Ventilator Dyspnea: Optimizing Ventilator/Patient Synchrony

Kenneth Miller, MEd, MSRT, RRT-ACCS, FAARC
Clinical Educator
Respiratory Care
Lehigh Valley Health Network
Allentown, Penna.

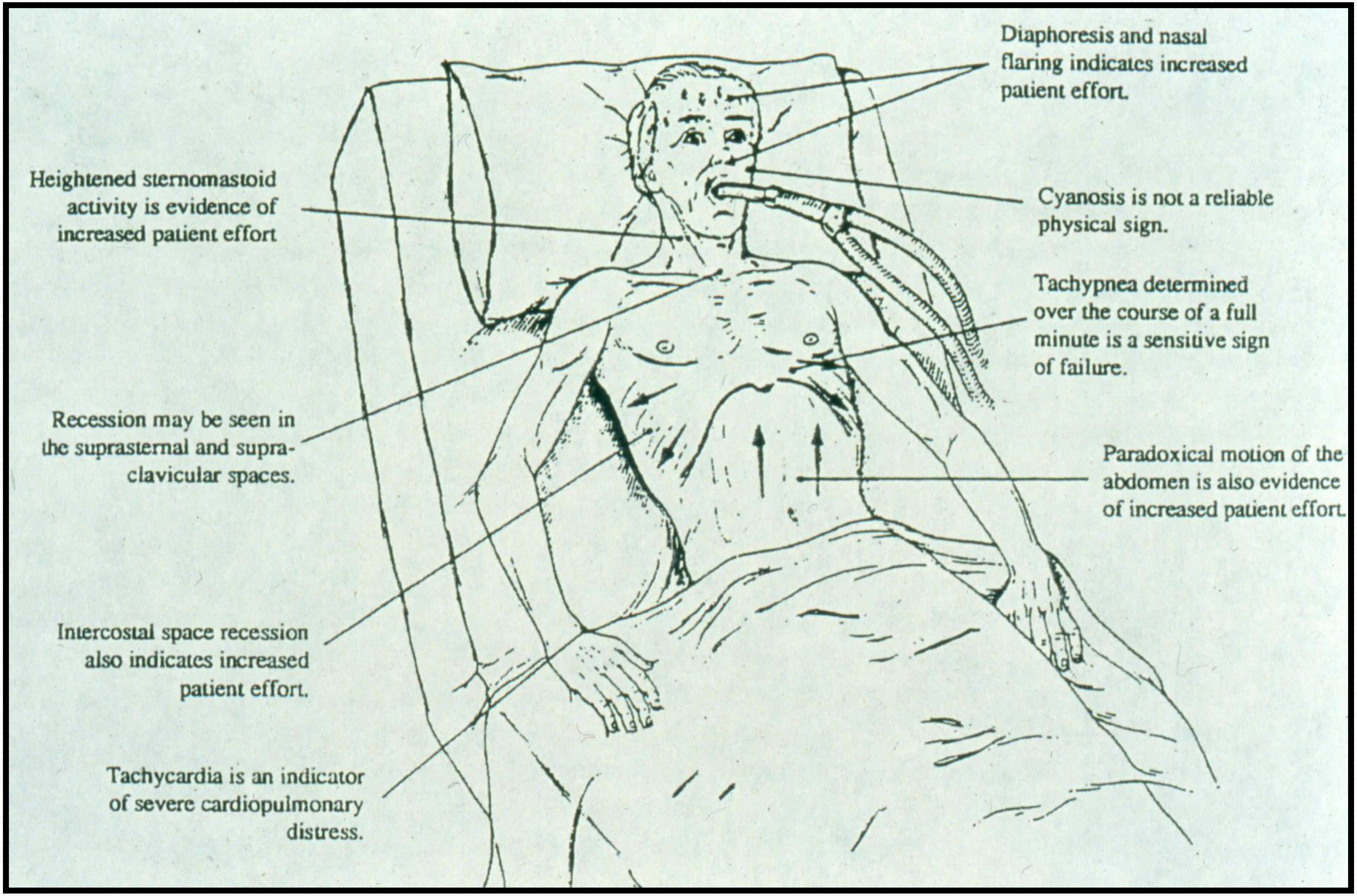
Learning Objectives

- Review the basics of breathing
- Describe relationship between the control of breathing & mechanical ventilation
- Define what is ventilator asynchrony
- Describe the potential negative sequale of ventilator asynchrony
- Describe clinical interventions to maximize ventilator synchrony

Goals of Mechanical Ventilation

- Optimize gas exchange
- Maximize ventilator-patient interfacing
- Minimize ventilator induced injury
- Facilitate ventilatory liberation

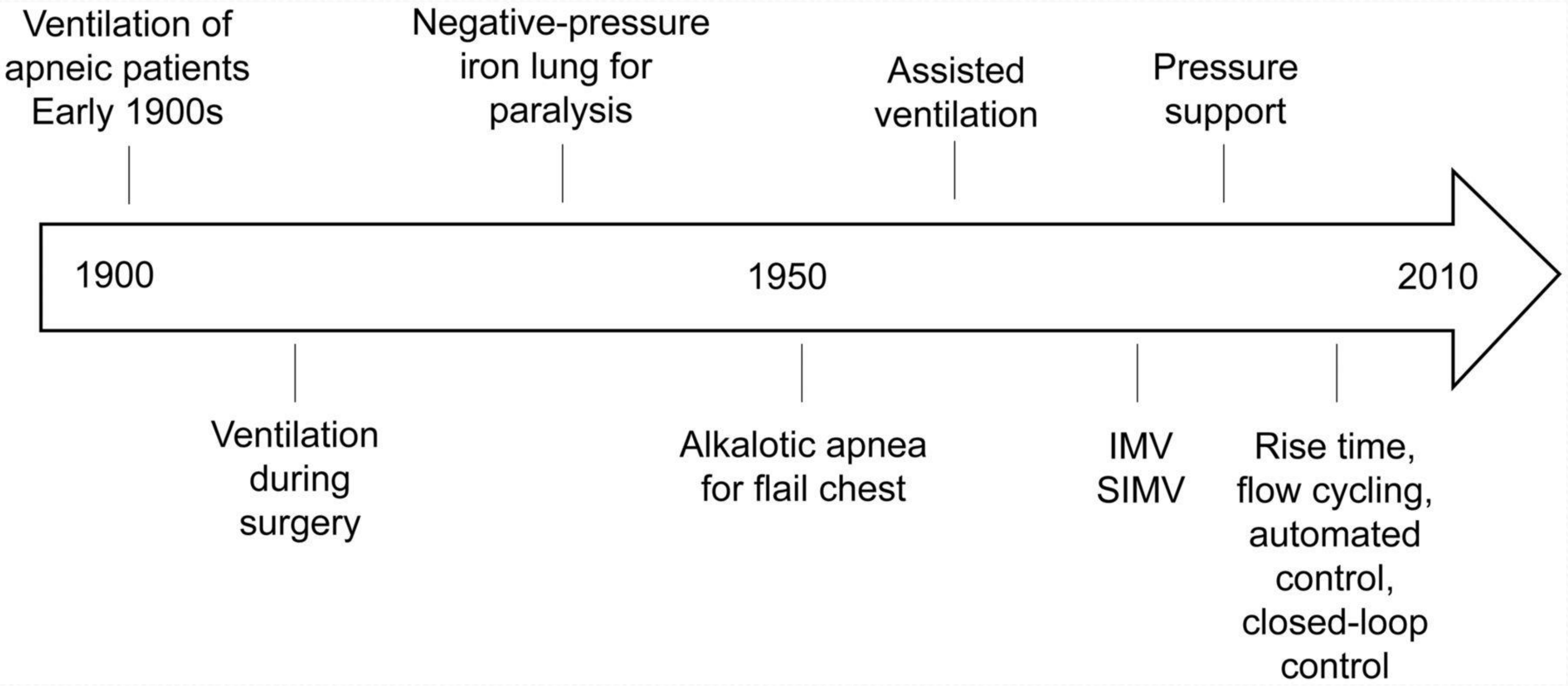
NEVER!!!


Diaphoresis and nasal flaring indicates increased patient effort.
Heightened sternomastoid activity is evidence of increased patient effort
Cyanosis is not a reliable physical sign.
Tachypnea determined over the course of a full minute is a sensitive sign of failure.
Recession may be seen in the suprasternal and supra-clavicular spaces.
Paradoxical motion of the abdomen is also evidence of increased patient effort.
Intercostal space recession also indicates increased patient effort.
Tachycardia is an indicator of severe cardiopulmonary distress.

Historical Prespective

- Controller-ventilator unable to respond to patient effort
- Assistor-ventilator capable of “triggering”
- 1930-Barach et al. recognized the need for high flows to make patient’s comfortable on CPAP
- **1950-1960s-Avery-therapuetic hyperventilation**
- 1962-Harrison first true champion of patient-triggered augmented ventilation
- 1973-Downs introduced IMV
- 1986-Marini published classic paper of WOB during mechanical ventilation

Timeline of patient-ventilator interaction

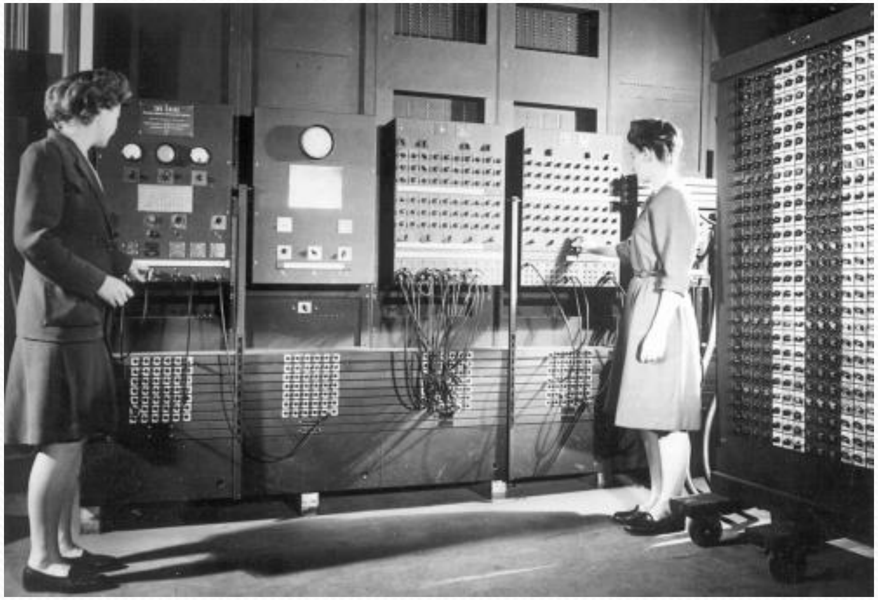


Branson, R. D. Respir Care 2011;56:15-24

First Generation

- Controlled Mechanical Ventilation **ONLY**
- Limited monitoring
- No alarms
- All simple mechanical devices
- First application of PEEP
- Machine variables had to be counted –could not be set
- I/E ratio fixed @ 1:2

Engstrom Ventilator-Weight 500 lbs!!!



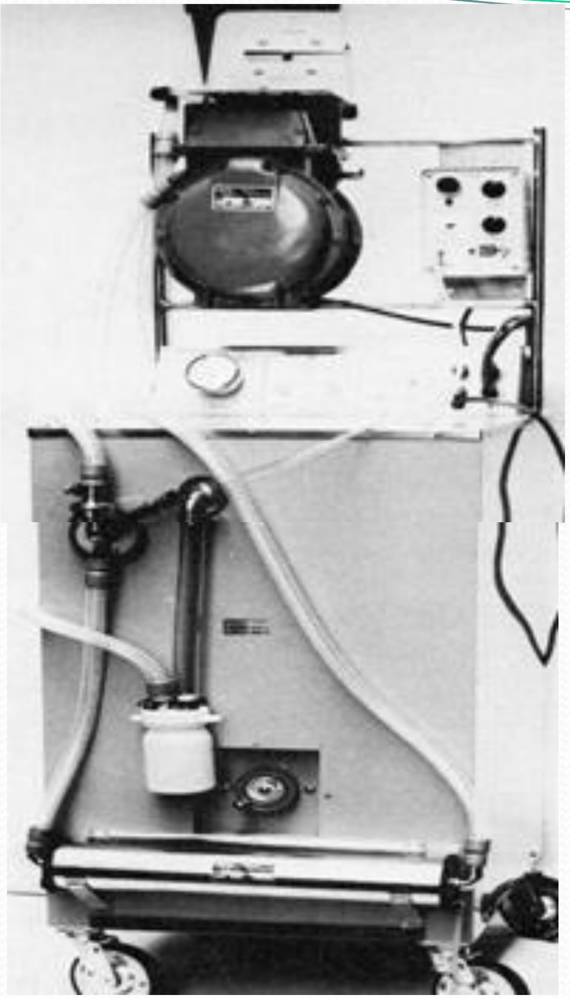
First computers

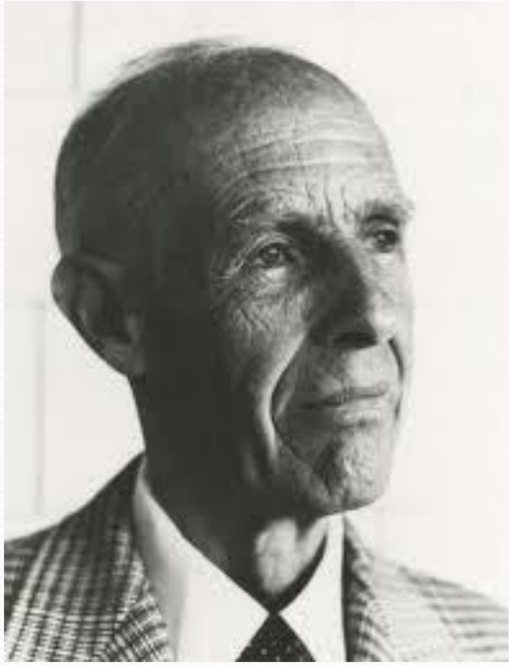
The Bird Mark 7 being used as a pressure ventilator
Note: no alarms, etc.

