Patient Ventilator Synchrony

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Controlled vs Assisted MV

- Controlled
  - Machine determined rate and VT
    - Patient does no work
    - Useful in florid resp failure with fatigued muscles?
    - Need for excessive NMBs?
- Assisted
  - pt. triggers and interacts with the breath
    - Load depends on effort and applied support
    - Risk of fatigue, asynchrony/"fighting"

Controlled vs Assisted MV

- Clinically, assisted offers opportunity to avoid NMBs, maintain muscle function
  - Shorter length of mechanical ventilation
  - Less long term myopathy

AJRCCM 2004;169:336, NEJM 2008;358:1527, CCM 1997;25:1187

Controlled vs Assisted MV

- General consensus is to use assisted modes as soon as clinically possible
- However, assisted modes require patients and ventilators to interact
  - These interactions must be synchronous and comfortable
  - asynchrony and discomfort leads to unnecessary sedation needs and muscle overload

Factors the Affect Patient Ventilator Synchrony

Patient

- Sedation level
- Inspiratory effort/neural timing
- Respiratory system mechanics
- Intrinsic PEEP
- Size and type of airway
- Presence of leaks

Ventilator

- Trigger variables
- Rise time capability
- Flow response
- Cycling criteria

- What is Patient Ventilator Asynchrony (PVA) and how do you recognize it?
- How often does PVA occur?
- New modes designed to increase synchrony
  - PAV, NAVA

Patient Ventilator Asynchrony (PVA)

- When the ventilator trigger, gas delivery and/or cycle to expiration does not match patient demand
  - Can be too much or too little
- Has been termed a “tug of war” between the patient and ventilator

Effects of PVA

- Pt “fights” the ventilator
  - Sedation
- Higher WOB
- Dynamic hyperinflation
- Muscle damage
- Delayed or prolonged weaning
- Longer stays/higher costs

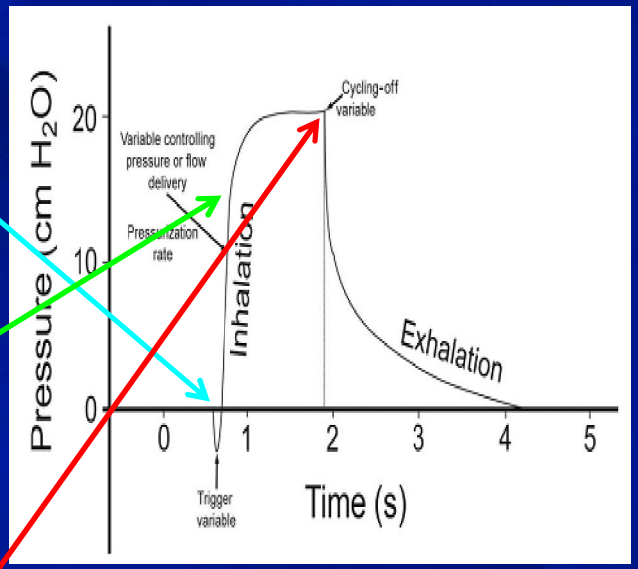
Types of PVA

- Delayed triggering
- Missed triggering
- Auto triggering
- Flow asynchrony
- Premature cycling
- Delayed cycling

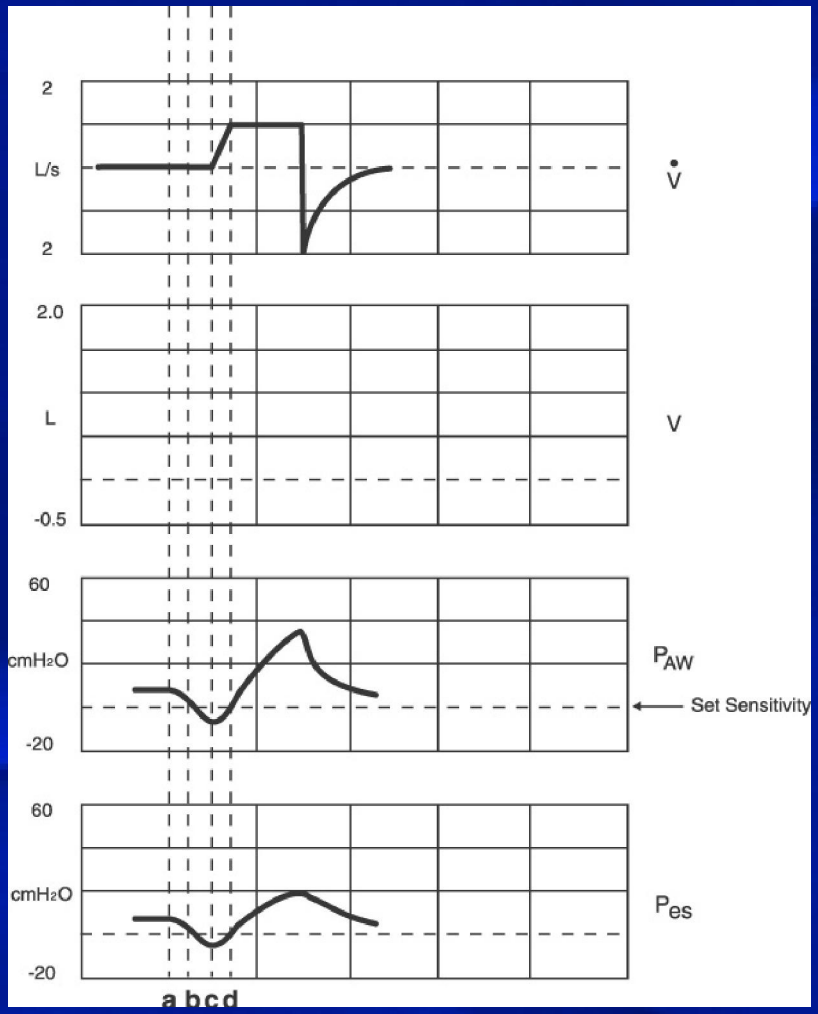
Onset

During

Termination



Triggering



A – start of neural inspiration

B – Vent recognition

C – Initiation of breath

D – Peak flow reached

Flow vs Pressure Trigger

- Though initial clinical studies indicated that flow-triggering offered some advantage in reducing PVA, recent advances in the development of pressure transducers have resulted in comparable results:
  - Calzia, Intensive Care Med 1998;24:931
  - Richard, Intensive Care Med 2002;28:1049
  - Takeuchi, Anaesthesiology 2002;96:162

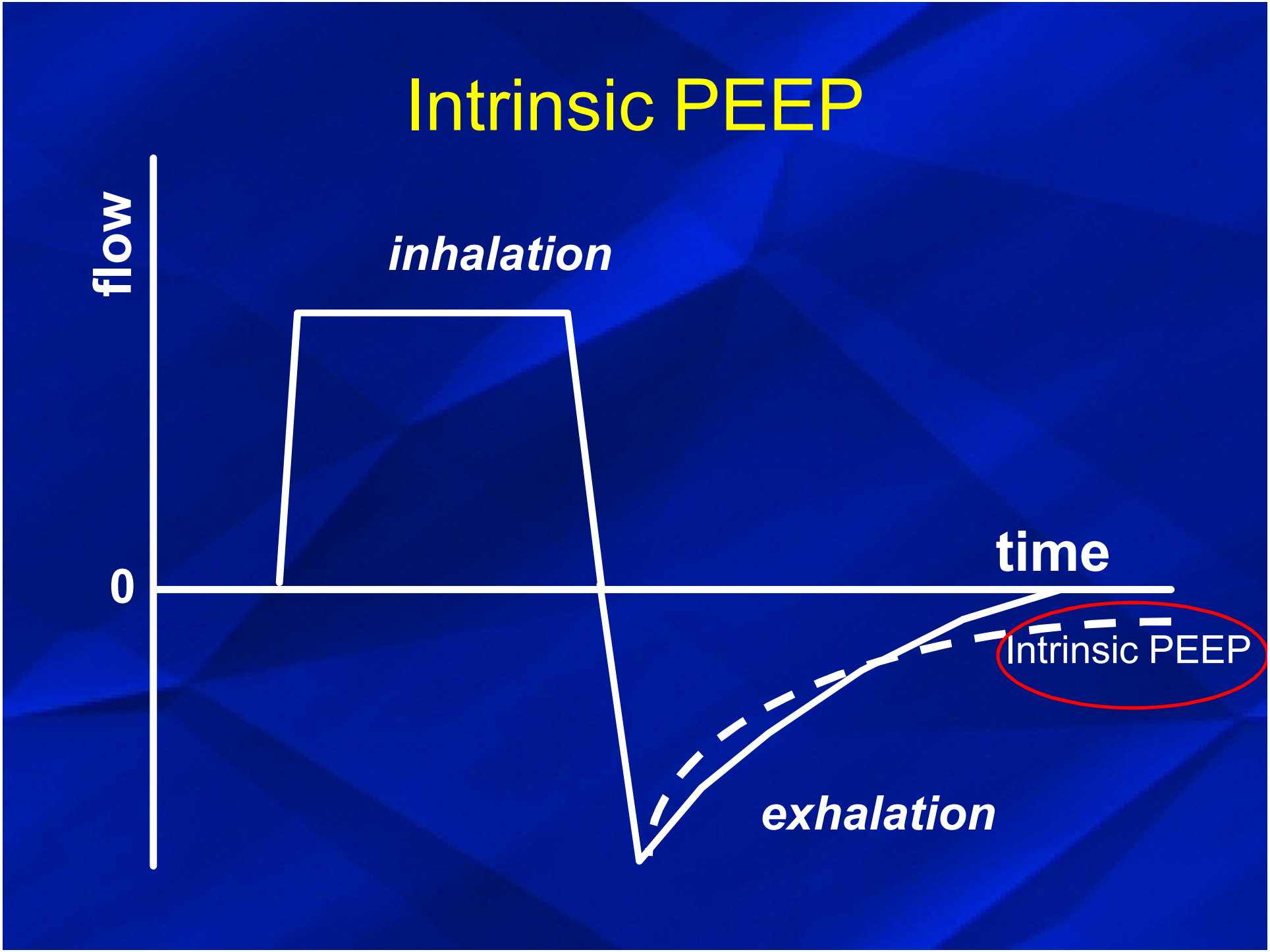
PVA at the Start of Inspiration

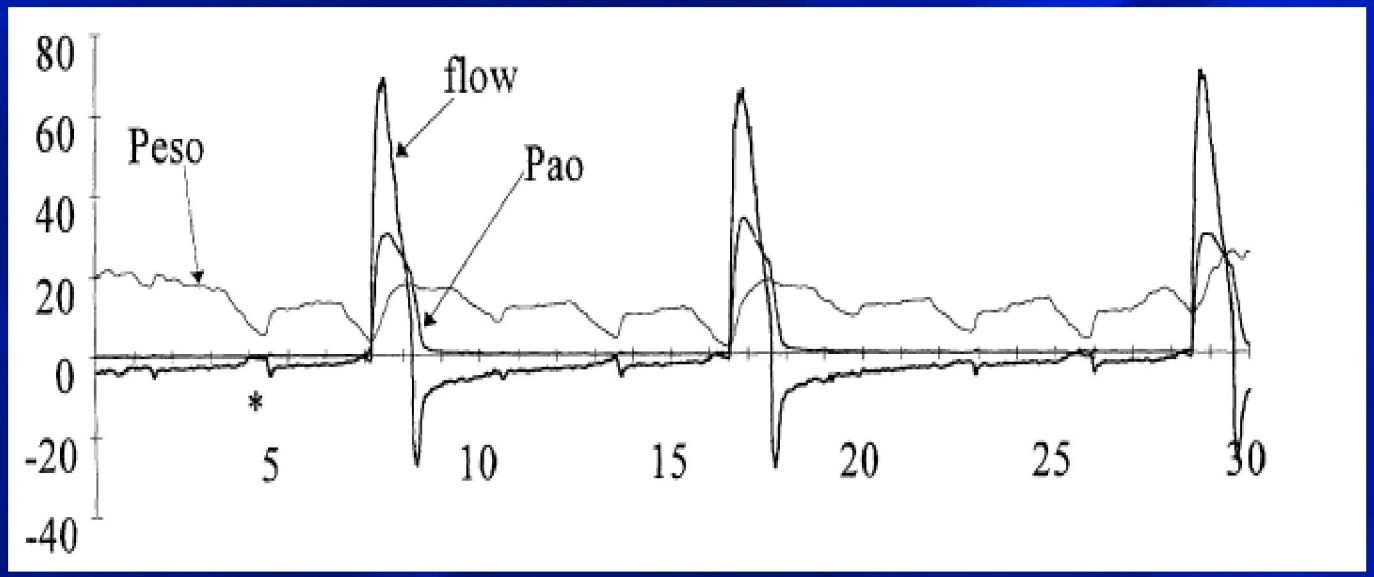
- Trigger asynchrony (TA)
  - Delayed triggering
  - Missed triggering
  - Auto triggering

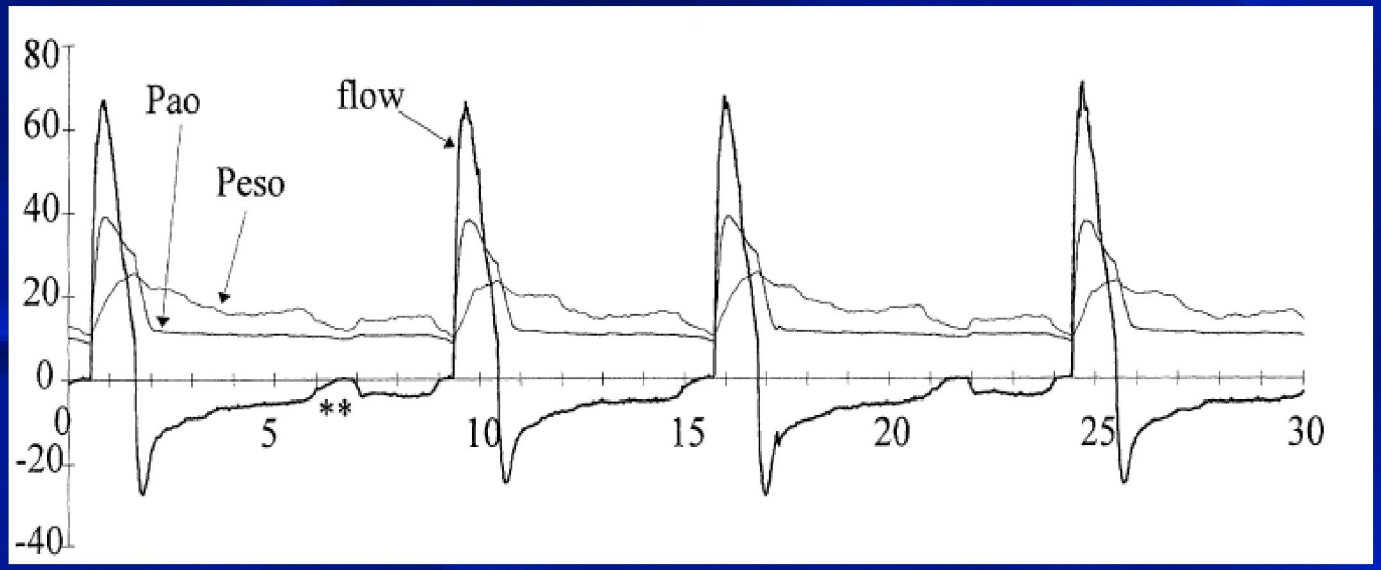
Delayed and Missed Triggering

- Delayed triggering
  - Insensitive trigger
  - Intrinsic PEEP and dynamic hyperinflation
    - Delayed inspiration termination from the previous breath
- Missed triggers
  - Intrinsic PEEP and dynamic hyperinflation

