratory time increases to 3.5 sec



Effect of changing Inspiratory Flow Rate on Inspiratory and Expiratory times

(A) Increased Inspiratory Flow
→ Decreases insp time
→ Longer expiration time

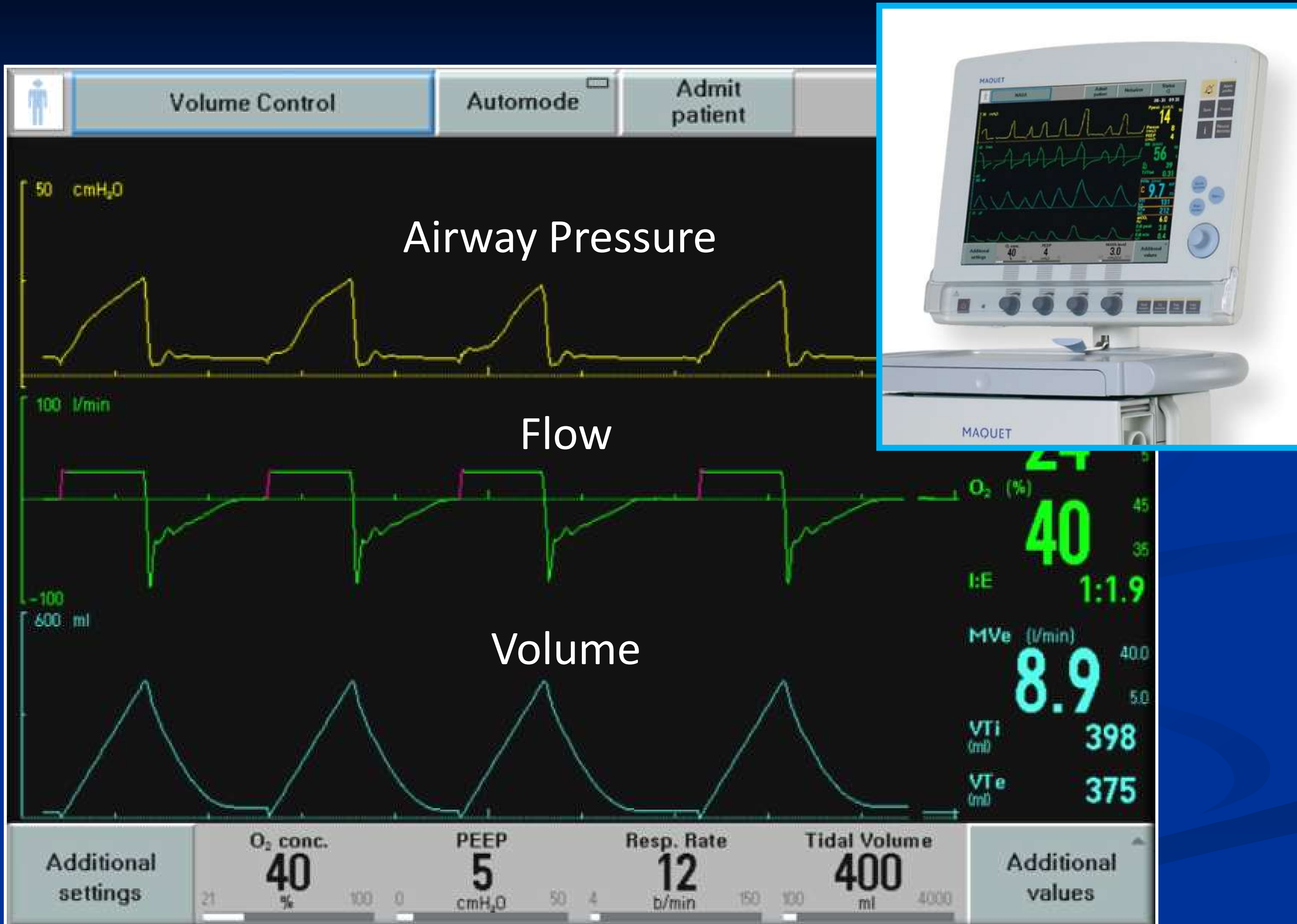
(B) Decreased Inspiratory Flow
→ increases insp time
→ decreases exp time



Modes of Ventilation

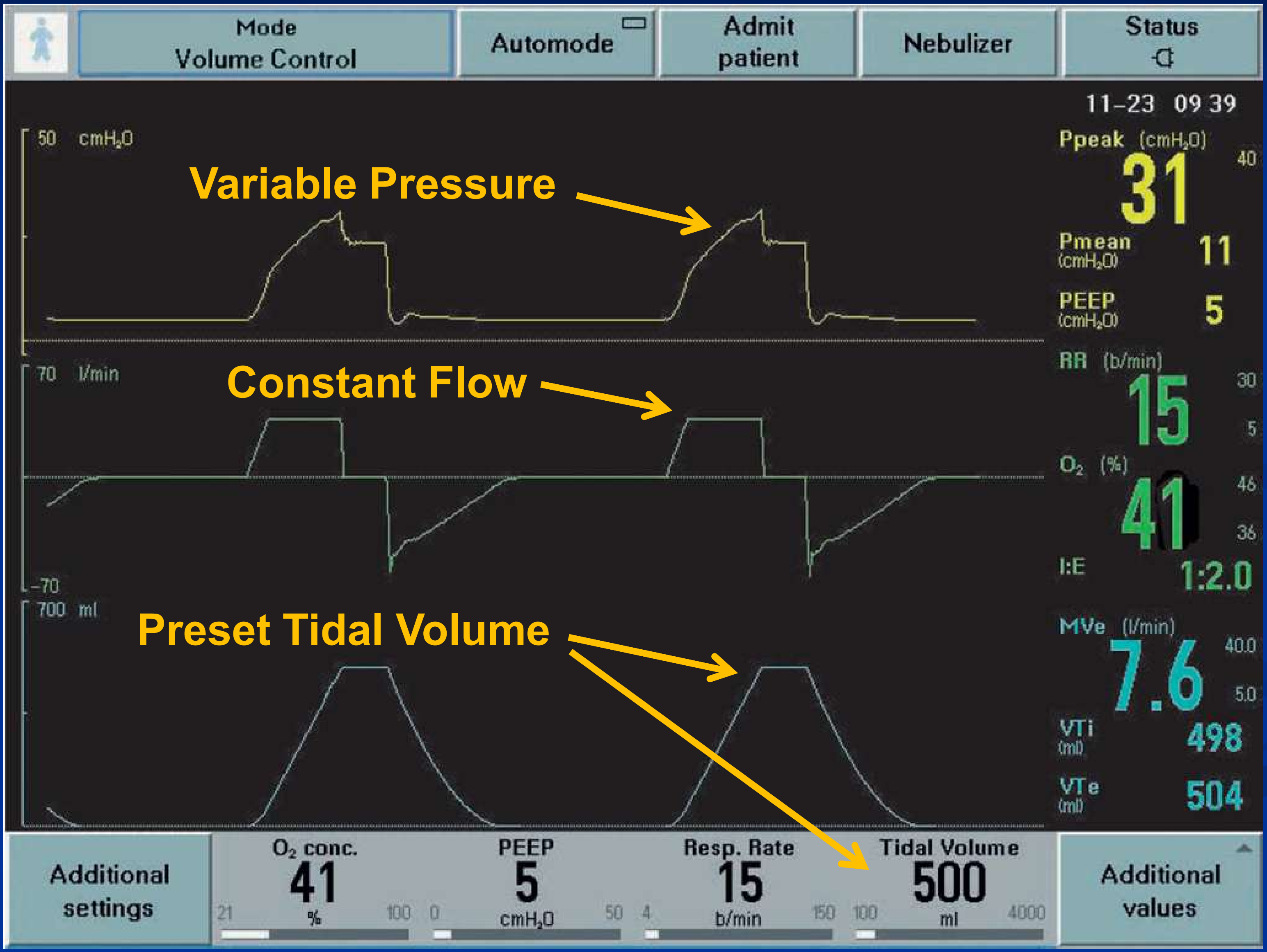
Selection of ventilator mode depends on:

- Clinical setting and patient pathophysiology
- Institutional guidelines and clinician preferences



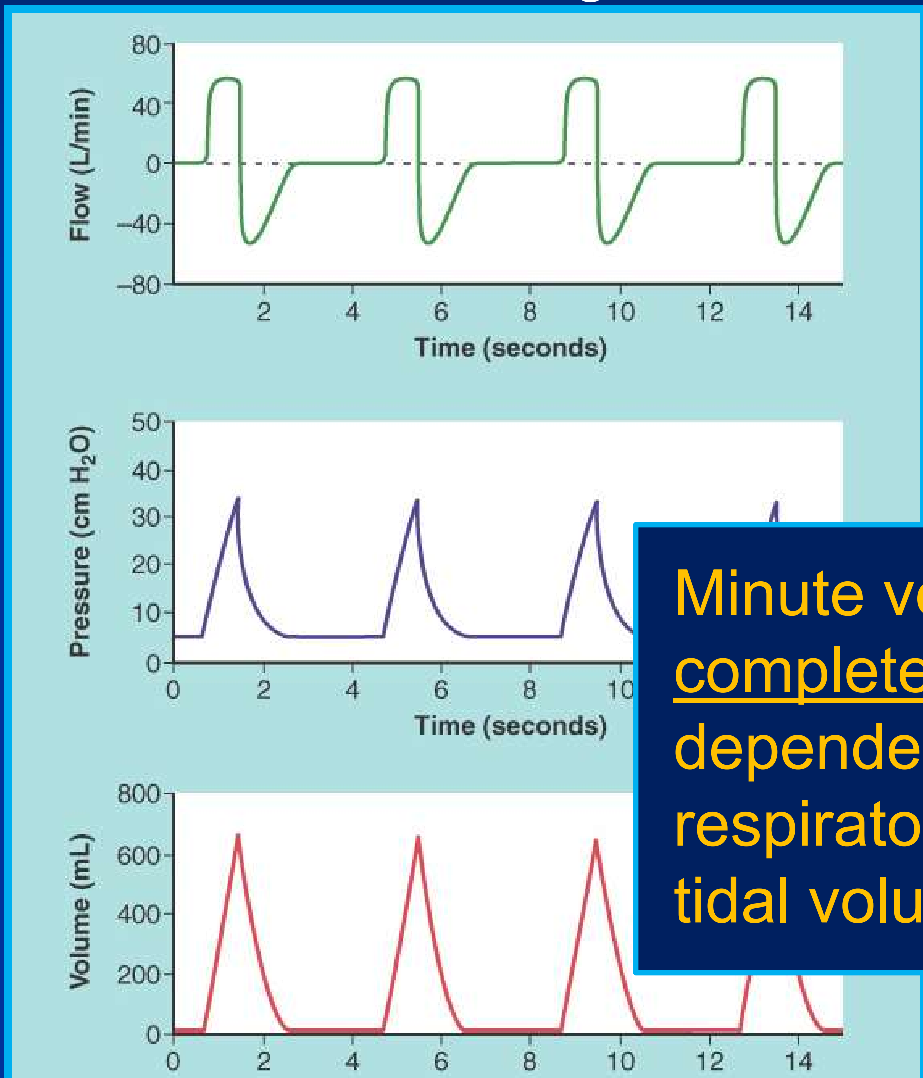
Maquet Pocket Guide, Modes of Ventilation , Servo-I

Volume Control

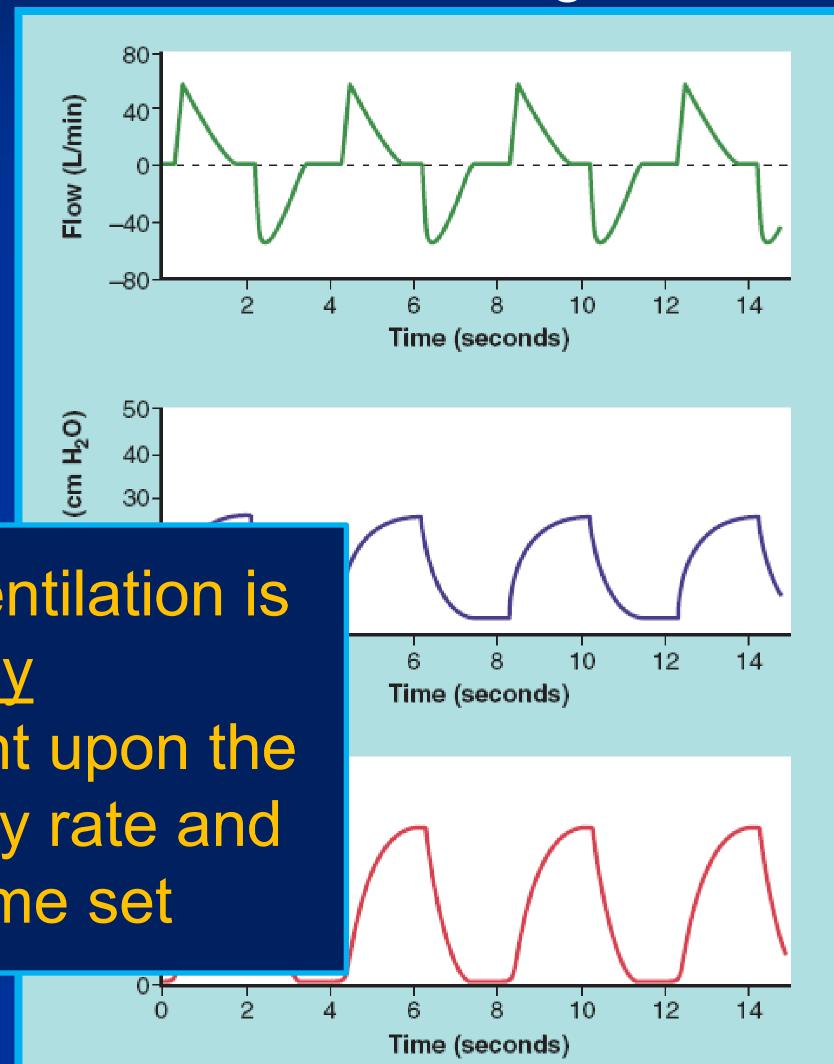


Controlled Mechanical Ventilation

Volume Targeted

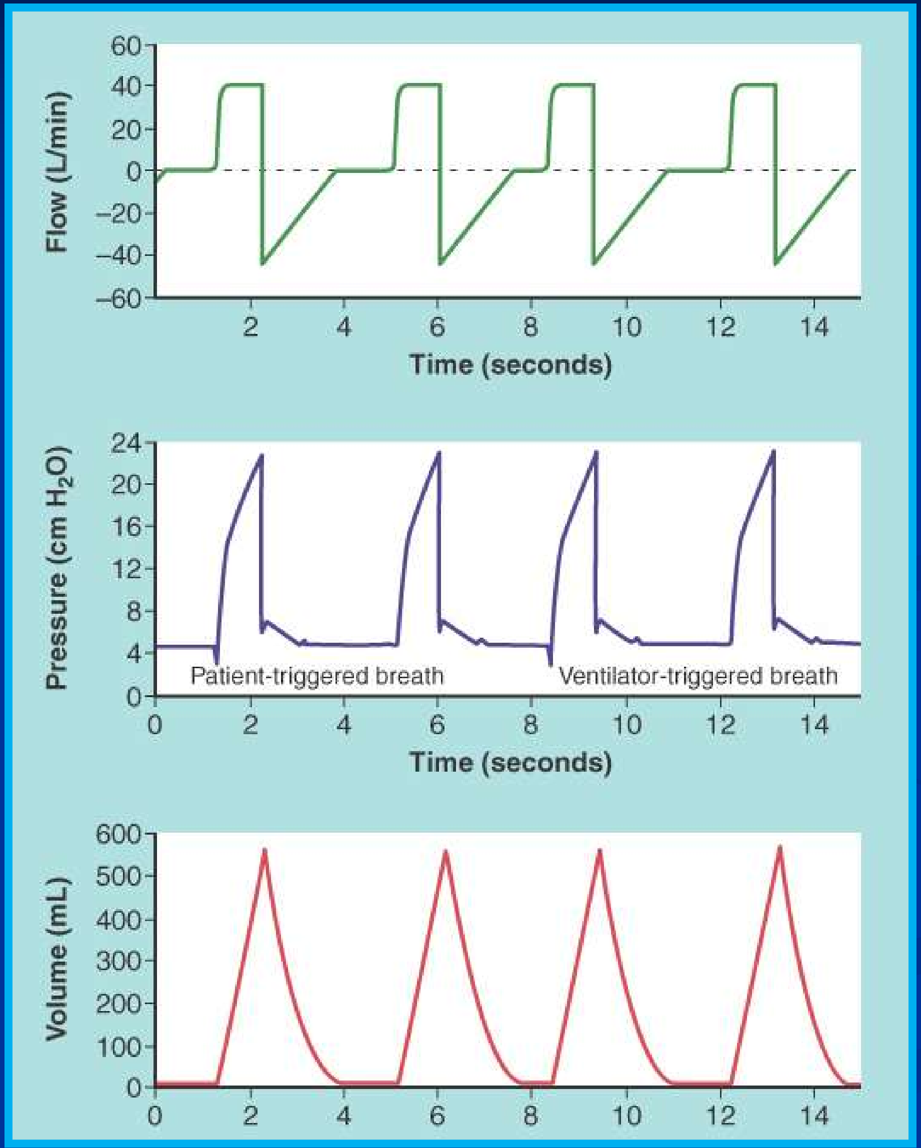


Pressure Targeted

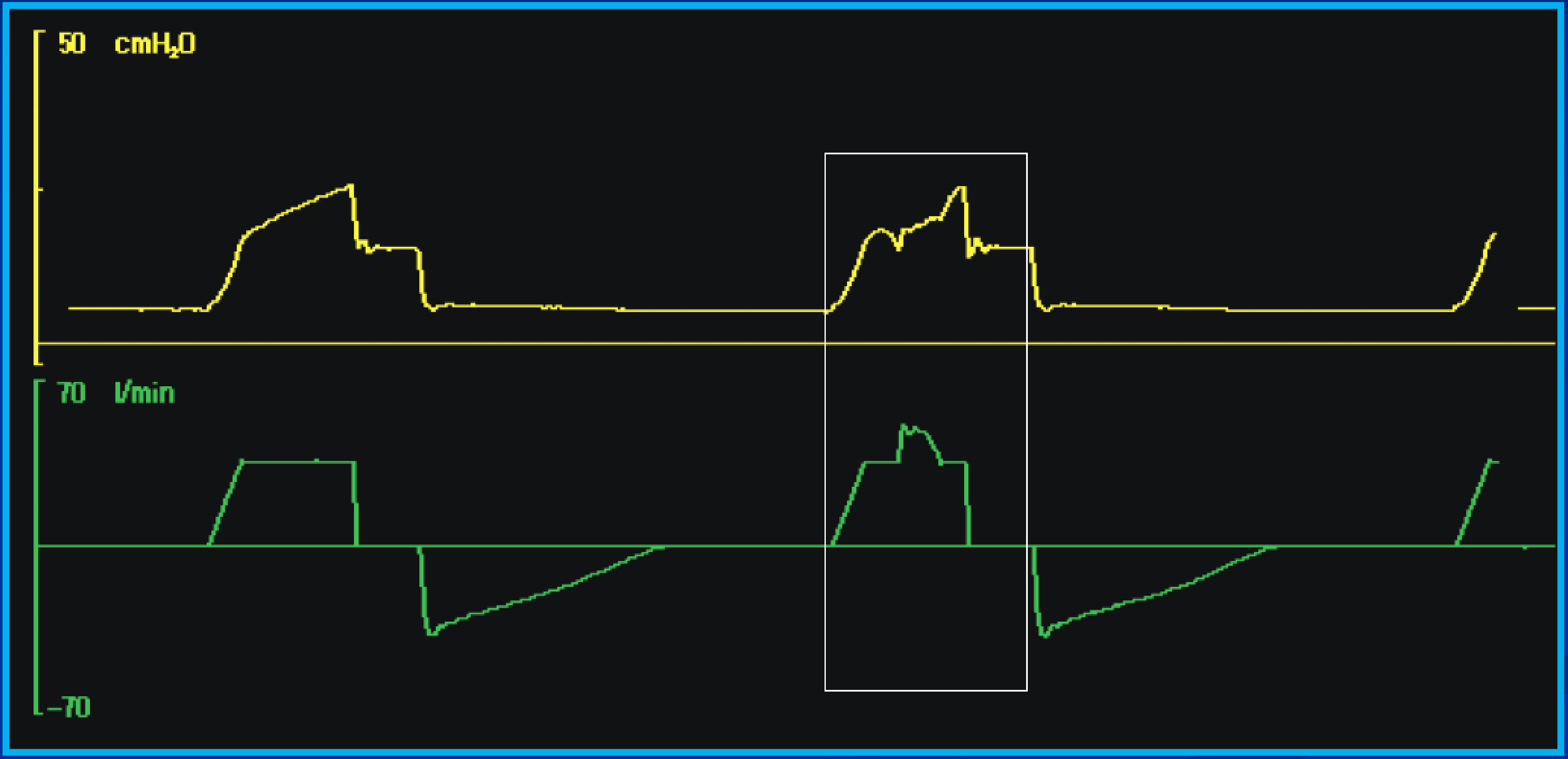


Minute ventilation is <u>completely</u> dependent upon the respiratory rate and tidal volume set