Second Generation 1970-1980

- Assist/ Control Ventilation
- Simple monitoring
- Basic alarms
- External IMV at end of period
- Demand valves
- Integrated IMV or SIMV

Emerson
Post-op
Ventilator

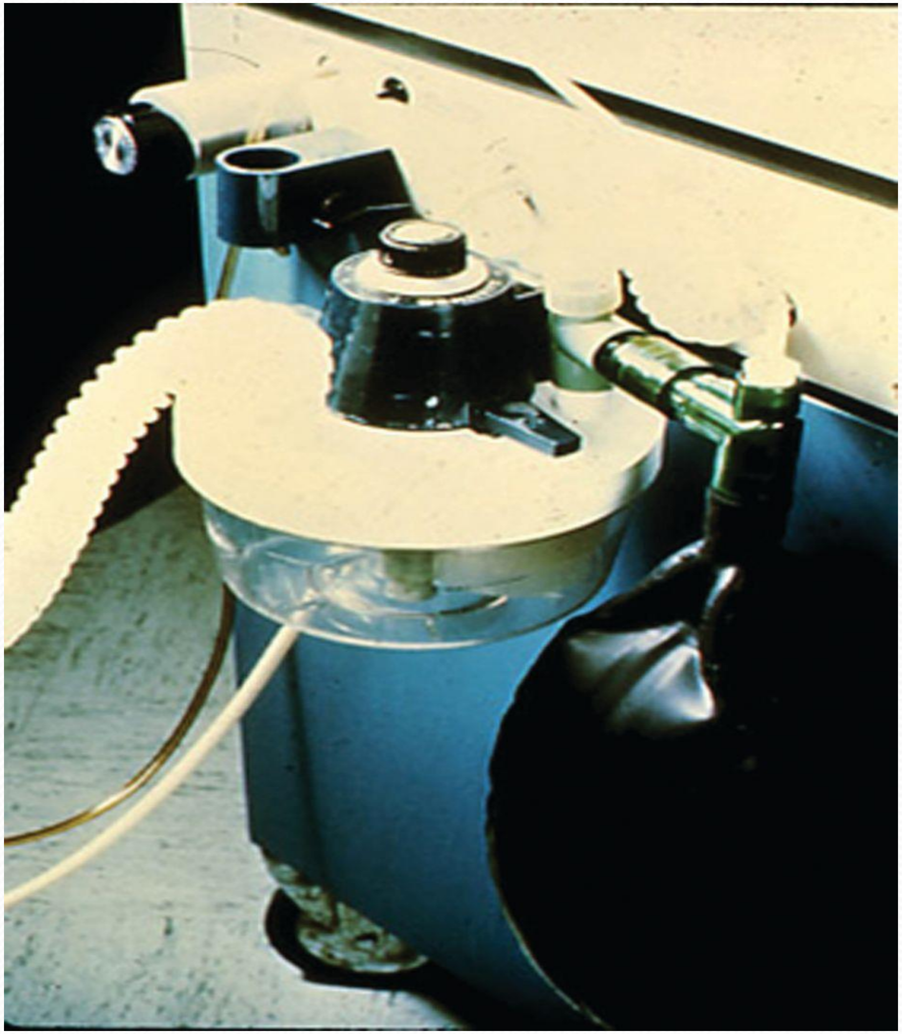




Jack Emerson

Puritan Bennett MA-1

An early intermittent mandatory ventilation system that included an H-valve and an integral one-way valve to provide continuous flow for spontaneous breathing.

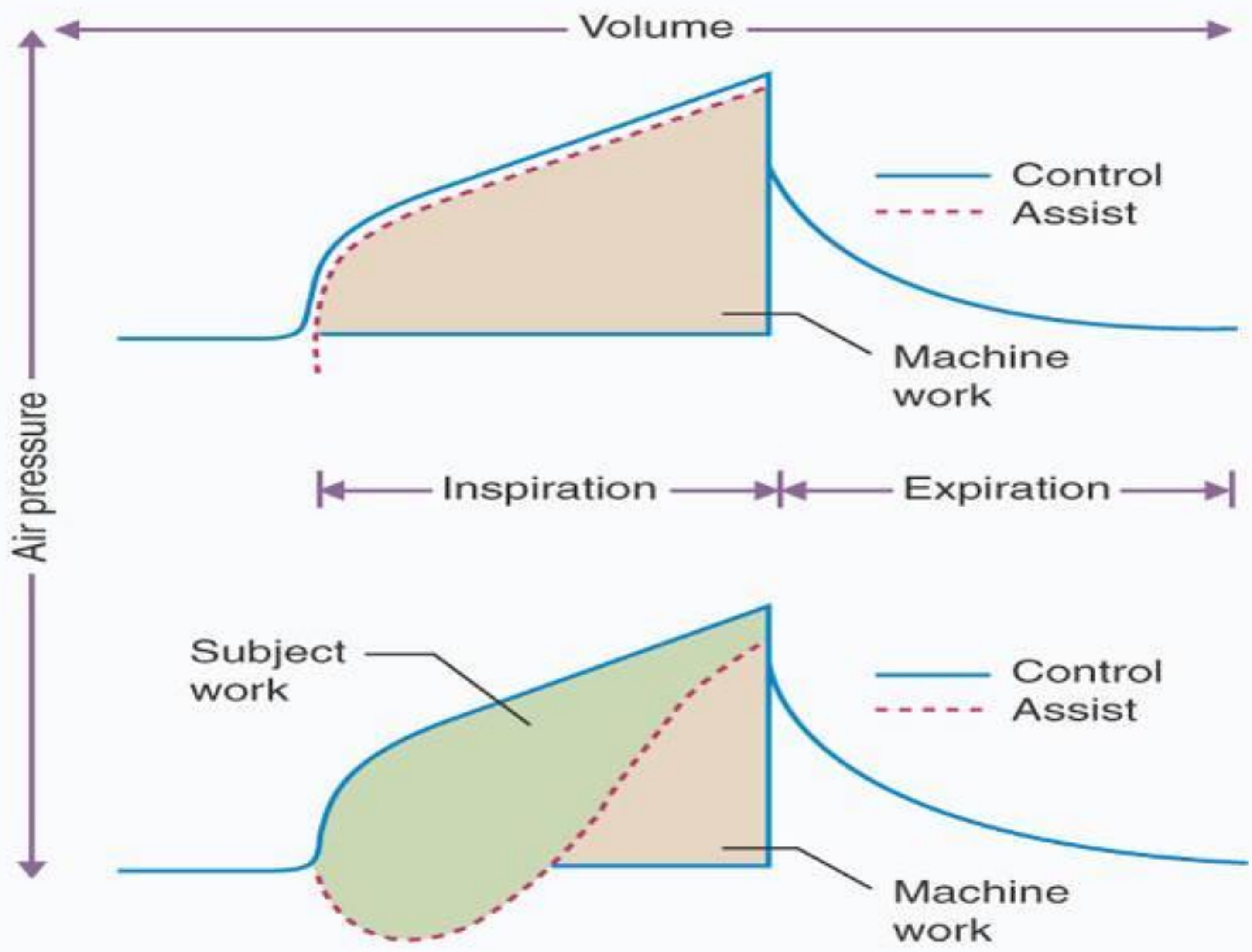


Branson, R. D. Respir Care 2011;56:15-24

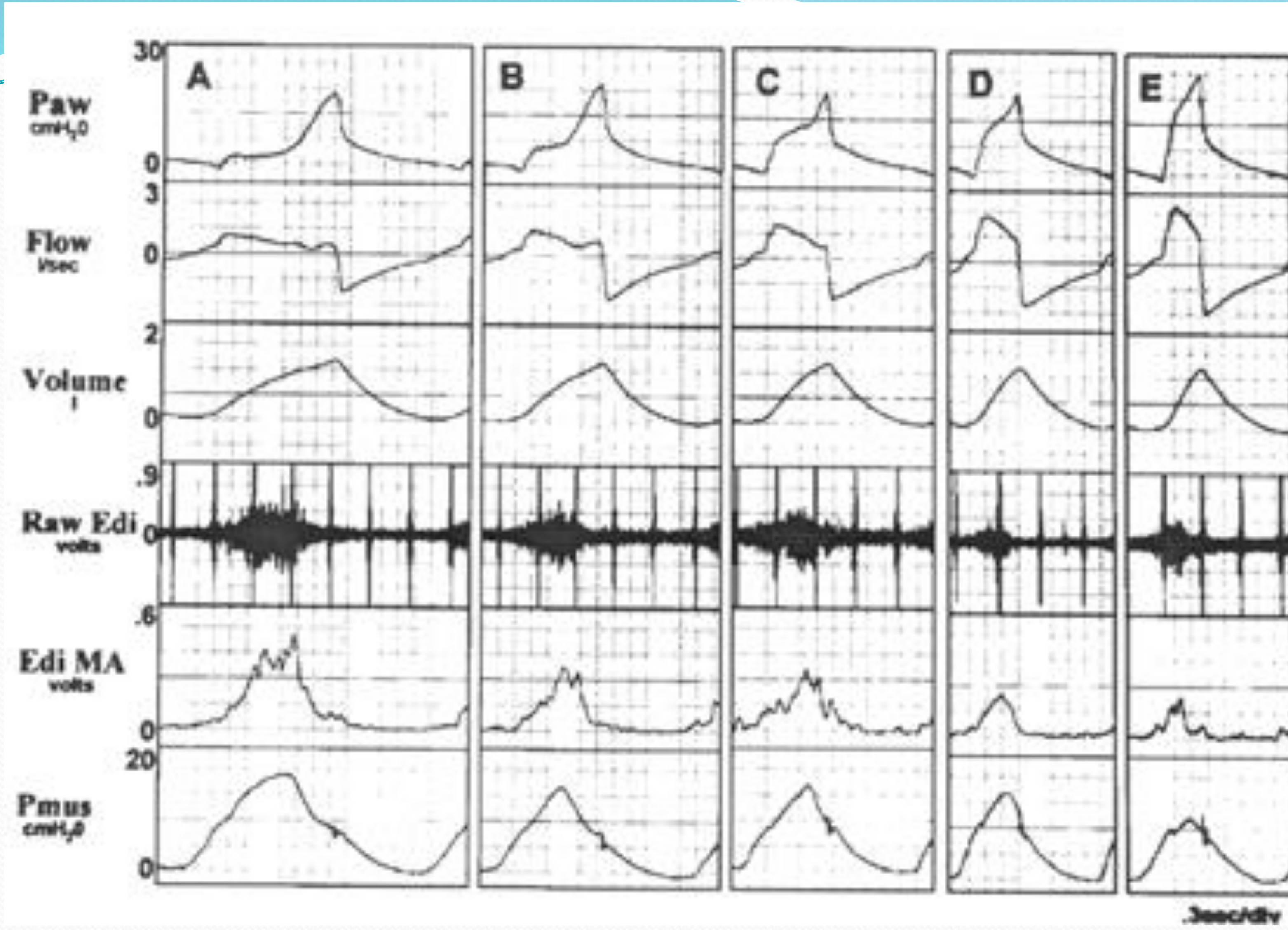
Bourns Bear 1

First to Recognize Ventilator Asynchrony

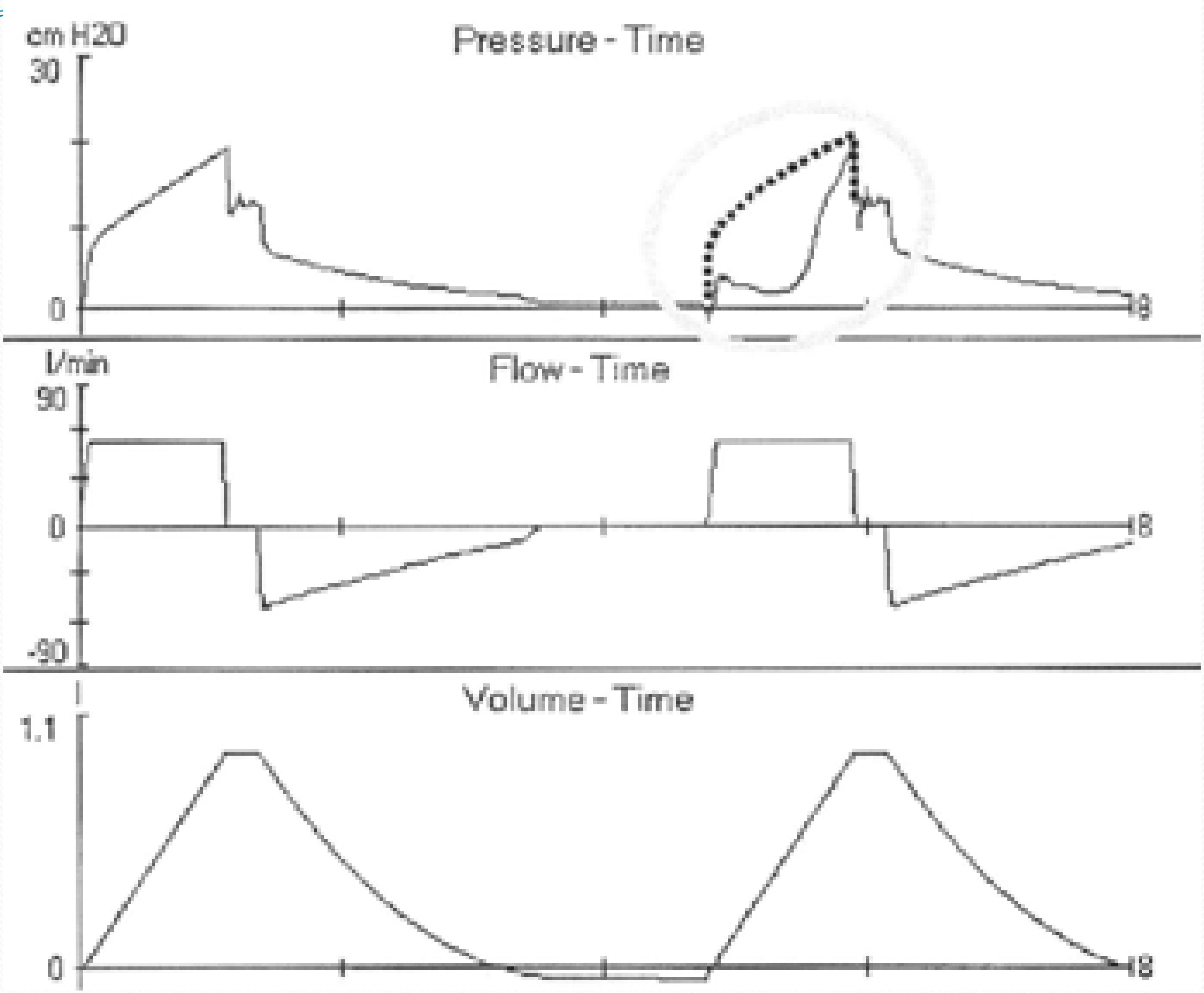
- J.J Marini
  - Patient work during the inspiratory phase
- McIntyre
  - Imposed work through ventilator circuit and artificial airway
- Fernandez
  - Active muscle work during a ventilator battern
- Hargell
  - Utilization of ventilator graphics to determine ventilator asynchrony



(Modified from Marini JJ, Rodriguez M, Lamb V: Am Rev Respir Dis 134:902, 1986.)



