Kinder, Gentler Mechanical Ventilation of Neonates

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"The vast majority of lung injury is man made."

- Dr. Theodor Kolobow

K eep

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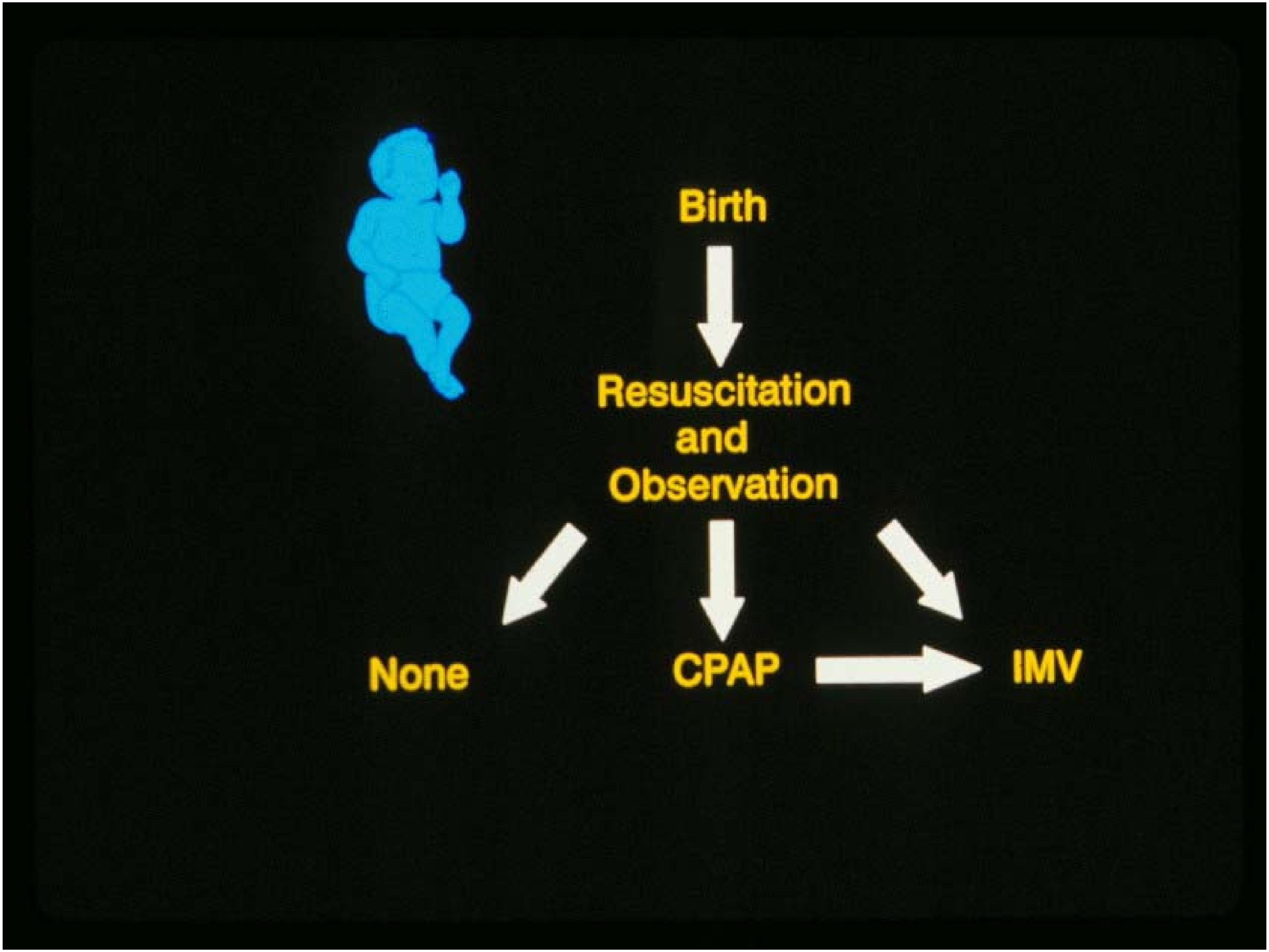
S tupid (**S** afe)


Birth
Resuscitation and Observation
None
CPAP
IMV

- CPAP
- NIPPV +/-
- IMV (CMV) or PTV (SIMV, A/C, PS, NAVA etc.)
- HFV
- Surfactant
- Inhaled nitric oxide
- ECMO

Mechanical Ventilation

Indications

1. Marked retractions on CPAP (not due to nasal obstruction)
2. Frequent apnea and bradycardia on CPAP
3. PaO_2 < 50 mm Hg with FiO_2 > 60%
4. $PaCO_2$ > 70 mm Hg (except 1st ABGS)
5. Intractable metabolic acidosis
   (BD > 10 meq/L after Rx with $NaHCO_3$)
6. Others (Cardiovascular collapse, Neuromuscular disorder, Congenital diaphragmatic hernia, or for Surgery, MRI, Cardiac catheterization, etc.)