Volume Control: Assist Control



Volume Control: *Flow Adapted*



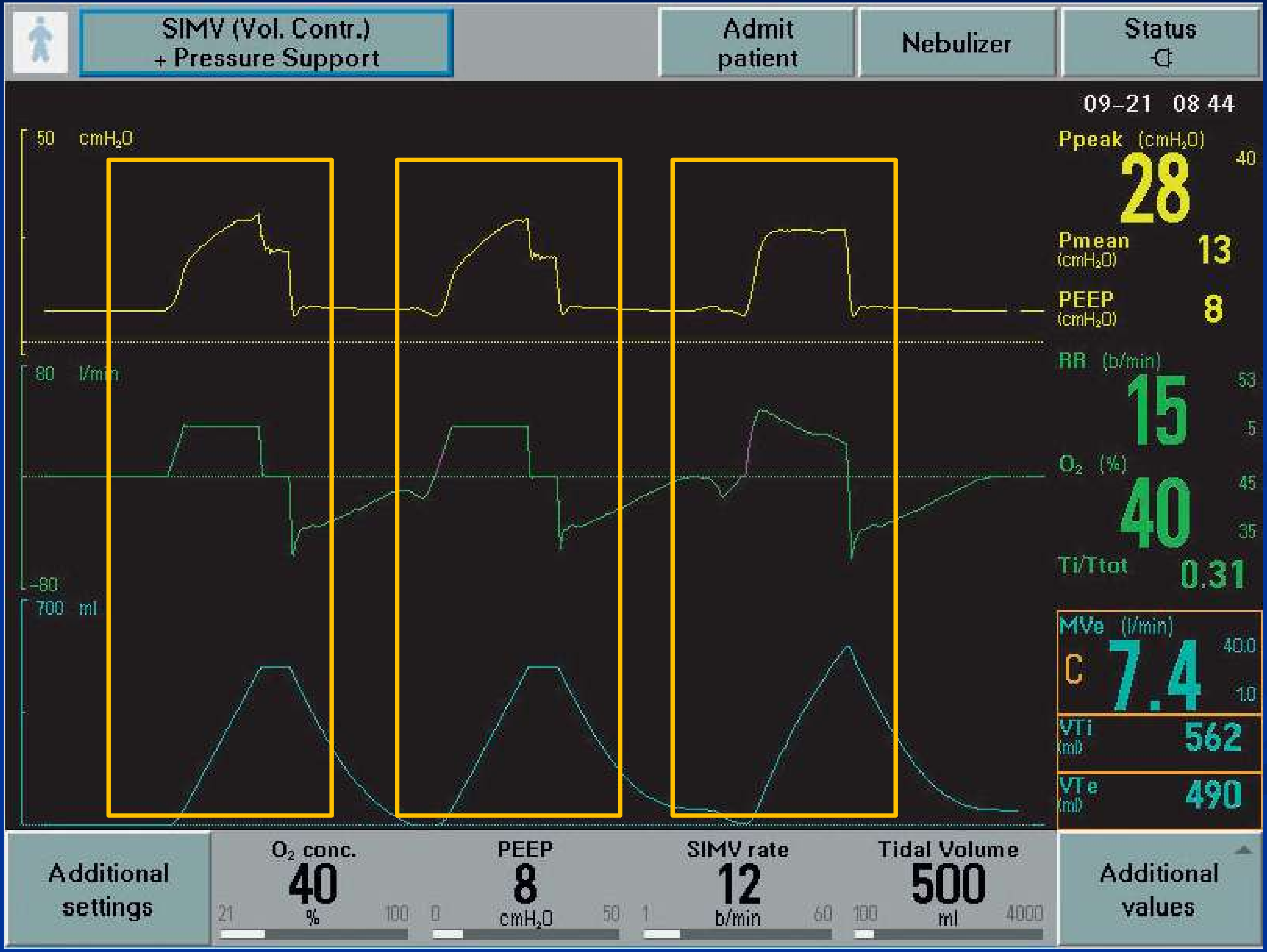
Volume Control: Assist Control

- Advantages:
  - Reduced work of breathing
  - Guarantees delivery of set tidal volume and minute ventilation
- Disadvantages:
  - Potential adverse hemodynamic effects
  - May lead to inappropriate hyperventilation and excessive inspiratory pressures
  - Cannot ventilate effectively and consistently unless the airway is well sealed

Volume or Pressure

- Volume Assist:
  - T_V guaranteed, less worry about CO_2 clearance
- Pressure Assist:
  - Decelerating flow more comfortable
  - Better synchrony and more physiological

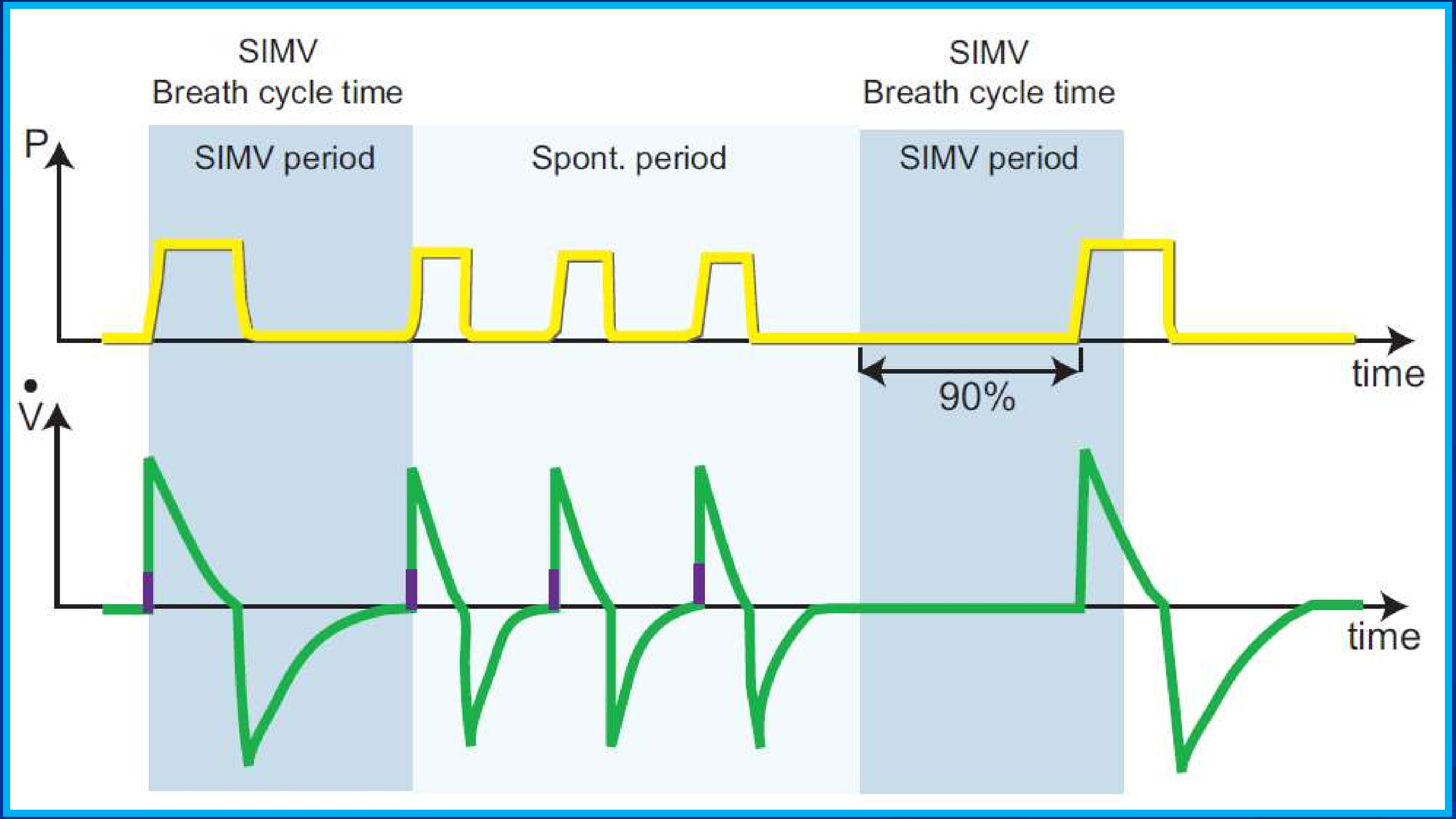
SIMV: Synchronized Intermittent Mandatory Ventilation (Volume Control)



SIMV: Synchronized Intermittent Mandatory Ventilation (Pressure Control)

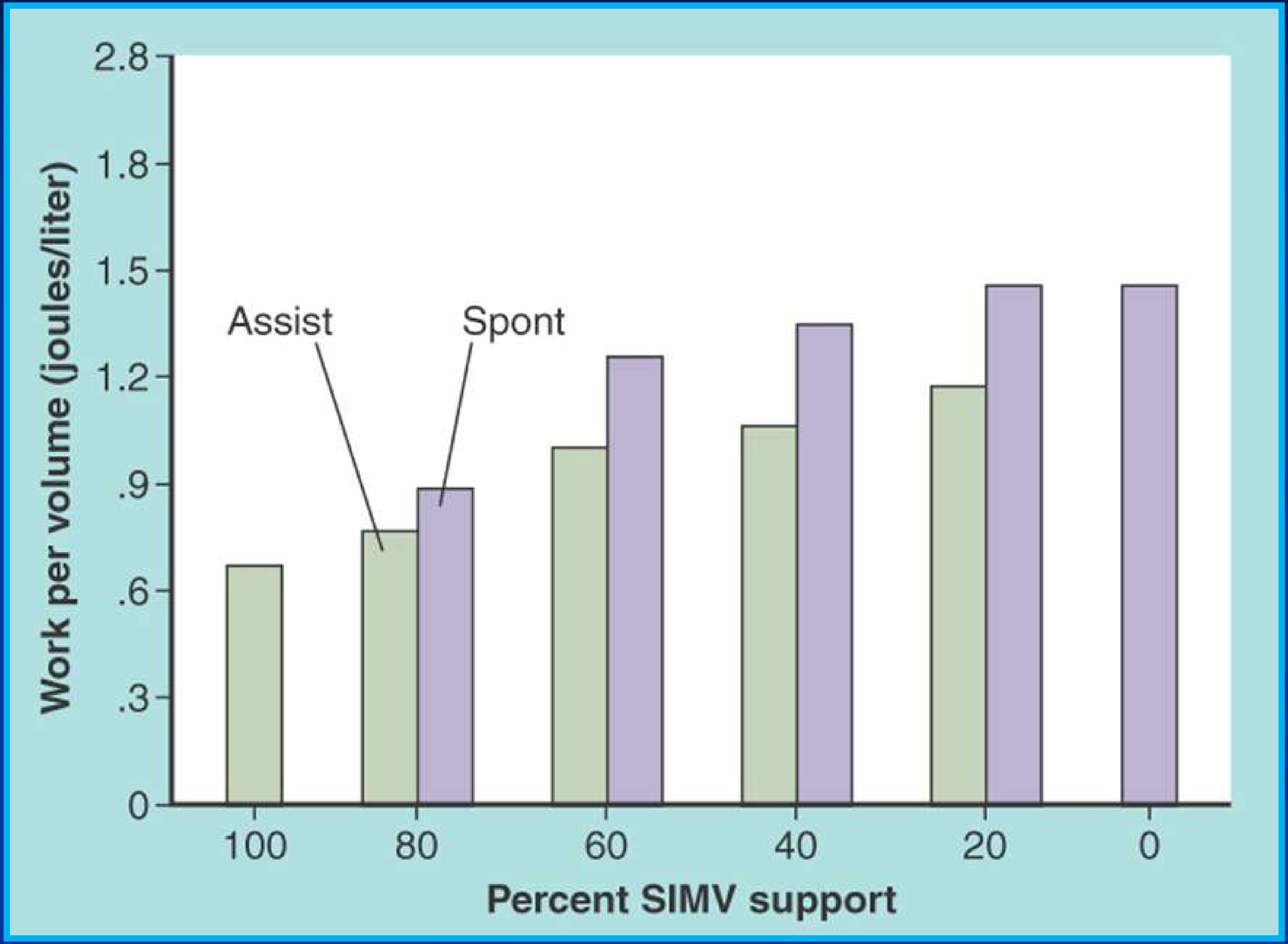
SIMV: Synchronized Intermittent Mandatory Ventilation (PRVC)

SIMV: Breath Cycle Time



Maquet Pocket Guide, Modes of Ventilation , Servo-I

Inspiratory work per unit volume done during SIMV

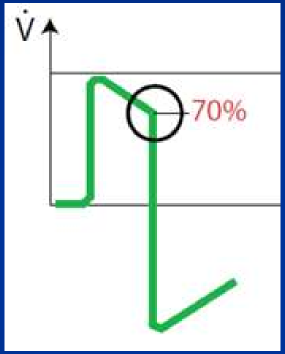


SIMV

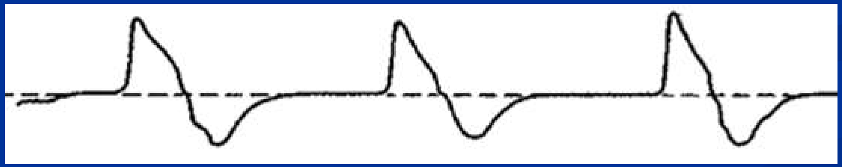
- Advantages:
  - Improved synchrony
  - Preservation of respiratory muscle function
  - Lower mean airway pressures
  - Decreased tendency to develop auto-PEEP
- Disadvantages:
  - Increased work of breathing compared to ACV
  - Not shown to be effective for weaning

Pressure Support

- Spontaneous breathing with a ventilator "boost"
- Patient triggers all the breaths
- Flow-cycled:
  - once triggered, the set pressure is sustained until the inspiratory flow tapers



- V_T and RR (minute volume) are a consequence of the patient-related variables (ie. the underlying disease, sedation) plus ventilator settings

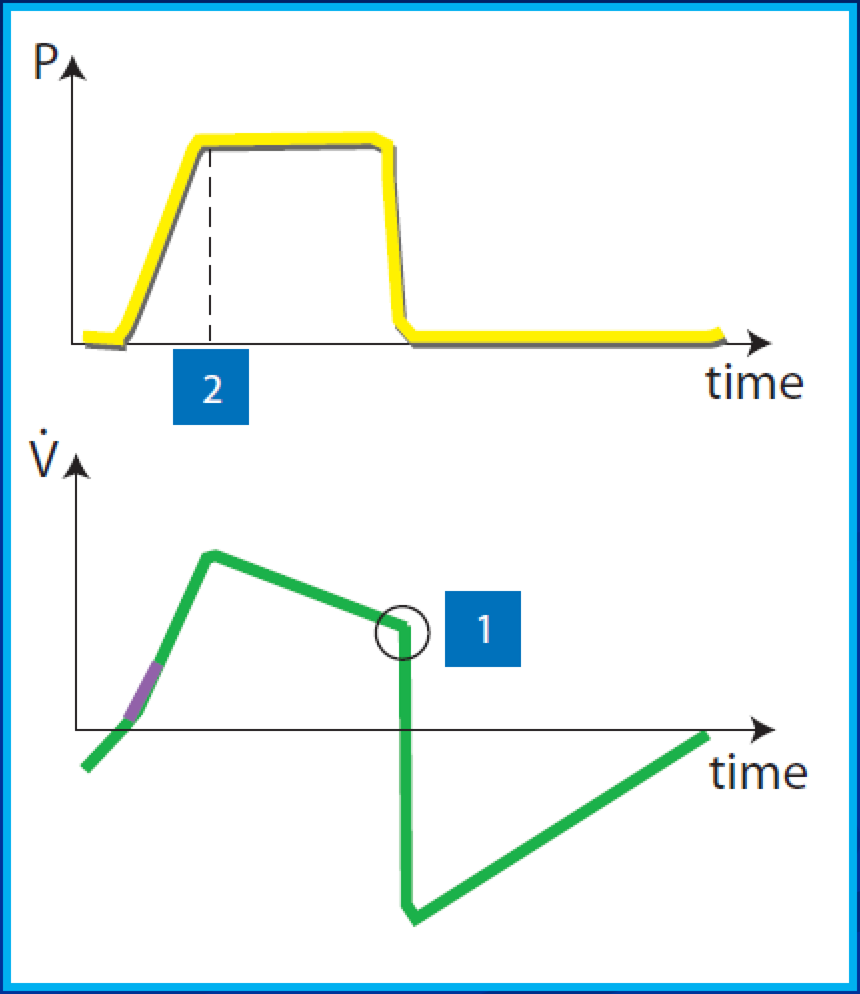


Respir Care Clin N Am. 2005 Jun;11(2):247-63

Pressure Support

Pressure Support

- Gas flows into lungs at a constant pressure
- Since pressure is constant, the flow will decrease until Inspiratory cycle off (1)
- Pressure will either rise quickly or slowly, depending on Insp rise time (2)



Maquet Pocket Guide, Modes of Ventilation , Servo-I

Pressure Support

Advantages:

- Comfortable: patient has greater control over ventilator cycling and flow rates
- Work of breathing is inversely proportional to the level of pressure support

Disadvantages:

- Close monitoring is required
- Neither tidal volume nor minute ventilation is guaranteed

Respir Care Clin N Am. 2005 Jun;11(2):247-63

7:30 AM

Trauma Department

- 32 Male

MVC – LOC & TBI

GCS: 7

BP: 160/80 P: 70 R: 5

(L) Pupil 5 mm

(R) Pupil 3 mm

Bilateral Breath Sounds

Other trauma exam (-)


84

Ventilator Settings

Mode: Control

Tidal Volume (V_T): 750 mL

Resp Frequency (f): 15 b/min

Insp Flow Rate (V): 30 L/min

Airway Resistance (R_{AW}):

10 cm H_2O/L/sec

Respiratory System Compliance (C_{RS}):

0.05 L/cm H_2O

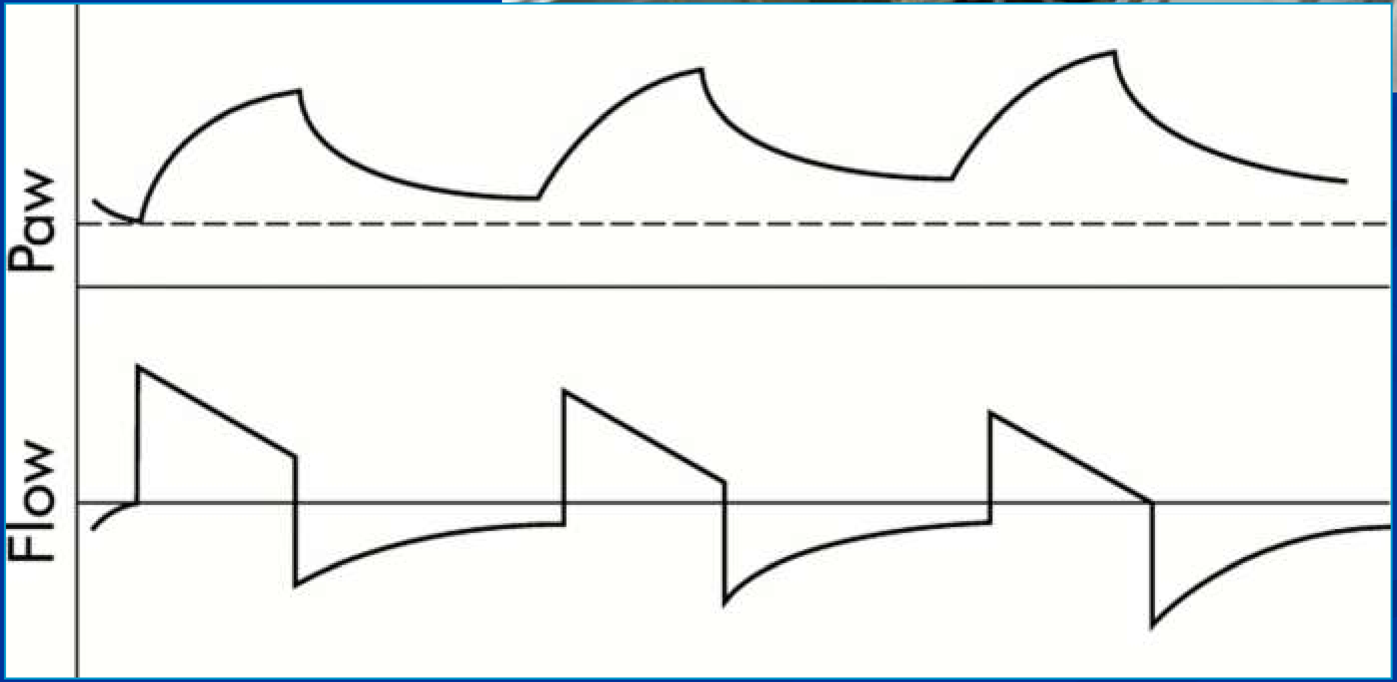
50 mL/cm H_2O

Neurosurgery resident:

“ No sedation for Neuro Exam ”

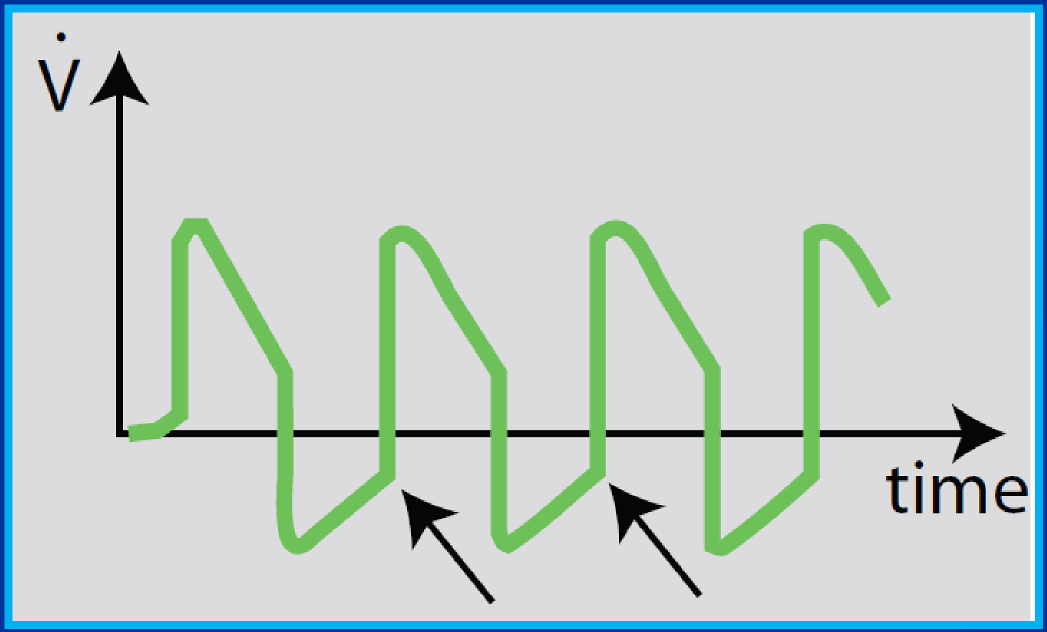
20 min later..