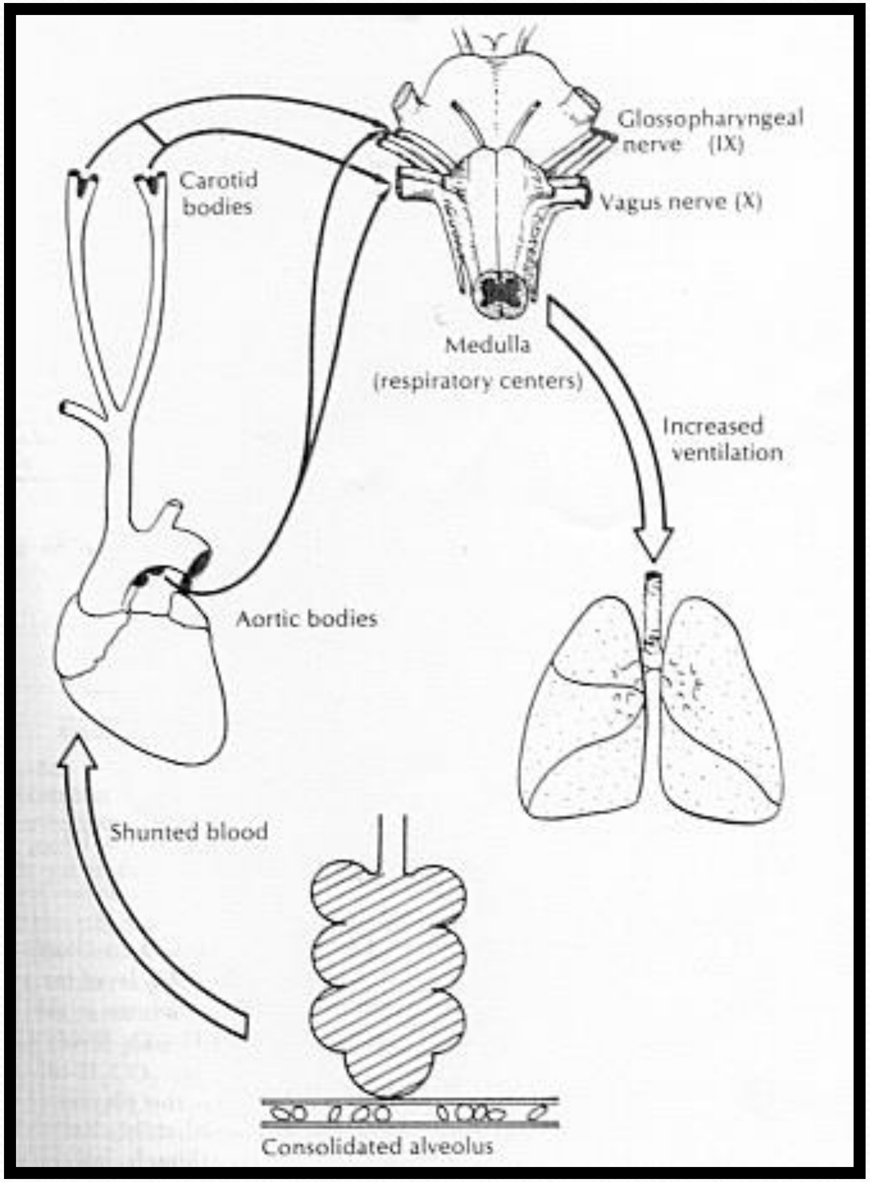
Fernandez AJRCCM 1999;159:710

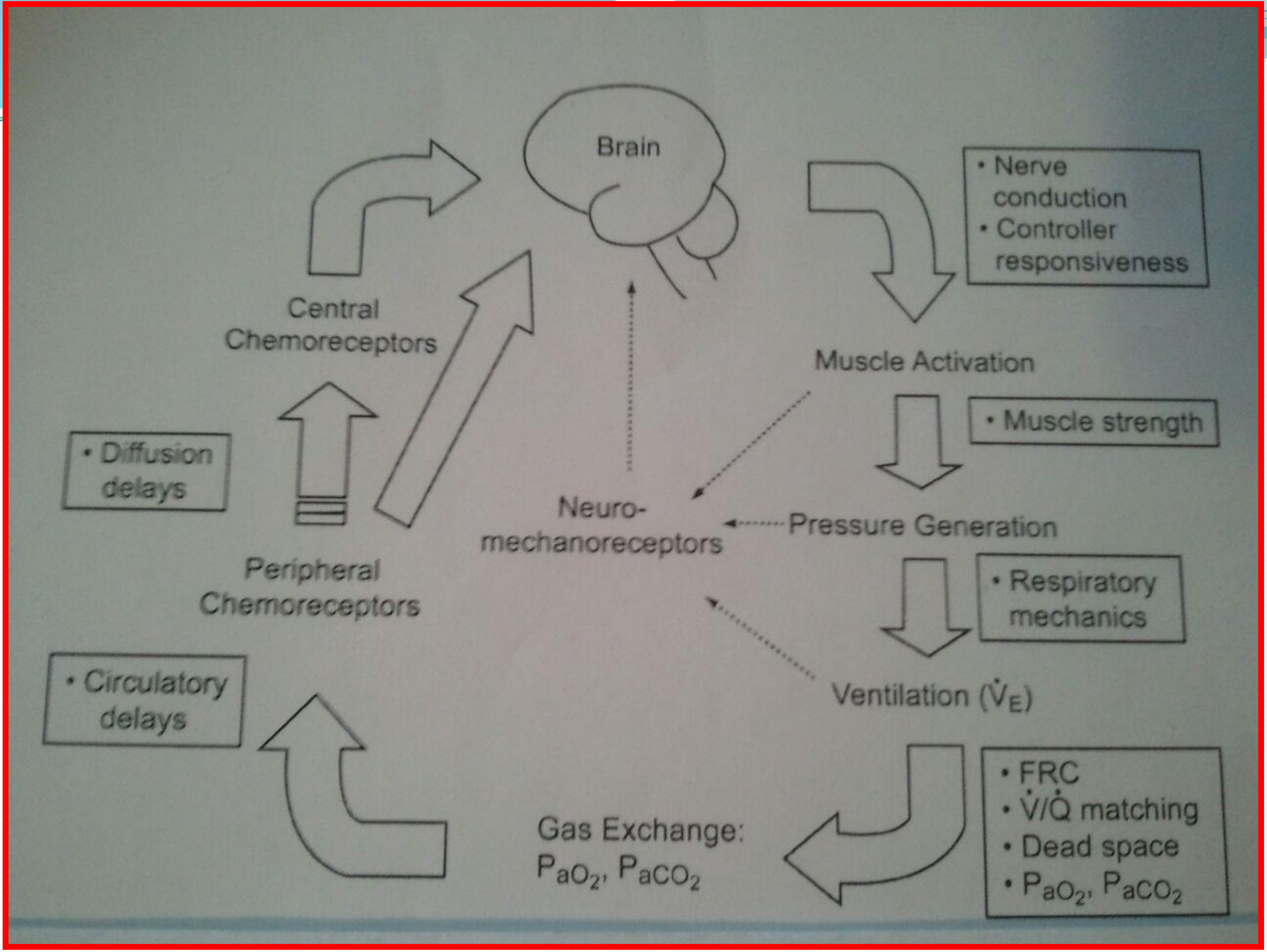


Nilsestuen, Hargett RC 2005;50:202

Why Is There Ventilator Asynchrony?

Control of Ventilation





(Williams MD, Hinojosa-Kurtzberg PhD & Parthasarathy MD, 2011)

Ideally, ventilator gas delivery would perfectly match patient demand. This patient-ventilator interaction depends on how the ventilator responds to patient respiratory effort and, in turn, how the patient responds to the breath delivered by the ventilator. It is now evident that the interaction between patient and ventilator is frequently suboptimal, with consequences that appear to have substantial clinical relevance. Indeed, some clinicians have referred to this state as a **“tug-of-war!!**


CAVES
2

Patient-Ventilator Synchrony

- Adequate resting of respiratory muscles
- Improved gas exchange
- Patient comfort

Evidence of Ventilator Synchrony

What is Ventilator Asynchrony?

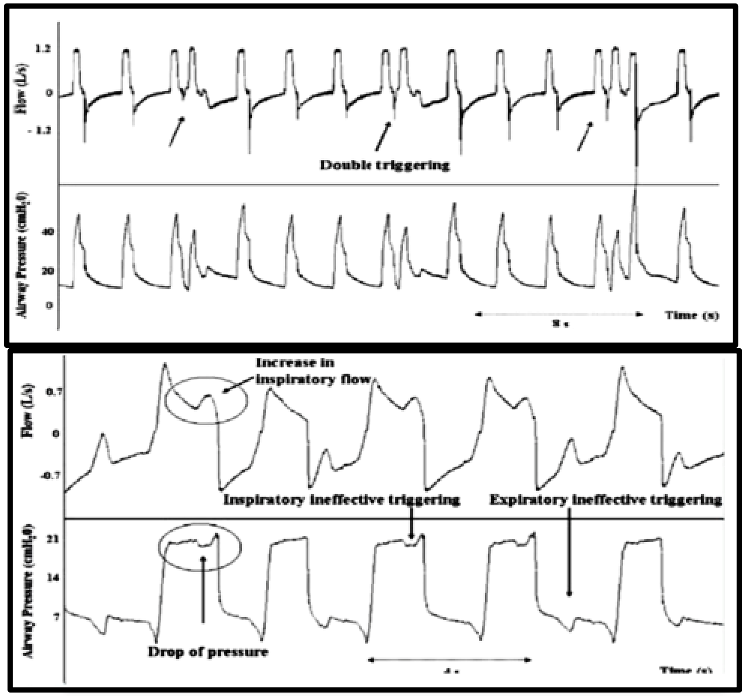
- Defined as a “mismatch” between the patient and ventilatory inspiratory time, flow and expiratory time.
- Chao et al. found that more than 10% of patients admitted to a weaning center exhibited this phenomenon.
- This mismatching results in weaning failure secondary to due to diaphragmatic muscle energy waste.

Patient-ventilator Asynchrony

- 24% of mechanically ventilated patients exhibit patient-ventilator asynchrony in > 10% of their respiratory efforts during AVC and PS ventilation (ineffective triggering and double triggering).
- Patient-ventilator asynchrony during assisted mechanical ventilation Intensive Care Med. 2006;32:1512

Arnold W. Thille, Pablo Rodriguez, Belen Cabello
Francois Lellouche, Laurent Brochard

Length of Stay



Asynchrony

↓

Sedation

↓

Prolonged ventilation time[1]

↓

Possible muscle atrophy[2] **and VAP**[3]

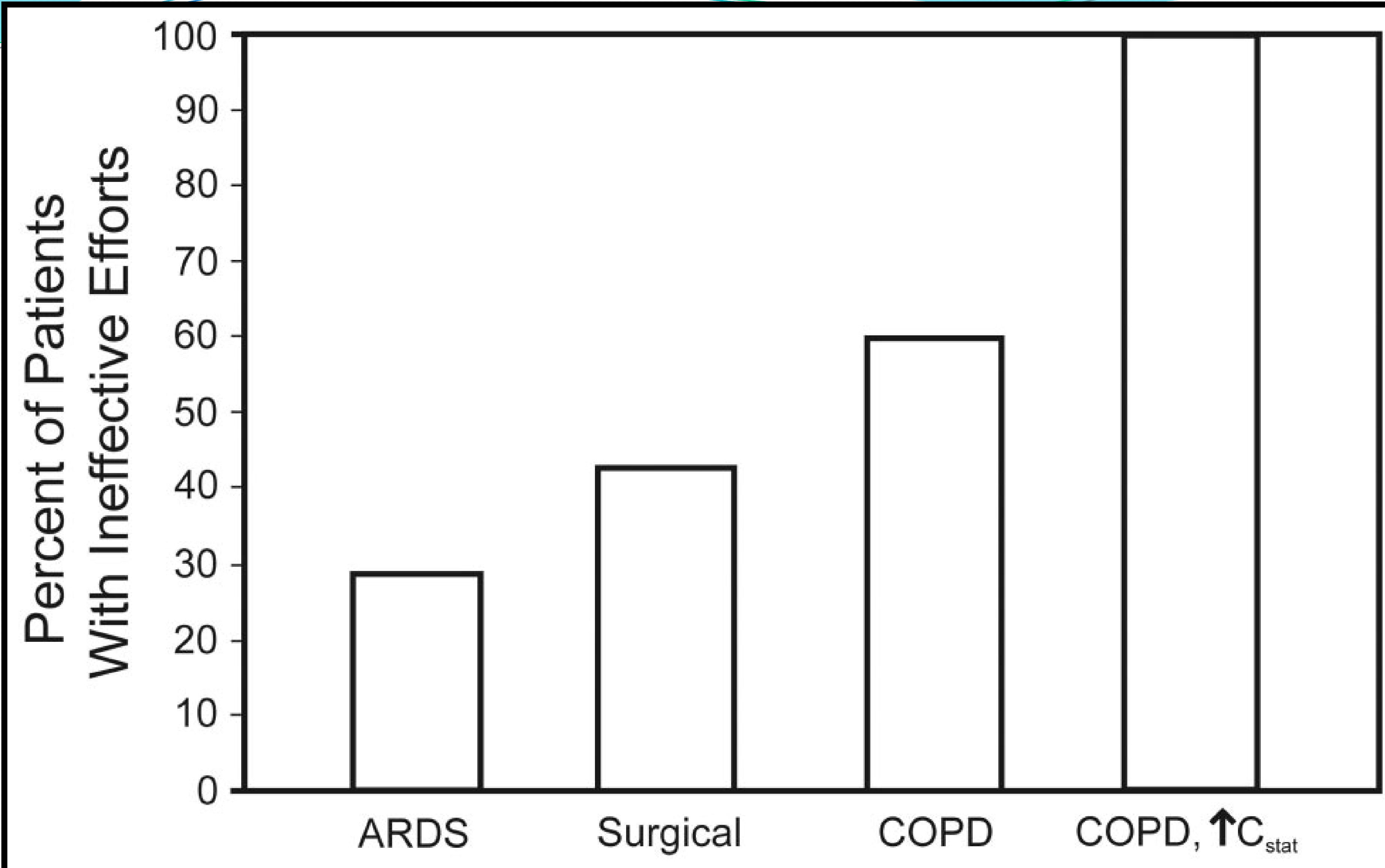
↓

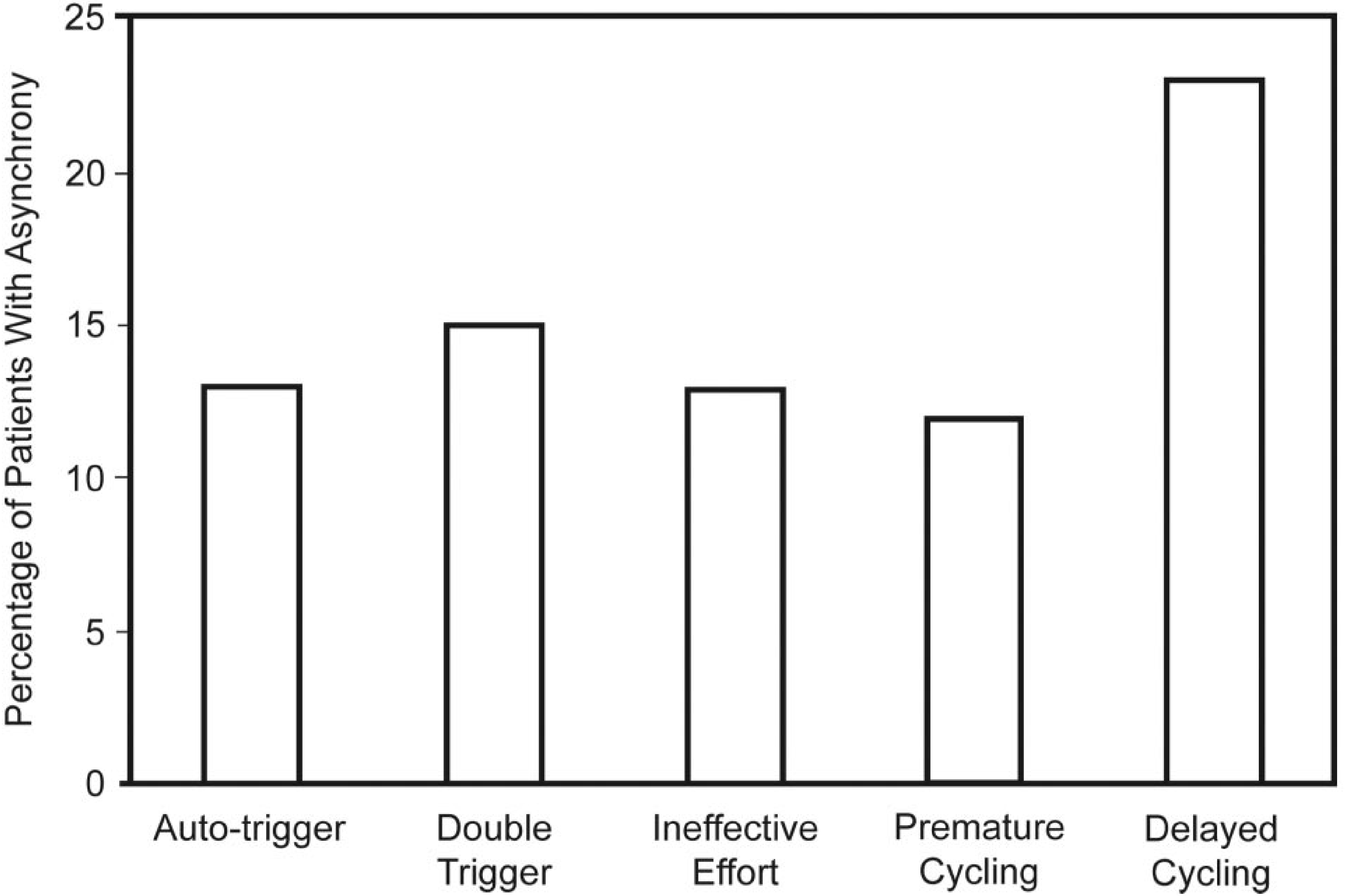
Weaning is delayed

1. Kollef M et al. *Chest*. 1998;114:541–548.
2. Levine S et al. *NEJM* .2008;358:1327-1335.
3. Rello J et al. *Chest* .2002;122:2115-2121.