Intrinsic PEEP





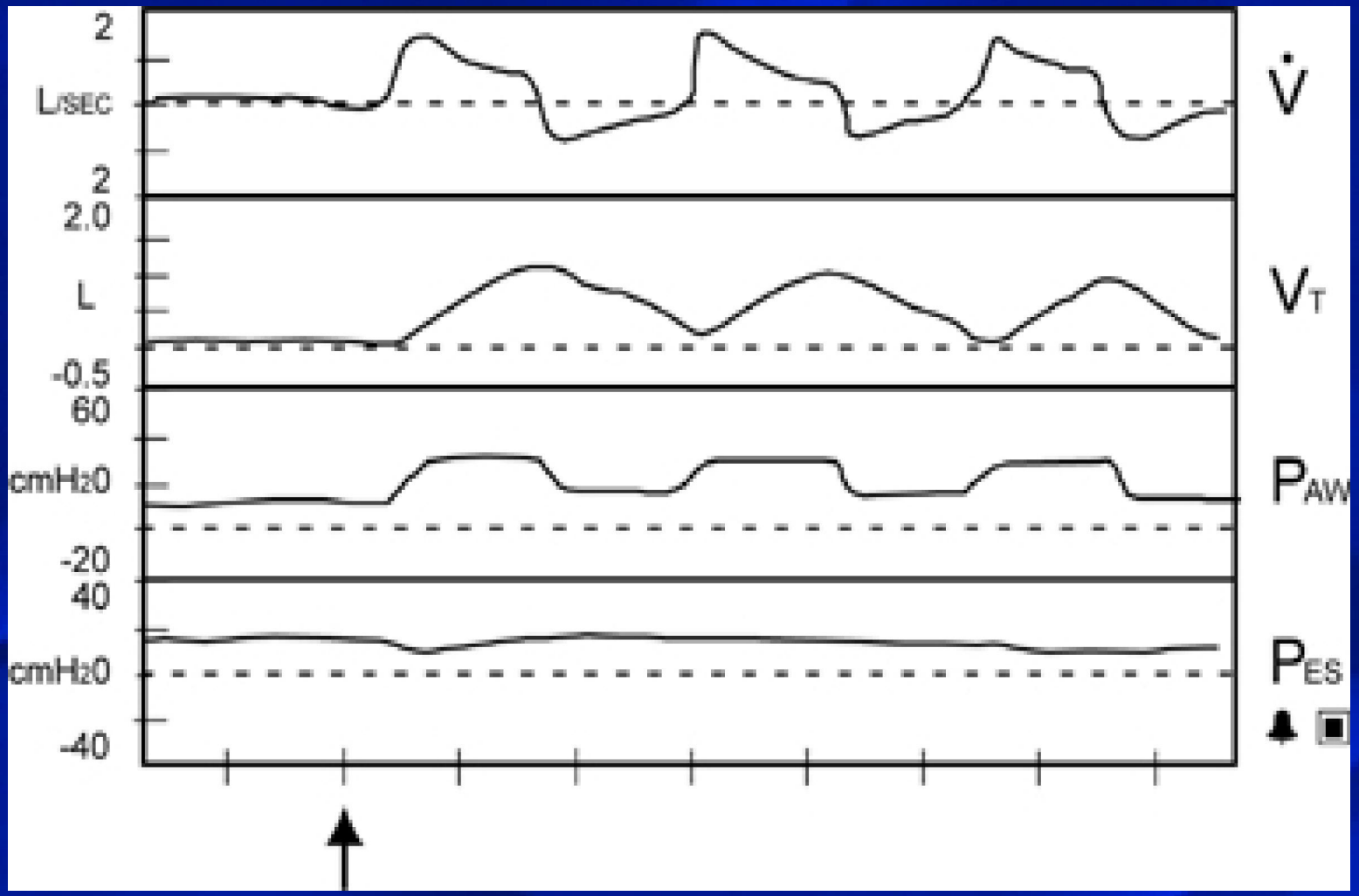


Chao, Chest 1997;112:1592

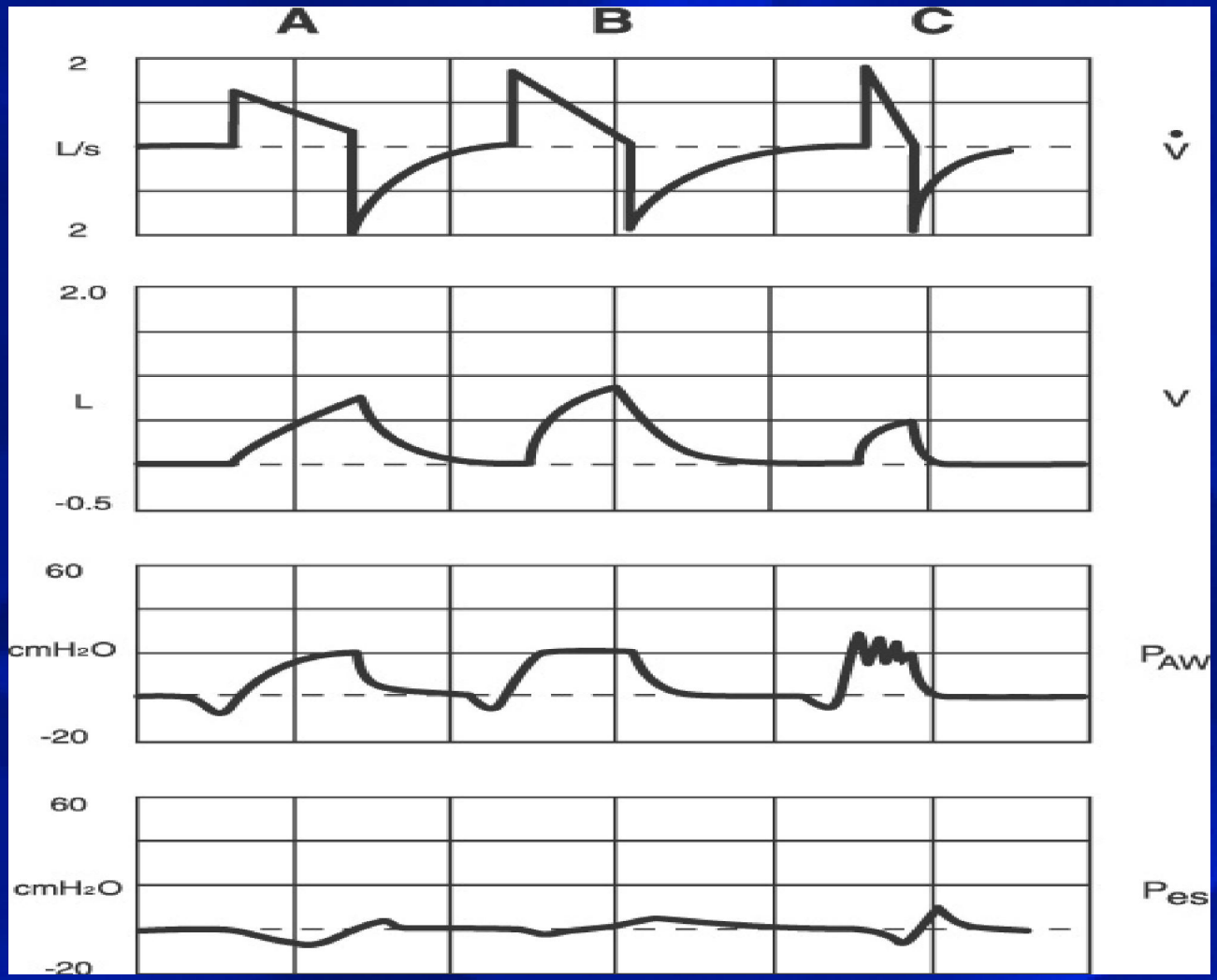
Autocycling

- Water in the circuit
- Leak
- Cardiac oscillation
- Hand on the diaphragm, eyes on the graphics