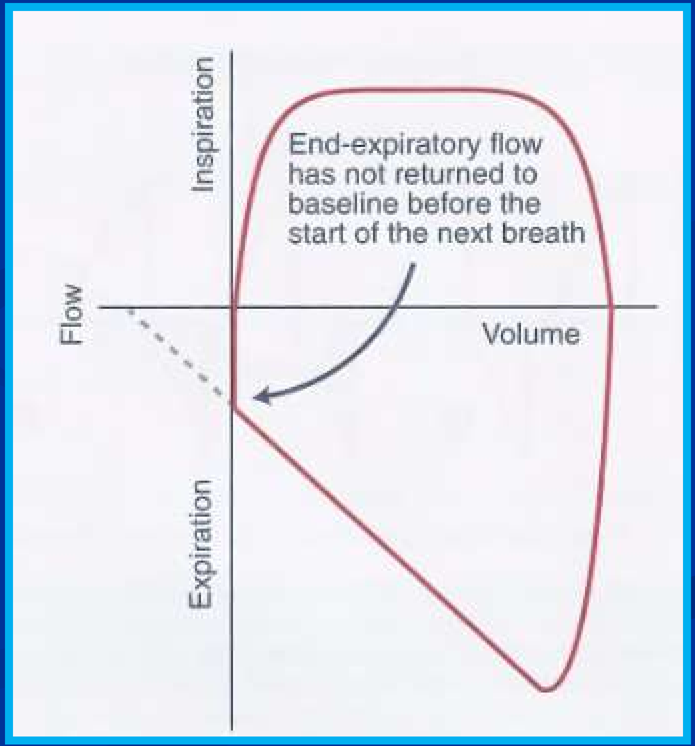
ALARM !
BP: 80/40
P: 120
R: 40



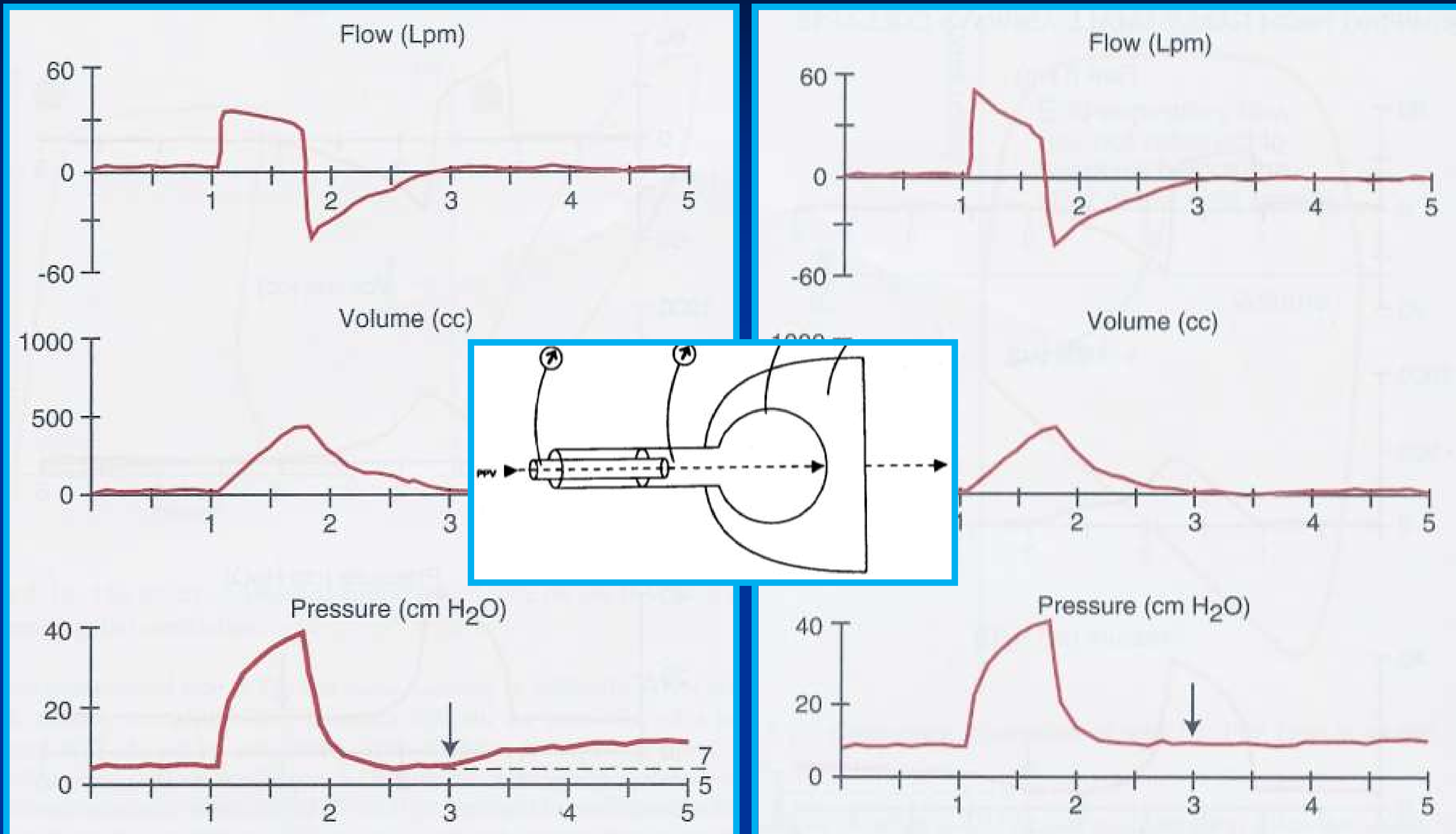
Auto PEEP:

- High respiratory rate, short expiratory time
- Not enough time to exhale → Air Trapping





Interpretation of waveforms, Waugh, Deshpande, 2007

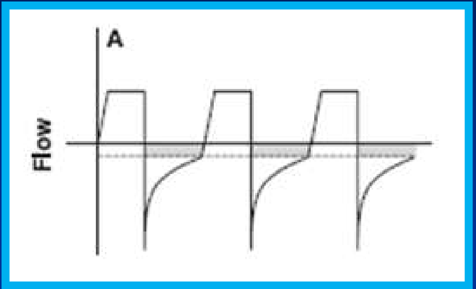


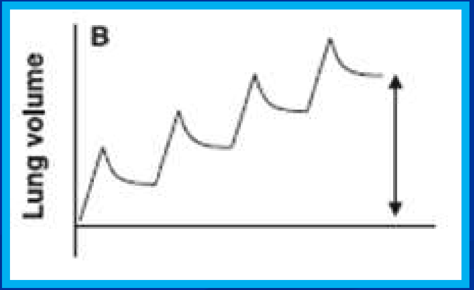
Interpretation of waveforms, Waugh, Deshpande, 2007

Determinants of AutoPEEP

- Minute Ventilation (V_T and RR)
- Expiratory Time constant

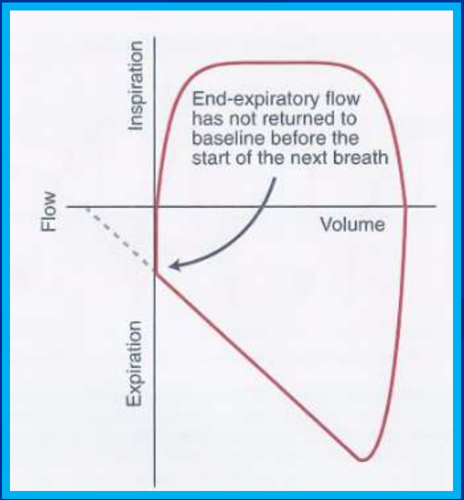
  Longer I:E ratio = short expiratory time
- High resistance, floppy lung





Clues to diagnosis..

- Increase P_{Peak} and $P_{Plateau}$ (VC)
- Decreases in V_T (PC)
- Problems with inspiratory trigger
- Dyssynchrony
- Hemodynamic abnormalities ..



Treatment of AutoPEEP

- Decrease Minute Ventilation (RR, V_T)
- Increase Inspiratory Flow / pattern
  → Increase Expiratory Time
- Treat underlying cause
  (Bronchodilators, suction)
- Apply extrinsic PEEP
- Sedation
- Disconnect ventilator circuit

56 year old man with SAH, receiving MV using Volume Assist Control for last 36 h. Settings are:

V_T: 600 R: 24 FiO2: 0.4 PEEP: 5. You decide to switch him to Pressure Support with 22cm Insp Pressure to obtain comparable V_T. He becomes dyspneic and appears to be triggering the ventilator only 8-10 times/min. Next maneuver should be ?

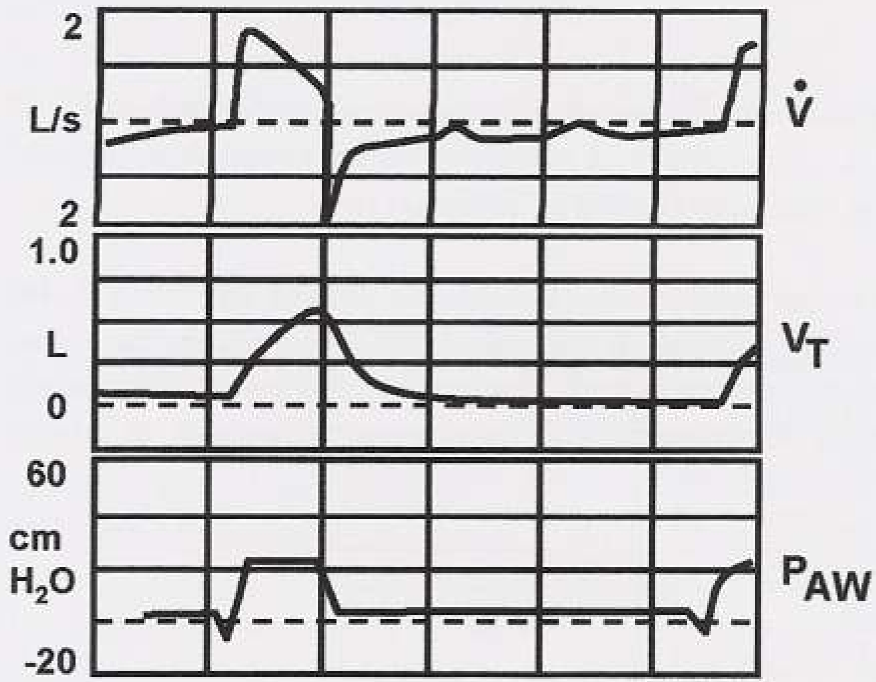


Figure 69-A

V̇ = airway flow; V_T = tidal volume; P_{aw} = airway pressure

A. Provide sedation and continue current settings
B. Switch from Pressure to Flow triggering
C. Add 5 cmH_2O additional PEEP and increase until better trigger
D. Switch to SIMV with back up rate of 8 along with PS
E. Return to volume assist Control with backup rate 6/min.

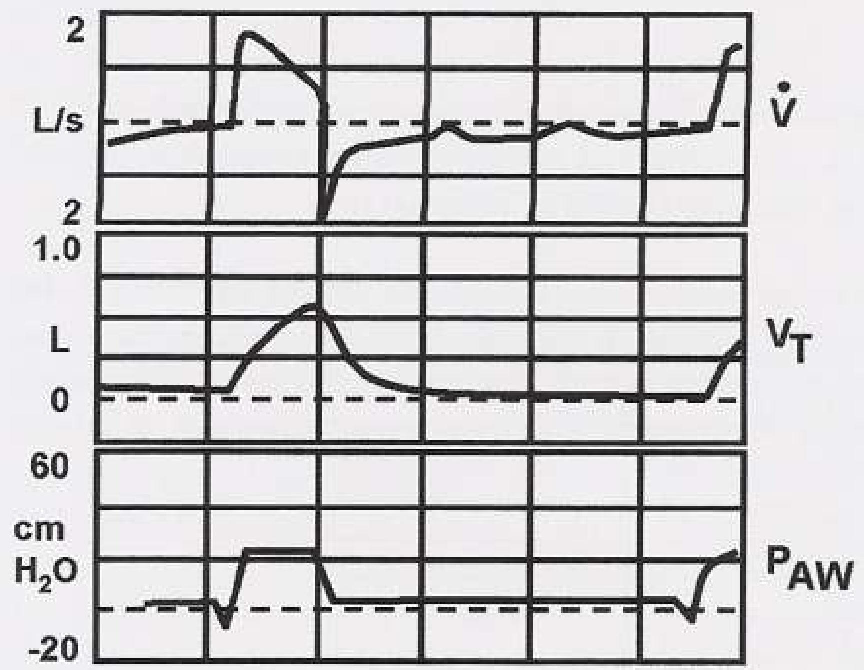


Figure 69-A
$\dot{V}$ = airway flow; V_T = tidal volume; P_{aw} = airway pressure

A. Provide sedation and continue current settings
B. Switch from Pressure to Flow triggering
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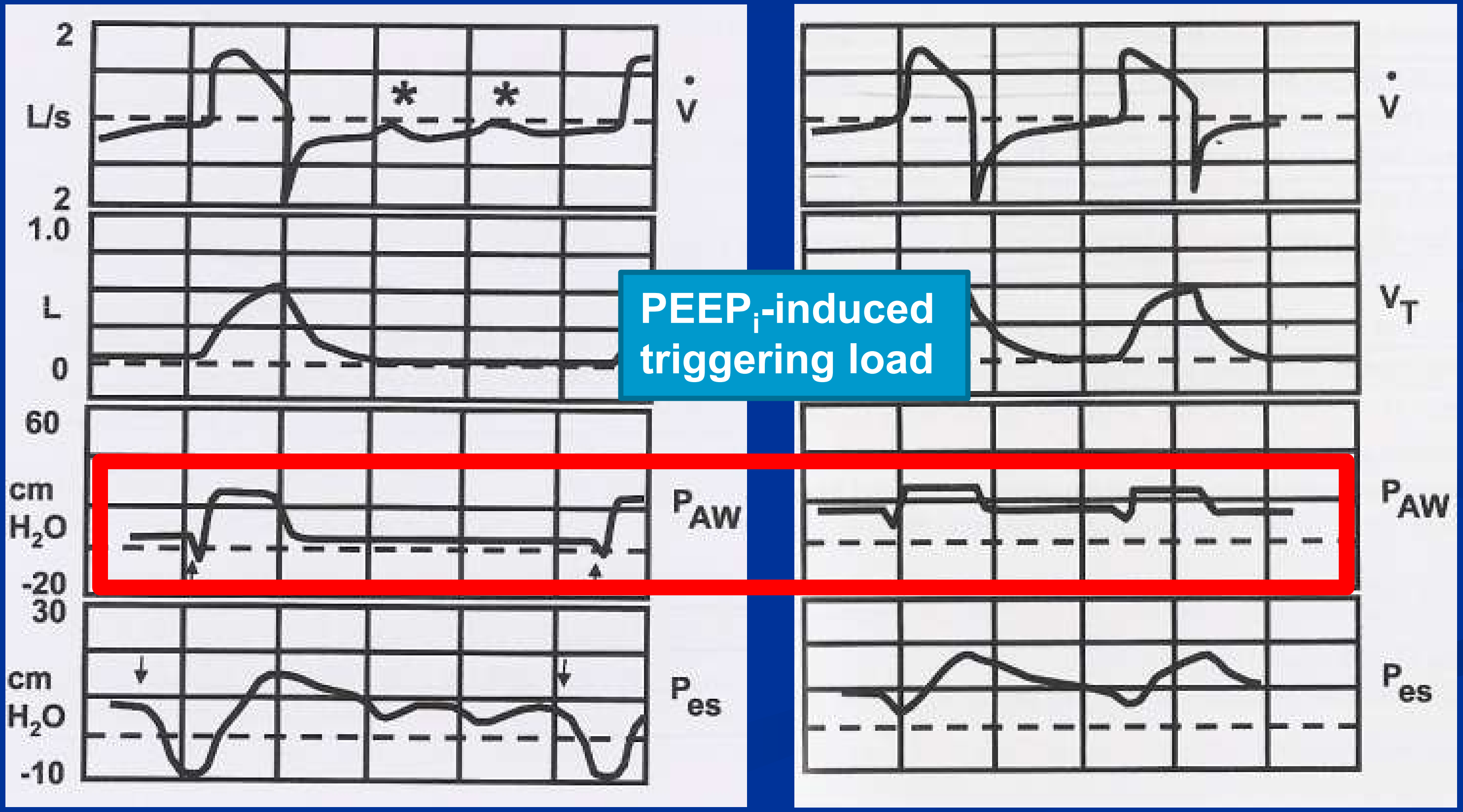
D. Switch to SIMV with back up rate of 8 along with PS
E. Return to volume assist Control with backup rate 6/min.