Three Main Patterns of Asynchrony

- **Trigger asynchrony:**
  - Can manifest as a delay or absent of inspiration or unwanted breaths(auto-triggering)
- **Flow asynchrony:**
  - This can manifest as to slow or to fast of delivered flow to match the patient's flow requirements
- **Cycle or termination asynchrony:**
  - This can manifest when the inspiratory time of the breath is longer than what the patient desires or termination inspiratory can not be reached secondary to leaks or prolonged exhalation.


Percent of Patients
With Ineffective Efforts
100
90
80
70
60
50
40
30
20
10
0
ARDS
Surgical
COPD
COPD, ↑C_{stat}


25
20
15
10
5
0
Percentage of Patients With Asynchrony
Auto-trigger
Double Trigger
Ineffective Effort
Premature Cycling
Delayed Cycling

Factors in Patient-Vent Synchrony

- Trigger setting/type
- Rise-time
- Flow delivery pattern
- Sedation level
- Respiratory drive
- AutoPEEP
- Airway size
- Pathology of respiratory system
- Thoracic-abdominal impedance
- Airway patency

Treat the Patient and You May Achieve Synchrony!!!

- Examples:
  - Metabolic acidosis
  - Pain/anxiety/fear
  - Hypoxemia
  - Airway obstruction
  - Fever

Effect of Patient-Ventilator Asynchrony* on Outcomes in an Observational Study.

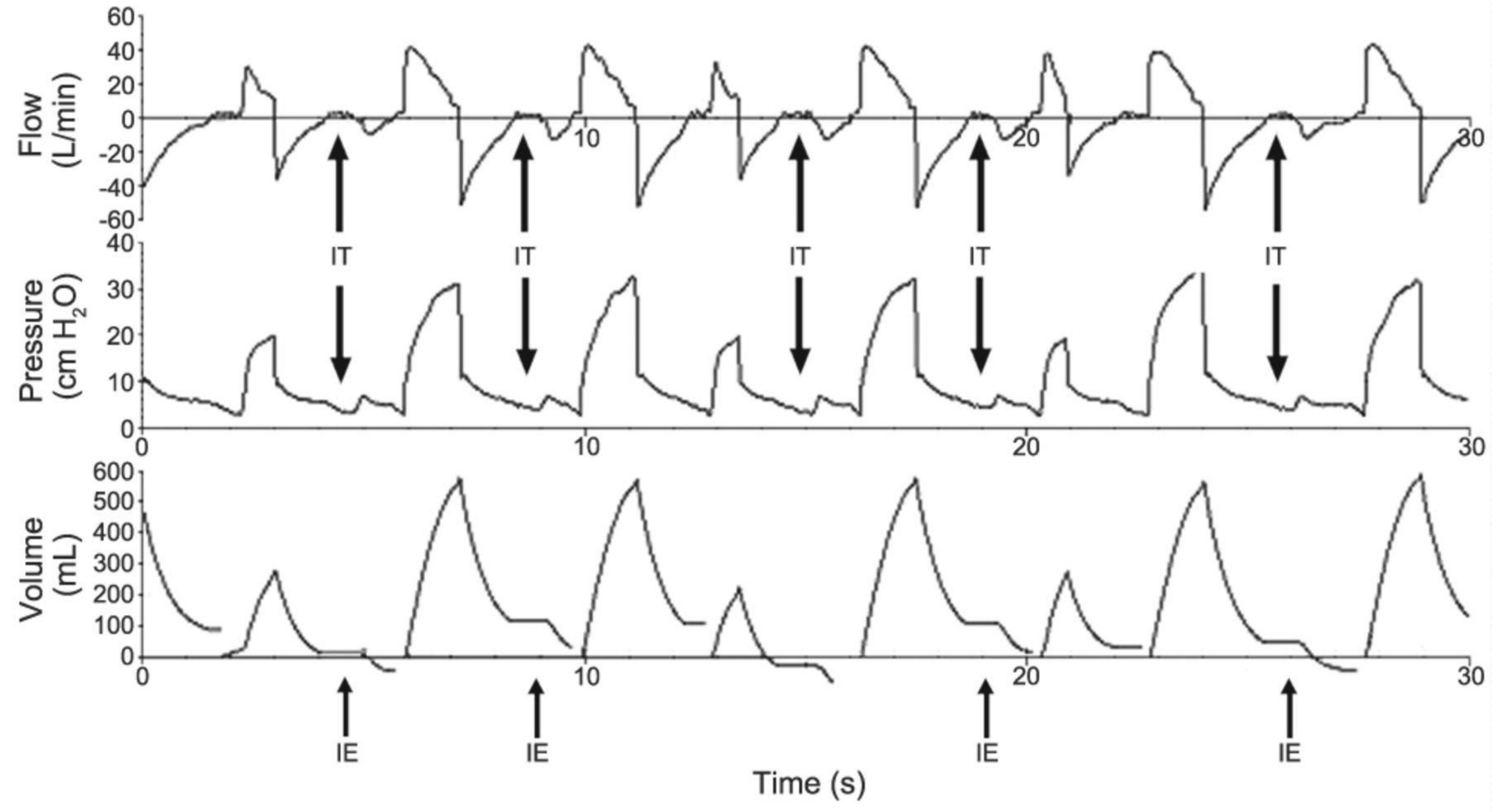
	Ineffective-Effort Index > 10%	Ineffective-Effort Index < 10%	*P*
Number of patients	16	44	
Duration of mechanical ventilation (median d)	6	2	<.05
28-d ventilator-free survival (median d)	21	25	<.05
ICU stay (median d)	8	4	<.05
Hospital stay (median d)	21	8	<.05
ICU mortality (%)	25	14	NS
Hospital mortality (%)	30	20	NS

* Patient-ventilator asynchrony was defined as an ineffective-effort index > 10%.

NS = difference not significant

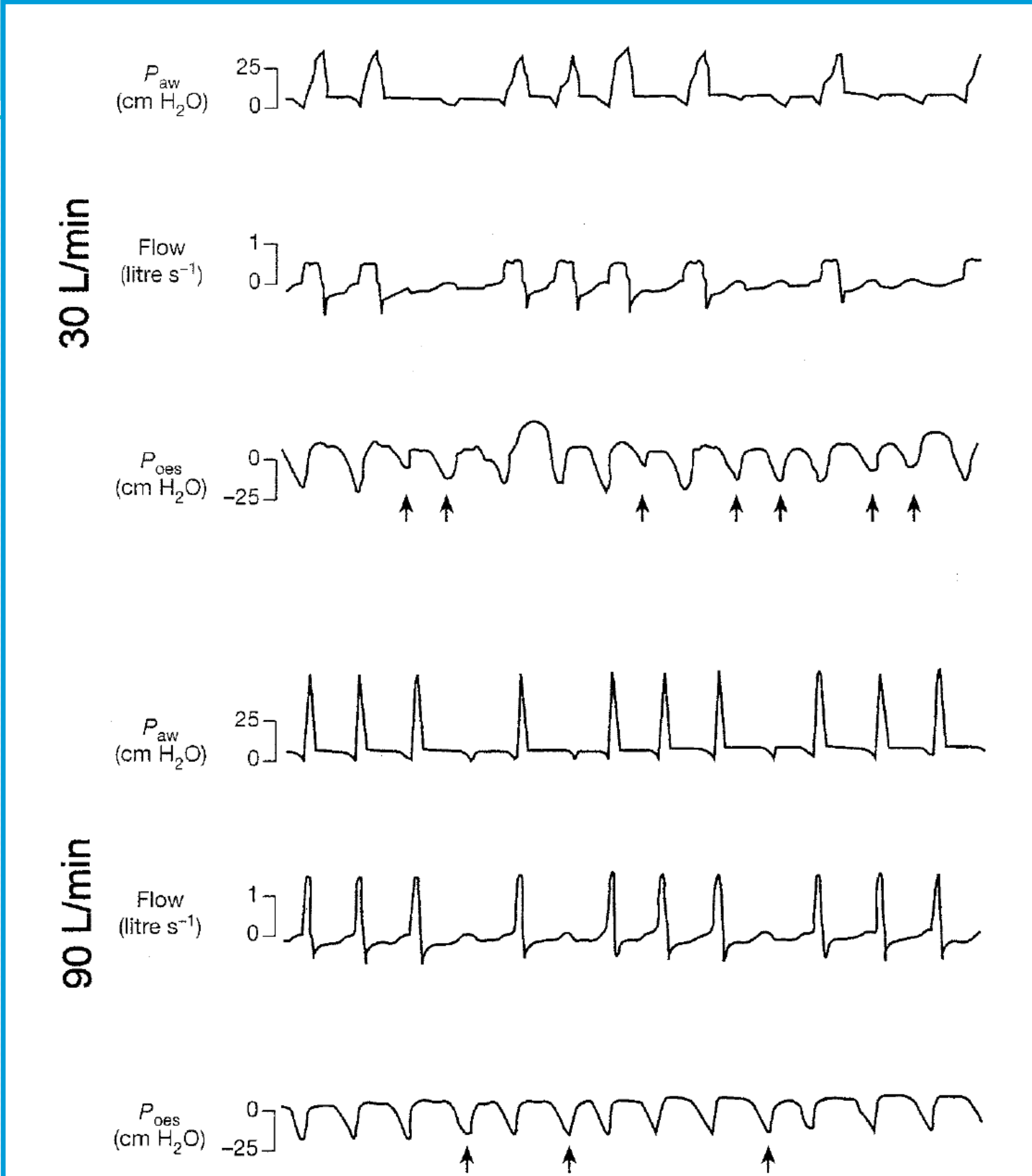
Epstein, S. K. Respir Care 2011;56:25-38

During this tracing of 30 seconds, the ventilator displays that the patient rate is 16 breaths/min.



de Wit, M. Respir Care 2011;56:61-72

5 missed patient triggered efforts



-Ineffective triggering at 30 l/mn

- Increase in flow rate

- Subsequent increase of expiratory time

- Decreased dynamic hyperinflation

- Subsequent decrease in ineffictive trigerring

Missed triggered breath on G-5

Increased WOB noted by Pressure time curve scoping

Air trapping

Excessive P01 inspiratory trigger effort

Secretions, bronchospasm, air-trapping

2021-05-25
08:28:56
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
Trend
IntelliCuff
44
26 Ppeak cmH2O
20 Pmean cmH2O
750
250
462 VTE ml
15.0
8.0
11.3 ExpMinVol l/min
32
fTotal
Paw cmH2O
Flow l/min
26 b/min Rate
430 ml Vtarget
15 cmH2O PEEP/CPAP
60 % Oxygen
1
2
SpO2raw
Paw/Paux
26 Ppeak cmH2O
27 Pplateau cmH2O
20 Pmean cmH2O
15 PEEP/CPAP cmH2O
--- ΔP cmH2O
4.3 AutoPEEP cmH2O
--- P0.1 cmH2O
--- PTP cmH2O*s
37.8 Insp Flow l/min
37.8 Exp Flow l/min
307 VTI ml
462 VTE ml
--- VTESpont ml
11.3 ExpMinVol l/min
0.00 MVSpont l/min
30 fTotal b/min
0 fSpont b/min
0.85 TI s
1.46 TE s
1:1.7 I:E
6 Rinsp cmH2O/l/s
9 Rexp cmH2O/l/s
33.0 Cstat ml/cmH2O
0.20 RCinsp s
0.58 RCexp s
5.6 VT/IBW ml/kg
0 %
0 VLeak ml
0.00 MVLeak l/min
63 Oxygen %
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC


2021-05-25
08:30:19
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
44 29 Ppeak cmH2O
20 Pmean cmH2O
750 250 670 VTE ml
15.0 8.0 12.6 ExpMinVol l/min
32 fTotal
Paw cmH2O
Flow l/min
Trend
IntelliCuff
26 b/min Rate
430 ml Vtarget
15 cmH2O PEEP/CPAP
60 % Oxygen
1
2
SpO2raw
Paw/Paux
29 Ppeak cmH2O
--- Pplateau cmH2O
20 Pmean cmH2O
16 PEEP/CPAP cmH2O
3.6 ΔP cmH2O
0.6 AutoPEEP cmH2O
-13 P0.1 cmH2O
0.3 PTP cmH2O*s
60.4 Insp Flow l/min
51.8 Exp Flow l/min
561 VTI ml
670 VTE ml
--- VTESpont ml
12.6 ExpMinVol l/min
0.00 MVSpont l/min
30 fTotal b/min
0 fSpont b/min
0.85 TI s
1.46 TE s
1:1.7 I:E
5 Rinsp cmH2O/l/s
12 Rexp cmH2O/l/s
51.4 Cstat ml/cmH2O
0.25 RCinsp s
0.60 RCexp s
8.1 VT/IBW ml/kg
0 VLeak %
0 VLeak ml
0.00 MVLeak l/min
63 Oxygen %
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC


2021-05-25
08:29:23
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
44
23 Ppeak cmH2O
19 Pmean cmH2O
750
250
303 VTE ml
15.0
8.0
11.4 ExpMinVol l/min
32
fTotal
Paw cmH2O
Flow l/min
Trend
IntelliCuff
26 b/min
Rate
430 ml
Vtarget
15 cmH2O
PEEP/CPAP
60 %
Oxygen
1
2
SpO2raw
Paw/Paux
23 Ppeak cmH2O
24 Pplateau cmH2O
19 Pmean cmH2O
14 PEEP/CPAP cmH2O
7.6 ΔP cmH2O
1.1 AutoPEEP cmH2O
--- P0.1 cmH2O
--- PTP cmH2O*s
37.0 Insp Flow l/min
29.9 Exp Flow l/min
323 VTI ml
303 VTE ml
--- VTESpont ml
11.4 ExpMinVol l/min
0.00 MVSpont l/min
26 fTotal b/min
0 fSpont b/min
0.85 TI s
1.20 TE s
1:1.4 I:E
7 Rinsp cmH2O/l/s
5 Rexp cmH2O/l/s
36.1 Cstat ml/cmH2O
0.25 RCinsp s
0.53 RCexp s
3.7 VT/IBW ml/kg
0 VLeak %
0 VLeak ml
0.00 MVLeak l/min
63 Oxygen %
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