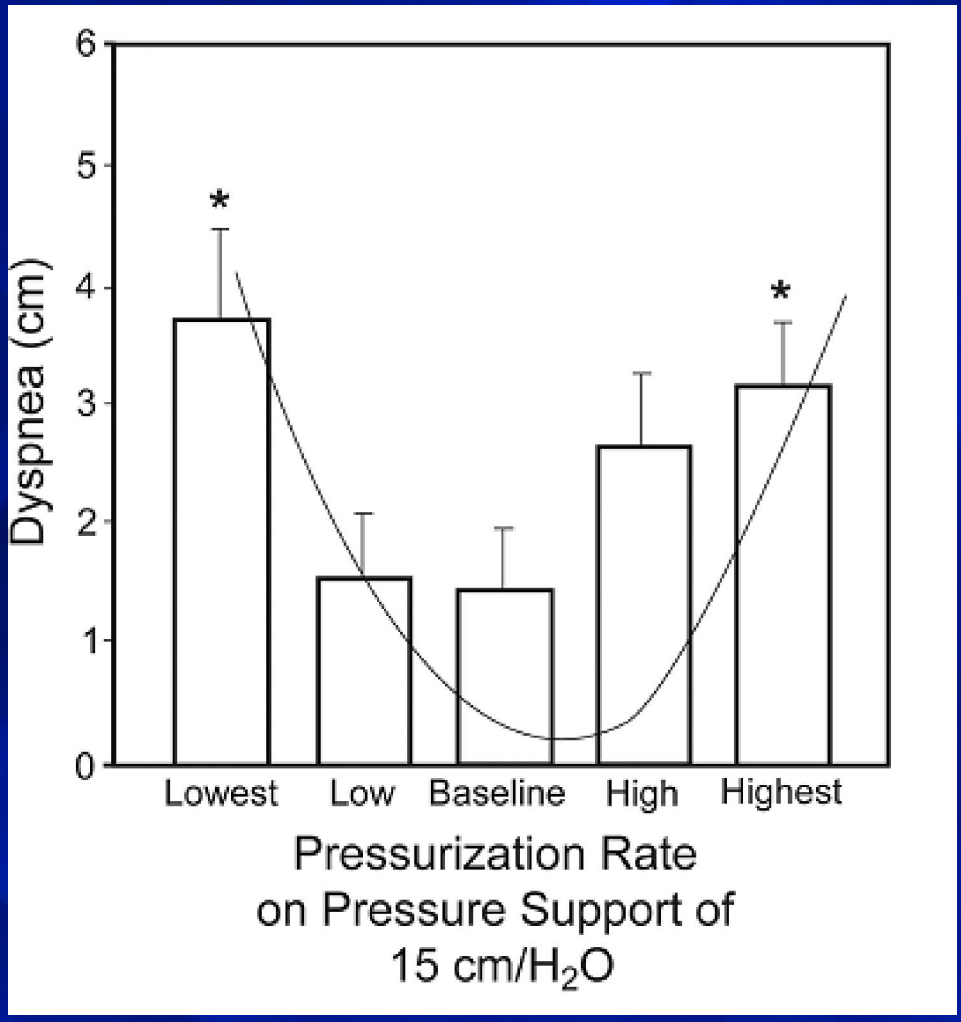
Auto Cycling



Rise Time

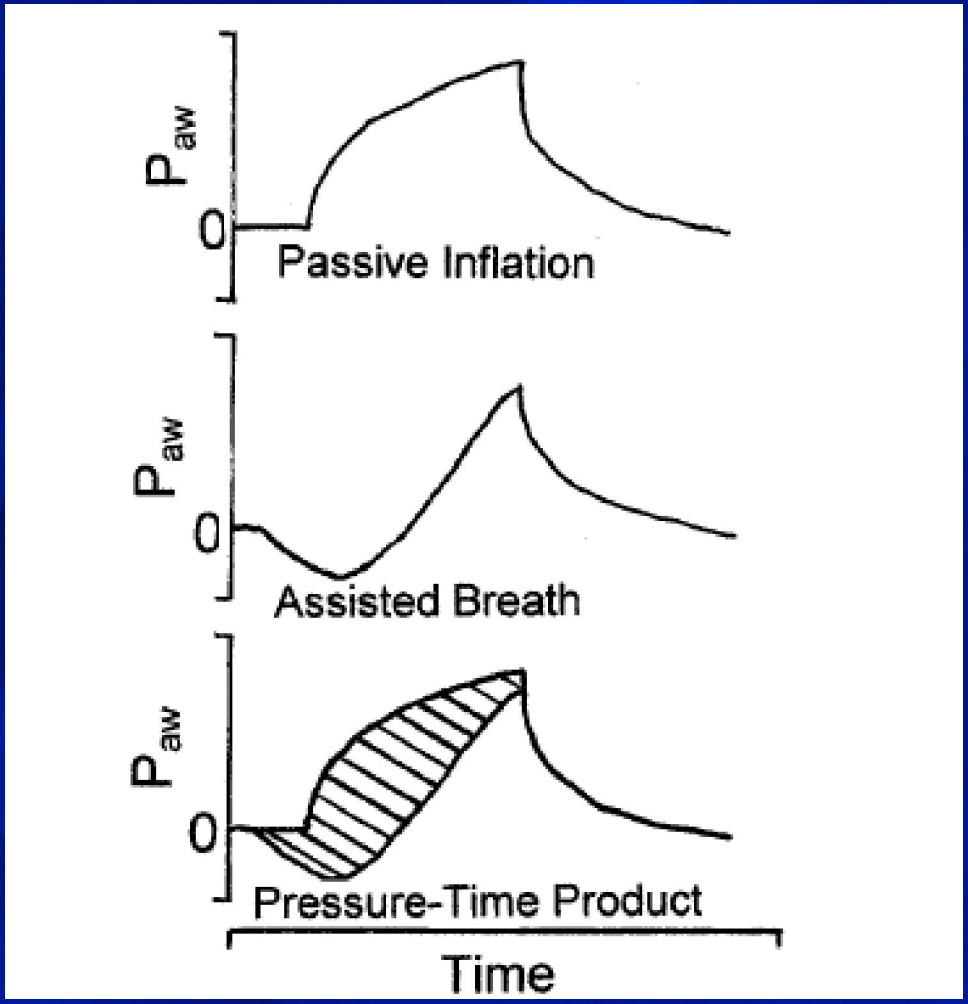


Pressurization Rate

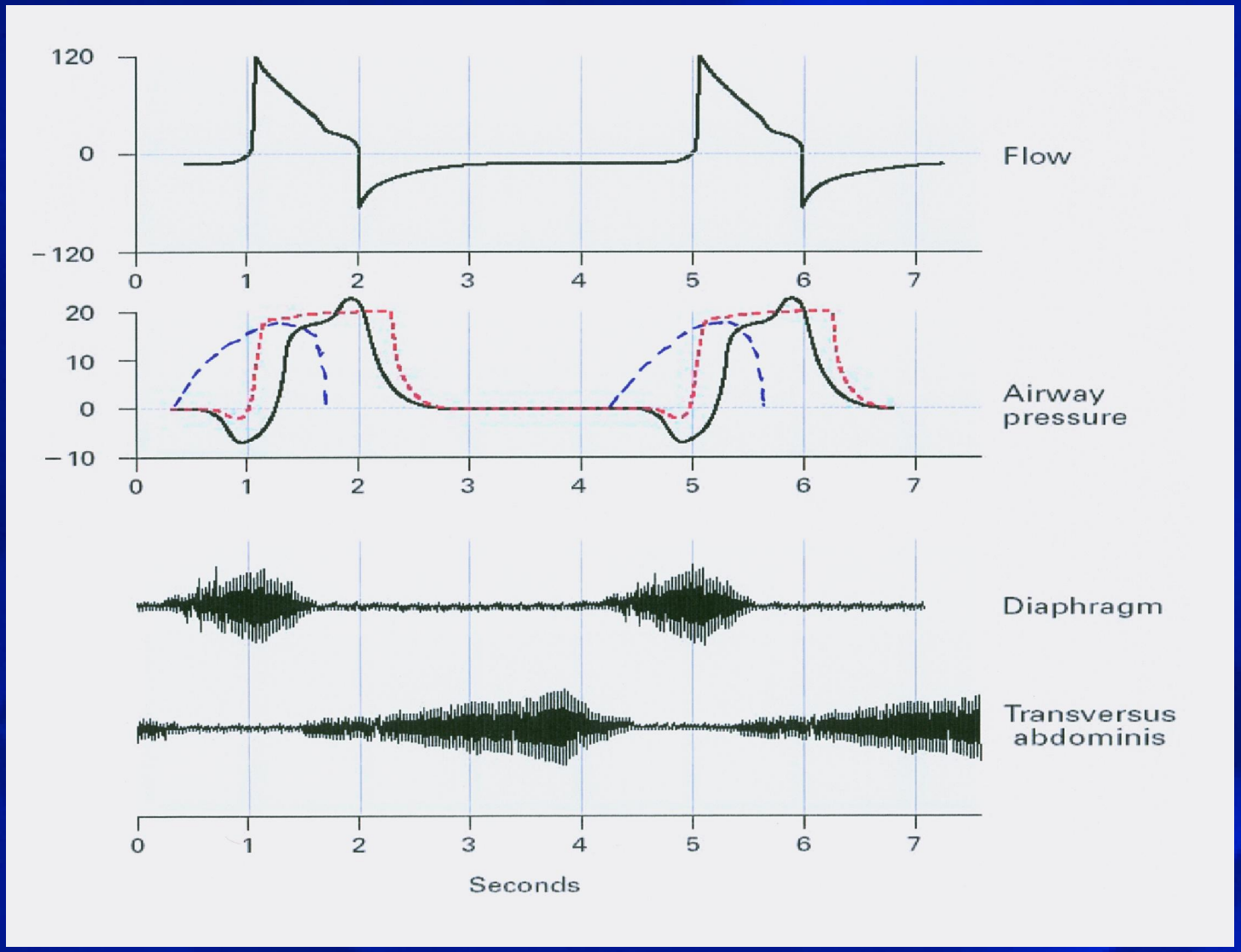


Chiumello. Eur respir J 2001:18:107

Flow Asynchrony



Tobin. Respir Care 1991;36:395

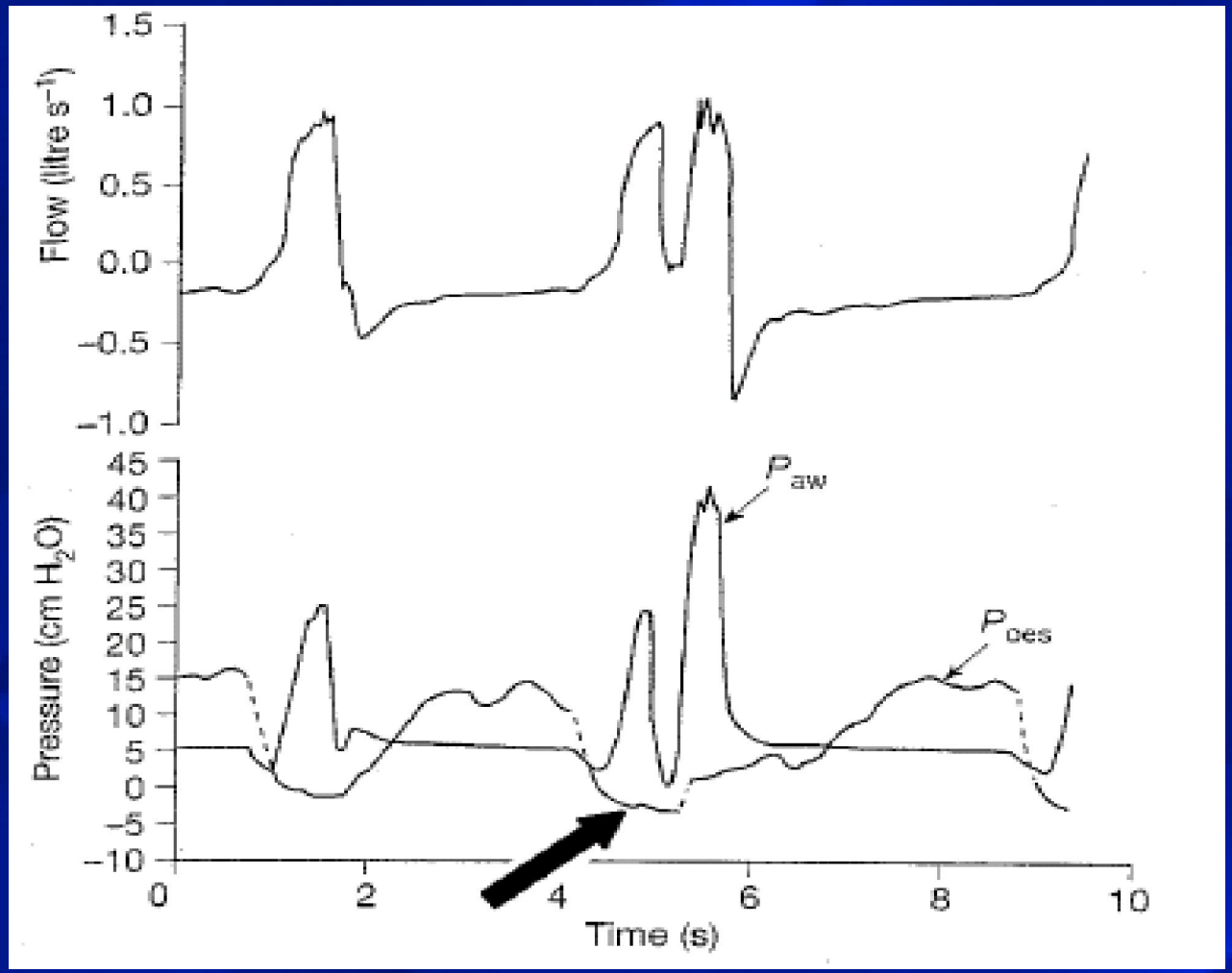


Tobin. NEJM 2001 344:1986

PVA at the End of Inspiration

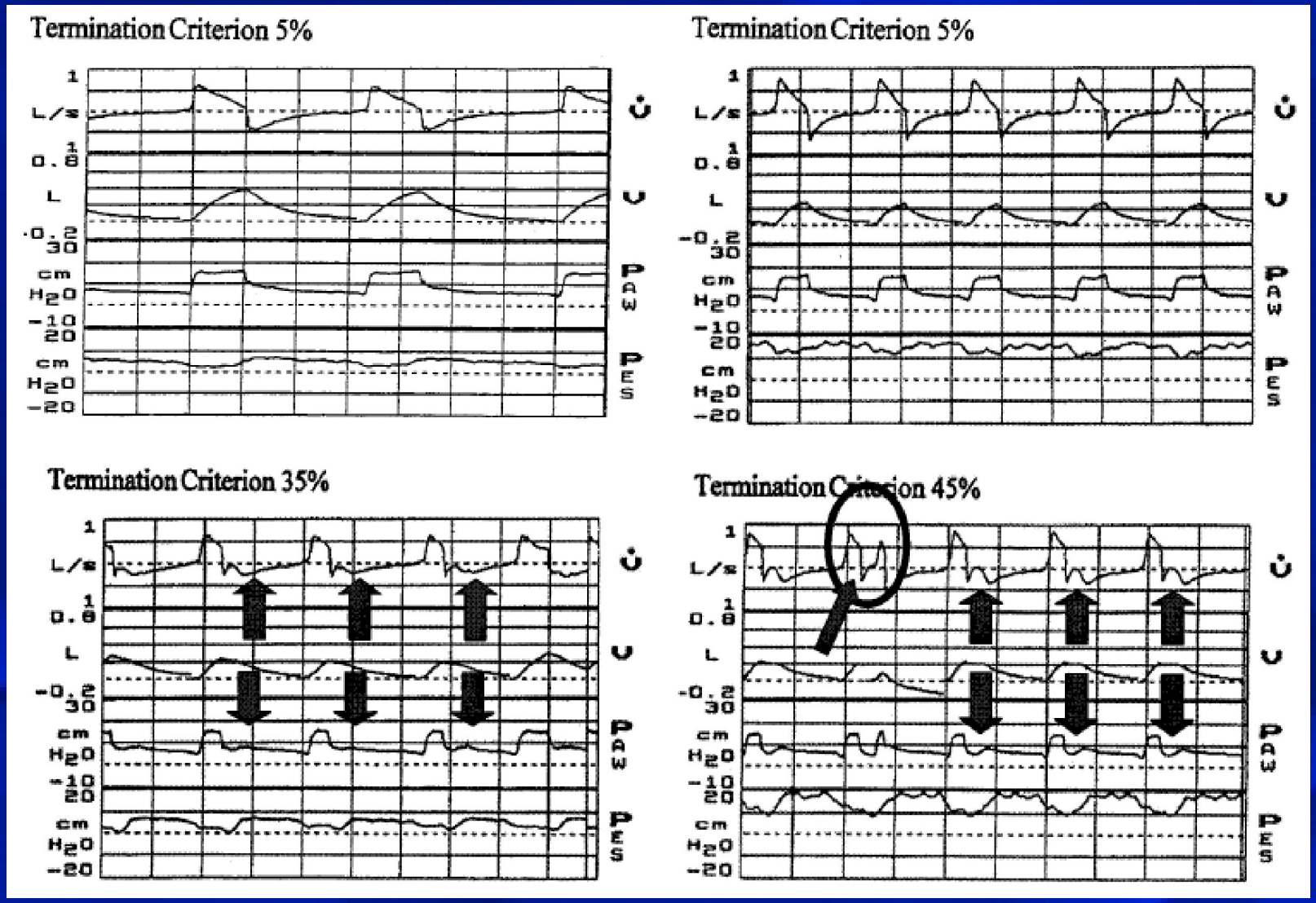
- Cycle asynchrony (CA)
  - Premature cycling
  - Delayed cycling