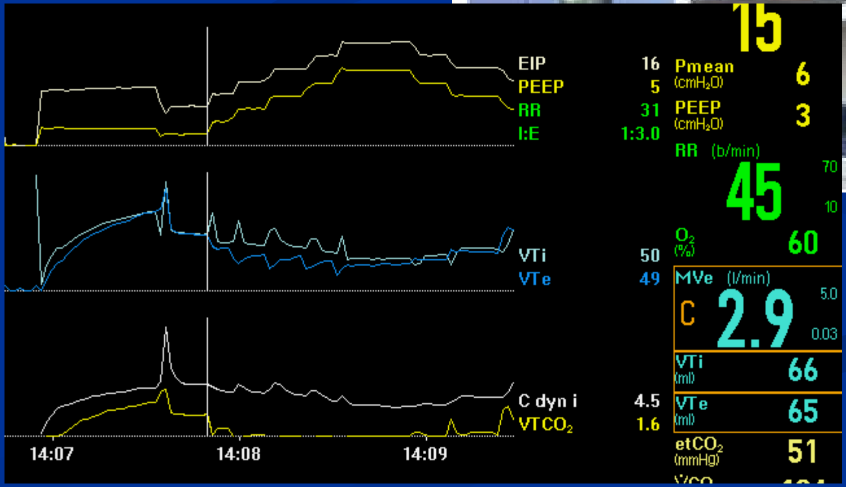


Modern Ventilators:

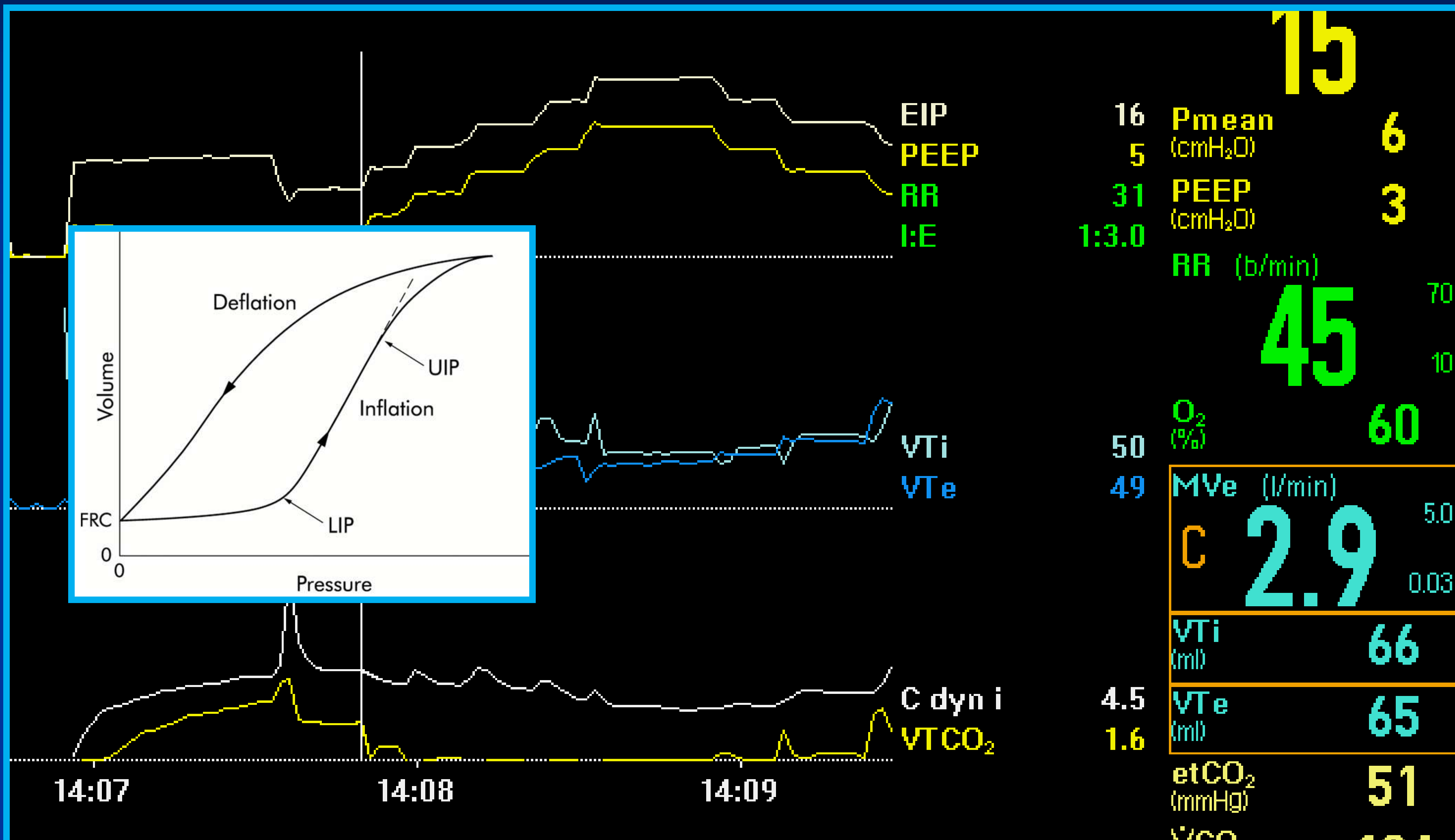
- **Computer Based & Smart**

Use complex algorithms

- Airway Pressures (ARDs Net)
- Mode Switch
- Waveform analysis
- Synchrony
- Patient Comfort
- Weaning
- Open Lung Tool



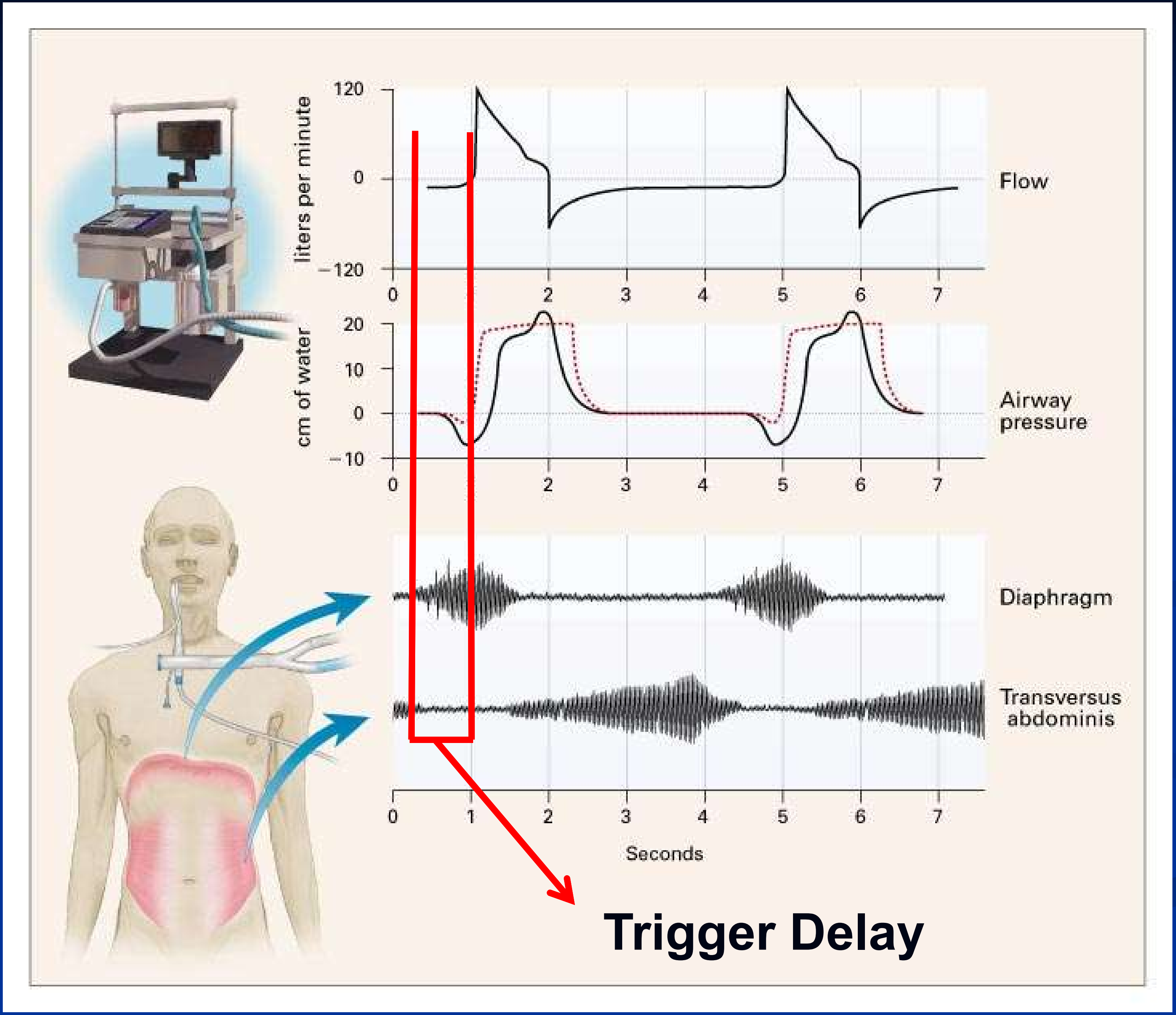
Open Lung Tool (OLT)



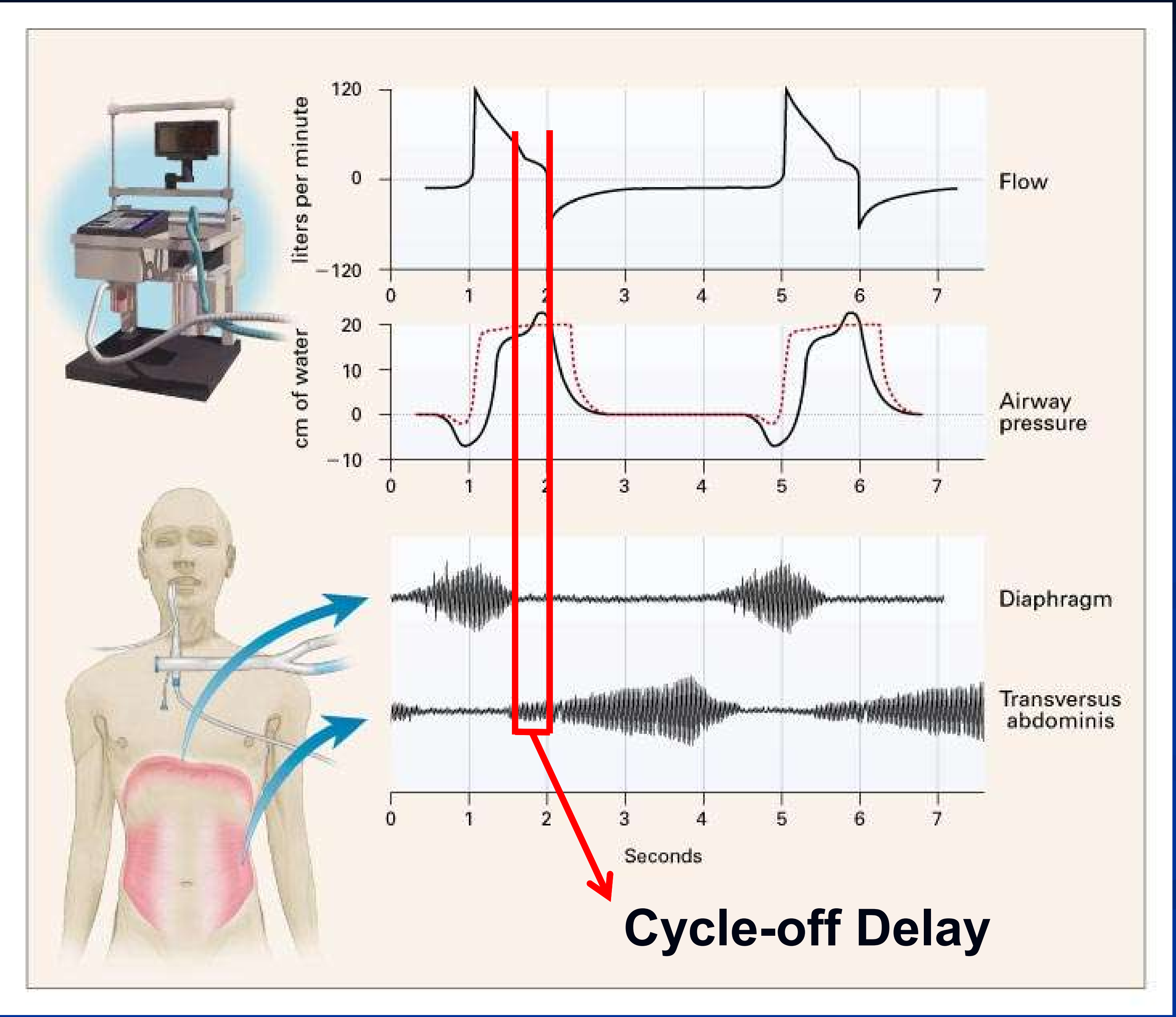
Pressure Control Ventilation *

NAVA

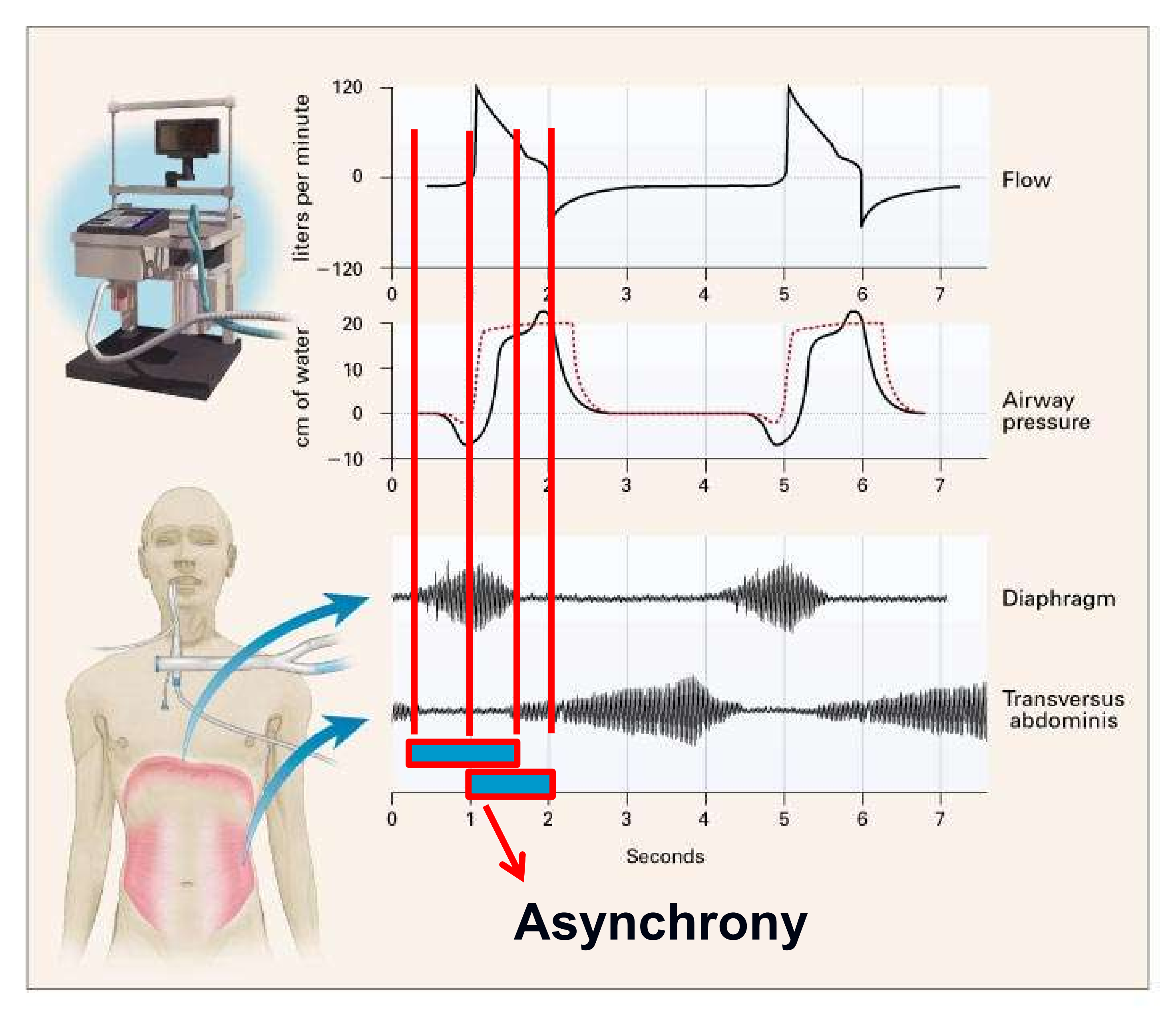
Amirali Nader, M.D.
Critical Care Medicine
Suburban Hospital
Johns Hopkins Medicine



Tobin. N Engl J Med 2001; 344:1986-1996 Data from Jubran et al and Parthasarathy et al



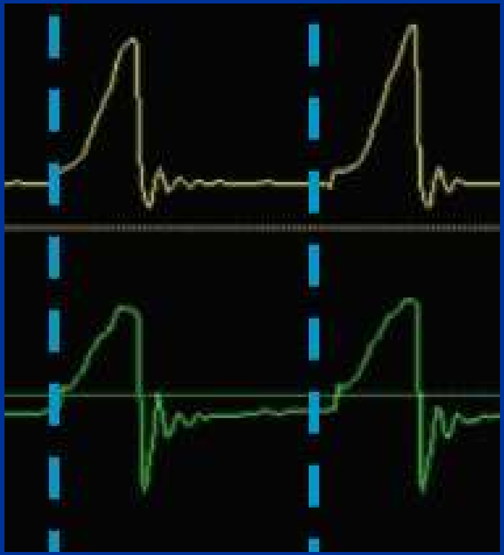
Tobin. N Engl J Med 2001; 344:1986-1996 Data from Jubran et al and Parthasarathy et al



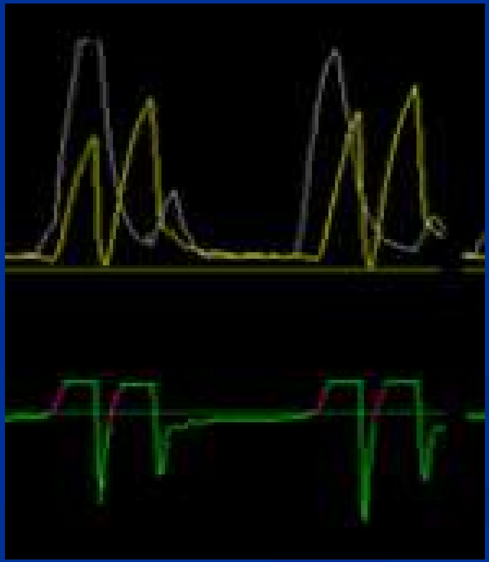
Tobin. N Engl J Med 2001; 344:1986-1996 Data from Jubran et al and Parthasarathy et al

Synchrony:

- **Initiation**, **delivery** and **termination** of the patient's and the ventilator's breaths coincide with each other



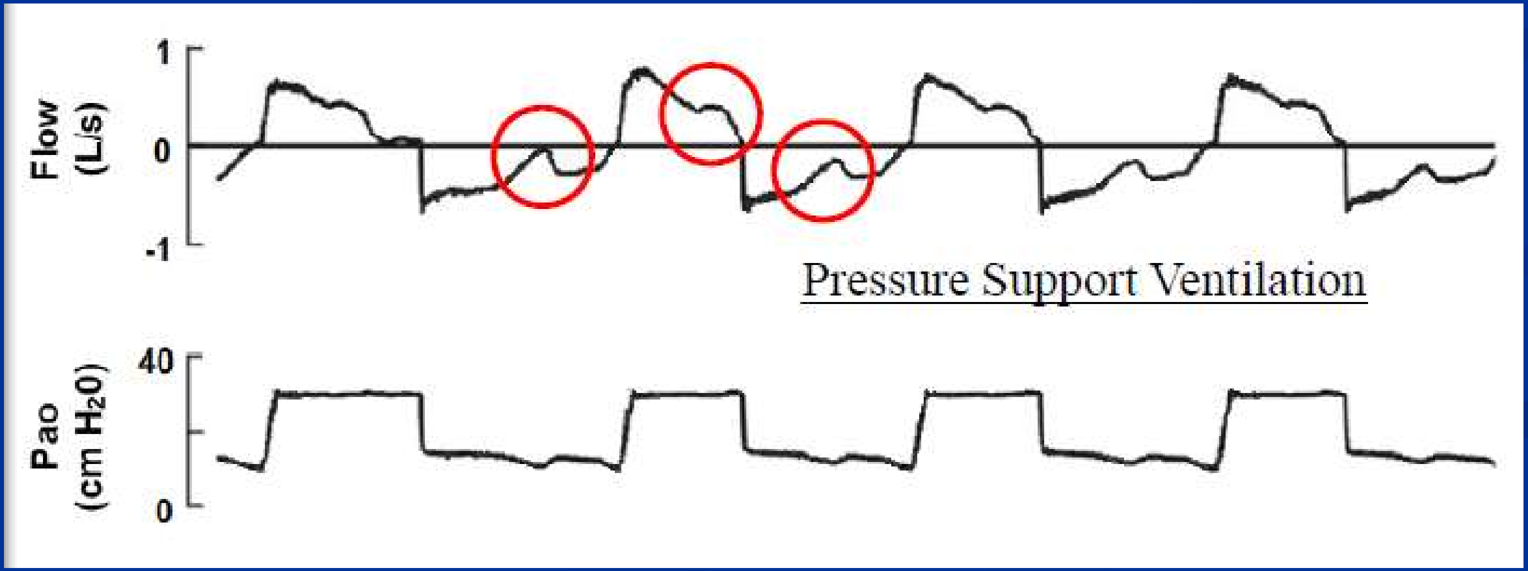
Synchrony

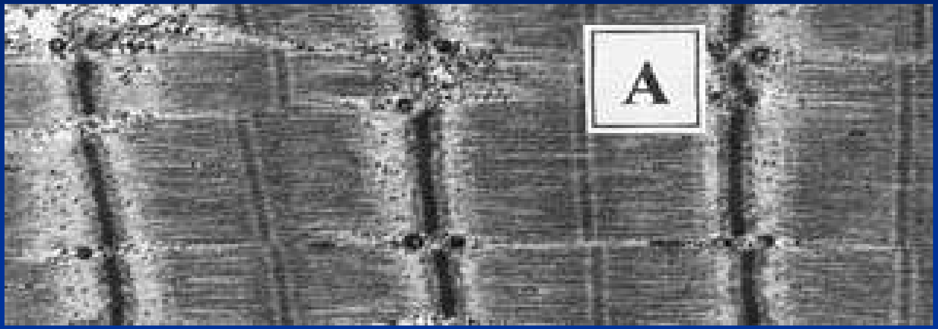


Dyssynchrony

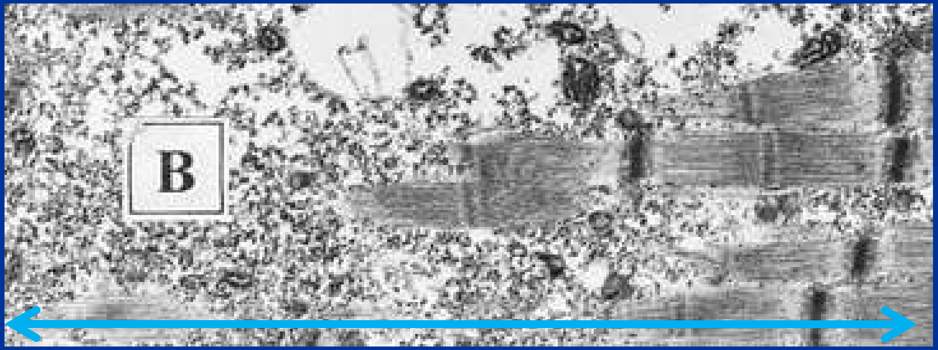
Dyssynchrony:

- 20-30% of patients on ventilators exhibit dyssynchrony
- Patients with frequent ineffective triggering may receive excessive levels of ventilatory support





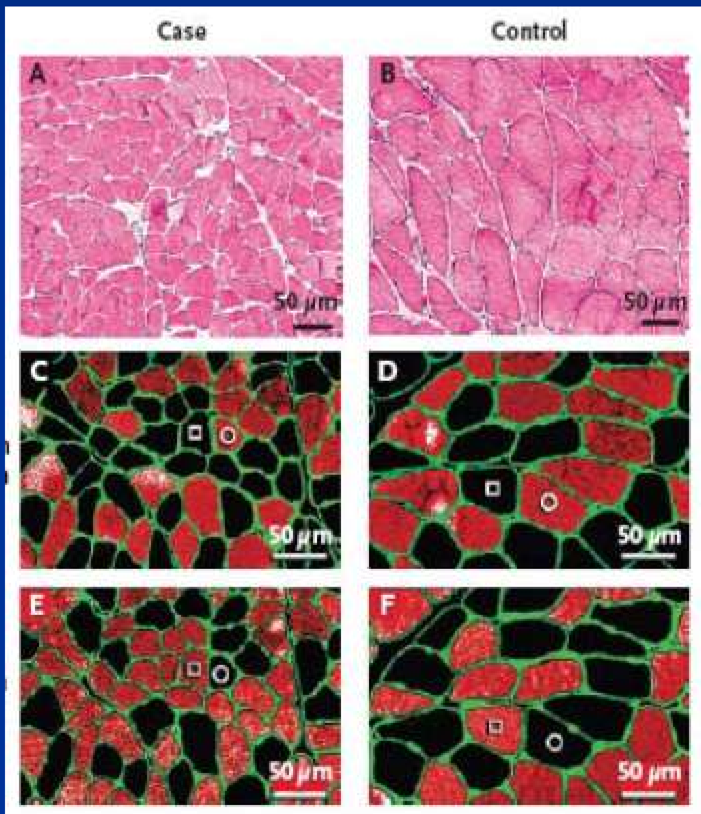
Normal Muscle

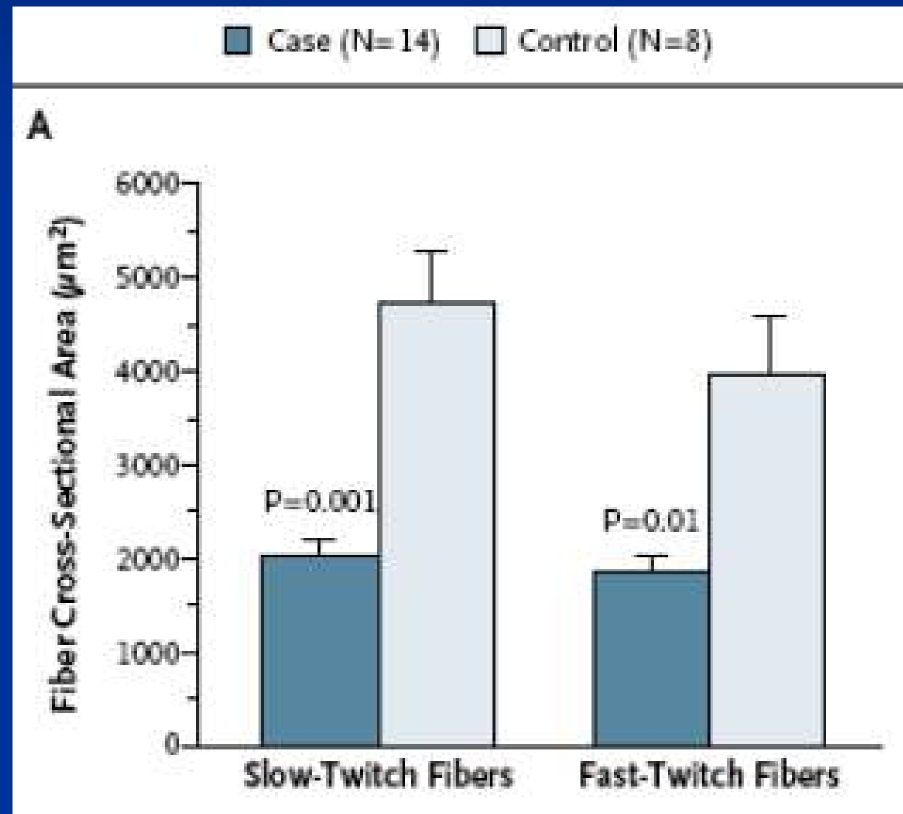


Wasted Efforts

Eccentric contractions

Rapid Disuse Atrophy of Diaphragm Fibers during asynchronous ventilation:





Usual solution to Patient-Ventilator Asynchrony:

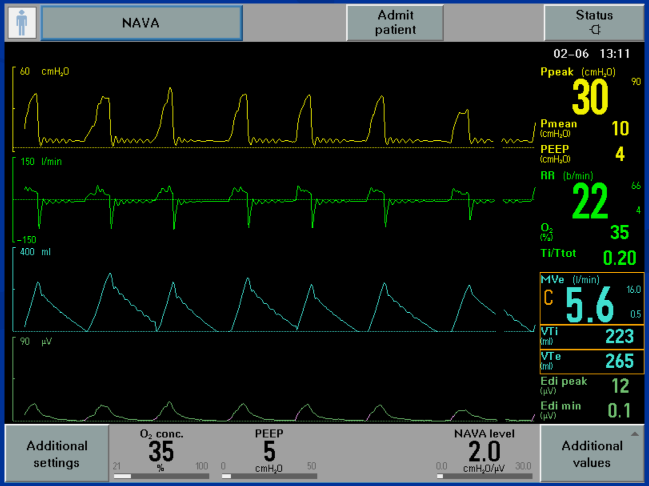
- Adjust Ventilator Settings
- Increase Sedation
- Neuromuscular blockers

2:00 AM PAGE !

Prolonged ICU stay

Neurally Adjusted Ventilatory Assist: **(NAVA)**

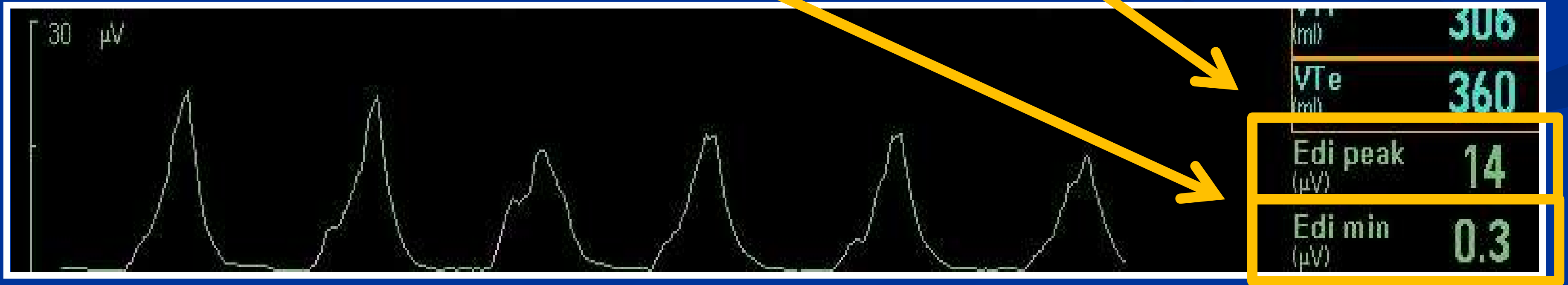
- New **Spontaneous, Interactive** mode of mechanical ventilation
- Delivers ventilatory assist in **Proportion** to and in **Synchrony** with the patient's Edi signal



Edi Signal:

- **Edi - Electrical Activity of diaphragm**
  (measured 62.5 times per second)

  - **Edi Peak** –The amount of impulse **sent to generate tidal volume** breath by breath.
  - **Edi Min** – The **tonic contractility of the diaphragm at rest**. Physiologic reflection of de-recruitment.



Central nervous system

↓

Phrenic nerve

↓

Diaphragm excitation

↓

Diaphragm contraction

↓

Chest wall, lung and esophageal response

↓

flow, pressure changes

Ideal Technology

Ventilator

Current Technology

Ideal Technology

Central nervous system

↓

Phrenic nerve

↓

Diaphragm excitation → **NAVA** →  **Ventilator**

↓

Diaphragm contraction

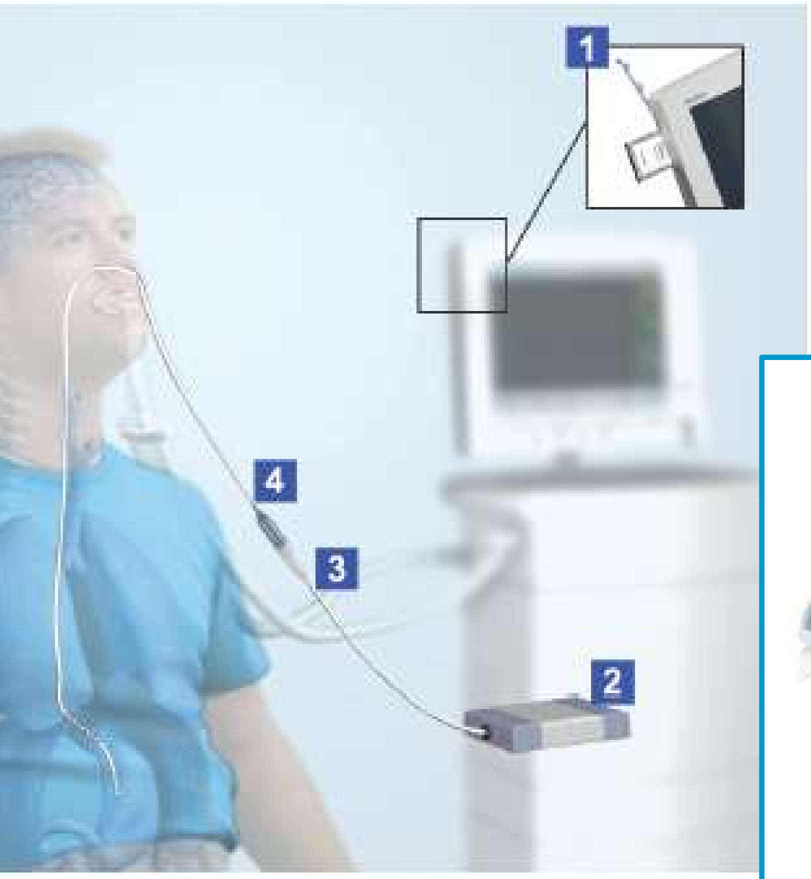
↓

Chest wall, lung and esophageal response

↓

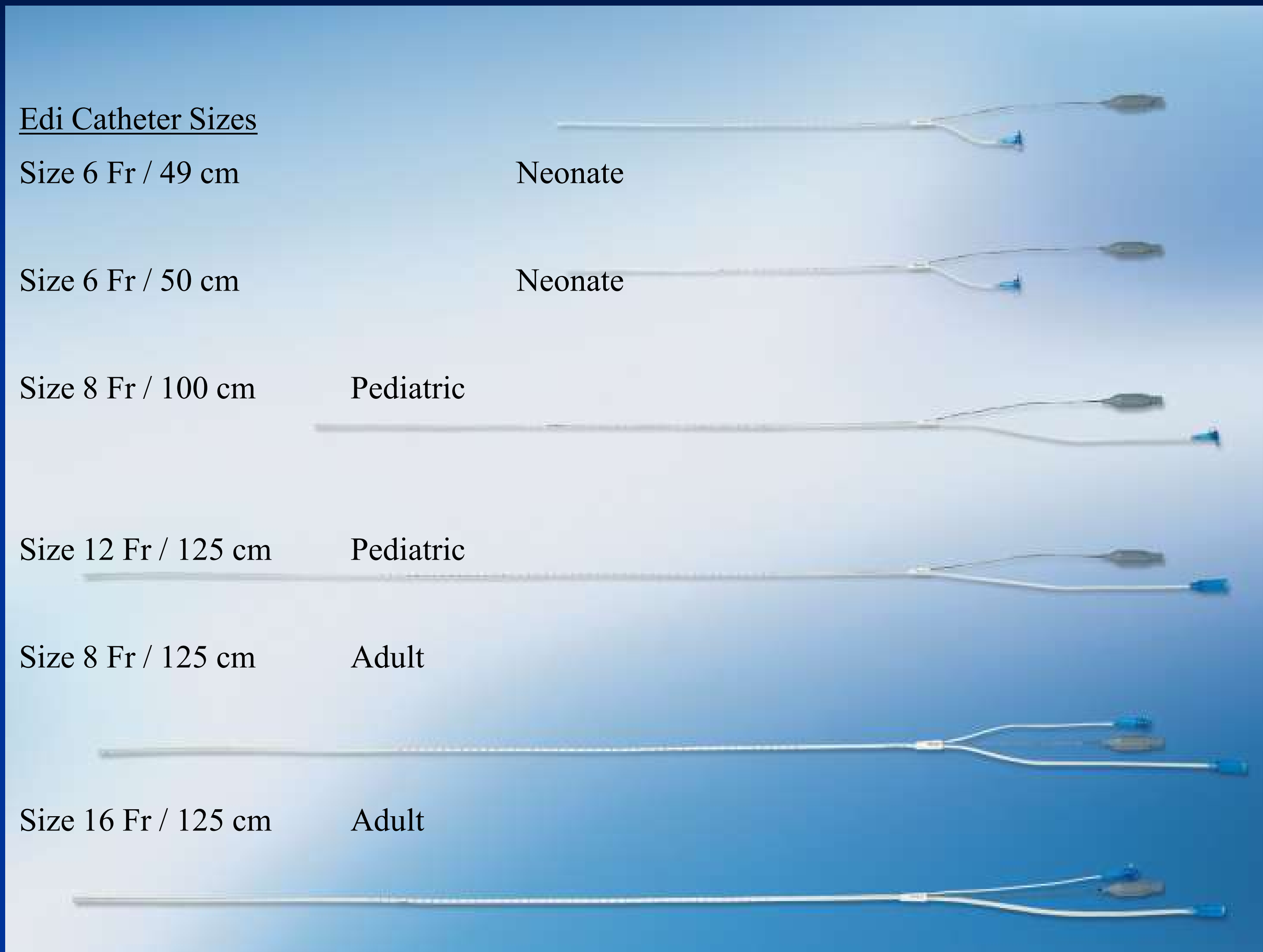
flow, pressure changes

Current Technology



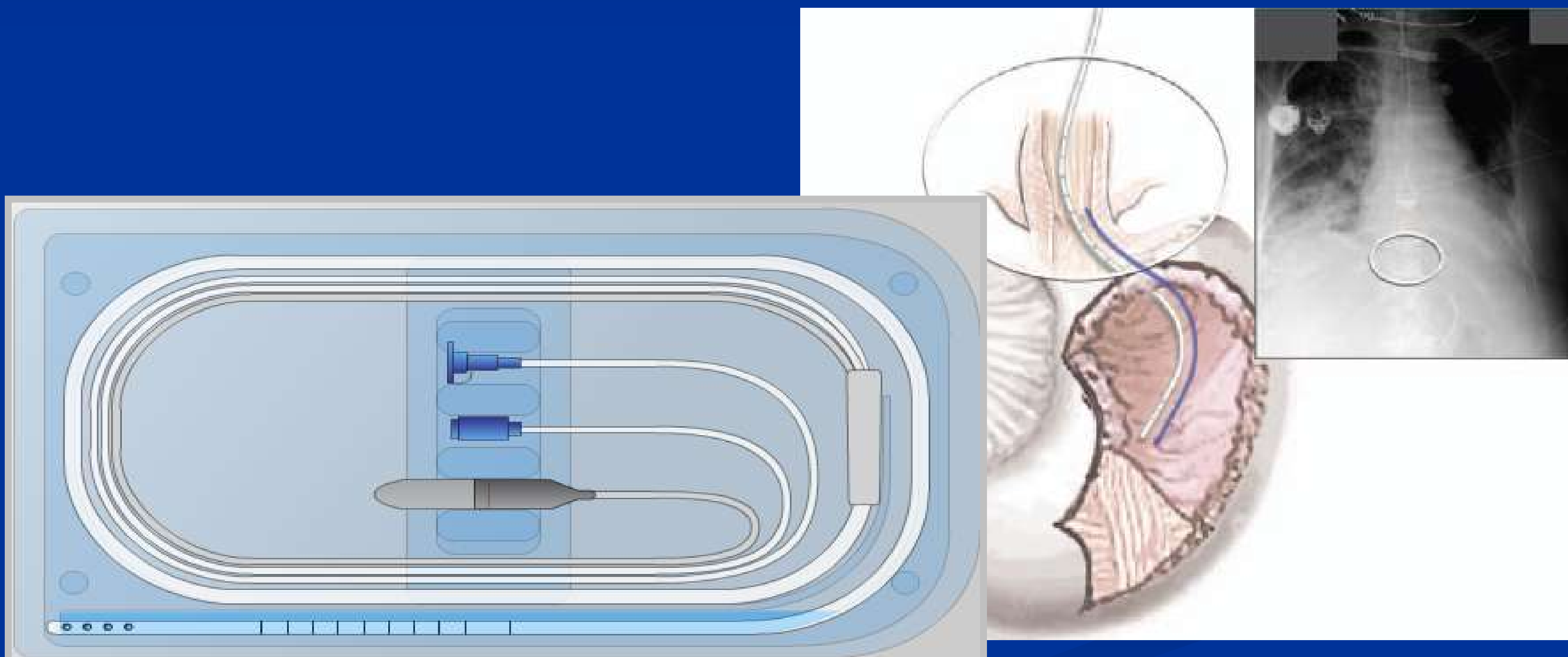
1. NAVA software option – if not already factory-install
   software can be installed using a PC Card.
2. Edi Module
3. Edi Cable
4. Edi Catheter

Servo-i ventilator


Edi Catheter Sizes
Size 6 Fr / 49 cm Neonate
Size 6 Fr / 50 cm Neonate
Size 8 Fr / 100 cm Pediatric
Size 12 Fr / 125 cm Pediatric
Size 8 Fr / 125 cm Adult
Size 16 Fr / 125 cm Adult

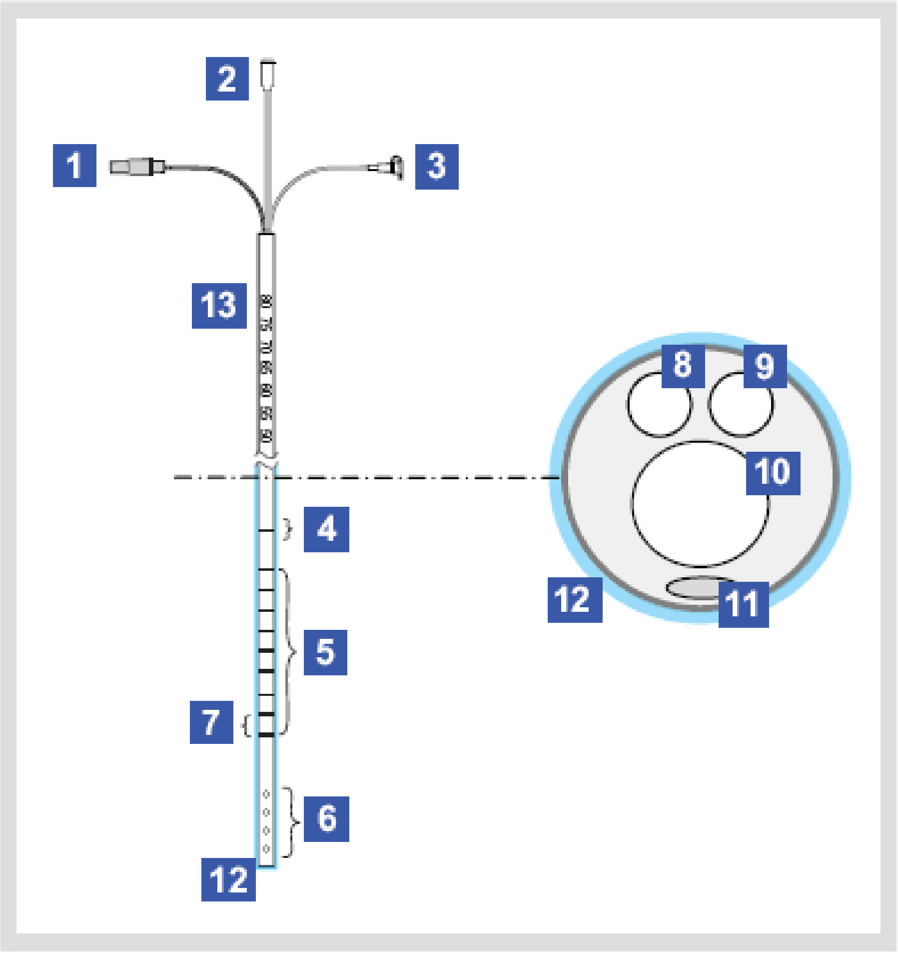
Instructions for catheter:

1. Dip the Edi Catheter in **water** for a few seconds to activate its lubrication prior to insertion, avoiding wetting connectors.
2. Insert Catheter and advance it down the esophagus
3. Confirm placement



Edi Catheter Anatomy:

1. Connection to Edi cable
2. Nutrition feed
3. Evacuation (only 12 and 16 Fr)
4. Reference electrode
5. Electrodes (9)
6. Holes for nutrition/evacuation
7. Inter Electrode Distance (IED)
8. Lumen for electrodes
9. Sump lumen (only 12 and 16 Fr)
10. Feeding lumen
11. Barium strip for X-ray identification
12. Coating for easier insertion and better electrical conductivity (indicated in the picture with light blue)
13. Scale in centimeters from the tip

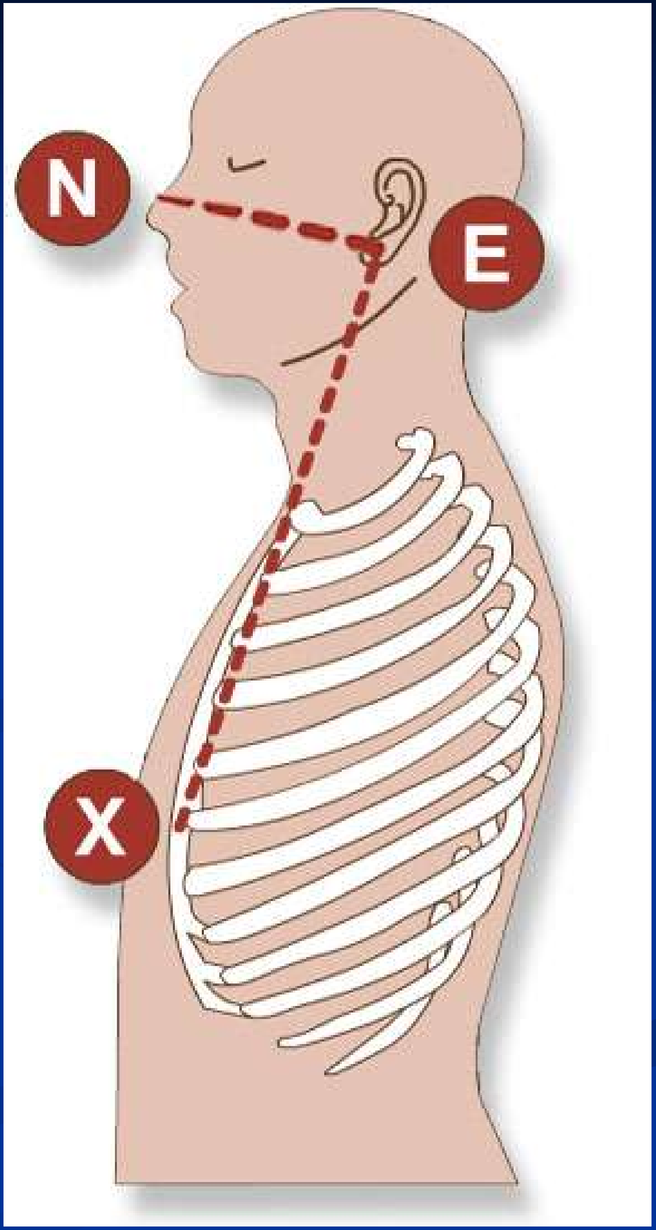


Insertion Depth:

Coefficient for nasal insertion = 0.9

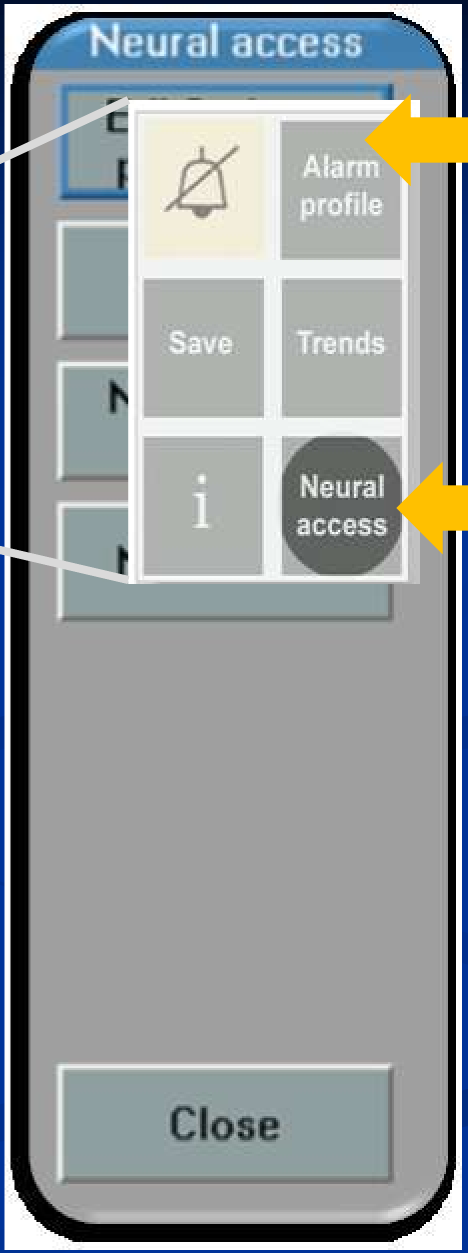
Coefficient for oral insertion = 0.8

Insertion distance Y for oral insertion	
Fr/cm	**Calculation of Y**
16 Fr	NEX cm · 0.8 + 18 = Y cm
12 Fr	NEX cm · 0.8 + 15 = Y cm
8 Fr 125 cm	NEX cm · 0.8 + 18 = Y cm
8 Fr 100 cm	NEX cm · 0.8 + 8 = Y cm
6 Fr 50 cm	NEX cm · 0.8 + 3.5 = Y cm
6 Fr 49 cm	NEX cm · 0.8 + 2.5 = Y cm

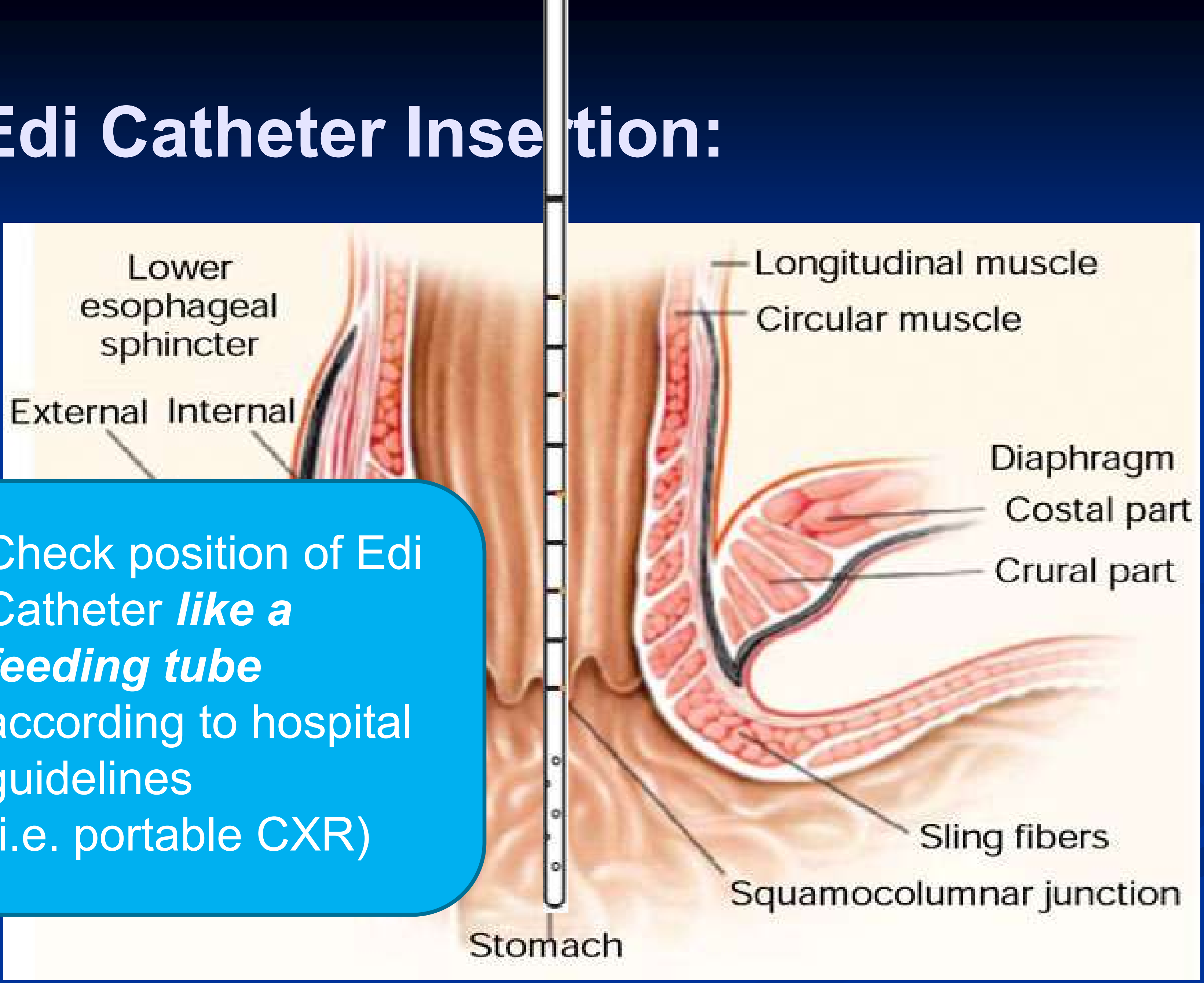


D. Rowley, Univ of Virginia, Resp Therapy Dept.

Catheter Insertion:



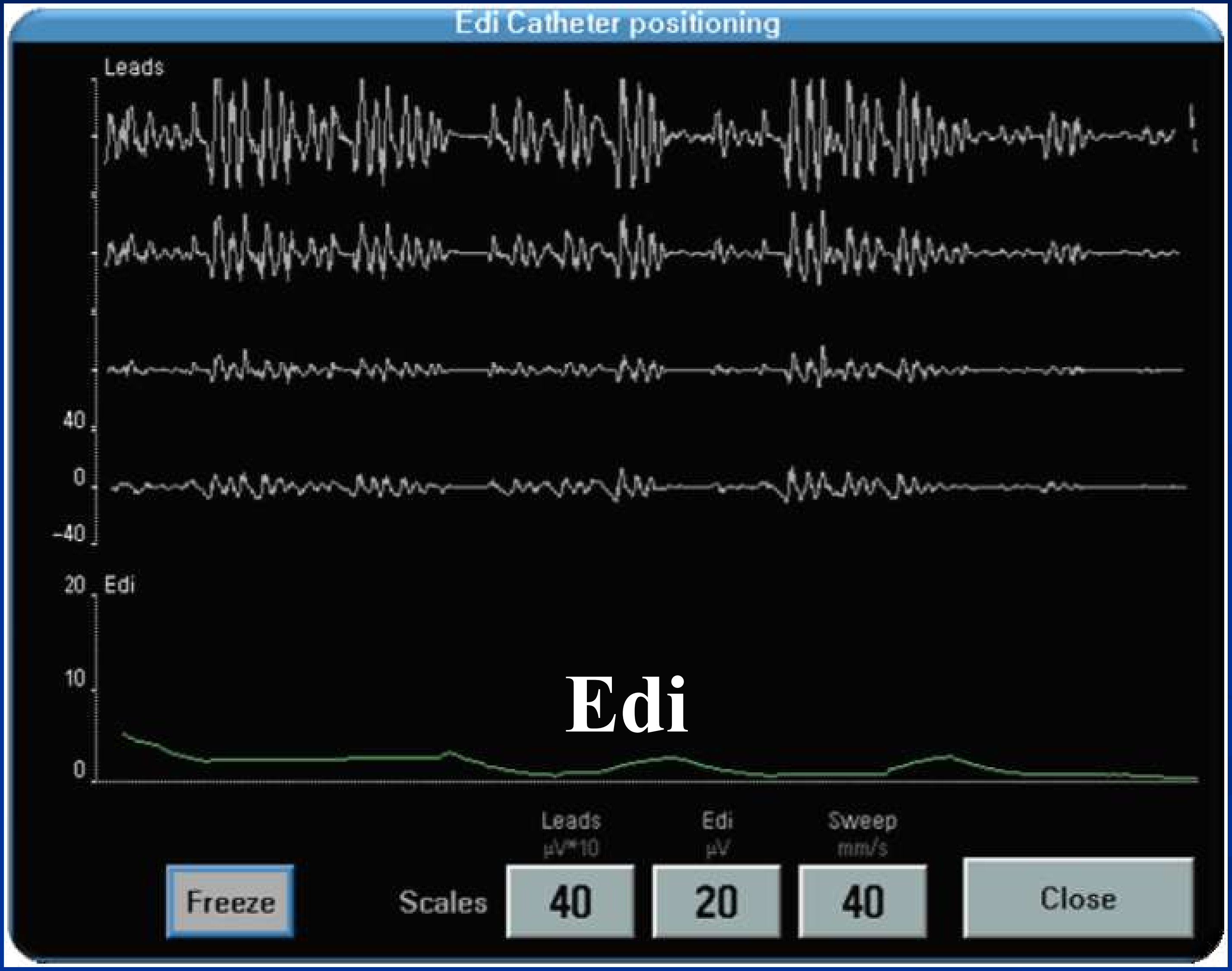
Edi Catheter Insertion:

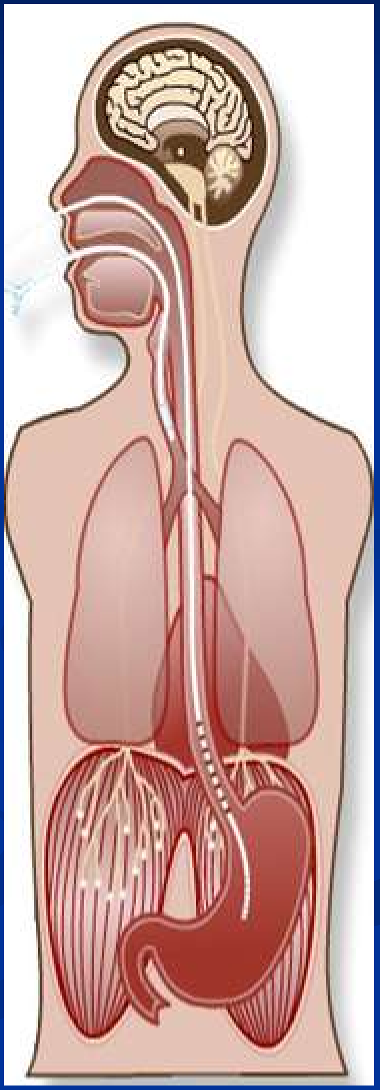


Check position of Edi Catheter ***like a feeding tube*** according to hospital guidelines
(i.e. portable CXR)

D. Rowley, Univ of Virginia, Resp Therapy Dept.

Catheter Insertion:



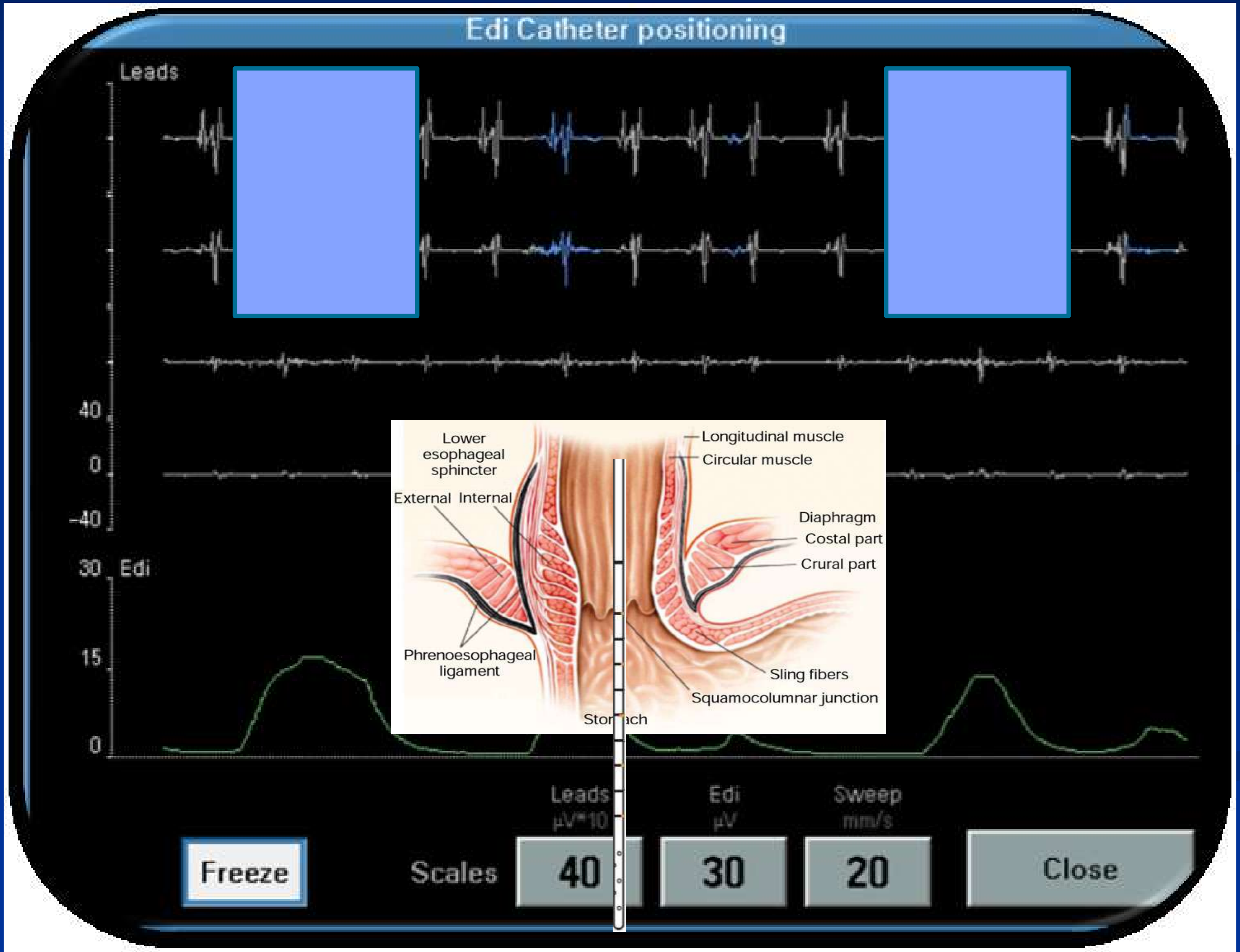


D. Rowley, Univ of Virginia, Resp Therapy Dept.

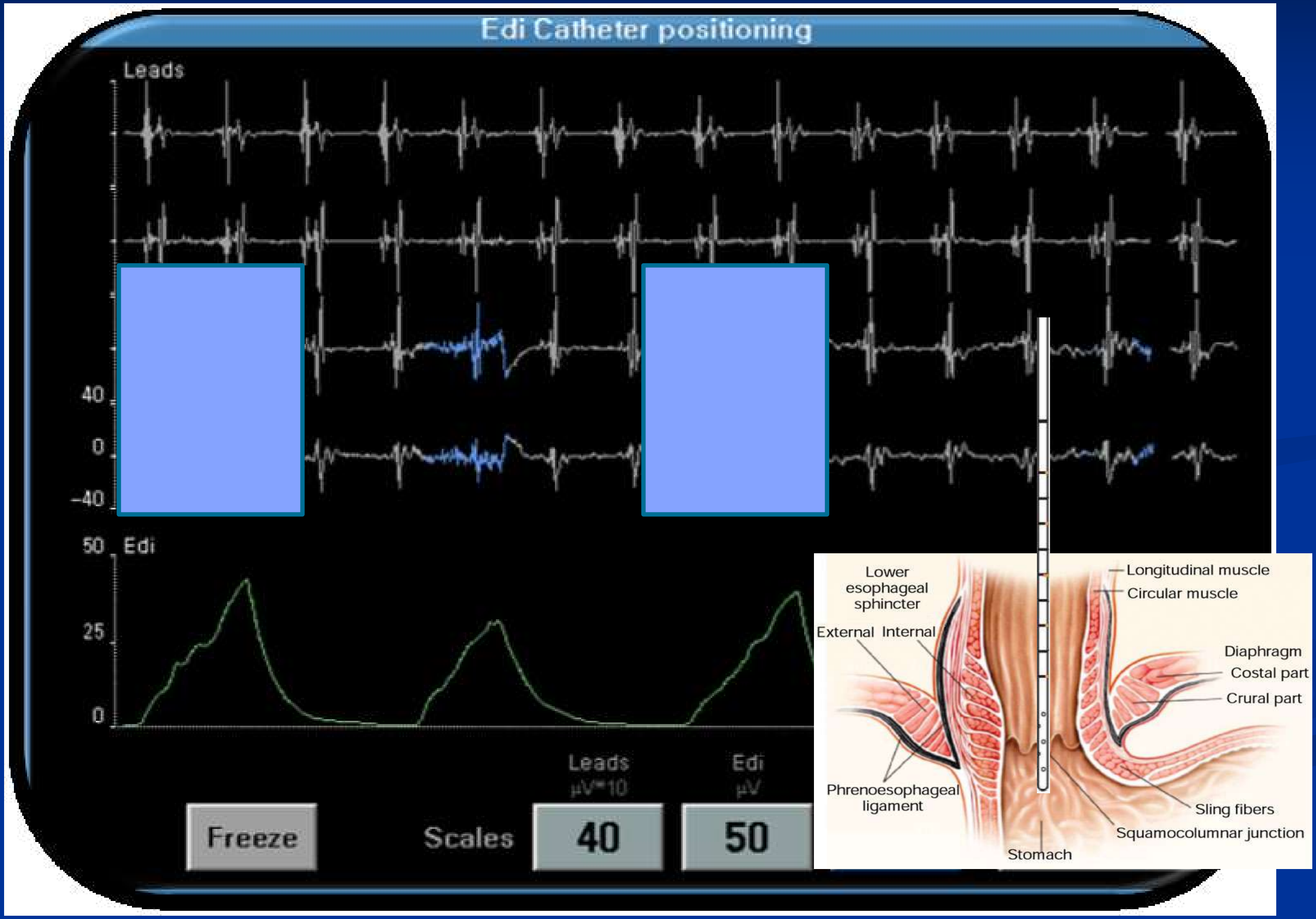
Good position:

D. Rowley, Univ of Virginia, Resp Therapy Dept.

Too Deep… (pull catheter back)

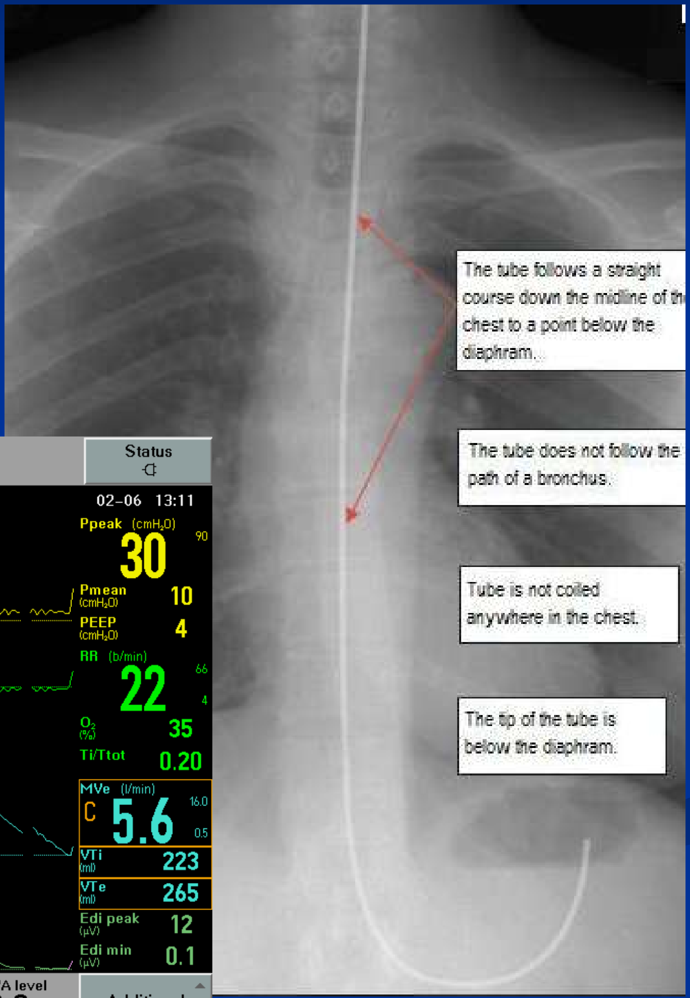


Too Shallow.. (advance catheter)

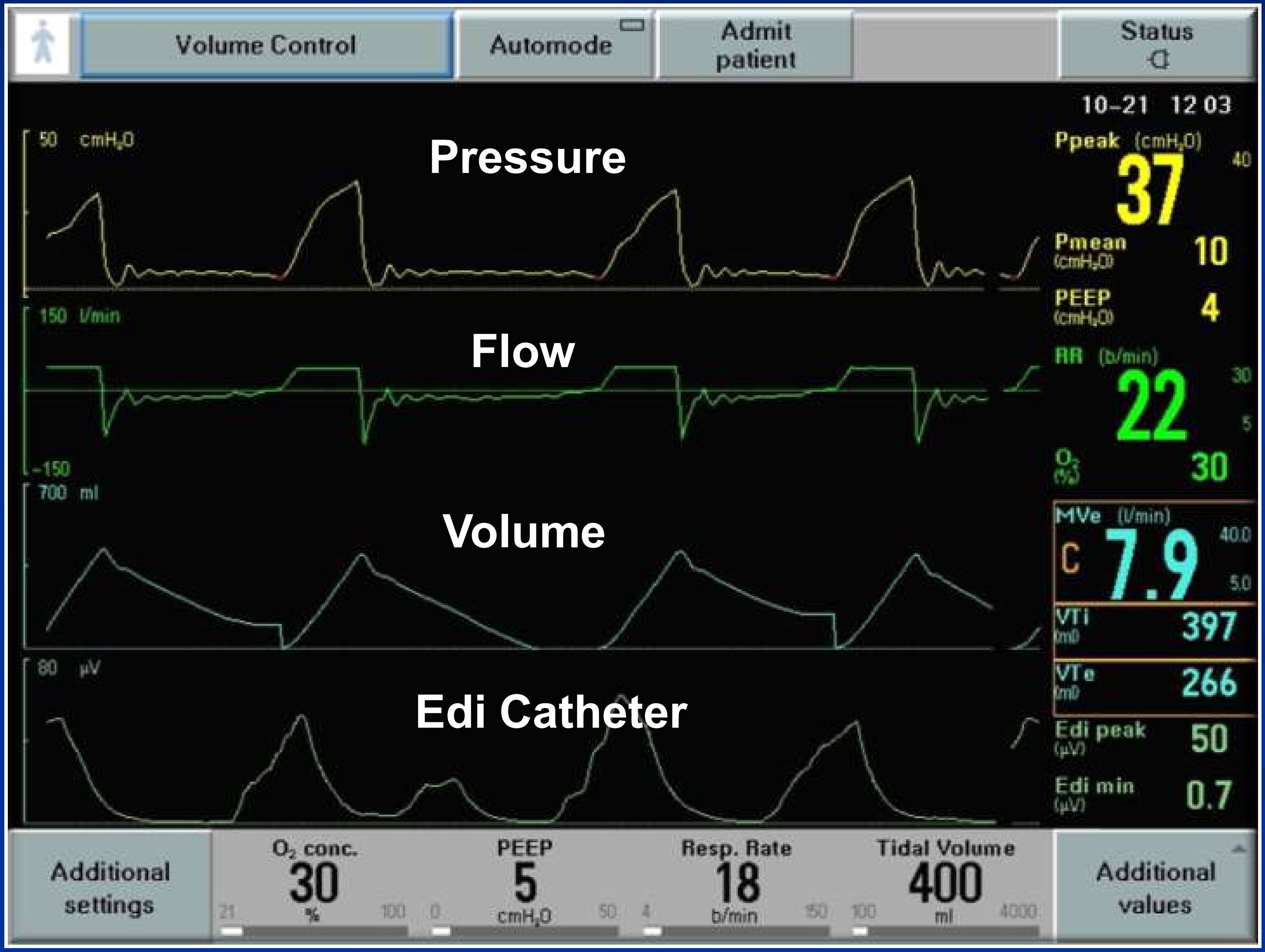


Factors affecting Edi signal:

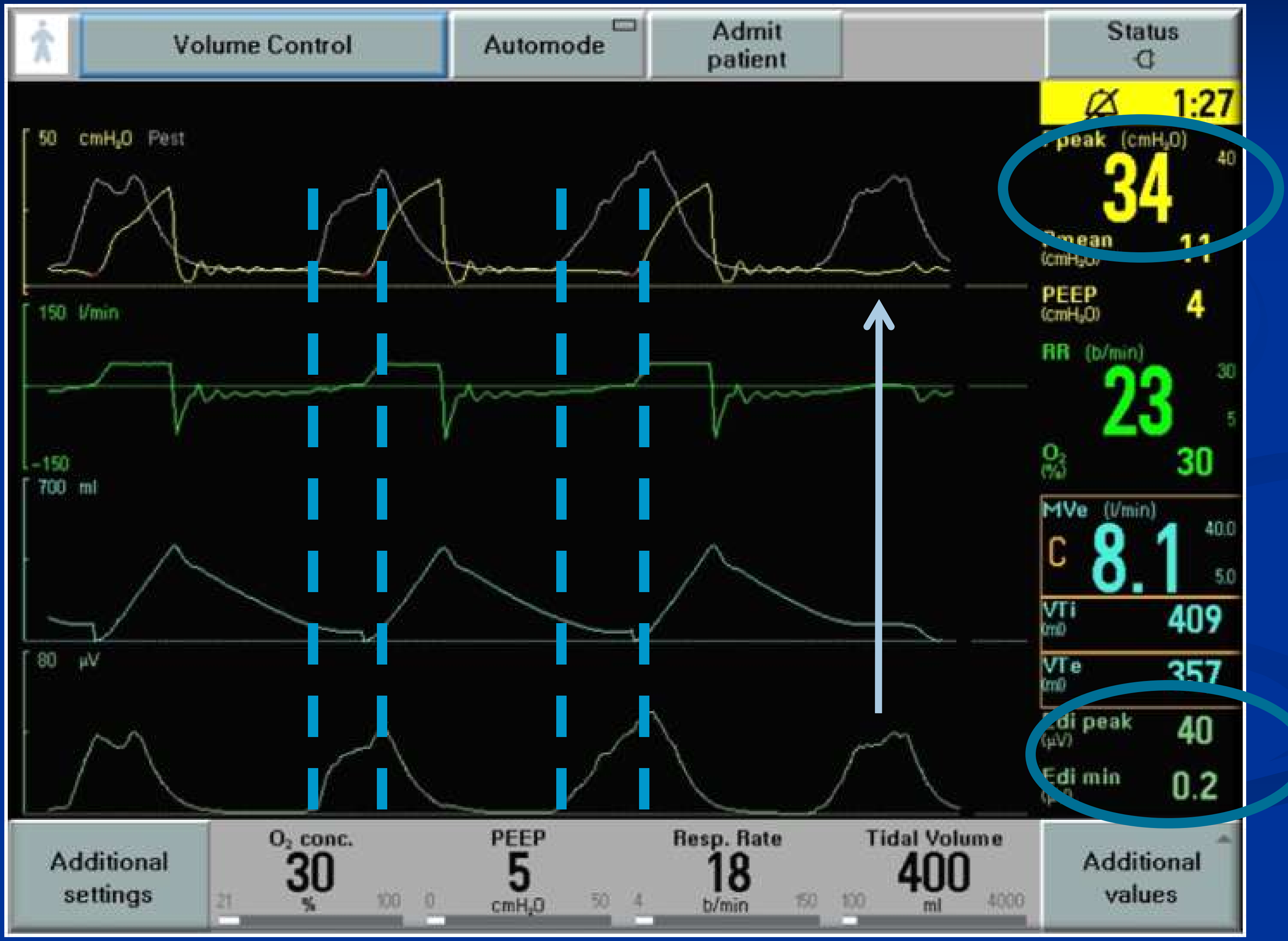
- Muscle relaxants / paralytics
- CNS depressant drugs, sedation
- Hyperventilation
- High PEEP , High support pressure



Volume Control with Edi:

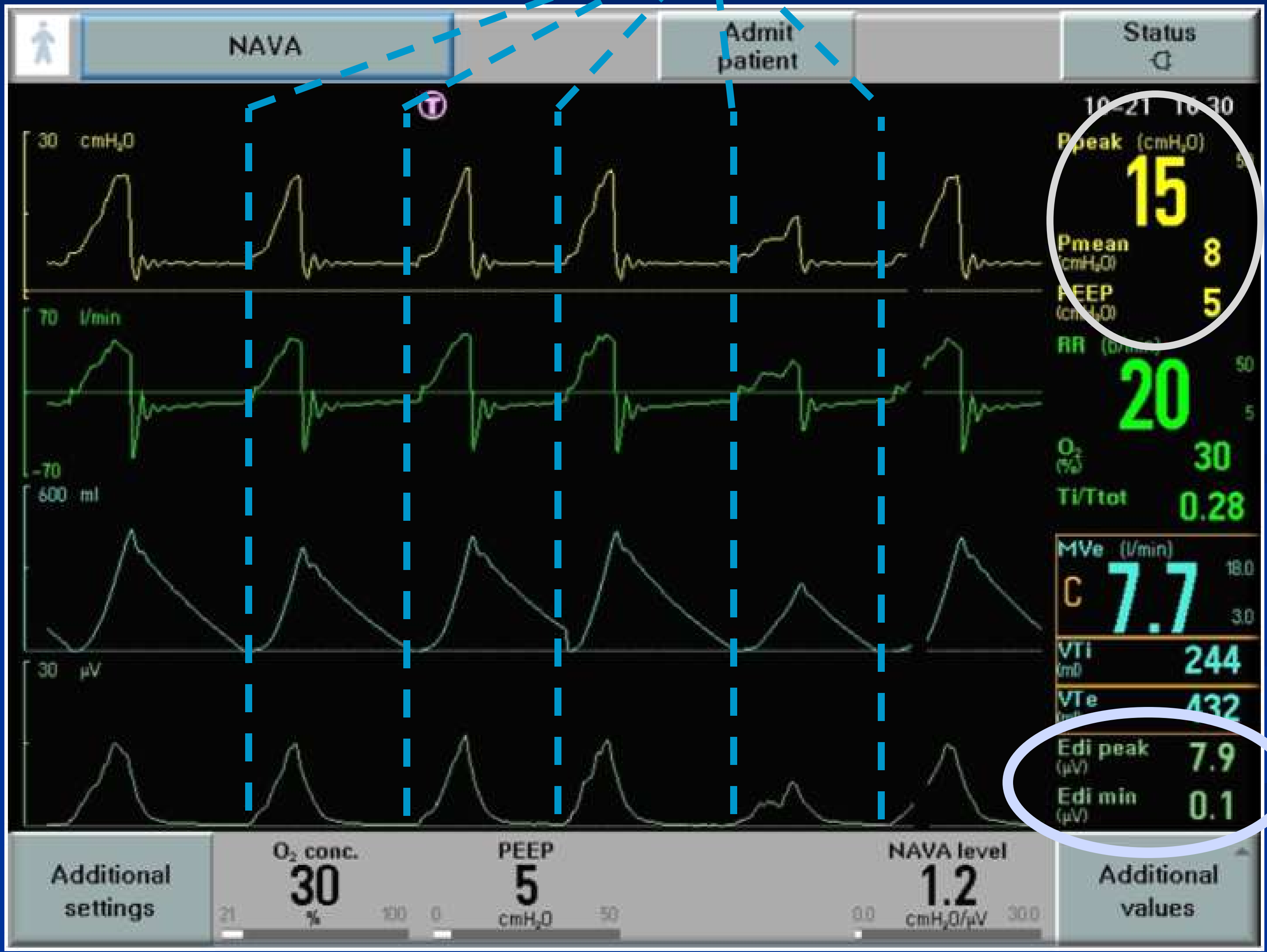


NAVA Pre-view: *unmasking asynchrony*



Same patient on NAVA:

Breath to Breath Synchrony
Decreased Airway Pressure

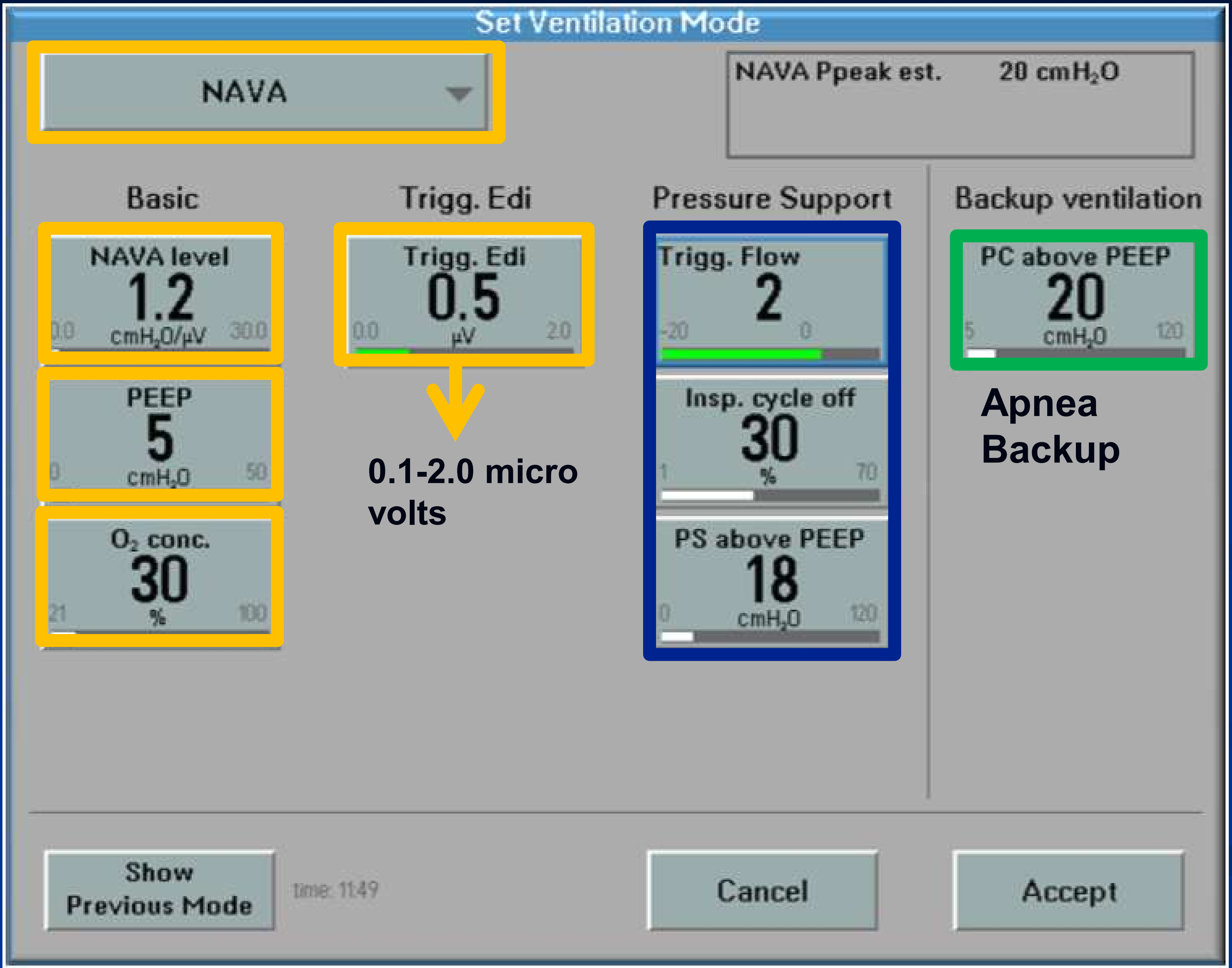


Asynchrony during VC:

D. Rowley, Univ of Virginia, Resp Therapy Dept.

Same Patient on NAVA:

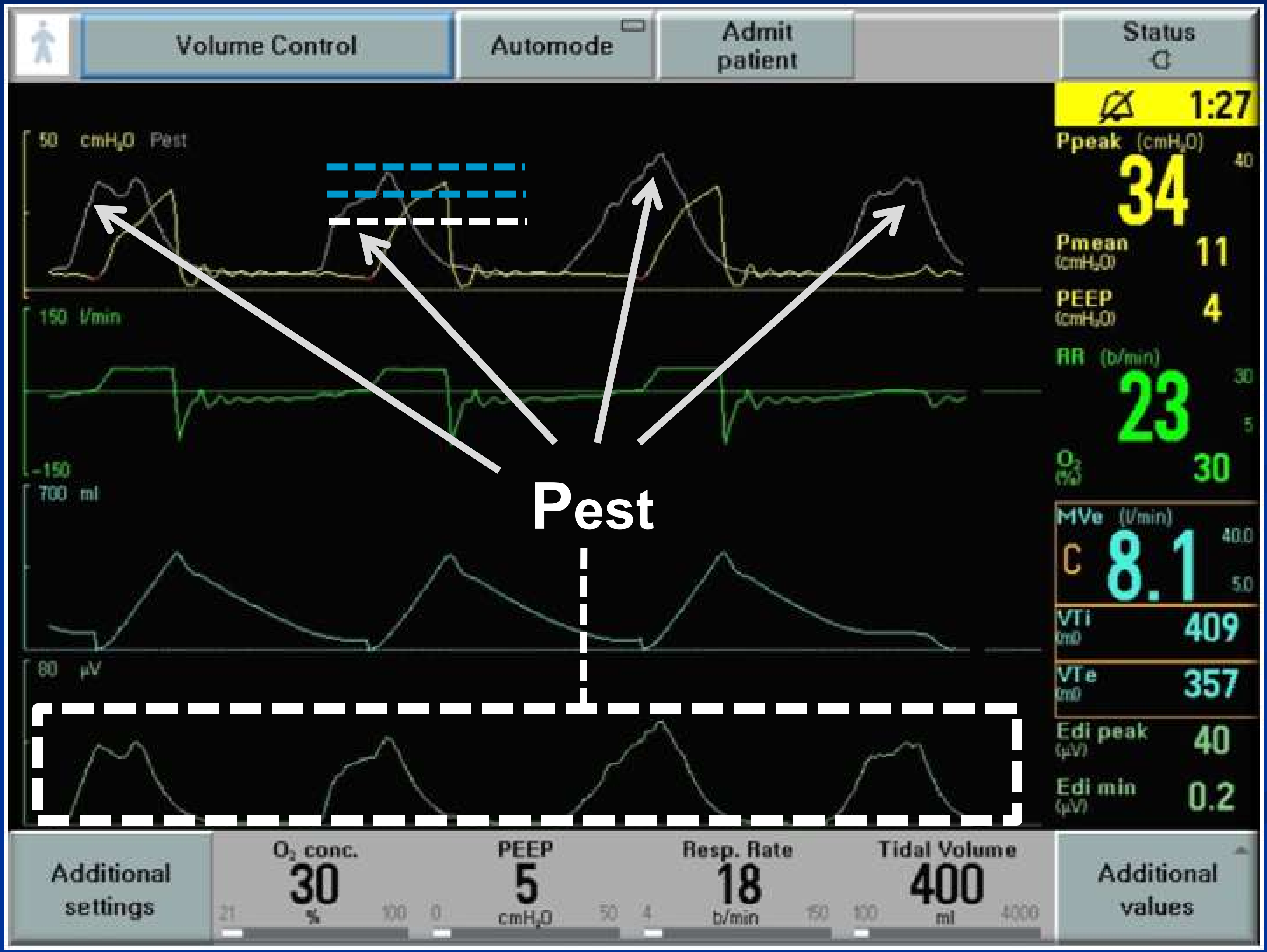
D. Rowley, Univ of Virginia, Resp Therapy Dept.