2021-05-25
08:29:44
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
Trend
IntelliCuff
26 b/min
Rate
430 ml
Vtarget
15 cmH2O
PEEP/CPAP
60 %
Oxygen
Controls
Alarms
44
29 Ppeak cmH2O
20 Pmean cmH2O
750
250
660 VTE ml
15.0
8.0
11.2 ExpMinVol l/min
32
fTotal
Paw cmH2O
Flow l/min
1
2
SpO2raw
Paw/Paux
29 Ppeak cmH2O
--- Pplateau cmH2O
20 Pmean cmH2O
16 PEEP/CPAP cmH2O
6.3 ΔP cmH2O
--- AutoPEEP cmH2O
-5.3 P0.1 cmH2O
0.2 PTP cmH2O*s
63.9 Insp Flow l/min
52.2 Exp Flow l/min
631 VTI ml
660 VTE ml
--- VTESpont ml
11.2 ExpMinVol l/min
0.00 MVSpont l/min
30 fTotal b/min
0 fSpont b/min
0.85 TI s
1.46 TE s
1:1.7 I:E
6 Rinsp cmH2O/l/s
8 Rexp cmH2O/l/s
59.2 Cstat ml/cmH2O
0.35 RCinsp s
0.60 RCexp s
8.0 VT/IBW ml/kg
0 VLeak %
0 VLeak ml
0.00 MVLeak l/min
63 Oxygen %
Monitoring
Graphics
Tools
Events
System
INT
AC

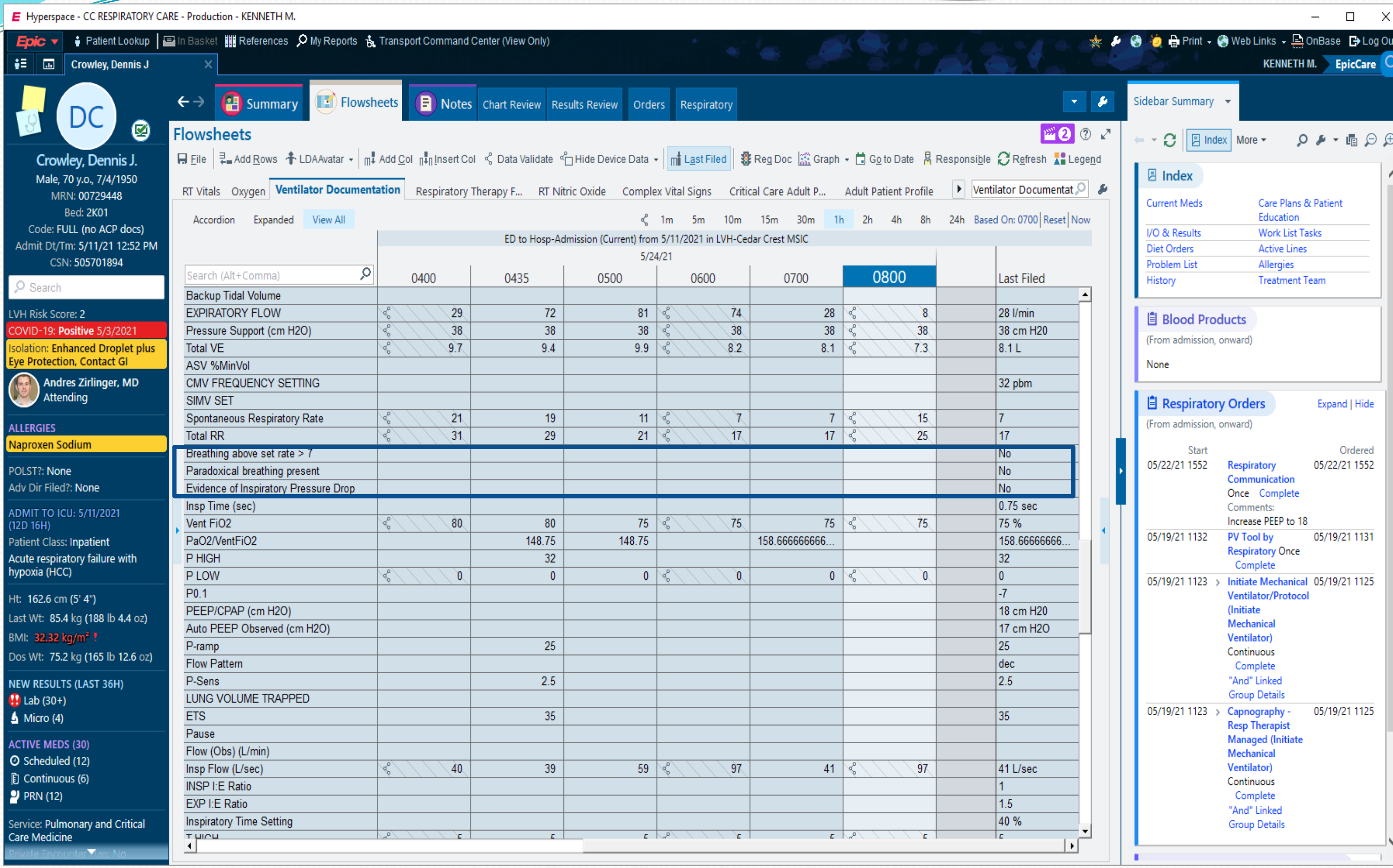
2021-05-25
08:29:08
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
44
31 Ppeak cmH2O
19 Pmean cmH2O
750
250
667 VTE ml
15.0
8.0
11.2 ExpMinVol l/min
32
fTotal
Paw cmH2O
Flow l/min
Trend
IntelliCuff
26 b/min
Rate
430 ml
Vtarget
15 cmH2O
PEEP/CPAP
60 %
Oxygen
1
2
SpO2raw
Paw/Paux
31 Ppeak cmH2O
--- Pplateau cmH2O
19 Pmean cmH2O
16 PEEP/CPAP cmH2O
--- ΔP cmH2O
2.7 AutoPEEP cmH2O
-15 P0.1 cmH2O
0.3 PTP cmH2O*s
64.1 Insp Flow l/min
49.1 Exp Flow l/min
452 VTI ml
667 VTE ml
--- VTESpont ml
11.2 ExpMinVol l/min
0.00 MVSpont l/min
28 fTotal b/min
0 fSpont b/min
0.85 TI s
1.46 TE s
1:1.7 I:E
3 Rinsp cmH2O/l/s
14 Rexp cmH2O/l/s
27.8 Cstat ml/cmH2O
0.07 RCinsp s
0.55 RCexp s
8.0 VT/IBW ml/kg
0 VLeak %
0 VLeak ml
0.00 MVLeak l/min
63 Oxygen %
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC


2021-05-25
08:25:59
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
44
26 Ppeak cmH2O
19 Pmean cmH2O
750
250
197 VTE ml
15.0
8.0
11.0 ExpMinVol l/min
32
27 fTotal b/min
0.4 AutoPEEP cmH2O
--- P0.1 cmH2O
--- PTP cmH2O*s
3 / 9
43.7 Insp Flow l/min
35.6 Exp Flow l/min
Paw cmH2O
Flow l/min
Adult Male
74 inch
IBW = 83 kg
Pcuff
---
cmH2O
Rinsp 8 cmH2O/l/s
Cstat 39.1 ml/cmH2O
PetCO2 41 mmHg
PetCO2 42 mmHg
ExpMinVol 10.8 l/min
Cstat 36.9 ml/cmH2O
08:25
Trend
IntelliCuff
26 b/min Rate
430 ml Vtarget
15 cmH2O PEEP/CPAP
60 % Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

29=-21=50cm

2021-05-25
08:27:31
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
Trend
IntelliCuff
44
29 Ppeak cmH2O
19 Pmean cmH2O
750
250
612 VTE ml
15.0
8.0
10.3 ExpMinVol l/min
32
30 fTotal b/min
7.4 AutoPEEP cmH2O
-21 P0.1 cmH2O
0.2 PTP cmH2O*s
3 / 9
27.4 Insp Flow l/min
39.4 Exp Flow l/min
Paw cmH2O
Flow l/min
Adult Male
74 inch
IBW = 83 kg
Pcuff
---
cmH2O
Rinsp
---
cmH2O/l/s
Cstat
5.5
ml/cmH2O
PetCO2
42
mmHg
PetCO2 40 mmHg
ExpMinVol 11.2 l/min
Cstat 41.0 ml/cmH2O
08:26
26 b/min
Rate
430 ml
Vtarget
15 cmH2O
PEEP/CPAP
60 %
Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

EPIC Documentation of Asynchrony



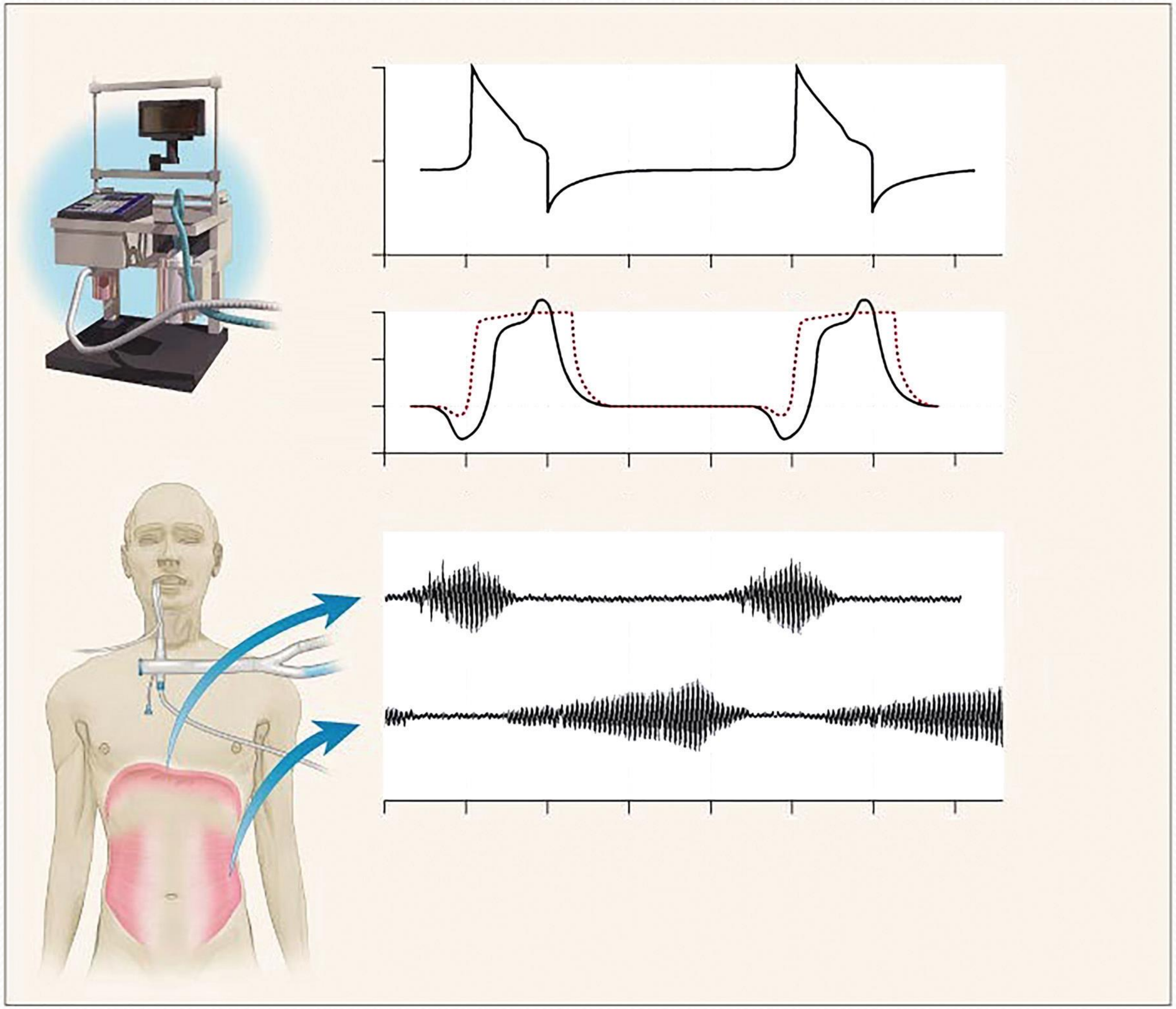
Search (Alt+Comma)	0400	0435	0500	0600	0700	0800	Last Filed
Backup Tidal Volume							
EXPIRATORY FLOW	29	72	81	74	28	8	28 l/min
Pressure Support (cm H2O)	38	38	38	38	38	38	38 cm H20
Total VE	9.7	9.4	9.9	8.2	8.1	7.3	8.1 L
ASV %MinVol							
CMV FREQUENCY SETTING							32 pbm
SIMV SET							
Spontaneous Respiratory Rate	21	19	11	7	7	15	7
Total RR	31	29	21	17	17	25	17
Breathing above set rate > 7							No
Paradoxical breathing present							No
Evidence of Inspiratory Pressure Drop							No
Insp Time (sec)							0.75 sec
Vent FiO2	80	80	75	75	75	75	75 %
PaO2/VentFiO2		148.75	148.75		158.666666...		158.66666...
P HIGH		32					32
P LOW	0	0	0	0	0	0	0
P0.1							-7
PEEP/CPAP (cm H2O)							18 cm H20
Auto PEEP Observed (cm H2O)							17 cm H20
P-ramp		25					25
Flow Pattern							dec
P-Sens		2.5					2.5
LUNG VOLUME TRAPPED							
ETS		35					35
Pause							
Flow (Obs) (L/min)							
Insp Flow (L/sec)	40	39	59	97	41	97	41 L/sec
INSP I:E Ratio							1
EXP I:E Ratio							1.5
Inspiratory Time Setting							40 %

Effects of Asynchrony

- Increased work of breathing
- Muscle damage/stress
- Patient anxiety
- Dynamic hyperinflation
- Prolonged weaning time
- Increased length of hospital stay
- Increased cost of health care

Adverse Effects of Patient-Ventilator asynchrony on outcomes:

-Ultrastructure injury to respiratory muscles
-Eccentric or plyometric contraction
-Worsens mechanics (intrinsic PEEP)
-Alters gas exchange (auto-triggering, increased $PaCO_2$).
-Wastes respiratory work (unnecessary load).
-Confounds lung-protective strategy (breath-stacking leads to increased tidal volume).
-May cause periodic breathing, sleep fragmentation.



How Do We Optimize Ventilator-Patient Interfacing?