Premature cycling



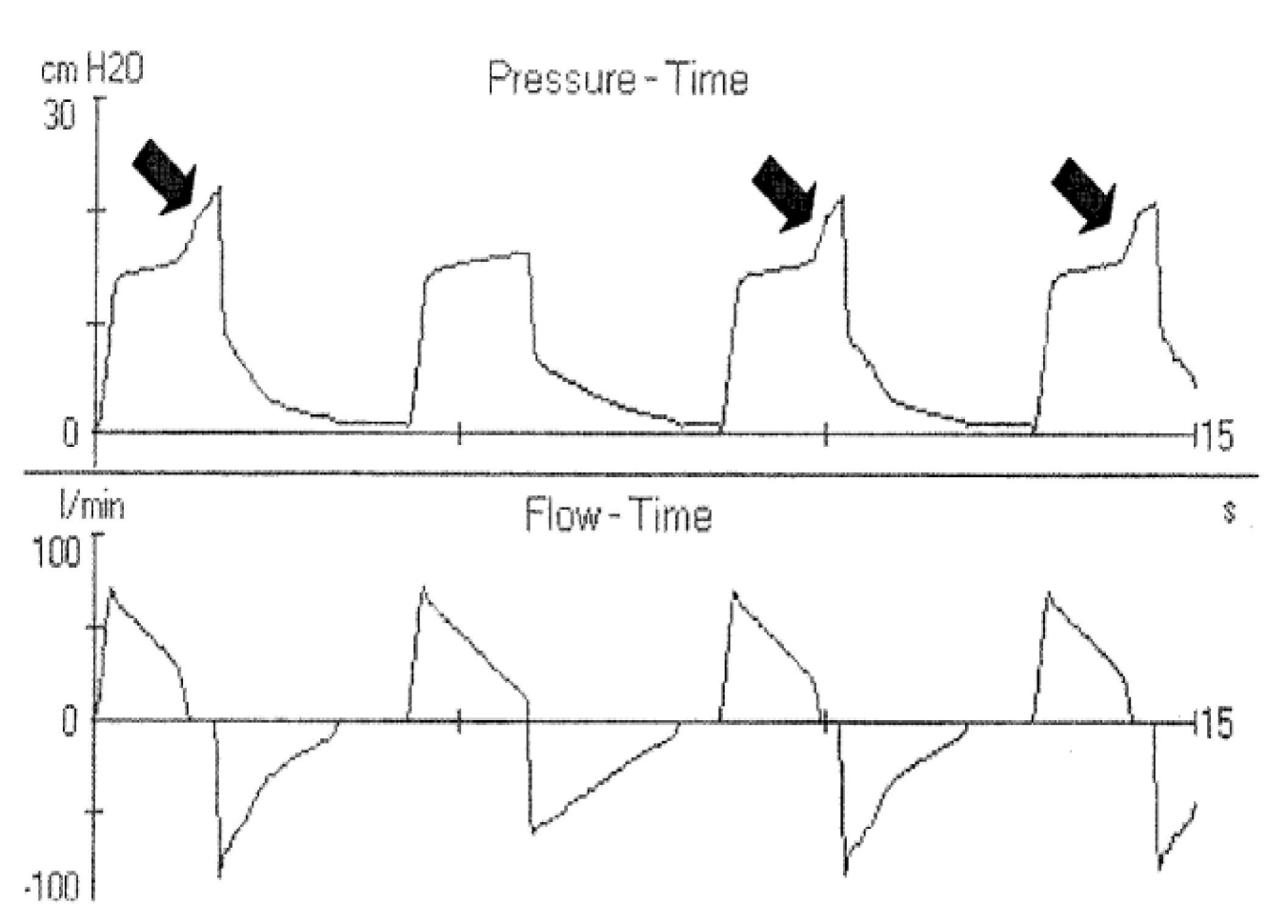
Kondili. Br J Anaesth 2003;91:106

Premature cycling



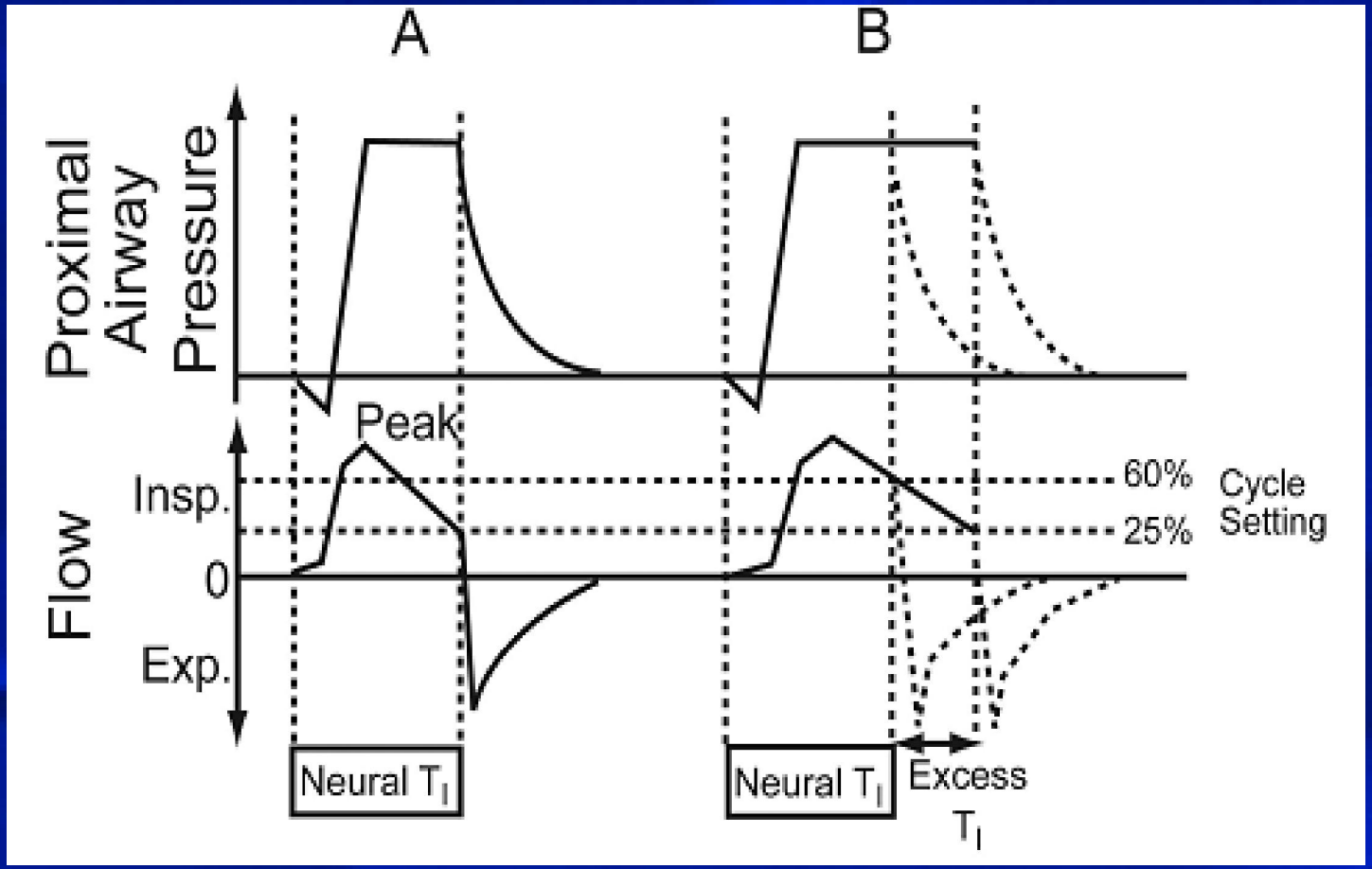
Tuxen. Am Rev Respir Dis 1992;146:1136

Delayed cycling



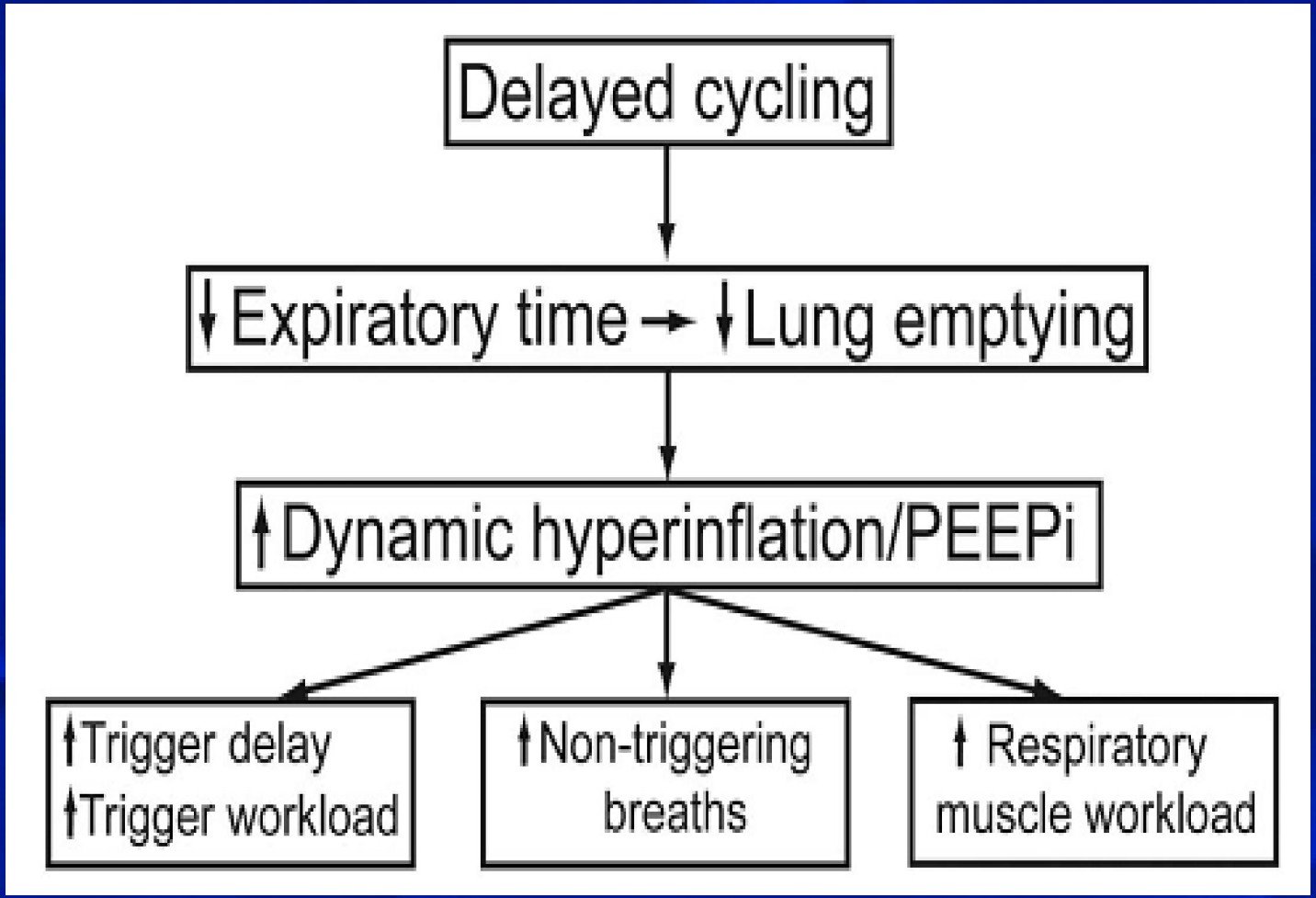
Nilsestuen. Respir Care 2005;50:202

Delayed cycling



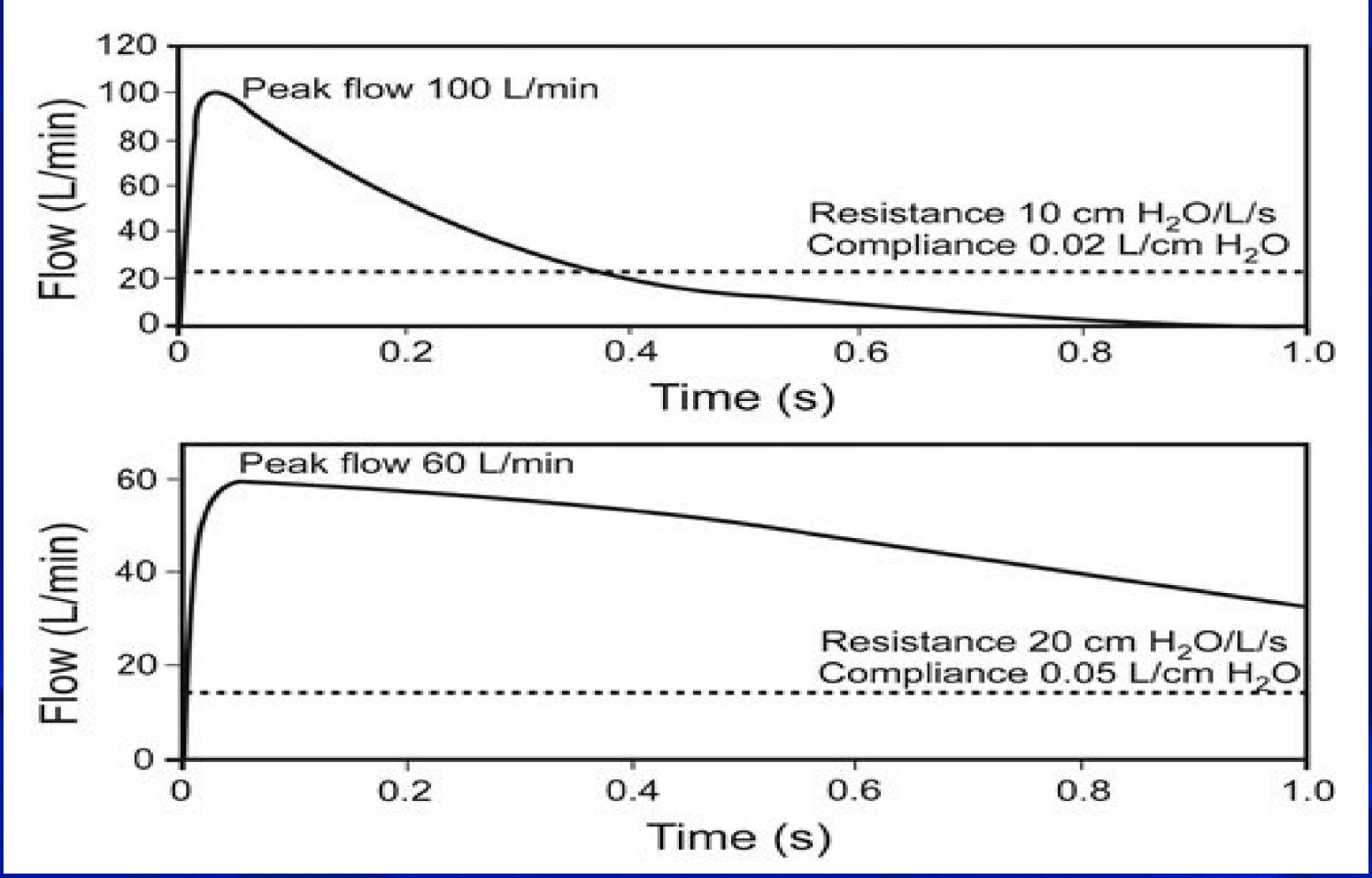
Jo;;iet. Crit Care 2006;10:236

Delayed Cycling



Jolliet. Crit Care 2006;10:236

Cycling Asynchrony



Hess DR. Respir Care 2005;50:166

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PVA Occurance

- Chao, Chest 1997
  - Trigger asynchrony in a regional weaning center
  - 19/174 (10.9%) exhibited triggering asynchrony
  - Direct observation and esophageal monitoring

PVA occurence

- Thille, Intensive Care Med 2006;32:1515
  - Prospective study 62 pts
  - VAC and PS
  - Asynchrony Index

	ACV ($n=11$)	PSV ($n=51$)	p
Asynchronies	4.3 ± 4.8	1.9 ± 3.8	0.04
Ineffective triggering	3.0 ± 4.9	1.8 ± 3.7	0.38
Double-triggering	1.2 ± 2.3	0.1 ± 0.4	0.01

	Asynchrony index $< 10\%$ ($n=47$)	Asynchrony index $\geq 10\%$ ($n=15$)	p
Duration of mechanical ventilation (days; IQR)	7 (3–20)	25 (9–42)	0.005
Duration of mechanical ventilation ≥ 7 days	23 (49%)	13 (87%)	0.01
Tracheostomy	2 (4%)	5 (33%)	0.007
Mortality	15 (32%)	7 (47%)	0.36