Mechanical Ventilation

Pressure-limit

For small child or large air leak with small endotracheal tube

Watch chest excursion

Volume-limit

tidal volume 4 - 7 ml/kg

compressed volume

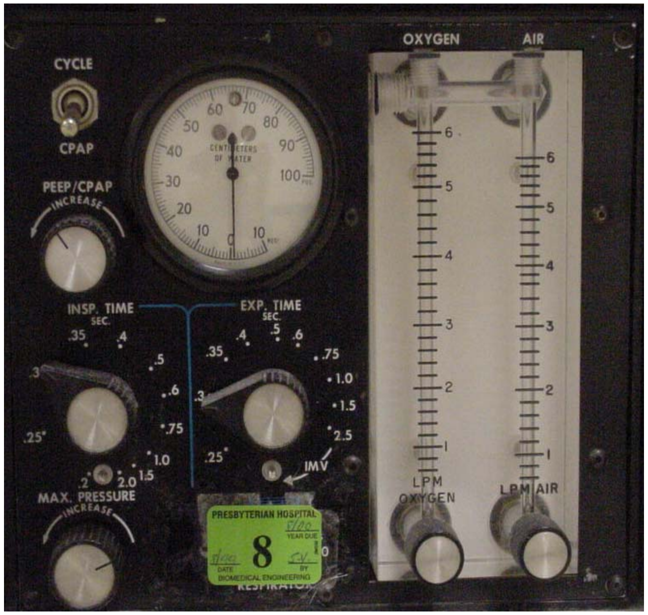
1 ml/cmH_2O/L

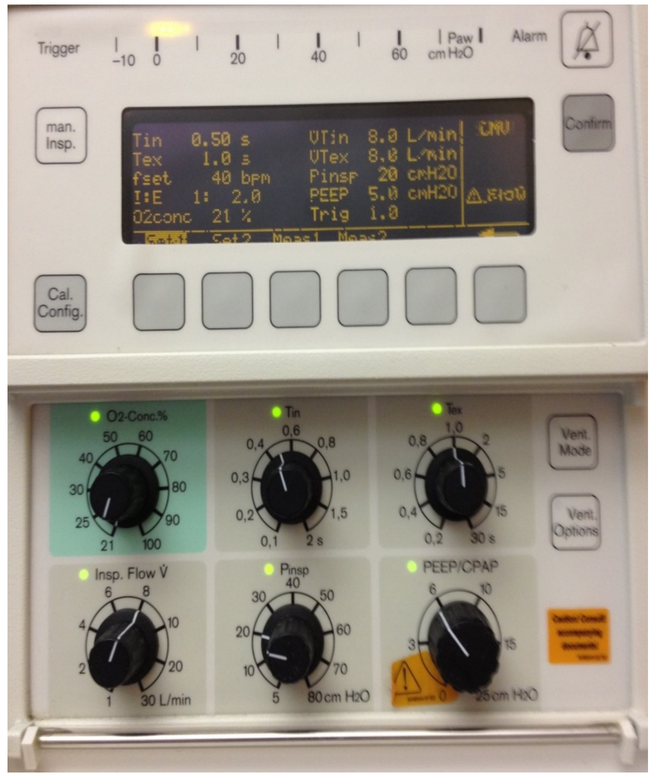
(>>small tidal volume, 6ml/kg)

Infant Ventilators

- Flo-Disc MVP-10
- Healthdyne(PremieCare, Infant Star-200)
- Infant Star-500, Star Sync, Infant Star-950
- V.I.P.Bird Gold, V.I.P. Bird Sterling
- Bear Cub 750PSV
- **Draeger Babylog 8000**
- Servo 300
- **Servo i**. U. & N., Babylog VN500, Avea,
- Puritan Bennett 840

Ventilators do about the same thing!