- Clinical management interventions
- Adjust the ventilator
- Utilize advance modes of ventilation

Clinical Management

- Maintain a patent airway
  - Secretion removal, aerosolized medications, correct endotracheal size, minimize auto-PEEP, remove soiled HMEFs, no H_2O in the circuit!
- Provide adequate sedation
  - Reduce anxiety and pain, minimize respiratory depression, correct underlying factors
- Facilitate extubation
  - Daily SBTs, extubate to BIPAP, High Flow Oxygen

Controlling Ventilation With Sedation

- Bolus vs. continuous infusion
- Narcotics vs. hypnotics
- Neuromuscular paralyzation

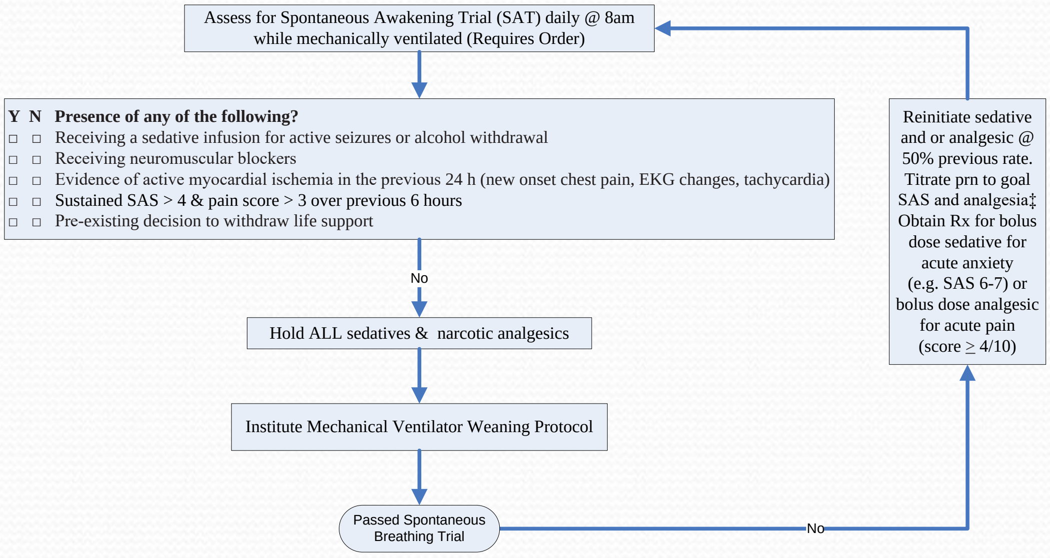
Table 2
Dosing and cost of selected analgesics and sedatives[1,2,13,27,32,99]

Drug	Comparative Dose (IV)[a]	Intermittent Dose[e]	Usual Infusion Dose
Analgesics[b]			
Fentanyl	100–200 mg	0.35–.5 mcg/kg q 0.5–1 h	0.7–10 mcg/kg/h
Hydromorphone	1.5 mg	10–30 mcg/kg q 1–2 h	7–15 mcg/kg/h
Morphine	10 mg	0.01–0.15 mg/kg q 1–2 h	0.07–0.5 mg/kg/h
Methadone	10–20 mg (po)	10–40 mg po q6–12 h	Not recommended
Meperidine	75–100 mg	Not recommended	Not recommended
Sedatives[c,d]			
Diazepam	—	0.03–0.1 mg/kg q 0.5–6 h	—
Lorazepam	0.035 mg/kg/hr	0.02–0.06 mg/kg q 2–6 h	0.01–0.1 mg/kg/h
Midazolam	0.106 mg/kg/hr	0.02–0.08 mg/kg q 0.5–2 h	0.04–0.2 mg/kg/h
Propofol	1.66 mg/kg/hr	—	5–80 mcg/kg/min

Awake & Breath

- Use of a protocol incorporating daily awakening has been shown to ↓ the amount of opioid administered and to ↓ both duration of MV & ICU LOS
- Proven NNT = 7 for the endpoint of mortality

Lancet 2008; 371: 126–34



Ventilator Adjustments

- Meet the patients ventilatory demands
  - Increasing inspirtory flow
  - Increasing set rate
- Change triggering threshold
  - Decreasing triggering sensitivity
  - Changing from pressure to flow triggering
  - Minimize auto-PEEP
- Adjust expiratory termination criteria
  - Adjust ETS% during pressure support
  - Shorten set inspiratory time
- Optimize ABGs

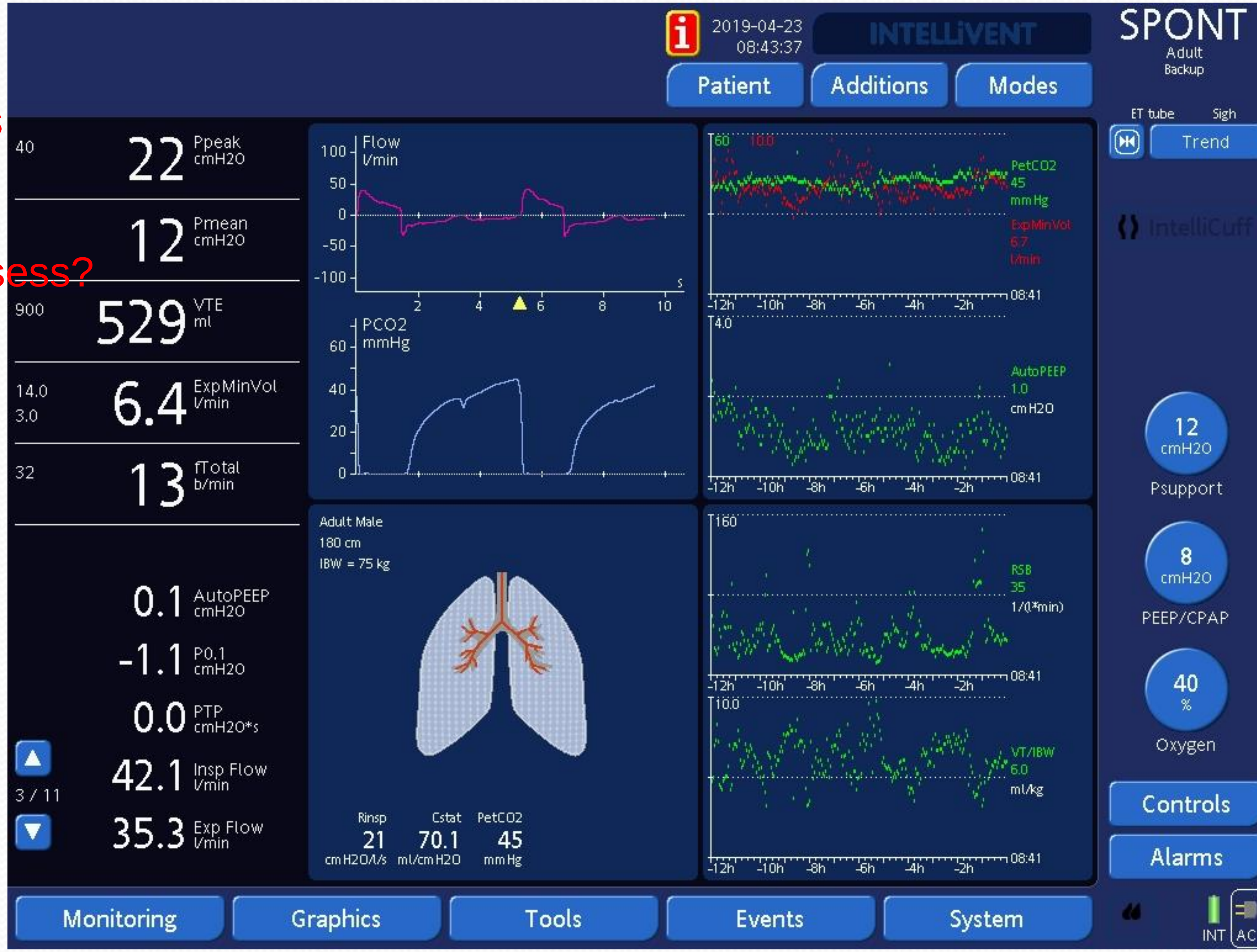
Let The Patient Breath?

- Patient self-inflected lung injury (P-SILI)
  - observed in low Clt physiology
- Vigorous spontaneous effort causing lung injury
- Noted by PO1>-6cm
  - Increased lung stress
  - Increased lung perfusion
  - Breath stacking
  - Increased driving pressure-Amato
    - PO1 +PIP=driving pressure (-8+20=28)
    - **High risk of patient self-inflicted lung injury in COVID-19 with frequently encountered spontaneous breathing patterns: a computational modelling study**
      - **doi:** https://doi.org/10.1101/2021.03.17.21253788

Excessive P01

During rounds encountered this screen

What do you assess?



Several signs of prolonged exhalation and over-inflation

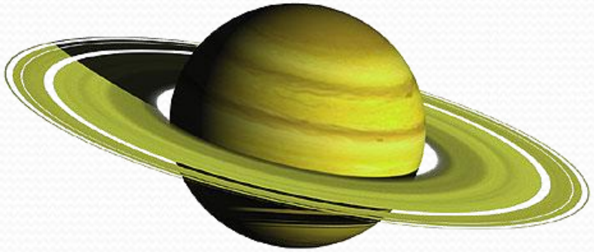
Where would you set the ETS%?

ETS% @ 25%
Is this optimal for
 this patient?

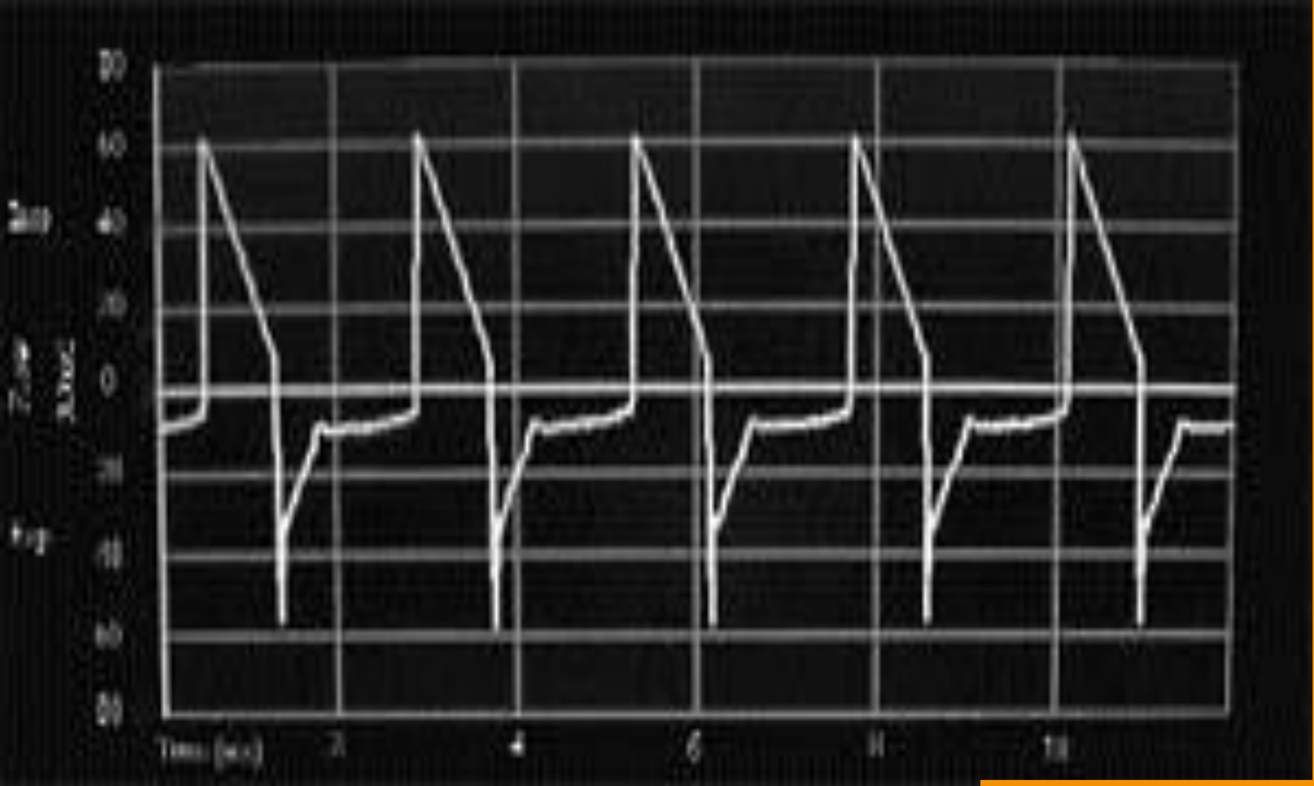
ETS% extend to 45%

What changes do you notice?

Lower tidal volume



Use Ventilator Graphics!!!



Auto-Peeping

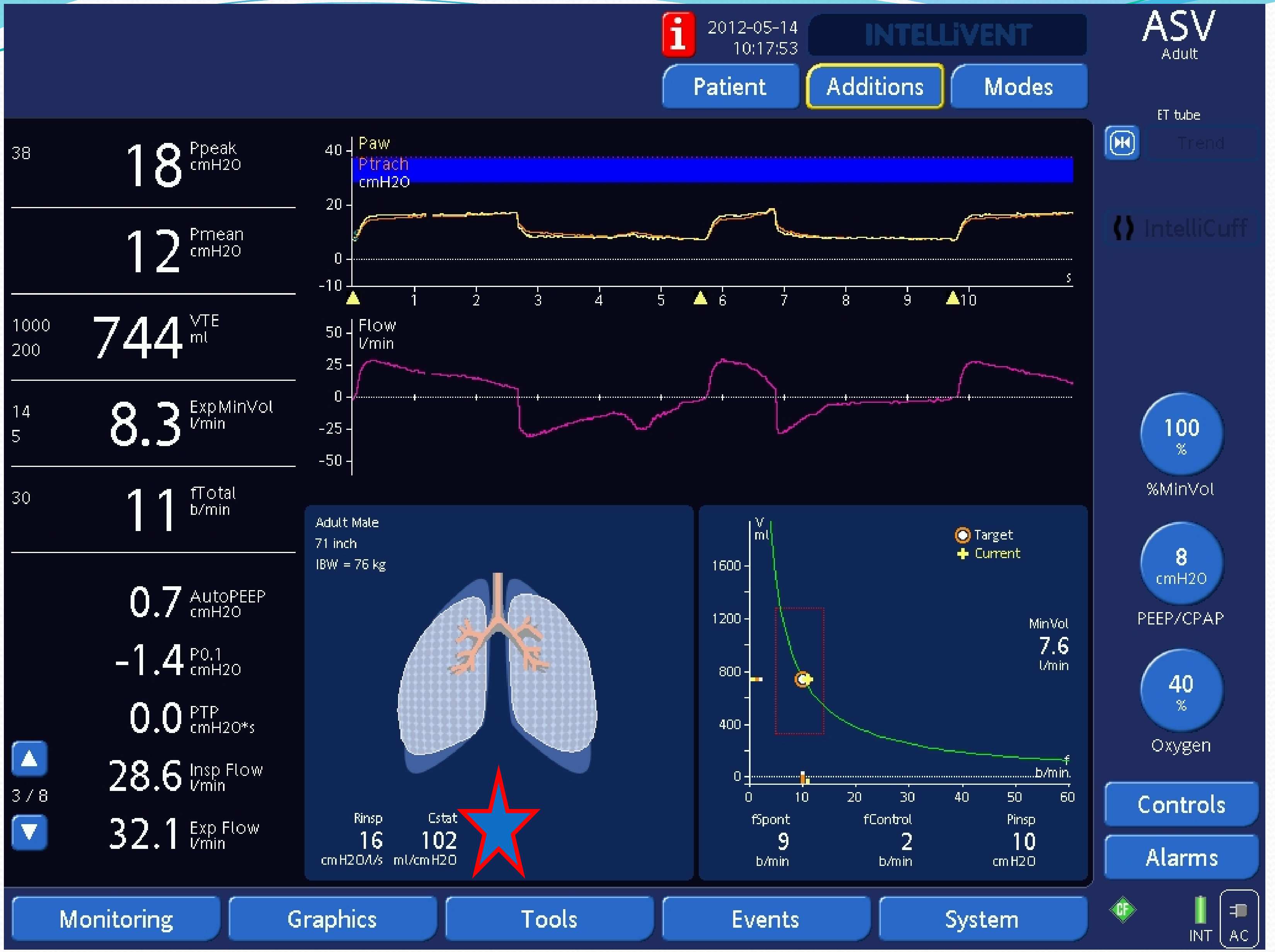
Self triggering with leak

Airway obs

2013-01-07
08:34:08
INTELLiVENT
APVcmv
Adult
Patient
Additions
Modes
47
33 Ppeak cmH2O
14 Pmean cmH2O
900
250
651 VTE ml
14
6
7.8 ExpMinVol l/min
25
12 fTotal b/min
--- WOBimp J/l
8 / 10
Paw cmH2O
PCO2 mmHg
Trend
IntelliCuff
12 b/min
Rate
650 ml
Vtarget
8 cmH2O
PEEP/CPAP
40 %
Oxygen
Adult Female
66 inch
IBW = 60 kg
Rinsp 33 cmH2O/l/s
Cstat 41.4 ml/cmH2O
PetCO2 52 mmHg
Oxygenation
CO2 elimination
Spont/Activity
Oxygen 40 %
PEEP 8 cmH2O
MinVol 7.8 l/min
Pinsp 27 cmH2O
RSB --- 1/(l*min)
%fSpont 0 %
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