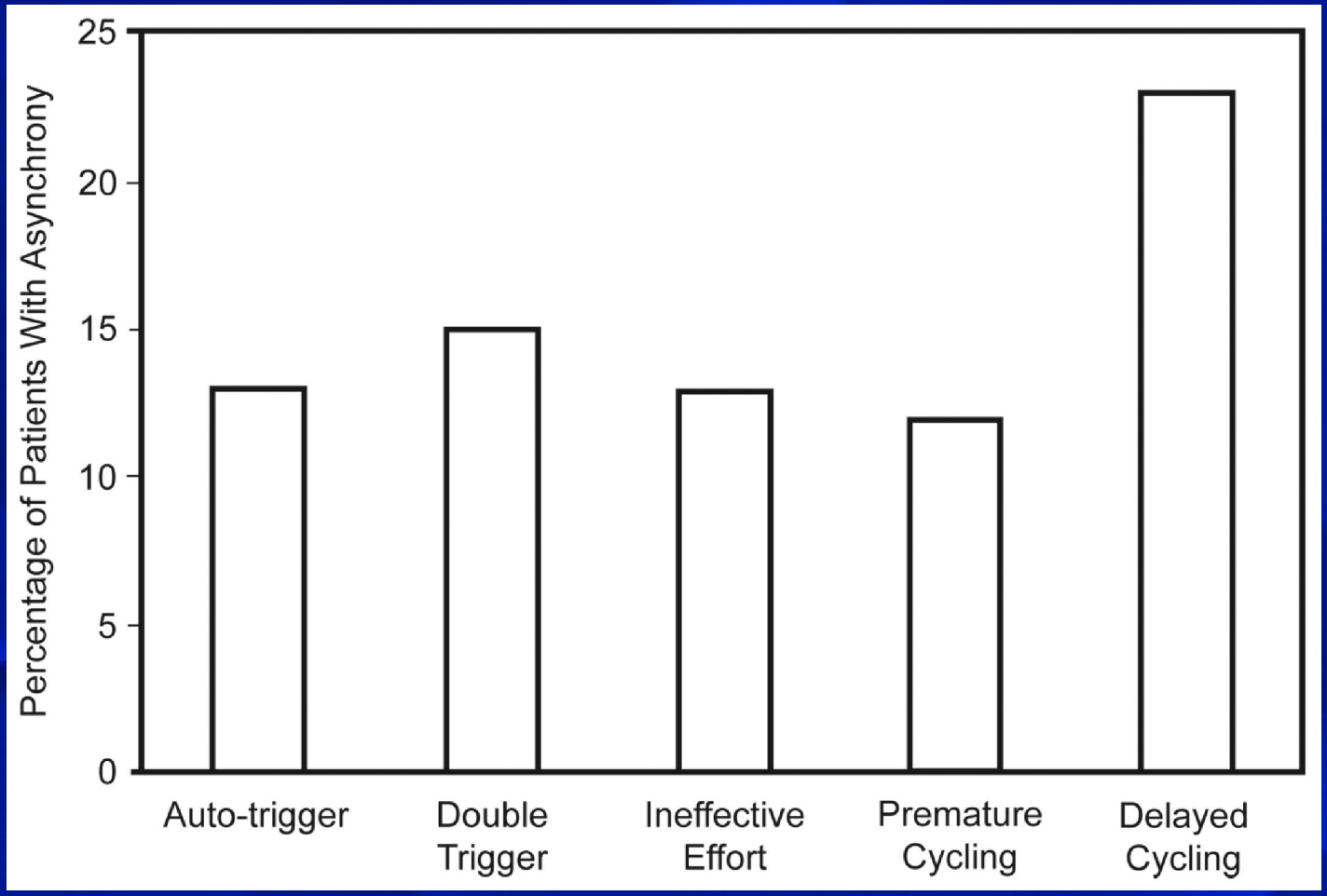
AI = # of events/total RR (including unrecognized) X 100

Effects of PVA

	Ineffective-Effort Index > 10%	Ineffective-Effort Index < 10%	*P*
# of pts	16	44	
Duration of MV	6	2	<.05
ICU stay	8	4	<.05
Hosp stay	21	8	<.05
ICU mortality (%)	25	14	NS
Hosp mortality (%)	30	20	NS

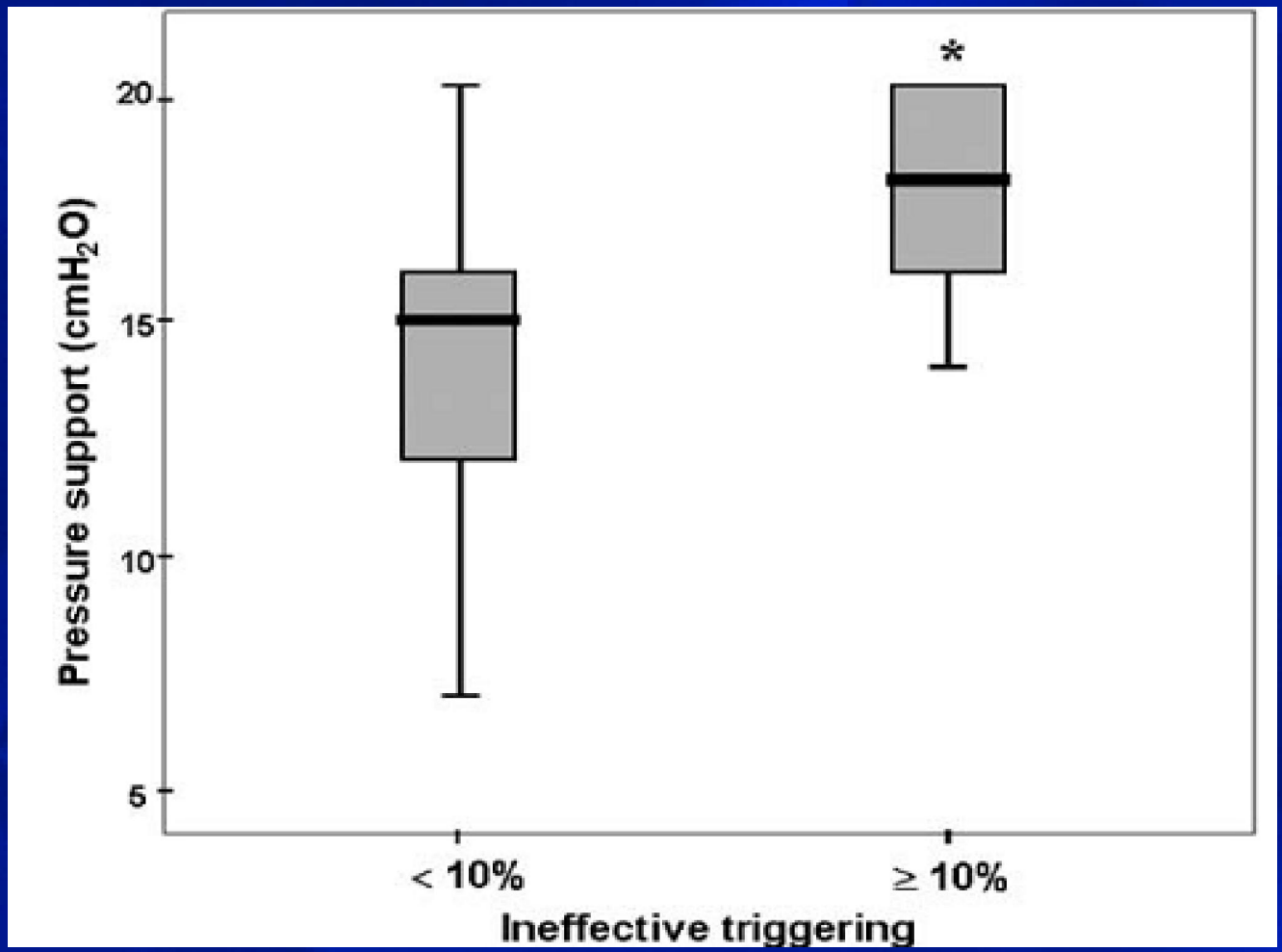
De Wit M, et al. CCM 2009; 37:2740

ARF and NIV



Vignaux L, et al. Intensive Care Med 2009;35:840

PVA in PS



Thille. Intensive Care Med 2006;32:1515

- What is Patient ventilator asynchrony (PVA) and how do you recognize it?
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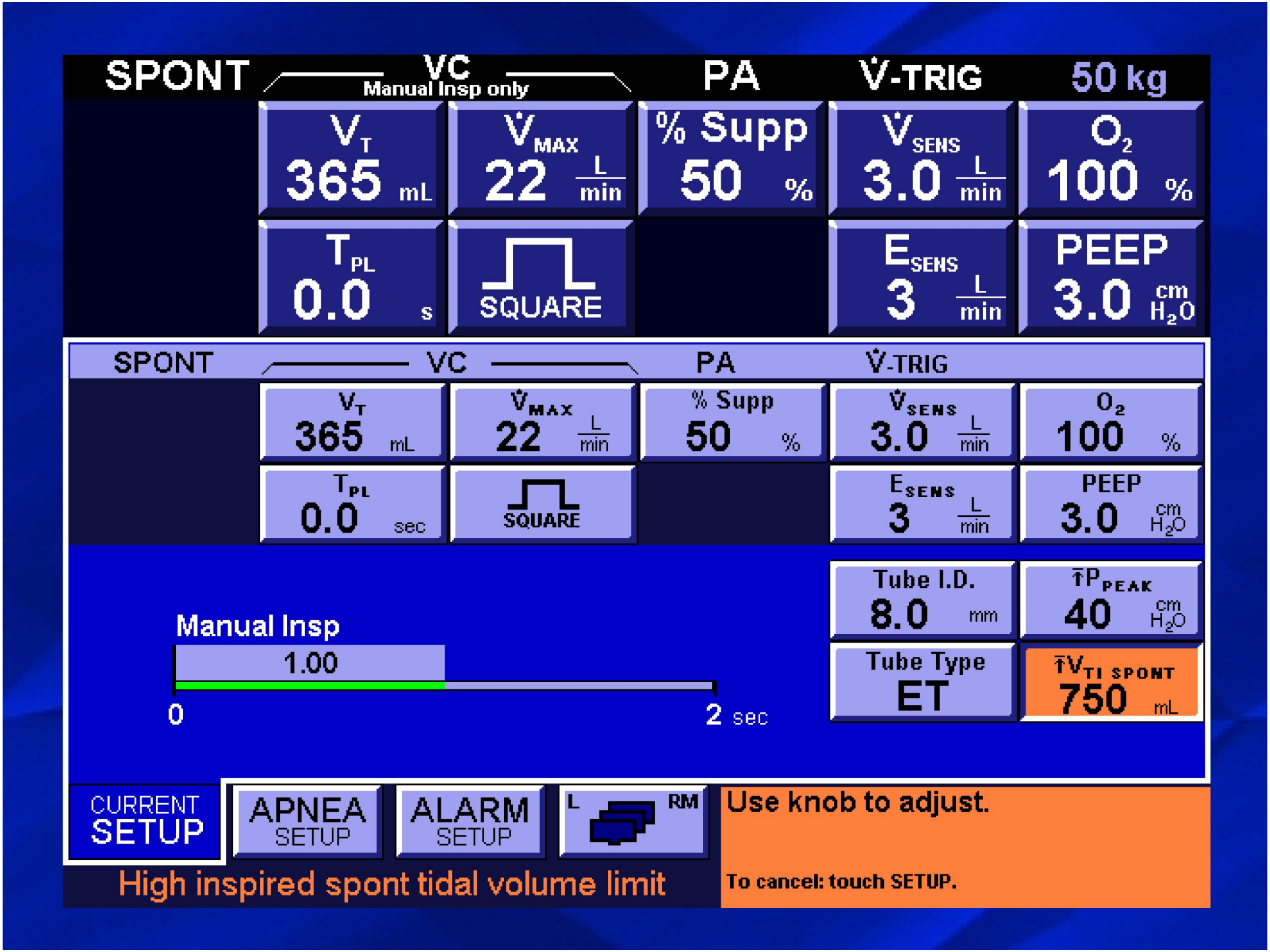
Proportional Assist Ventilation (PAV)

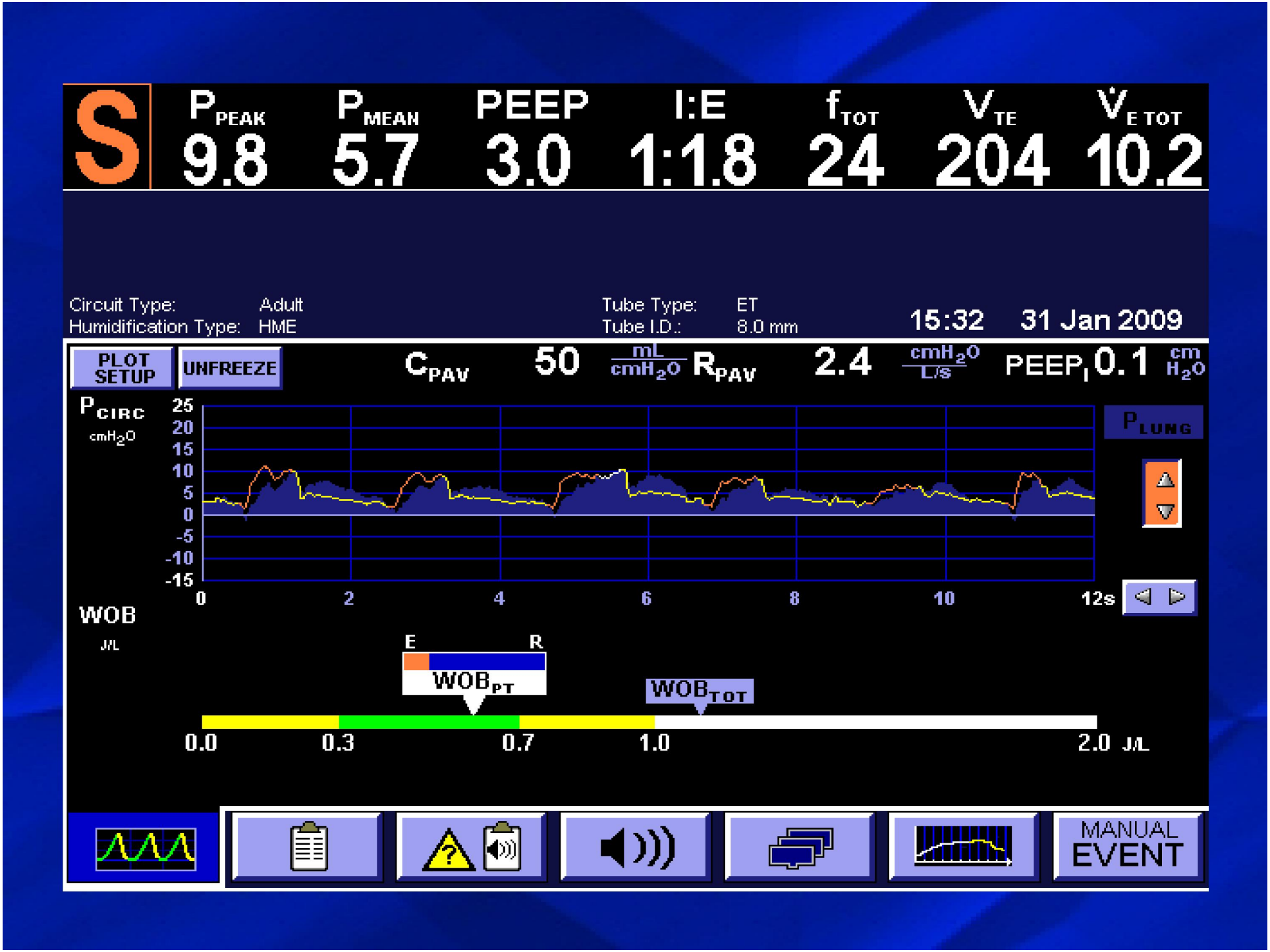
- Younes M. Am Rev Respir Dis 1992;145:114–120

- PAV is a form of synchronized partial ventilatory assistance with the characteristic that the ventilator generates pressure in proportion to the patient's instantaneous effort

PAV

- Calculates R and C (impedence)
- Monitors inspiratory flow demand
  - Calculates work of breathing (ie pressure requirements for desired flow and volume)
- Applies set “proportion” of required pressure
  - Also terminates (cycles) when effort ceases
- Like power steering on an automobile
  - Driver selects distance to turn wheel, system supplies pressure to reduce effort
  - Like the automobile driver – patient must be reliable!