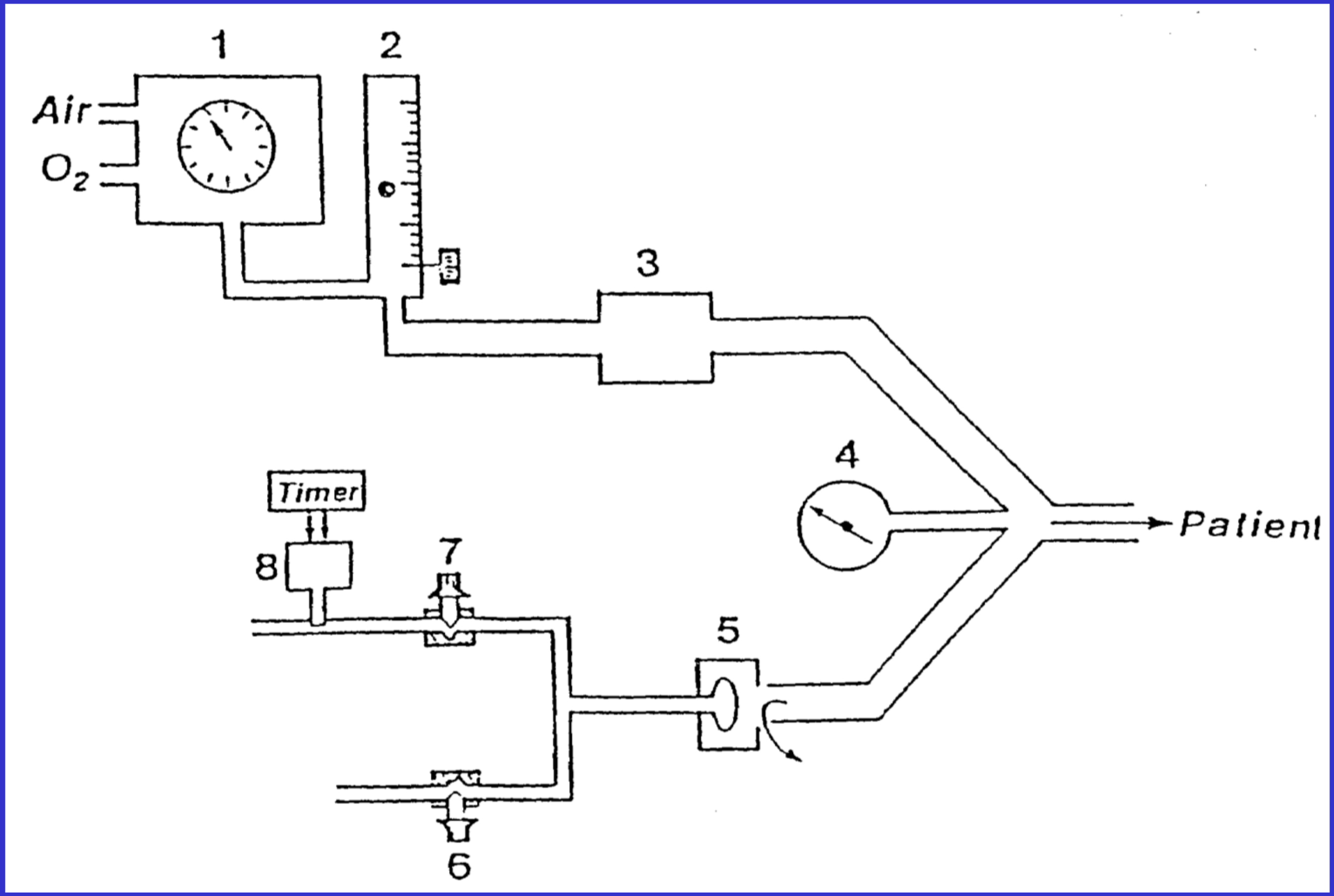




- FiO$_2$
- Flowrate
- IMV
- Ti (Ti/Te)
- PIP
- PEEP

Infant Ventilator

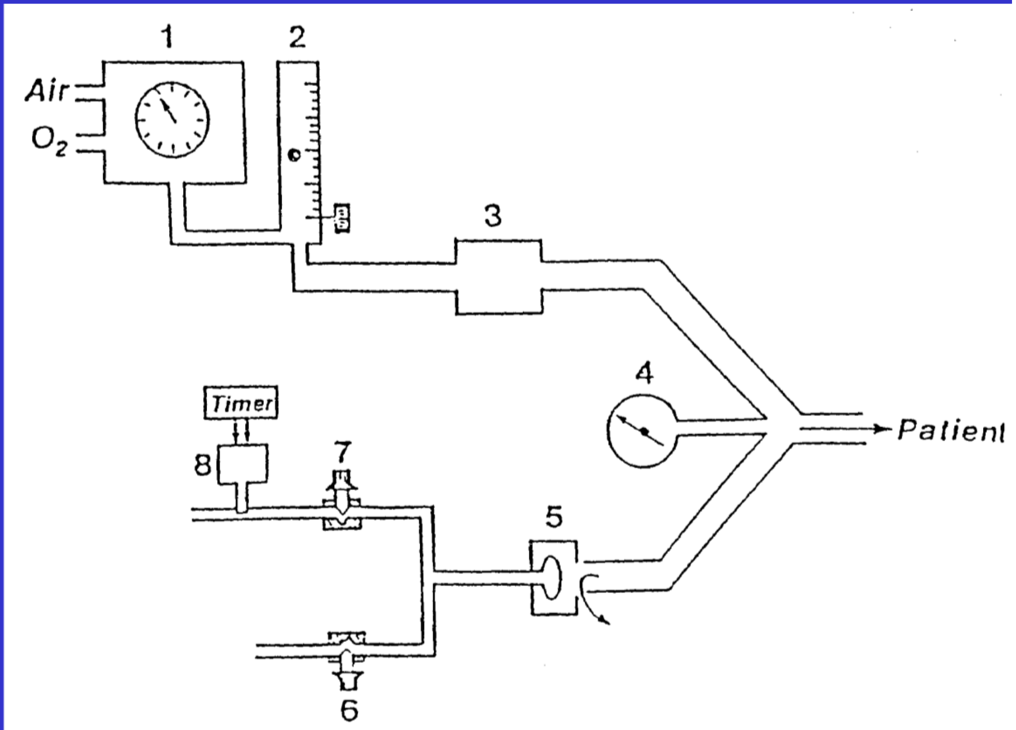
Simplified Schematic



1. O_2 blender. 2. flowmeter. 3. heated humidifier.
4. manometer. 5. exhalation valve. 6. PEEP/CPAP control.
7. PIP control. 8. solenoid valve/ timer.

Infant Ventilator
Parameters

- FiO_2
- Flow rate
- IMV rate
- Inspiration Time (Ti)
- Peak Inspiratory Pressure (PIP)
- Positive end expiratory Pressure (PEEP)



Mechanical Ventilation

Complications associated with endotracheal intubaton

1. Hypoxia, bradycardia
2. Esophageal perforation
3. Increased airway resistance
4. Obstruction of endotracheal tube (ETT)
5. Malposition or dislodged ETT
6. Nasal septum damage (nasotracheal tube)
7. Aquired palatal groove (orotracheal tube)
8. Vocal cord injury. Unilateral → dysphonia,
   Bilateral → aphonia
9. Subglottic edema
10. Subglottic stenosis
11. Tracheomalacia, Tracheal stenosis
12. Release of plasticizer (DEHP)

Mechanical Ventilation

Complications associated with Positive Pressure Ventilation :

A. Cardiovascular Effects
   1. The abolition of the "thoracic pump" mechanism, decrease of venous return and cardiac output
   2. "Tamponade" of the heart
   3. Interference with pulmonary blood flow