Improved Capnograph post continuous beta-agonist

Hyper-inflation Dynamic Lung



Help I need suctioning

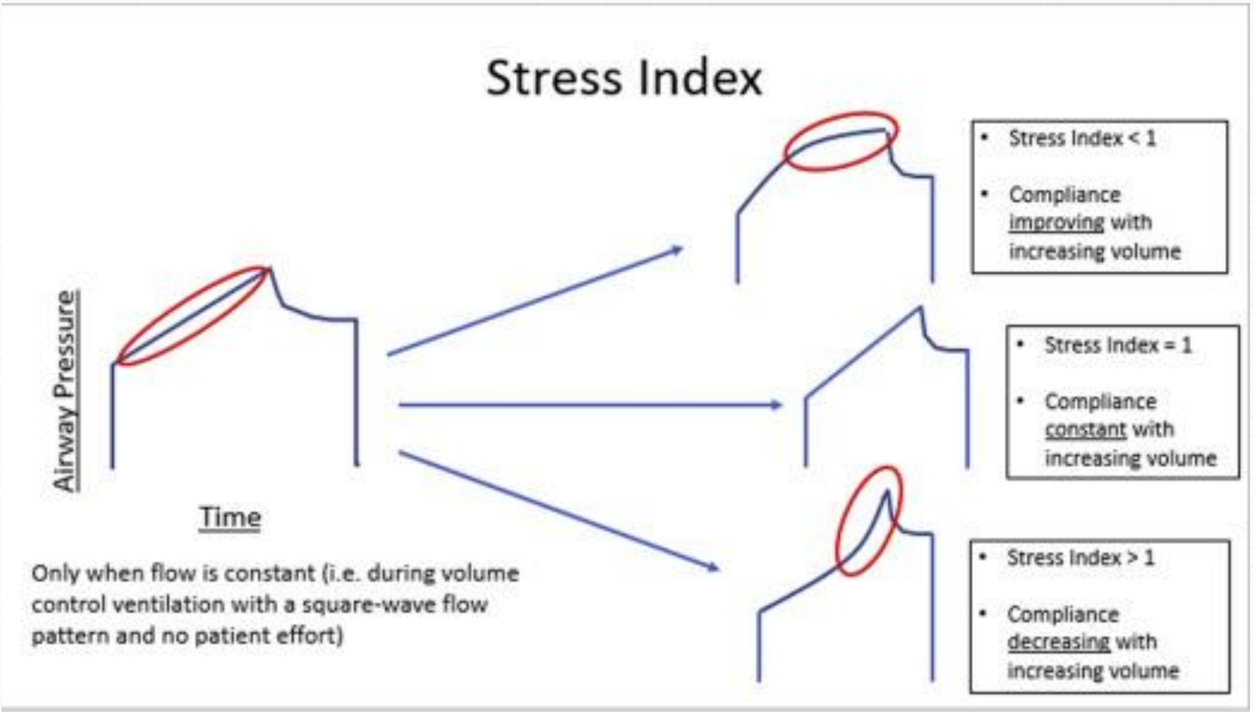
Pinched flow sensor

Leak causing auto-trigging

Patient not able to trigger ventilator despite respiratory efforts

Note total rate of 16 on ventilator-counting chest movement rate>40 bpm

Triggering sensitivity lowered-Note: the increase in triggered breaths and total respiratory rate on ventilator


Stress Index
Airway Pressure
Time
Only when flow is constant (i.e. during volume control ventilation with a square-wave flow pattern and no patient effort)
Stress Index < 1
Compliance improving with increasing volume
Stress Index = 1
Compliance constant with increasing volume
Stress Index > 1
Compliance decreasing with increasing volume

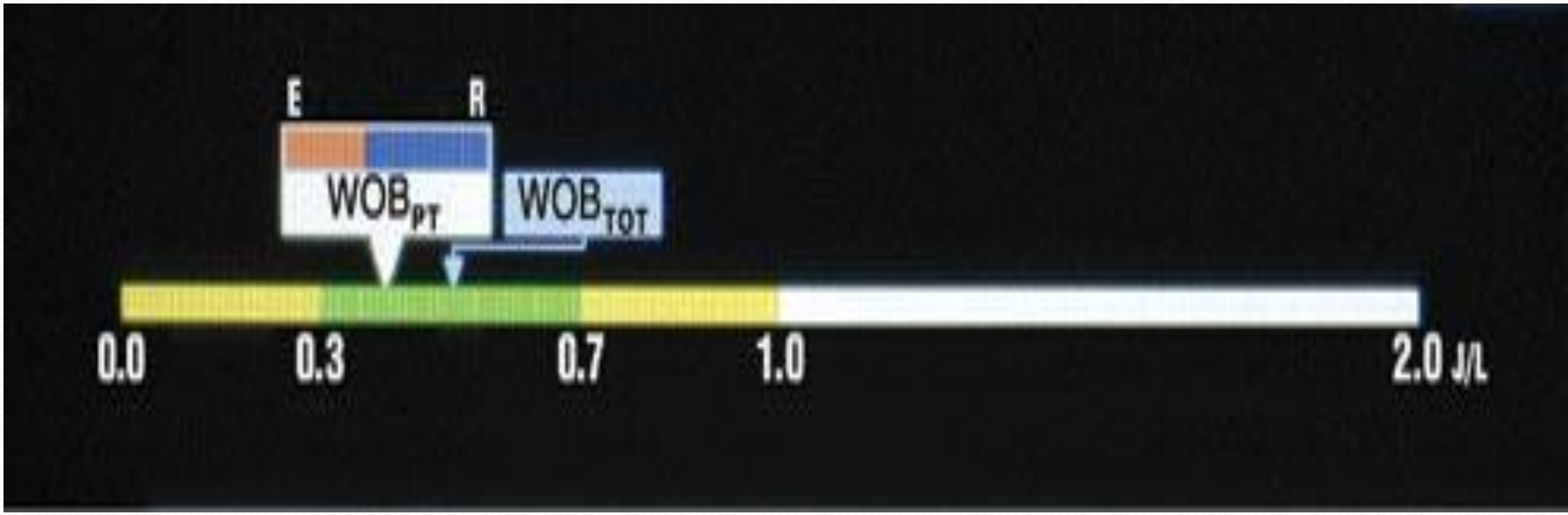
Advanced Modes

- Proportional Assist Ventilation(PAV)
- Neural Assisted Ventilation (NAVA)
- Adaptive Support Ventilation (ASV)
- Smart Care
- Asynchrony Indexes

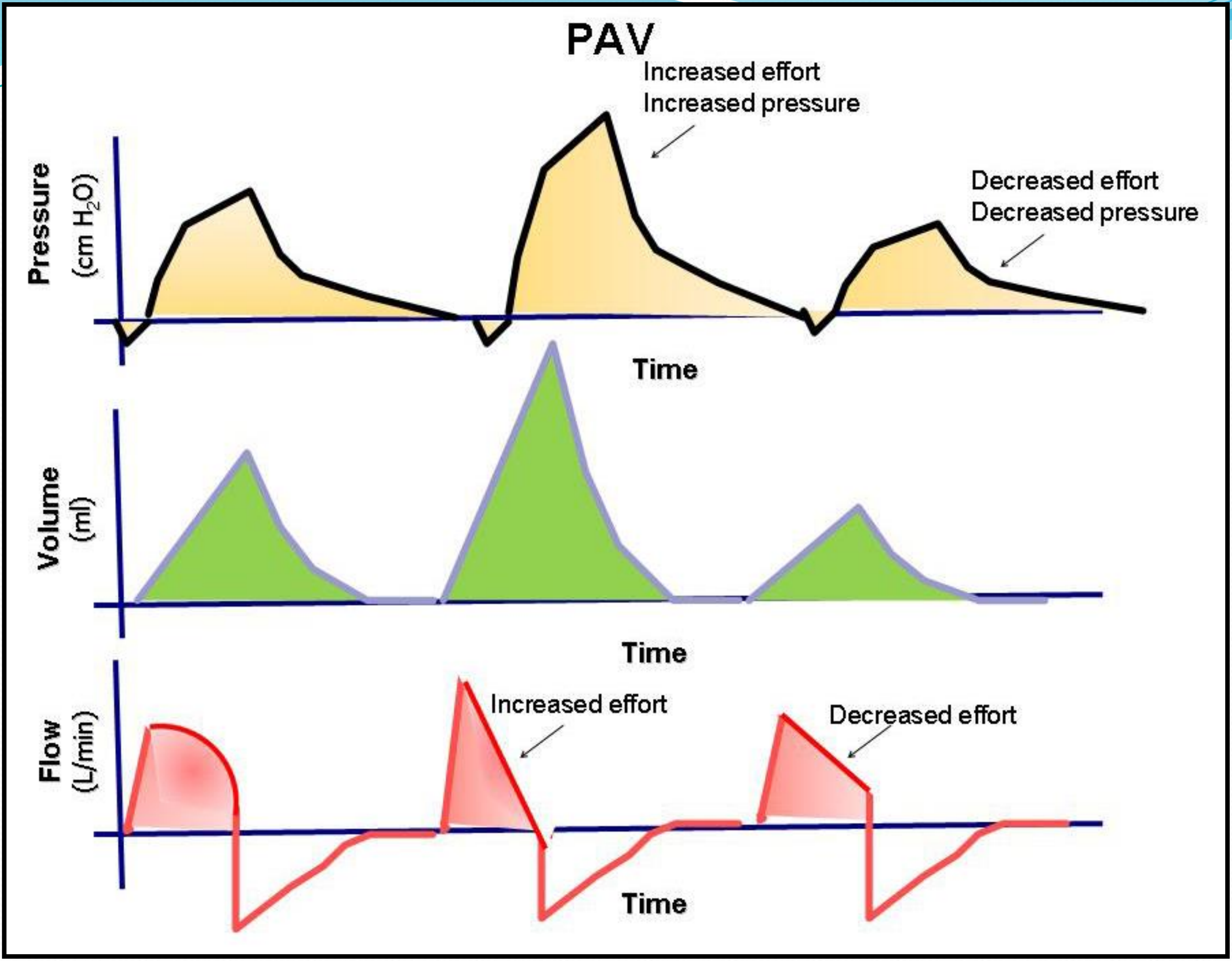
- **May optimize patient-ventilator interfacing!!!**

PAV

- PAV is a form of synchronised partial ventilatory assistance with the peculiar characteristic that the ventilator generates pressure in proportion to the patient's instantaneous effort—that is, the more the patient pulls, the more pressure the machine generates. Thus, with PAV the ventilator amplifies the patient's inspiratory effort without any preselected target volume or pressure.
- The aim of PAV is to allow the patient to attain whatever ventilation and breathing pattern seems to fit the ventilatory control system. PAV therefore assumes control of the breathing system and a condition in which the neuroventilatory uncoupling is determined by the discrepancy between the high ventilatory demand and the insufficient capability of the ventilatory pump to cope with the workload.
- PAV provides a sort of “additional muscle” under the complete control of the patient's ventilatory drive for determining the depth and frequency of the breaths.



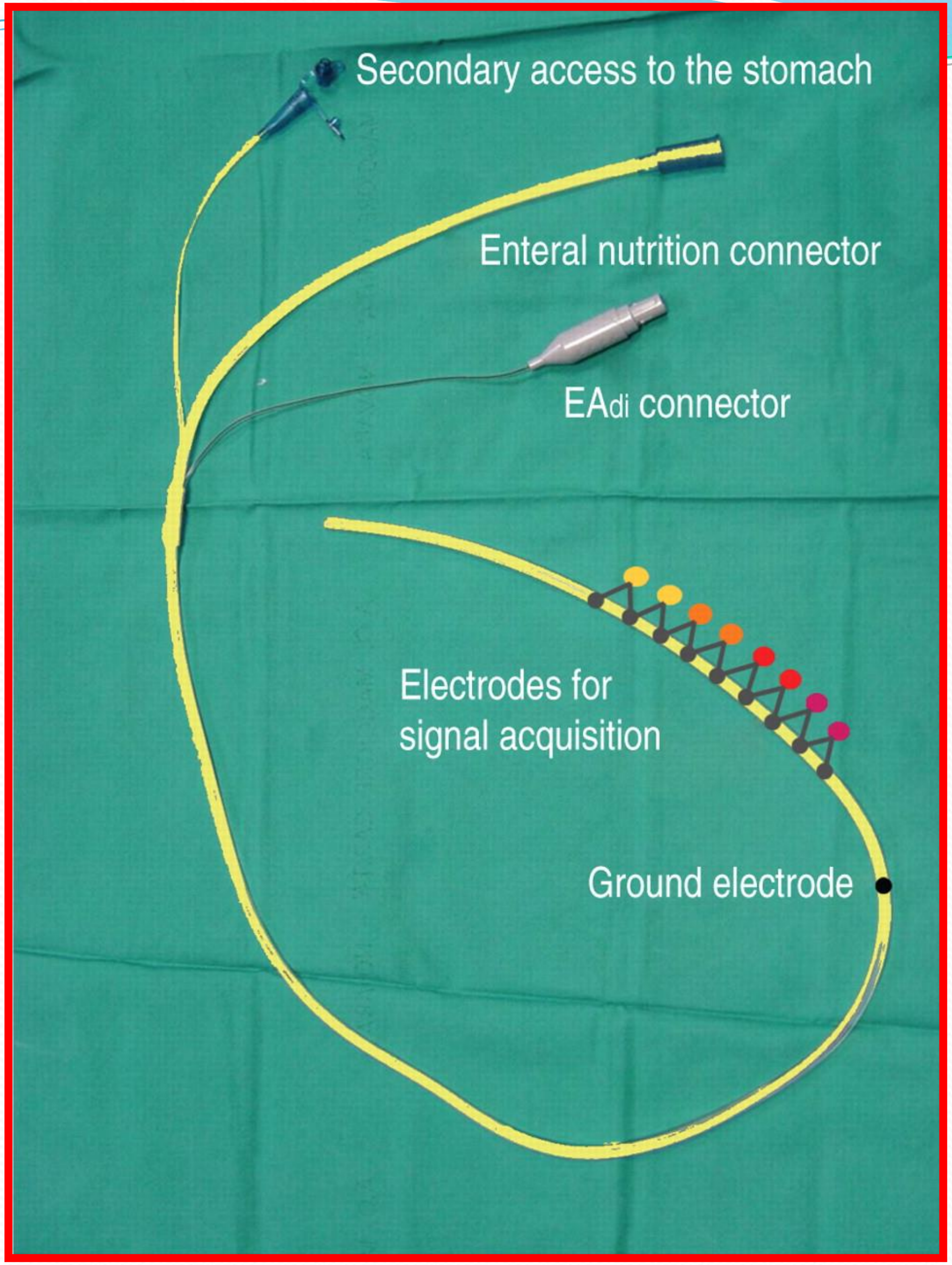
E
R
WOBPT
WOBTOT
0.0
0.3
0.7
1.0
2.0 J/L


PAV
Increased effort
Increased pressure
Decreased effort
Decreased pressure
Pressure
(cm H2O)
Time
Volume
(ml)
Time
Flow
(L/min)
Increased effort
Decreased effort
Time