SPONT
VC
Manual Insp only
PA
V̇-TRIG
50 kg
VT 365 mL
V̇MAX 22 L/min
% Supp 50 %
V̇SENS 3.0 L/min
O2 100 %
TPL 0.0 s
SQUARE
ESENS 3 L/min
PEEP 3.0 cm H2O
SPONT
VC
PA
V̇-TRIG
VT 365 mL
V̇MAX 22 L/min
% Supp 50 %
V̇SENS 3.0 L/min
O2 100 %
TPL 0.0 sec
SQUARE
ESENS 3 L/min
PEEP 3.0 cm H2O
Manual Insp
1.00
0
2 sec
Tube I.D. 8.0 mm
f̄PPEAK 40 cm H2O
Tube Type ET
f̄VTI SPONT 750 mL
CURRENT SETUP
APNEA SETUP
ALARM SETUP
L RM
Use knob to adjust.
To cancel: touch SETUP.
High inspired spont tidal volume limit


S
P PEAK
9.8
P MEAN
5.7
PEEP
3.0
I:E
1:1.8
f TOT
24
V TE
204
V̇ E TOT
10.2
Circuit Type: Adult
Humidification Type: HME
Tube Type: ET
Tube I.D.: 8.0 mm
15:32
31 Jan 2009
PLOT SETUP
UNFREEZE
C PAV
50
mL / cmH2O
R PAV
2.4
cmH2O / L/s
PEEP I 0.1
cm H2O
P CIRC
cmH2O
25
20
15
10
5
0
-5
-10
-15
0
2
4
6
8
10
12s
P LUNG
WOB
J/L
E
R
WOB PT
WOB TOT
0.0
0.3
0.7
1.0
2.0 J/L
MANUAL EVENT

Comparing PS and PAV

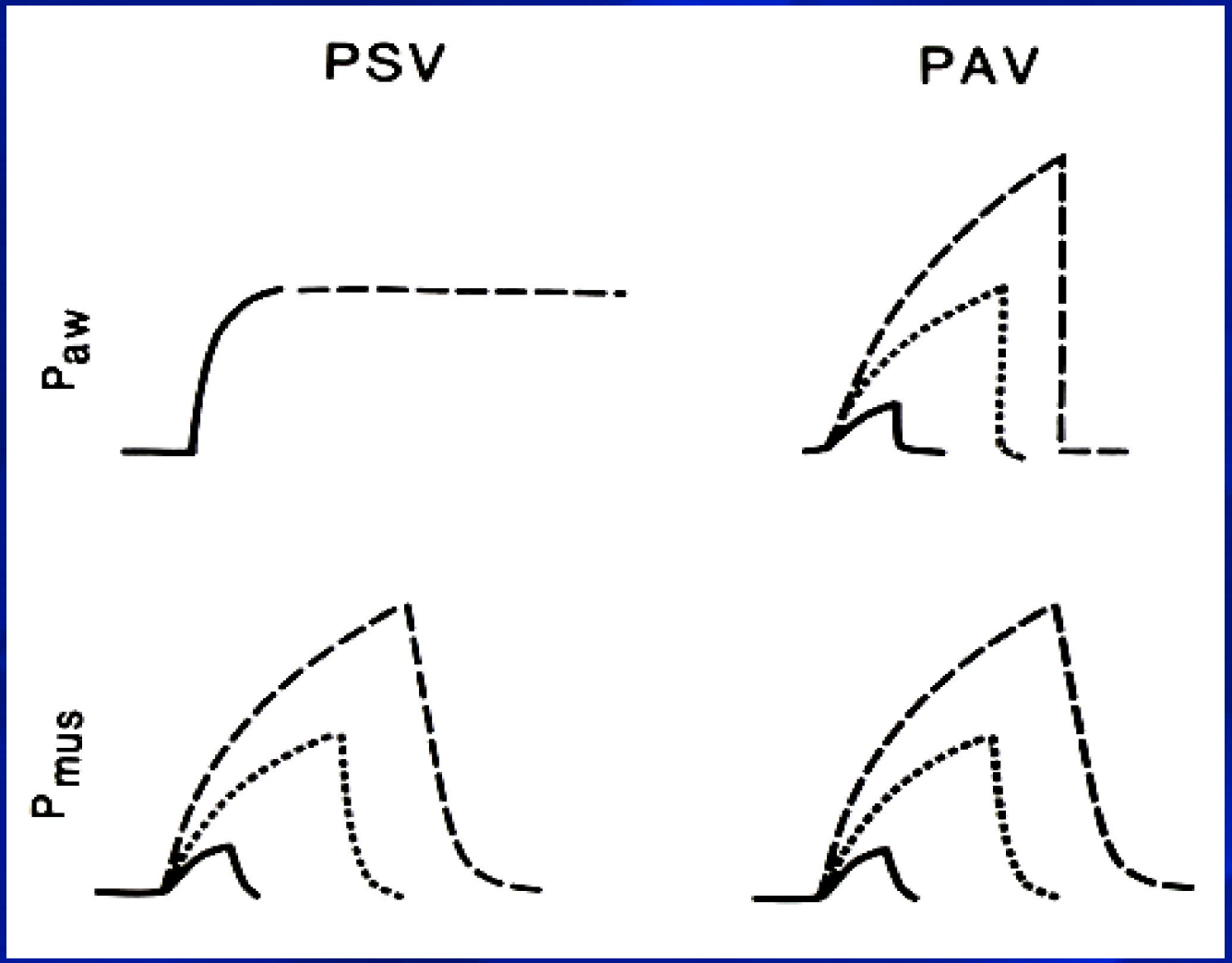
PS

- Preset pressure, unknown patient work
- An all-or-nothing breath type
- Breaths terminate based on several criteria (level of pressure, compliance and resistance of patient, rate of pressure rise, cycling criteria)

PAV

- Targets percent work with variable pressure
- Breath terminates when inspiratory flow (effort) stops