B. Acute lung injuries (barotrauma, volotrauma, biotrauma, atelectasis)

C. Airleaks

D. Uneven Ventilations, V/Q mismatch

E. Acid-base Imbalance

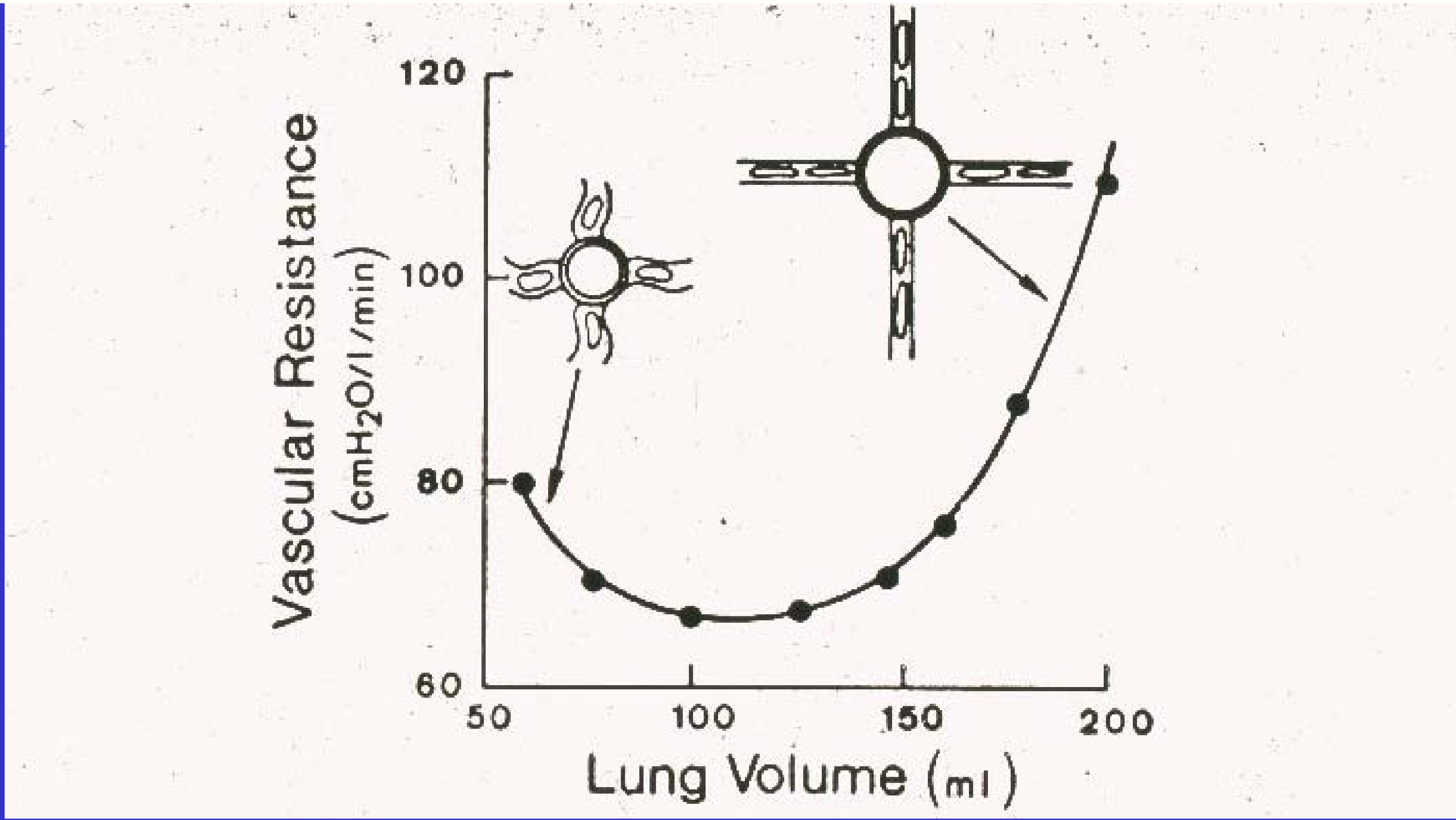
F. Neurologic; PV-IVH, PVL, Sensorineural hearing loss