Set Ventilation Mode
NAVA
NAVA Ppeak est. 20 cmH2O
Basic
Trigg. Edi
Pressure Support
Backup ventilation
NAVA level
1.2
0.0
cmH2O/μV
30.0
Trigg. Edi
0.5
0.0
μV
2.0
Trigg. Flow
2
-20
0
PC above PEEP
20
5
cmH2O
120
PEEP
5
0
cmH2O
50
Insp. cycle off
30
1
%
70
O2 conc.
30
21
%
100
PS above PEEP
18
0
cmH2O
120
0.1-2.0 micro volts
Apnea Backup
Show Previous Mode
time: 11:49
Cancel
Accept

Starting NAVA: Preview Screen

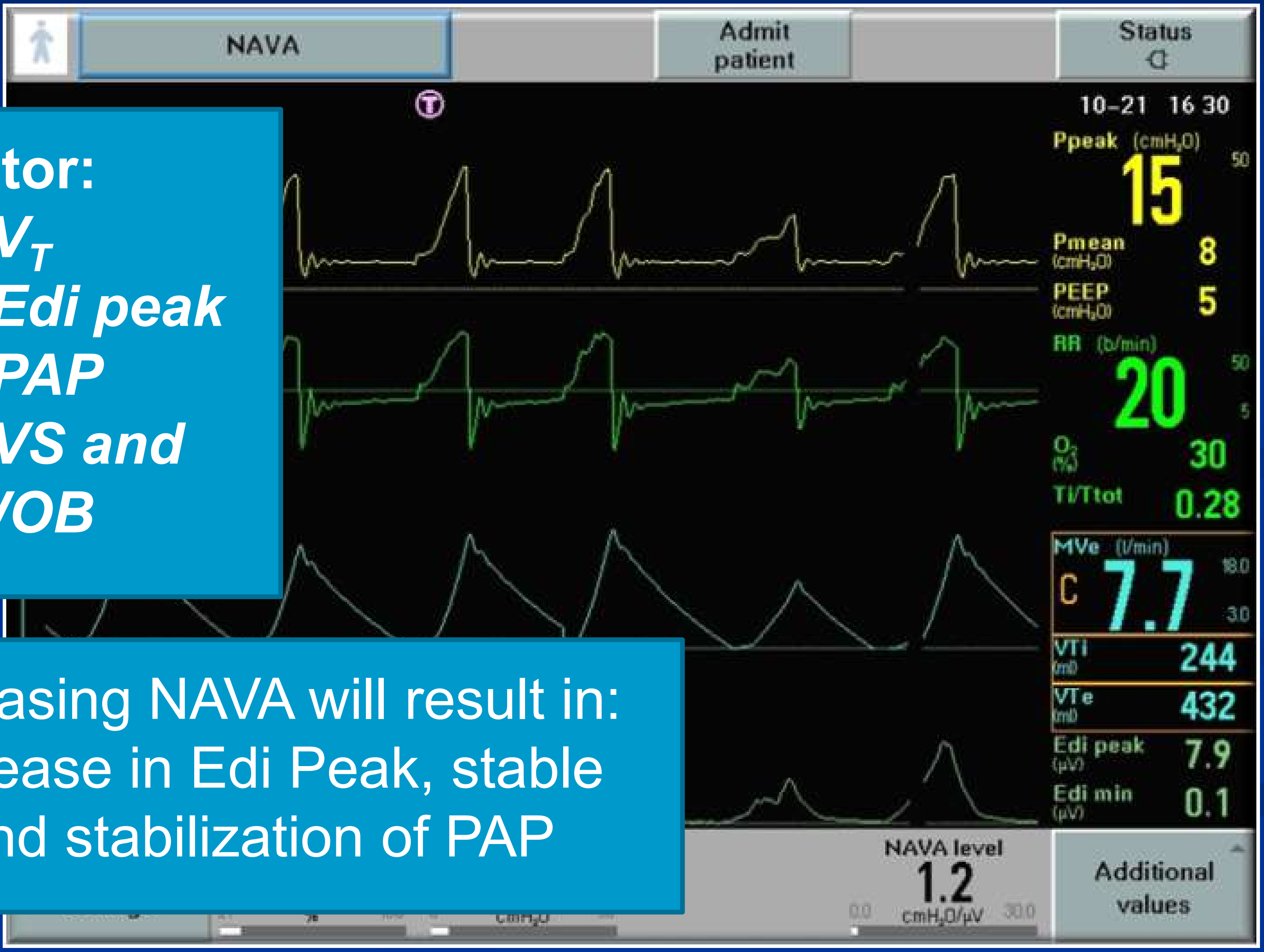
D. Rowley, Univ of Virginia, Resp Therapy Dept.

Increase NAVA level until Pest peak = current PAP



Estimated Ppeak (Pest) in NAVA = NAVA Level x (Edi peak – Edi min) + PEEP

Activate NAVA mode



Monitor:

- V_T
- *Edi peak*
- *PAP*
- *VS and WOB*

Increasing NAVA will result in: Decrease in Edi Peak, stable Vt, and stabilization of PAP

D. Rowley, Univ of Virginia, Resp Therapy Dept.

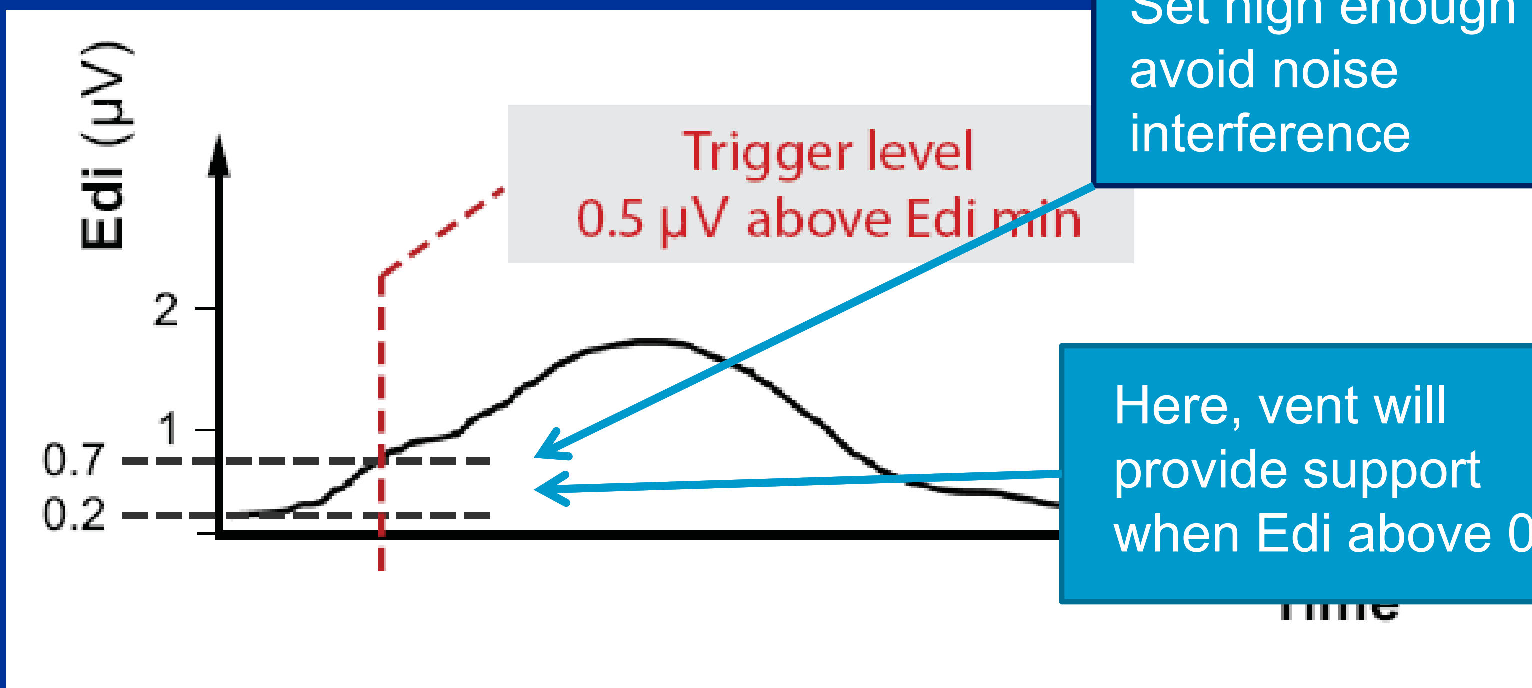
NAVA Inspiration:

- Triggering of a breath is either **Edi**, **flow** or **pressure** trigger
- Even if the breath is triggered on flow or pressure, **the breath delivered to the patient remains proportional to the patient's Edi signal**
- **1st come 1st serve basis**

1: Edi Triggered Breath
2: Flow Triggered Breath

NAVA Inspiratory Trigger:

- NAVA is triggered by an increase in Edi from the Edi minimum and not at any absolute level of Edi



Set high enough to avoid noise interference

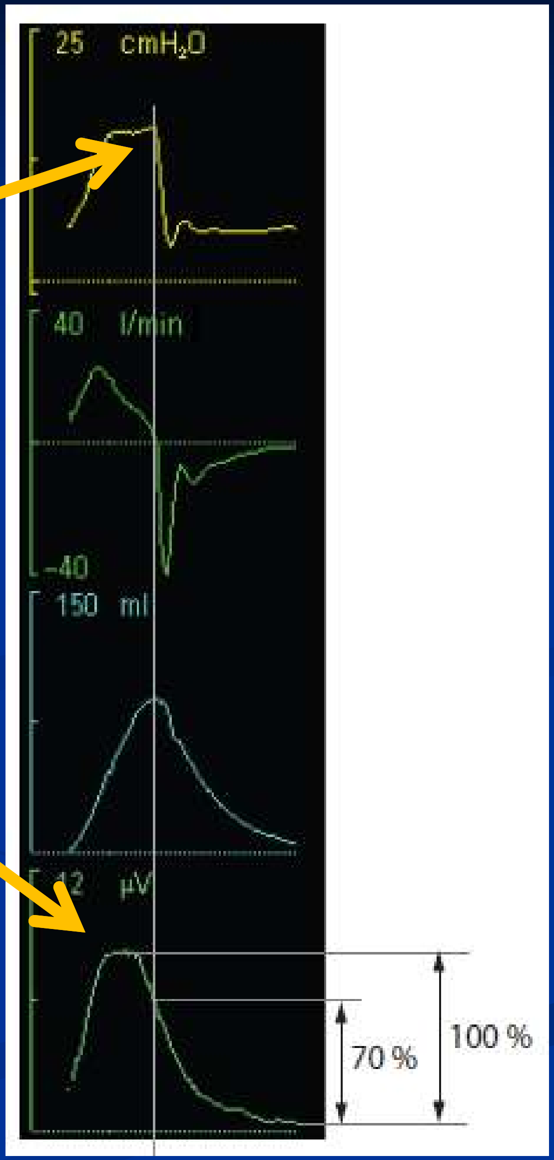
Here, vent will provide support when Edi above 0.7

Neth J Crit Care 2007:11(5):243-252

NAVA Expiration:

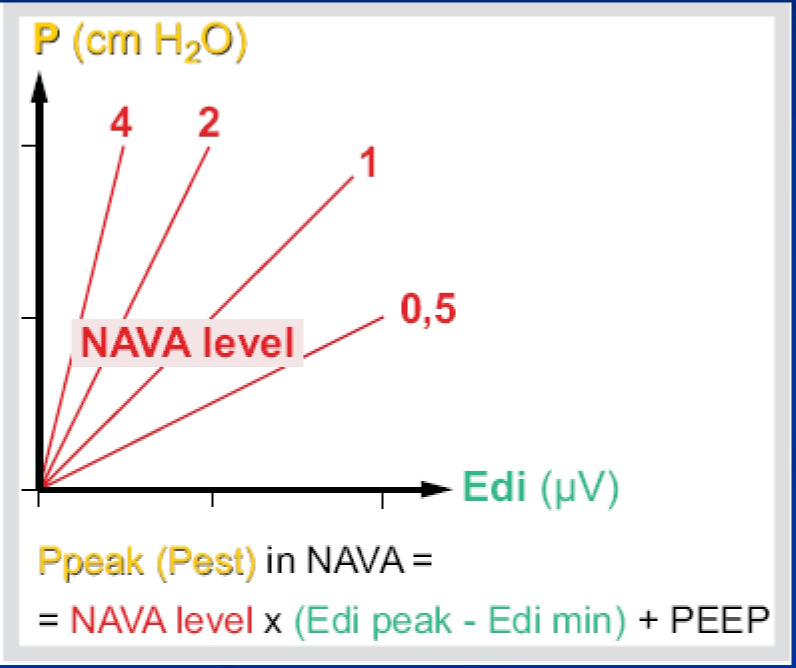
- If the **pressure** increases 3 cmH2O above the inspiratory target pressure
- When the Edi signal decreases **below 70%** of the peak value during the ongoing inspiration
- Also, If the upper pressure/time limit is exceeded

  (time for adults = 2.5 sec)

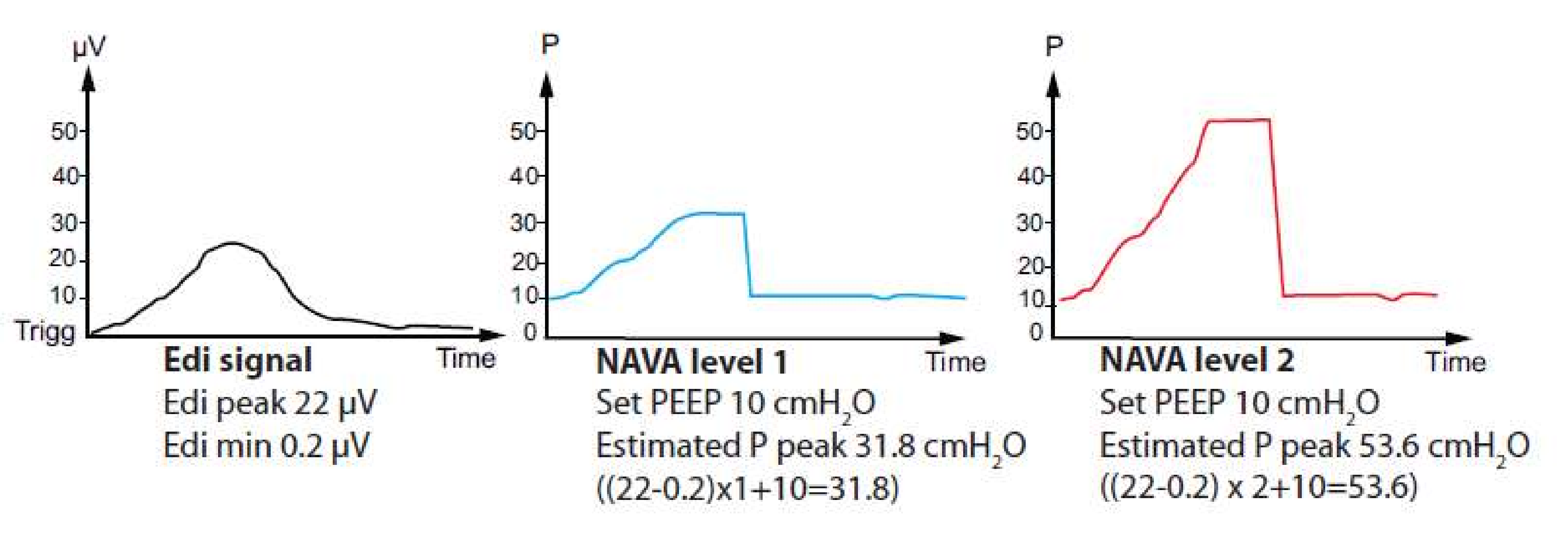


The NAVA signal – *what it means*

- NAVA level is **the factor by which the Edi signal is multiplied to adjust the amount of assist delivered to the patient**
- NAVA level **varies** for different patients because they will require different assist levels.
- Typically **1.0 - 4.0** cmH20/µV



Am J Respir Crit Care Med 2001
Nat Med 1999; 5(12): 1433-1436



The pressure delivered by the ventilator is derived from the following formula:

NAVA level x (Edi signal – Edi min) + PEEP

Am J Respir Crit Care Med 2001
Nat Med 1999; 5(12): 1433-1436

NAVA: Physiologic Principles

- Neural signal is increased as respiratory muscles weaken relative to load
- Synchrony in assist delivery is inherent
- Unloading can be done objectively
- Proportional assist gives freedom for variable breathing
- Patient ‘Oscillator’ controls breath timing and tidal volume

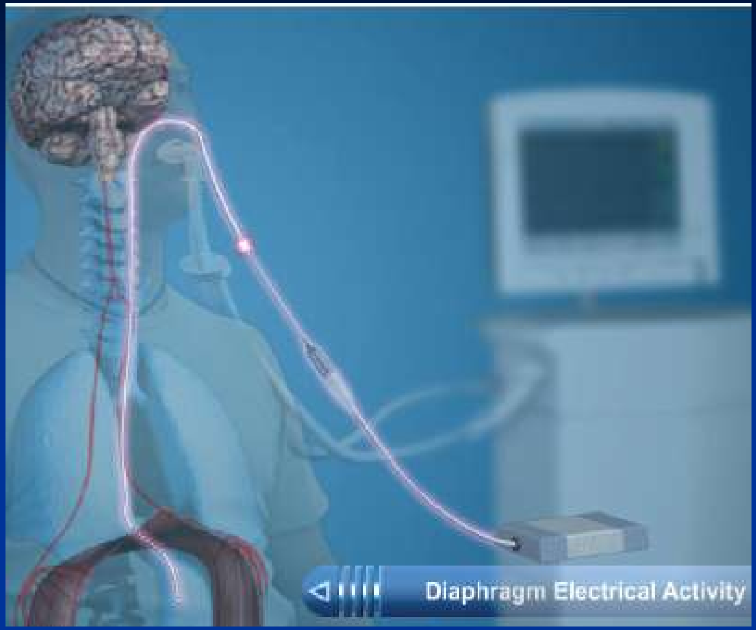
What we know so far…

- NAVA Improves patient ventilator synchrony
  (potentially less sedation)
- Allows real time monitoring of respiratory drive
- Adapts to patient's altered respiratory drive and reflexes
- Less damage to muscles, less disuse atrophy

Neth J Crit Care 2007:11(5):243-252
Chest 2007; 131(3): 711-717

Applications

- Good tool for weaning..
  - Can **watch Edi signal decrease as respiratory function improves**
- Proportional assist gives freedom for variable breathing
- The patient will control **Tidal Volume & Respiratory Rate**



Applications:

- Spinal Cord Injury
- Cardiothoracic surgery
- Edi signal as a tool to detect over-sedation and neuromuscular recover (ie. Guillan Bare)

Limitations:

- Lack of large randomized clinical trials
- Uncertainty whether synchrony leads to better outcome
- Reliability of equipment – NAVA Catheter integrity after prolonged ventilation
- Cost of equipment and resources