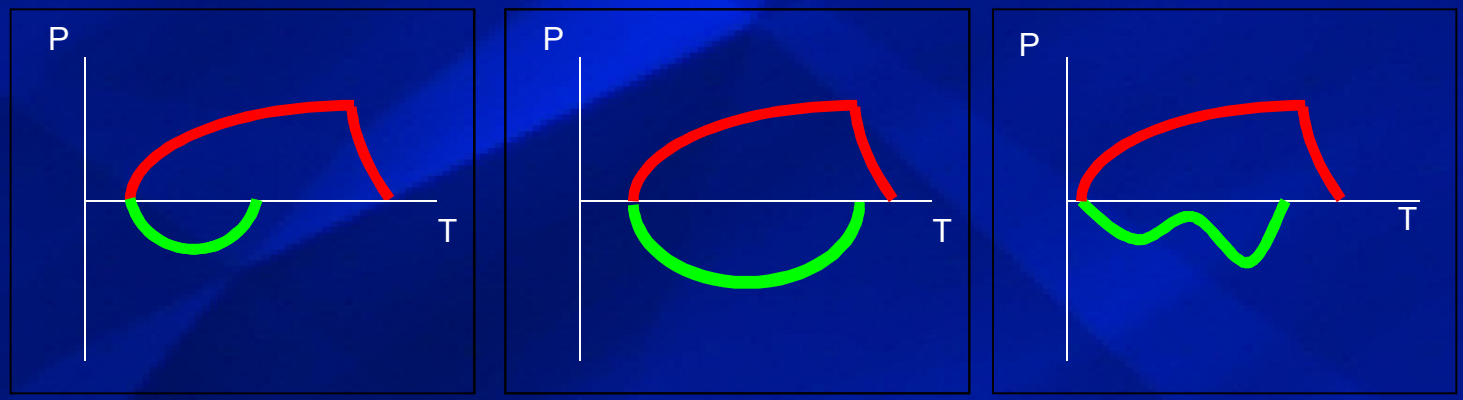
PAV vs PS



Matching Inspiratory Flow Demand

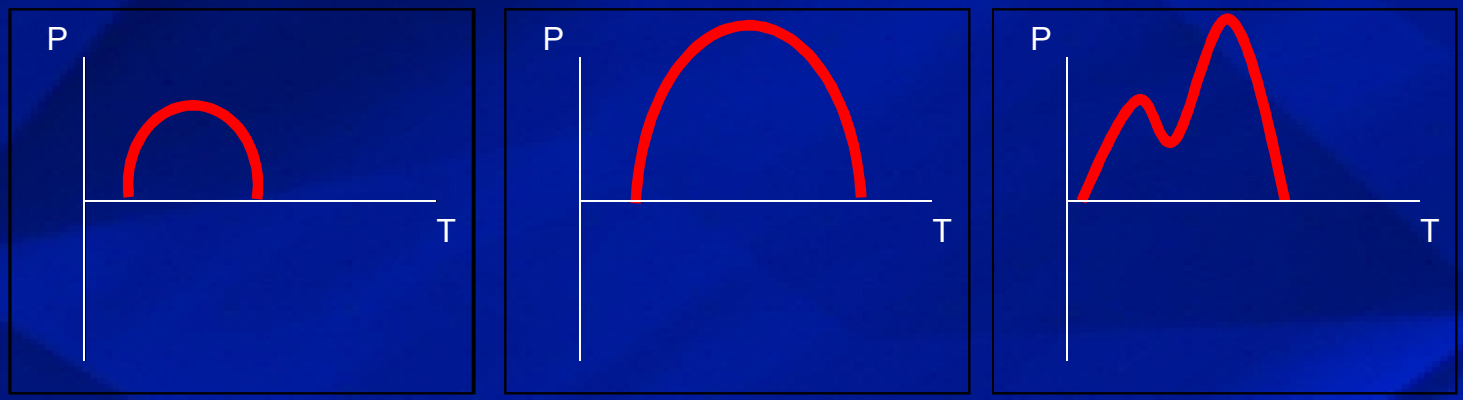
PAC

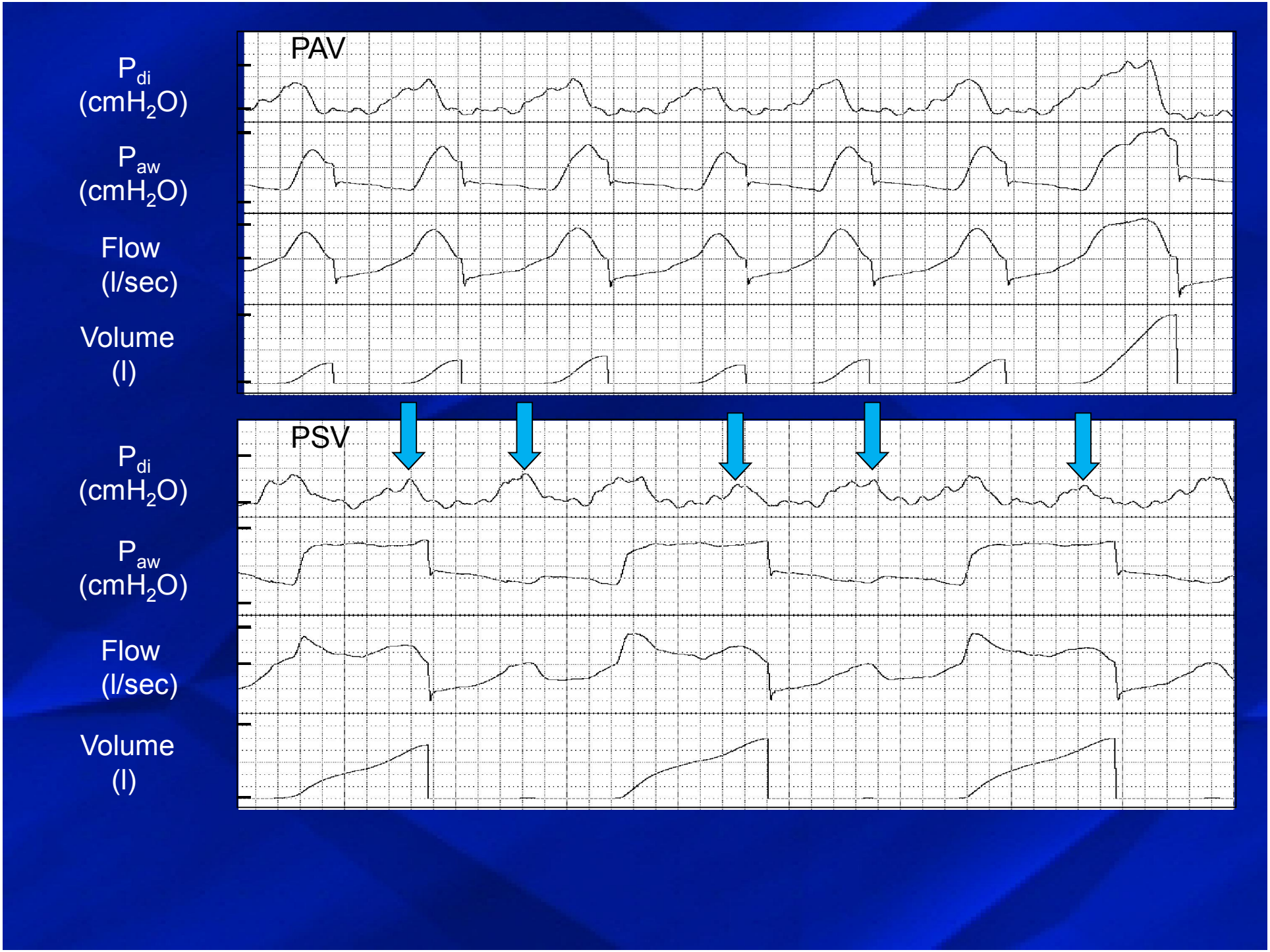
15 cmH2O



PAV

at 75%



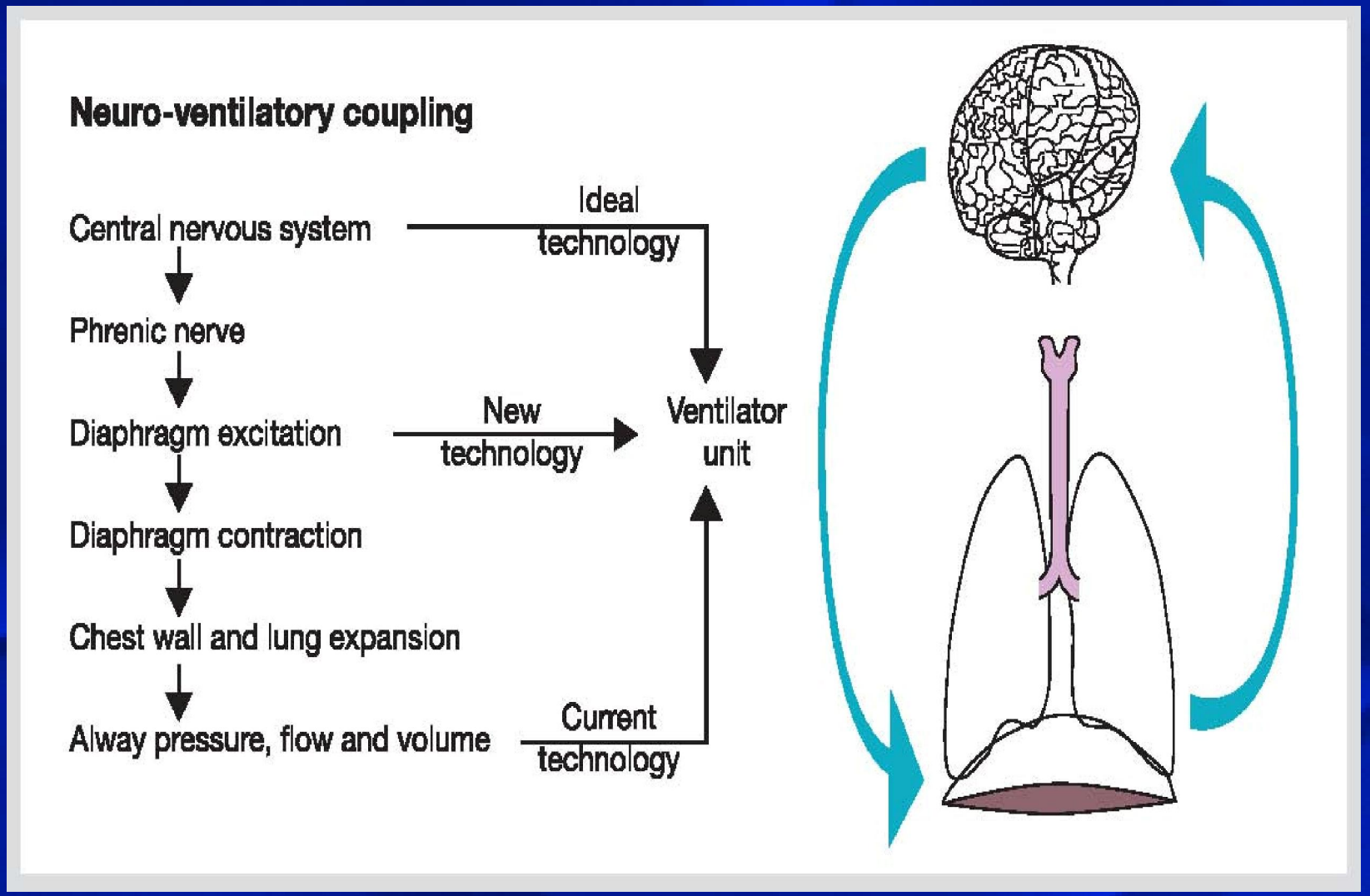

PAV
P_{di} (cmH_2O)
P_{aw} (cmH_2O)
Flow (l/sec)
Volume (l)
PSV
P_{di} (cmH_2O)
P_{aw} (cmH_2O)
Flow (l/sec)
Volume (l)

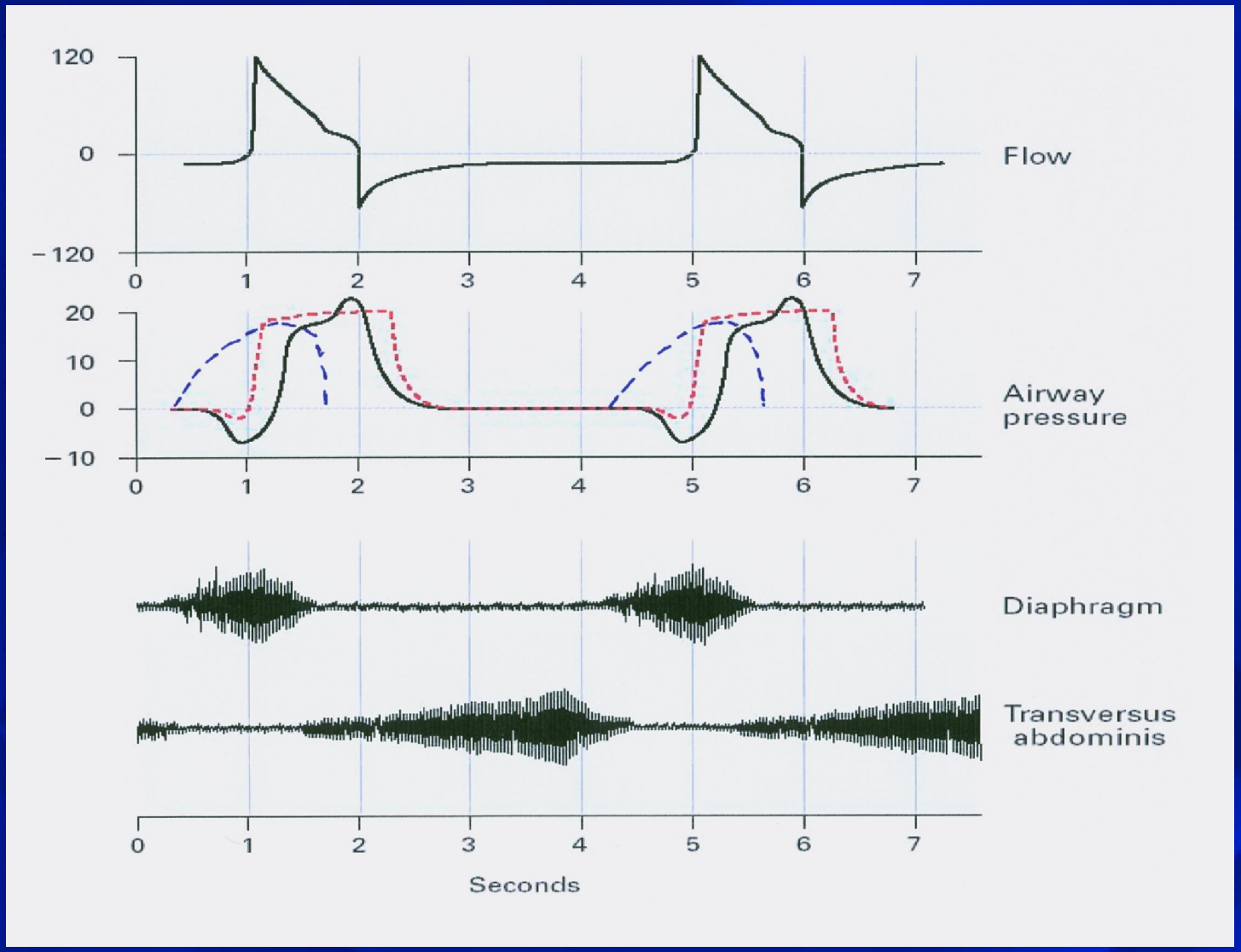
PAV – clinical application

- Improvement in synchrony over PSV
  - Xirirouchaki. Intensive Care Med 2008;34:2026
  - Costa. Intensive Care Med 2011;37:1494
- No good outcomes trials to date

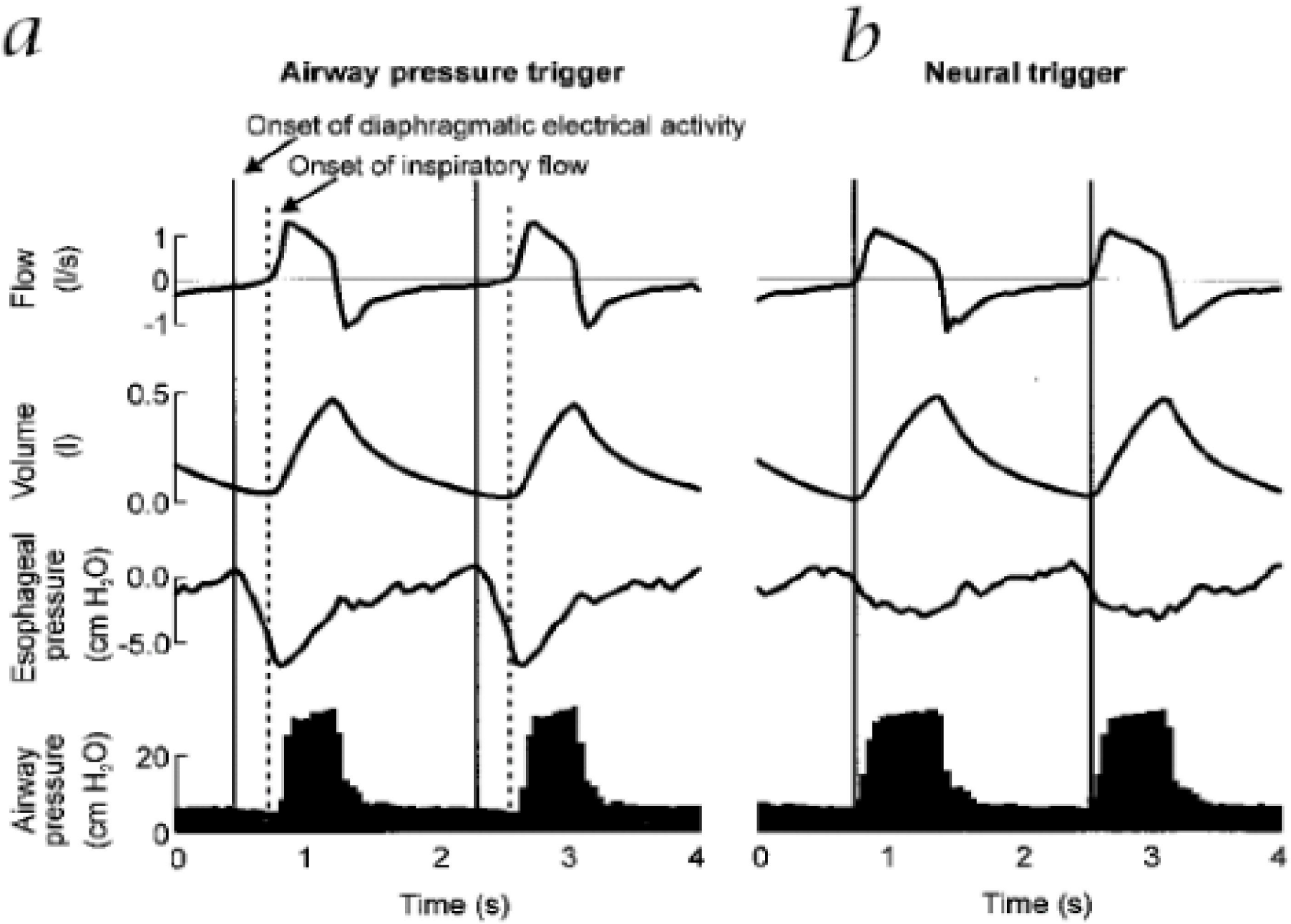
Neural-Adjusted Ventilatory Assist (NAVA)