G. Pulmonary Hypertension

H. Chronic Lung Disease (BPD)

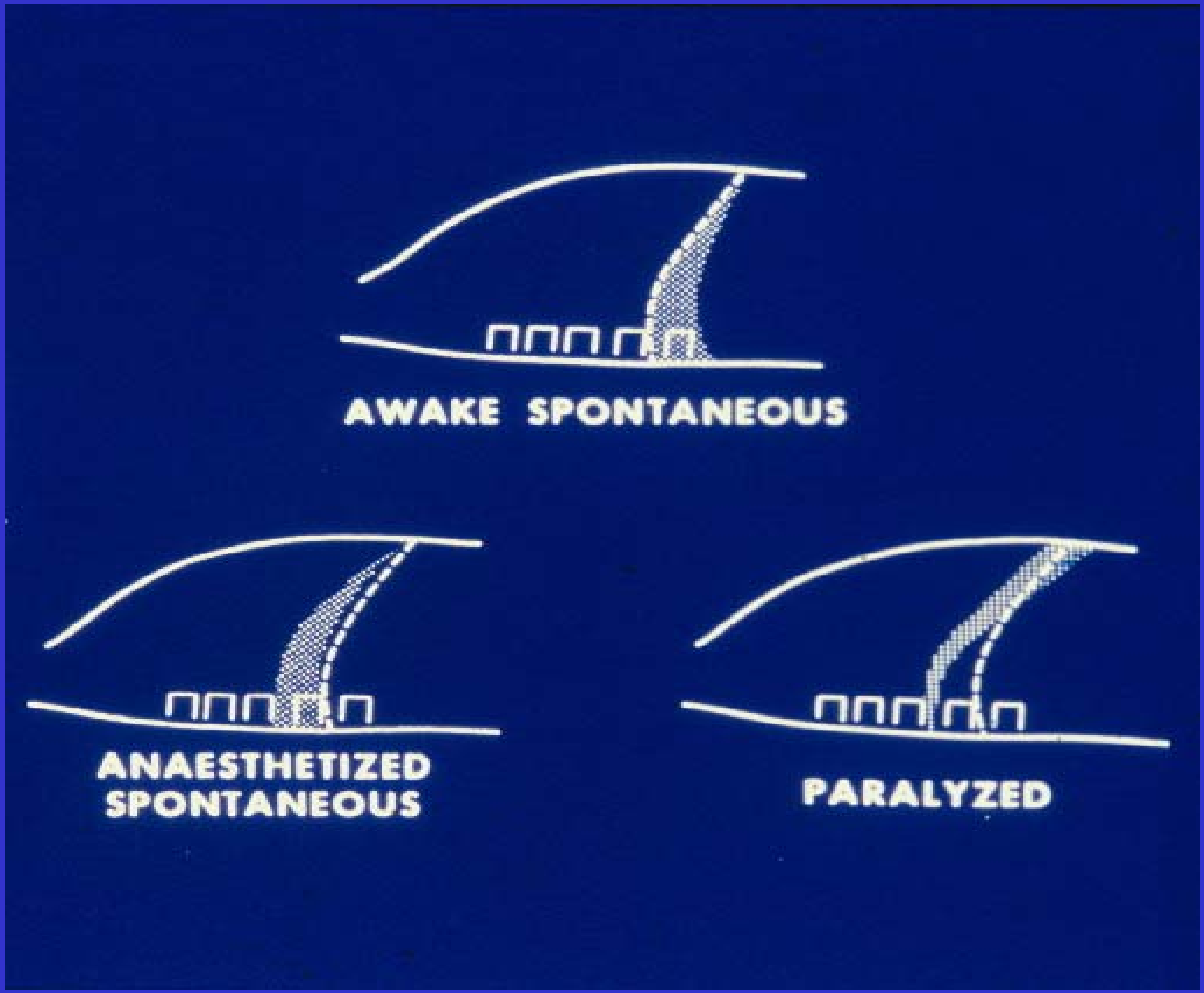
I. Cor Pulmonary

J. VAP (ventilator associated pneumonia)



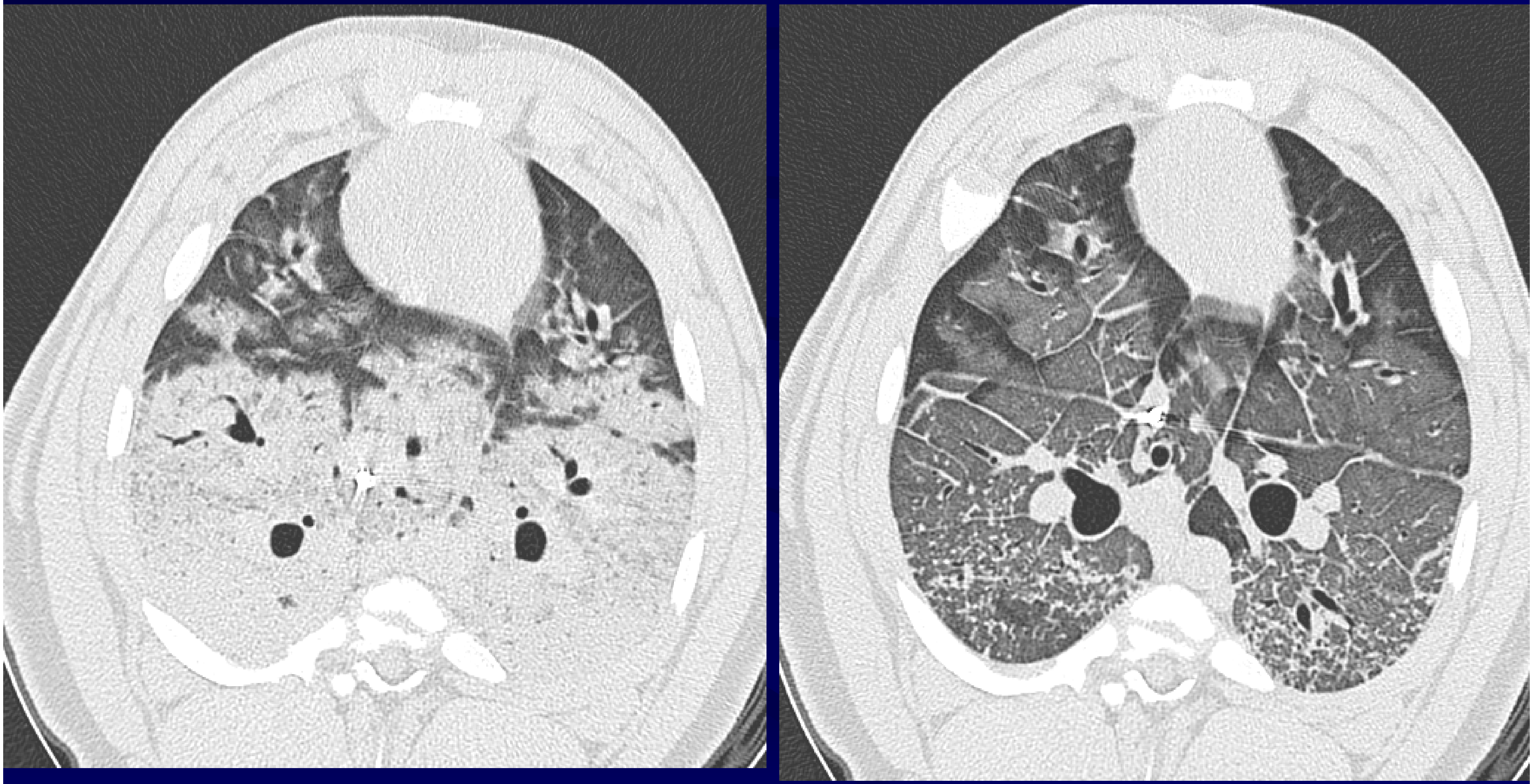
Effect of lung volume on pulmonary vascular resistance when transmural pressure of the capillaries is held constant. **At low lung volumes**, resistance is high because extra alveolar vessels become narrow. **At high volumes,** the capillaries become stretched as the caliber is reduced.