NAVA

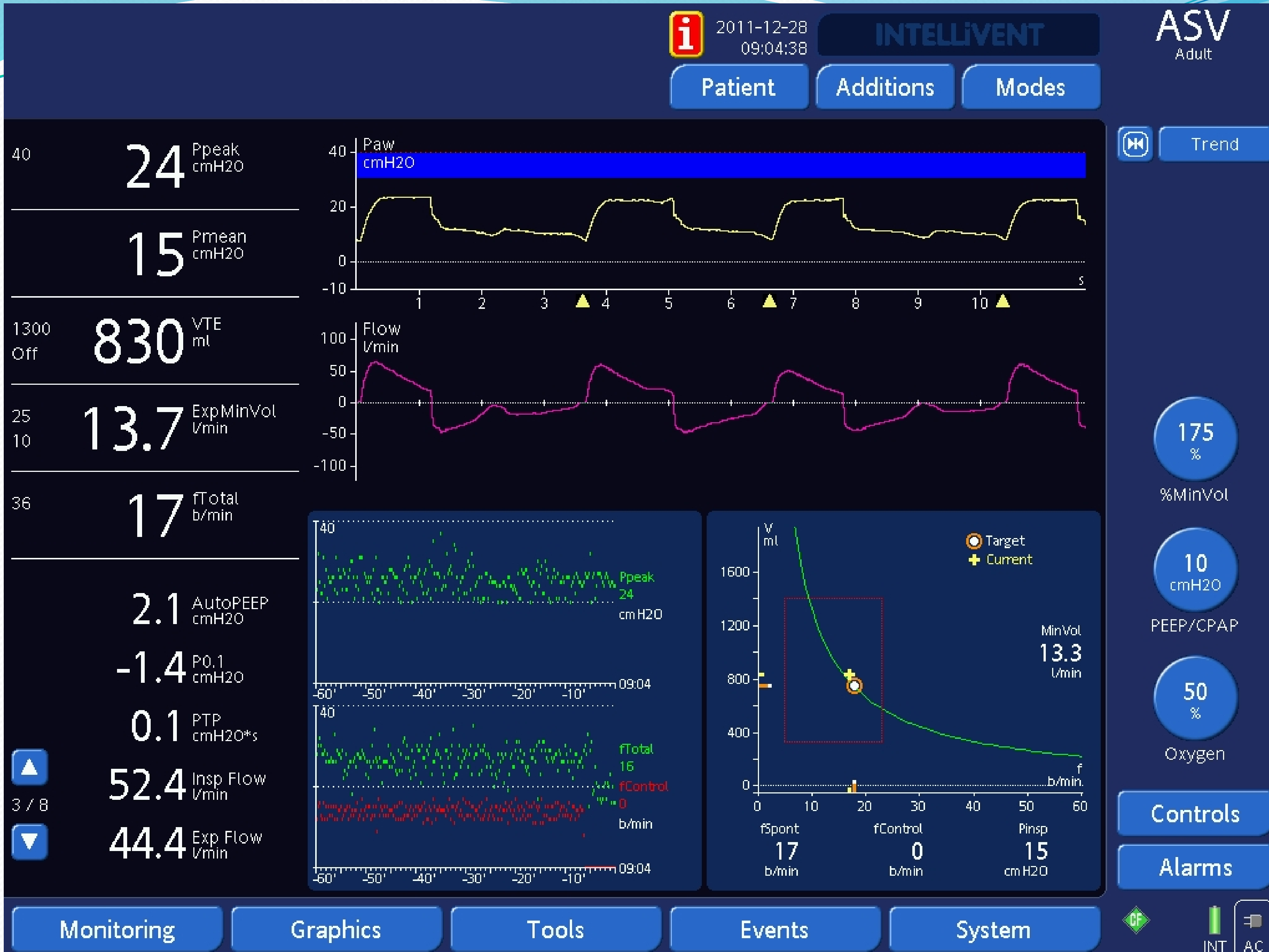
- **Neurally Adjusted Ventilatory Assist (NAVA)** - is a mode of ventilation ventilation. NAVA delivers assistance in proportion to and in synchrony with the patient's respiratory efforts, as reflected by the Edi signal. This signal represents the electrical activity of the diaphragm , the body's principal breathing muscle.
- The act of taking a breath is controlled by the respiratory center of the brain, which decides the characteristics of each breath, timing and size. The respiratory center sends a signal along the phrenic nerve, excites the diaphragm muscle cells, leading to muscle contraction and descent of the diaphragm dome. As a result, the pressure in the airway drops, causing an inflow of air into the lungs.
- With NAVA, the electrical activity of the diaphragm (Edi) is captured, fed to the ventilator and used to assist the patient's breathing in synchrony with and in proportion to the patients own efforts, regardless of patient category or size. As the work of the ventilator and the diaphragm is controlled by the same signal, coupling between the diaphragm and the SERVO-i ventilator is synchronized simultaneously.

Pressure Control
Automode
Admit patient
Nebulizer
Status
02–06 11:15
Recorded waveforms 2012–02–06 11:13:02
30 cmH2O
5
cmH2O
20 l/min
–20
–0
l/min
20 ml
2.4
ml
15 µV
2.1
µV
–1.01s
Settings
Cursor
Close
Ppeak (cmH2O)
20
50
Pmean (cmH2O)
8
PEEP (cmH2O)
5
RR (b/min)
30
79
20
O2 (%)
21
MVe (l/min)
0.36
5.0
0.01
VTi (ml)
14.4
VTe (ml)
12.0
Edi peak (µV)
7.0
Edi min (µV)
1.8
Additional values


Secondary access to the stomach
Enteral nutrition connector
EAdi connector
Electrodes for
signal acquisition
Ground electrode

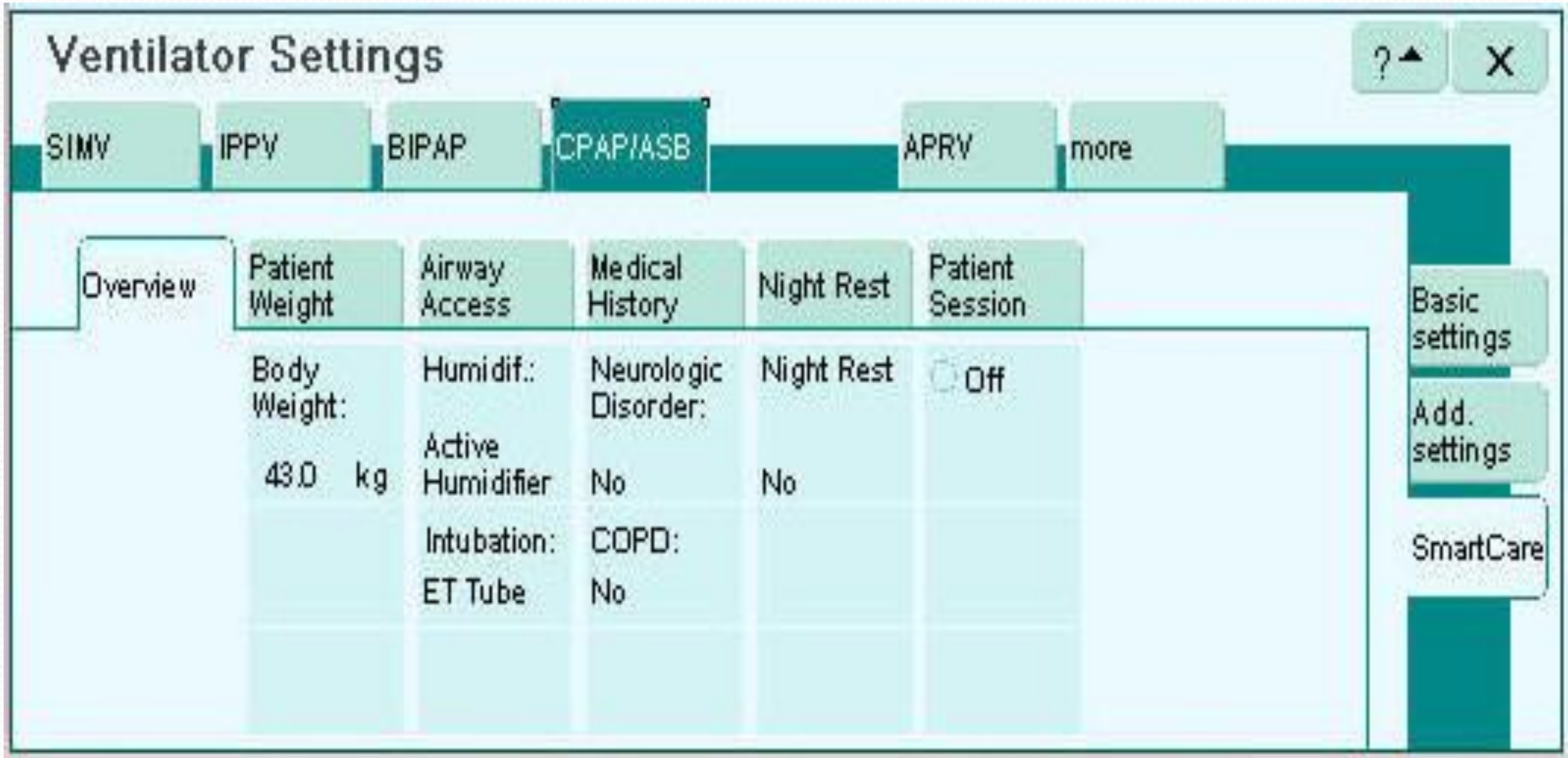
ASV

- ASV is a **closed loop** mode of ventilation designed to maintain goal-directed mechanical ventilation using a Lung Protective Strategy. Will deliver **time-cycled ventilations** when indicated and will switch to PSV when the patient starts spontaneous breathing. In PSV will continue target a desired tidal volume.
- ASV streamlines the set-up and weaning of the mechanical ventilation patient.
- Ventilation targets are derived from analysis of the patients pulmonary mechanics and are automatically implemented.
- All time-cycled delivered breaths are Pressure regulated volume targeted breaths. **(PRVC)**
  Spontaneous breaths are delivered with pressure support targeted at a desired tidal volume.
- **Ventilator parameters:** Tidal volume/respiratory rate are set based on **Otis**' least work physiology.


2011-12-28
09:04:38
INTELLiVENT
ASV
Adult
Patient
Additions
Modes
Trend
40
24 Ppeak cmH2O
15 Pmean cmH2O
1300
Off
830 VTE ml
25
10
13.7 ExpMinVol l/min
36
17 fTotal b/min
2.1 AutoPEEP cmH2O
-1.4 P0.1 cmH2O
0.1 PTP cmH2O*s
3 / 8
52.4 Insp Flow l/min
44.4 Exp Flow l/min
Paw cmH2O
Flow l/min
Ppeak 24 cmH2O
fTotal 16
fControl 0
b/min
09:04
Target
Current
MinVol 13.3 l/min
f b/min
fSpont 17 b/min
fControl 0 b/min
Pinsp 15 cmH2O
175 % %MinVol
10 cmH2O PEEP/CPAP
50 % Oxygen
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

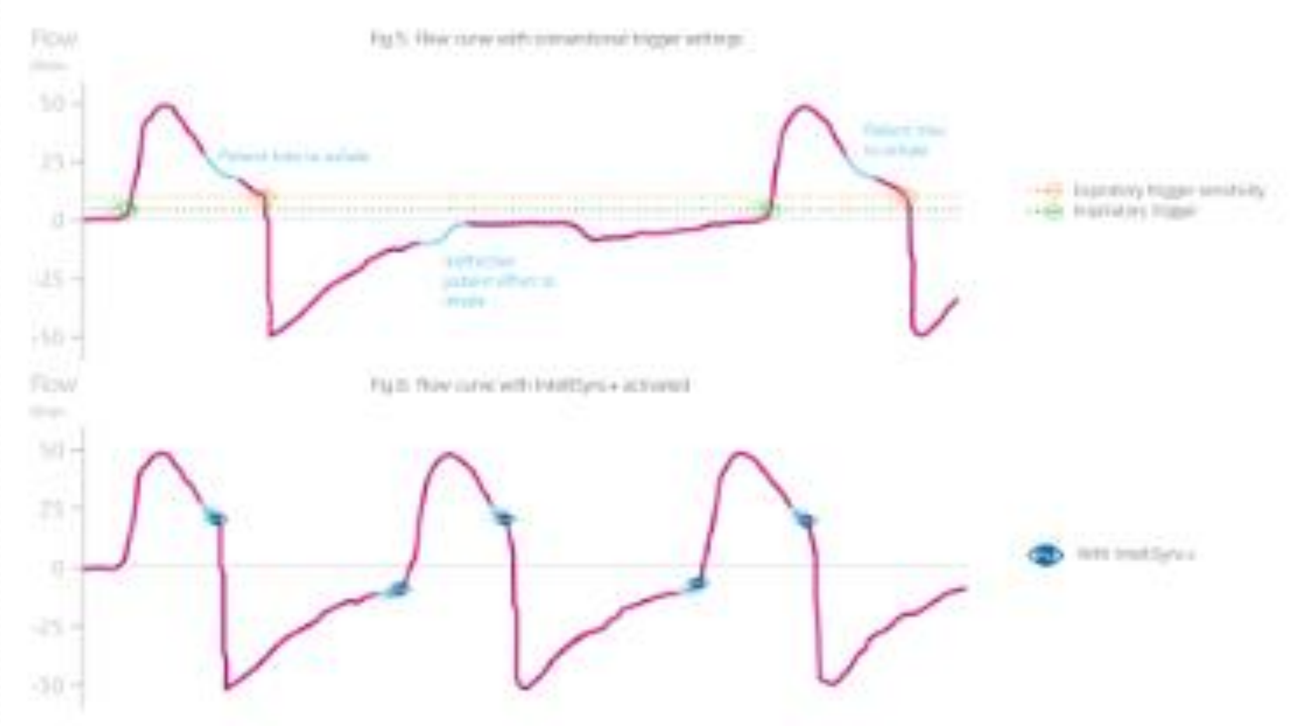
Smart Care

- SmartCare/PS is based on a clinical protocol for weaning. The system "divides the control process into three steps:"
- "Step 1: Stabilizing the patient within a respiratory comfort zone by regulating the level of pressure support based on three parameters: breathing rate, tidal volume and end tidal CO_2."
- "Step 2: Reducing invasiveness by testing whether the patient can tolerate a lower pressure support level without leaving the comfort zone."
- "Step 3: Testing readiness for extubation by maintaining the patient at the lowest limit of support“.


Ventilator Settings
?
X
SIMV
IPPV
BIPAP
CPAP/ASB
APRV
more
Overview
Patient Weight
Airway Access
Medical History
Night Rest
Patient Session
Body Weight:
43.0 kg
Humidif.:
Active Humidifier
Intubation:
ET Tube
Neurologic Disorder:
No
COPD:
No
Night Rest
No
Off
Basic settings
Add. settings
SmartCare

Ventilator Asynchrony Indexes

- **IntelliSync+=Hamilton G-5**



Puritan Bennett™ 980 Leak Sync Software

- The new Puritan Bennett™ 980 ventilator was designed with the challenges of safe and effective ventilation in mind. Automatically detecting and compensating for fluctuating leak sizes, Puritan Bennett™ Leak Sync software helps clinicians manage patients' work of breathing.
- Breathing circuit leaks can cause a ventilator to erroneously detect patient inspiratory efforts (called autotriggering) or delay exhalation in pressure support. Patient interfaces, such as masks and uncuffed endotracheal tubes, are particularly prone to significant leaks. Inaccurately declaring inspiration or exhalation can result in patient-ventilator asynchrony and increased work of breathing.

Summary

- Mechanical Ventilation not a normal breathing process.
- Clinical issues must be addressed.
- Lots of factors to consider in patient-ventilatory synchrony
- Newer modes of ventilation may promote better patient-ventilator inter-facing.
- The importance of minimizing ventilator asynchrony can not be minimized!!

Questions?

kenneth.miller@lvhn.org
610-402-5772