NAVA Concept





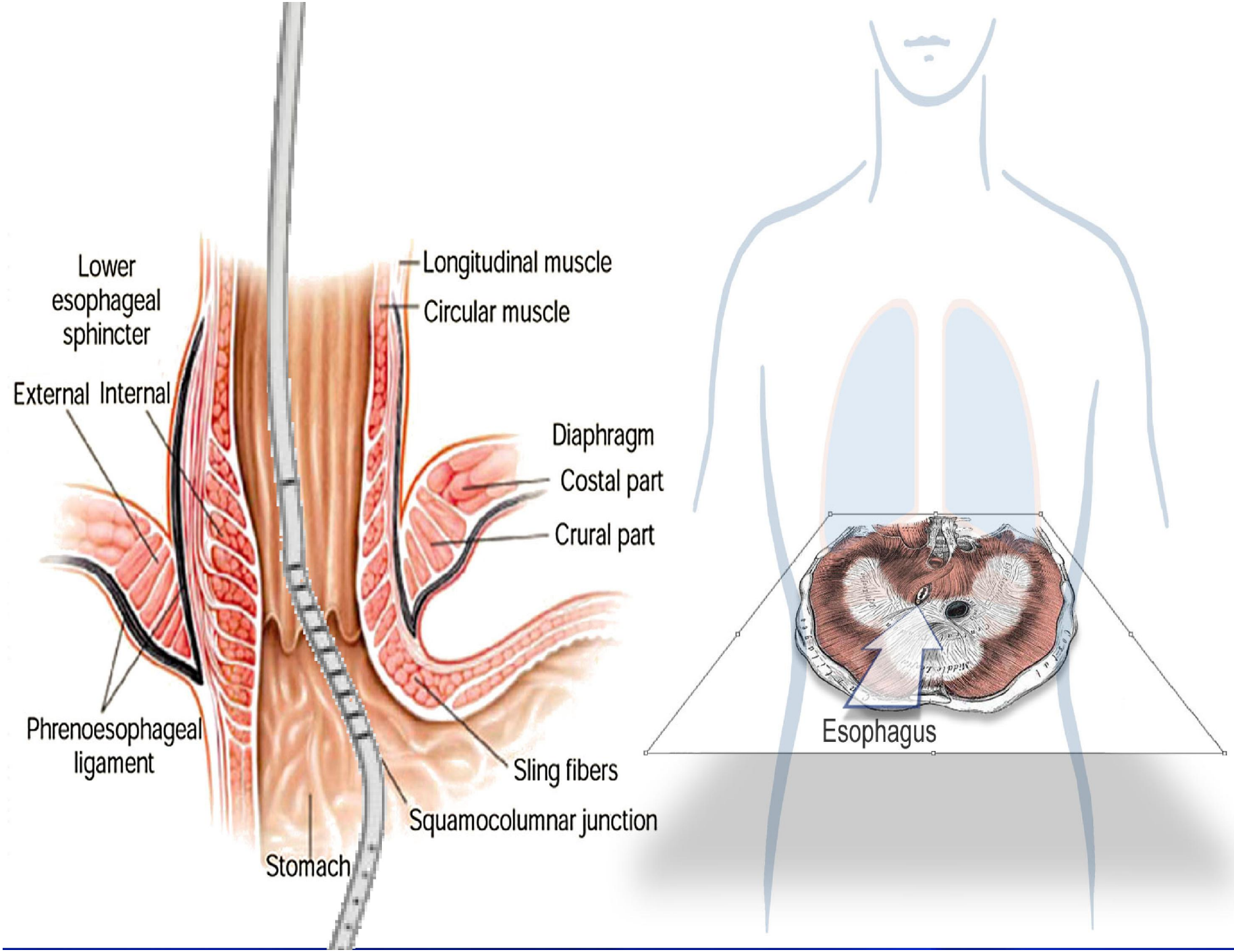
Tobin, *NEJM* 344:1986-1996,2001

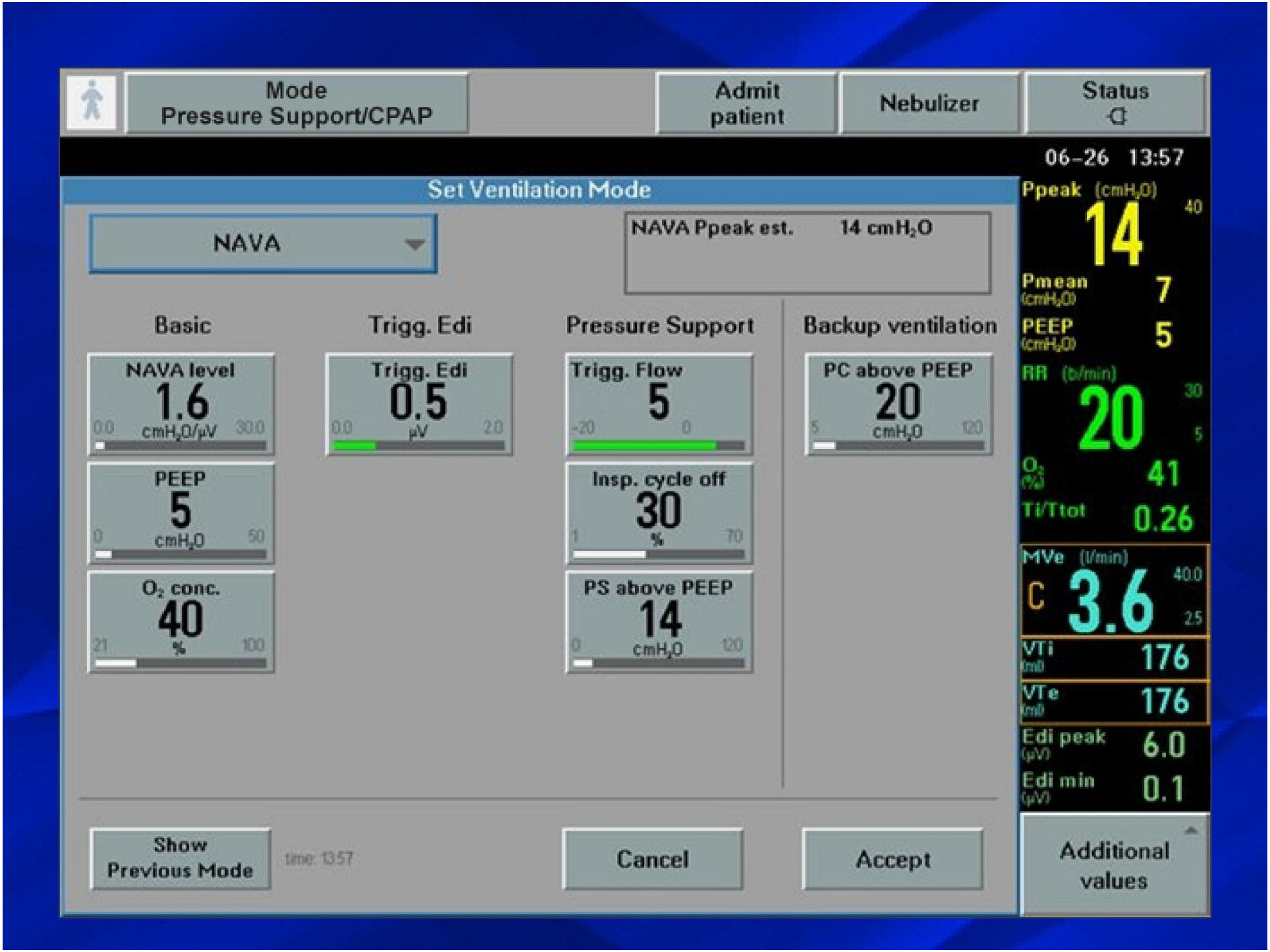


Sinderby et al, Nat Med 5:1433, 1999

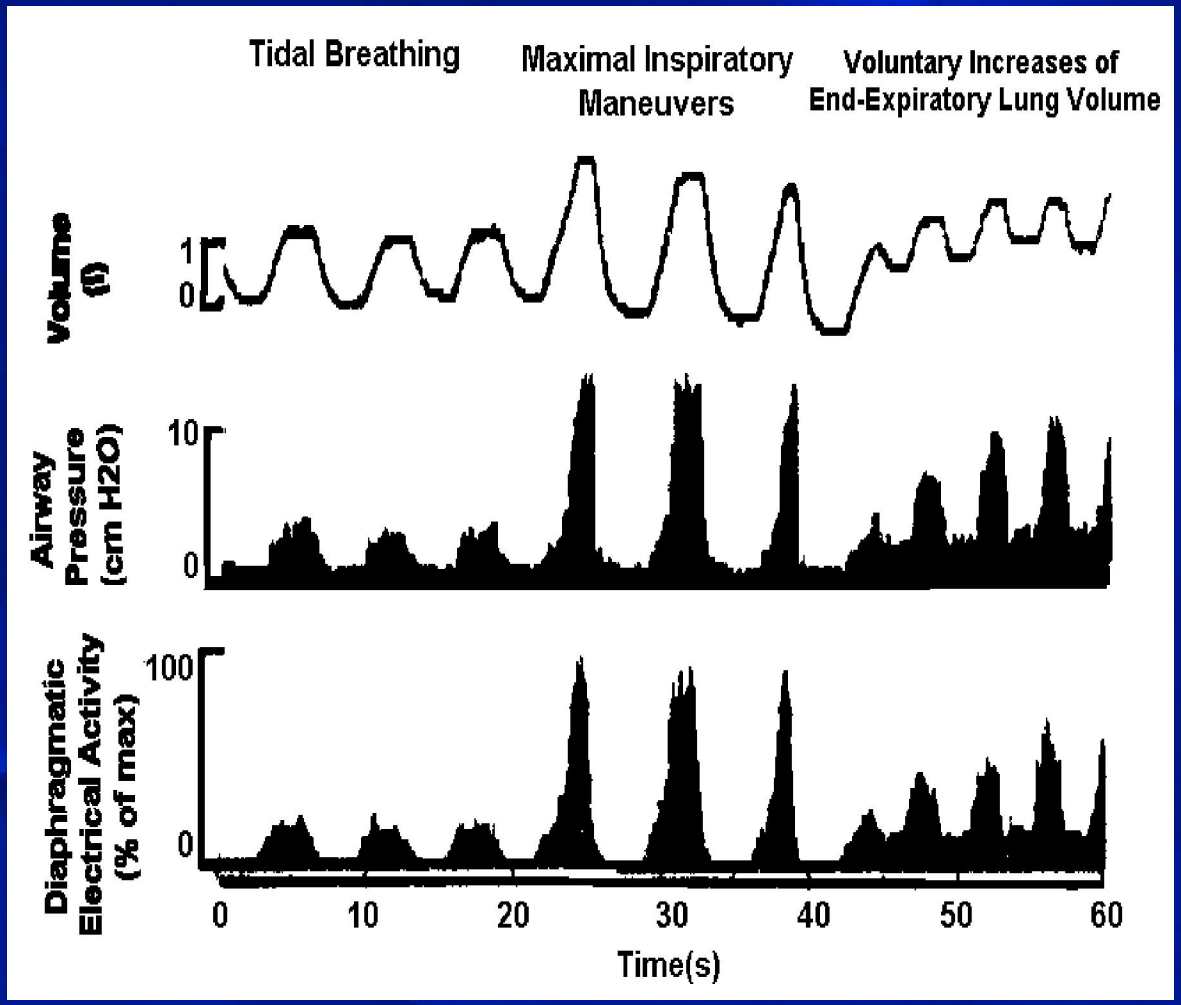
NAVA

- NAVA senses the desired assist using an array of esophageal EMG electrodes positioned to detect the diaphragm's contraction signal.


Lower esophageal sphincter
External
Internal
Longitudinal muscle
Circular muscle
Diaphragm
Costal part
Crural part
Phrenoesophageal ligament
Sling fibers
Squamocolumnar junction
Stomach
Esophagus


Mode
Pressure Support/CPAP
Admit patient
Nebulizer
Status
06-26 13:57
Set Ventilation Mode
NAVA
NAVA Ppeak est. 14 cmH2O
Basic
Trigg. Edi
Pressure Support
Backup ventilation
NAVA level
1.6
0.0
cmH2O/µV
30.0
Trigg. Edi
0.5
0.0
µV
2.0
Trigg. Flow
5
-20
0
PC above PEEP
20
5
cmH2O
120
PEEP
5
0
cmH2O
50
Insp. cycle off
30
1
%
70
O2 conc.
40
21
%
100
PS above PEEP
14
0
cmH2O
120
Ppeak (cmH2O)
14
40
Pmean (cmH2O)
7
PEEP (cmH2O)
5
RR (b/min)
20
30
5
O2 (%)
41
Ti/Ttot
0.26
MVe (l/min)
C
3.6
40.0
2.5
VTi (ml)
176
VTe (ml)
176
Edi peak (µV)
6.0
Edi min (µV)
0.1
Show Previous Mode
time: 13:57
Cancel
Accept
Additional values

Response to Effort



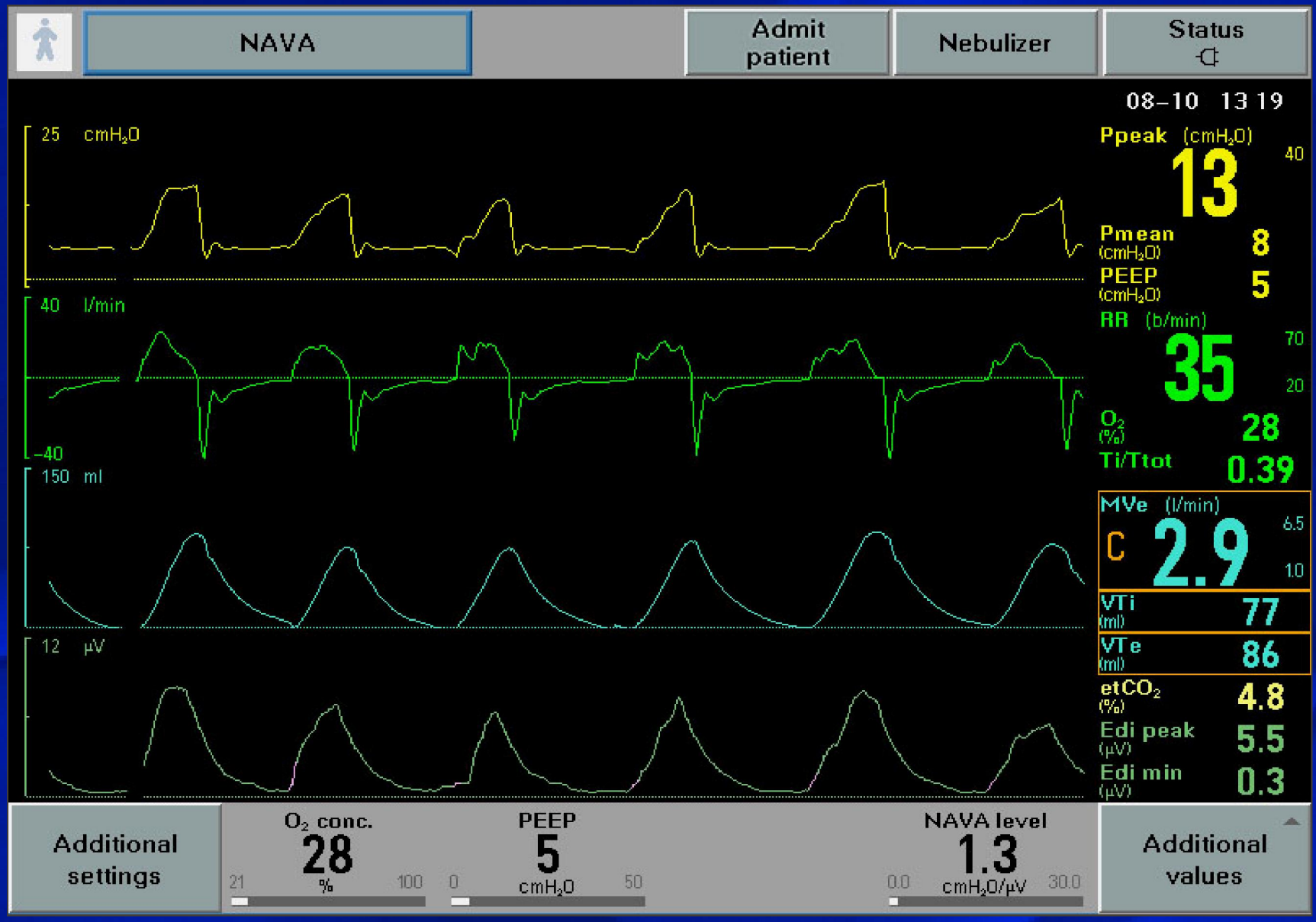
Volume

P_{AW}

D_{GM} EMG

Sinderby et al, Nature Medicine; 5(12):1433-1436

NAVA


NAVA
Admit patient
Nebulizer
Status
08–10 13 19
25 cmH2O
40 l/min
-40
150 ml
12 µV
Ppeak (cmH2O)
13
40
Pmean (cmH2O) 8
PEEP (cmH2O) 5
RR (b/min)
35
70
20
O2 (%) 28
Ti/Ttot 0.39
MVe (l/min)
C 2.9
6.5
1.0
VTi (ml) 77
VTe (ml) 86
etCO2 (%) 4.8
Edi peak (µV) 5.5
Edi min (µV) 0.3
Additional settings
O2 conc. 28 % 21 100
PEEP 5 cmH2O 0 50
NAVA level 1.3 cmH2O/µV 0.0 30.0
Additional values

NAVA

- Advantage
  - Potentially better patient-ventilator synchrony
    - Sinderby. Clin Chest Med 2008;29:329
- Problems
  - Inability to distinguish breathing from diaphragmatic contraction from other reasons (e.g. hiccups, subdiaphragmatic abscess)
  - Cost
  - Relatively invasive
- No good outcome trials to date

PVA Summary

- PVA is a real phenomenon
- PVA can be difficult to identify at times
- Clinicians should strive to optimize patient-ventilator synchrony to reduce WOB and the use of NMB's
- Newer modes, such as PAV and NAVA may have the potential to further optimize patient-ventilator synchrony

THANK YOU