Paralyzing the diaphragm is asking for trouble!



Froese, et al., Anesthesiology, 1974

It is not good to spend all day laying on your back!



Gattinoni, et al., Critical Care Medicine, 1991

The Best Mode of Ventilation is

Spontaneous Breathing

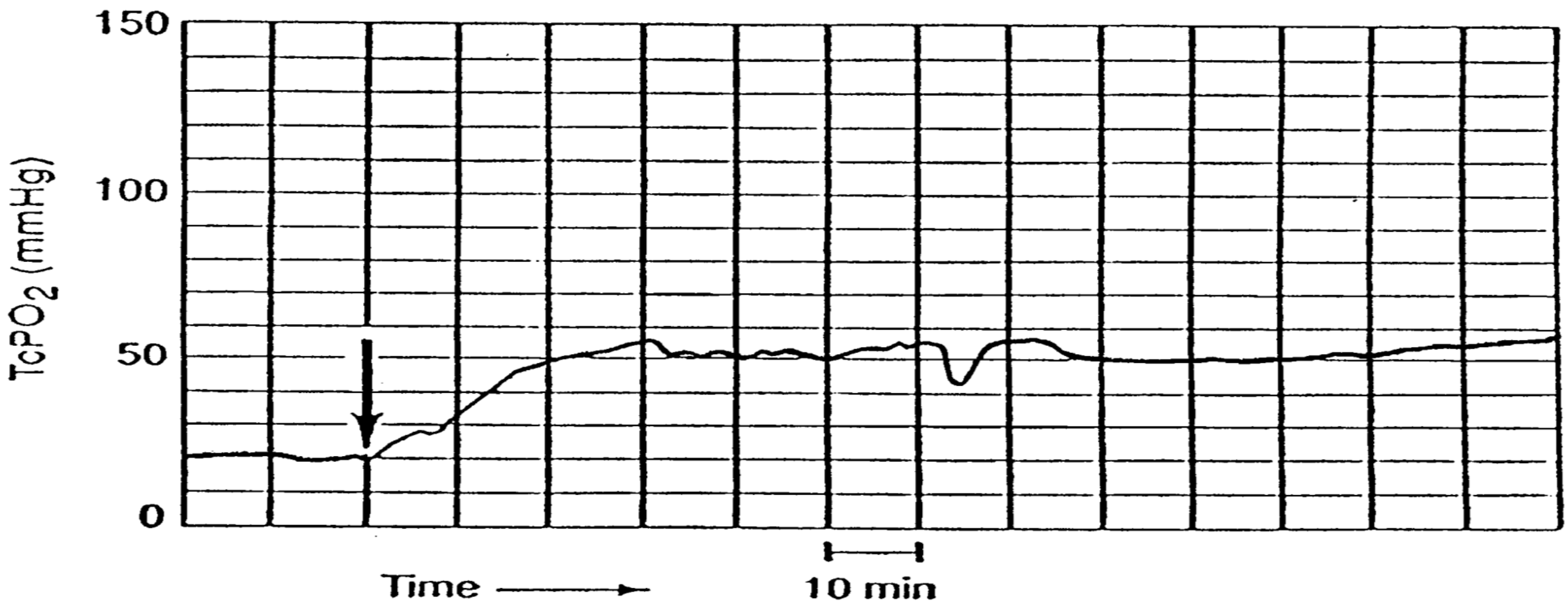
Spontaneous breathing improves lung aeration in oleic acid-induced lung injury

Anesthesiology 2003;99:376-384

Wrigge H, Zinserling J, Neumann P, et al

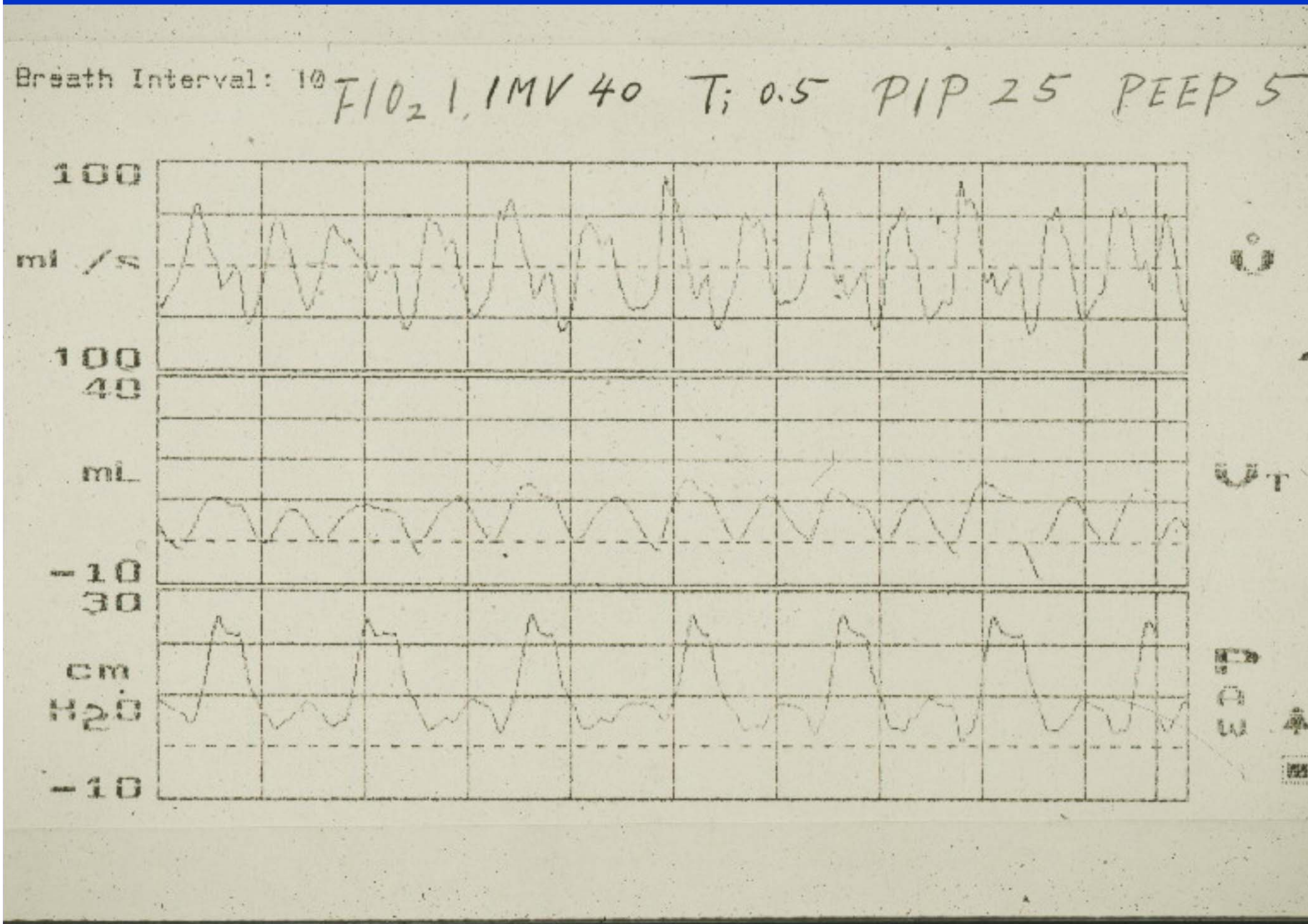
Spontaneous breathing during APRV (airway pressure release ventilation) is associated with better ventilation and more pulmonary blood flow to dependent lung regions located close to the diaphragm

Spontaneous breathing affects the spatial ventilation and perfusion distribution during mechanical ventilatory support
Crit Care Med 2005; 33:1090-1095
Newmann P. et al



	IMV	Ti	PIP	PEEP	FiO_2	pH	$PaCO_2$	PaO_2
Before transfer	**80**	**0.4**	*35*	**5**	**1.0**	**7.41**	**44**	**33**
After transfer	**40**	**0.6**	**30**	**5**	**1.0**	**7.30**	**55**	**31**
After reversal*	**25**	**0.6**	**30**	**5**	**1.0**	**7.34**	**53**	**68**

*TcPO2 rises (arrow) with spontaneous breathing after pavulon reversal



Breath Interval: 10
FIO2 1, IMV 40 Ti 0.5 PIP 25 PEEP 5
100
ml /s
100
40
mL
-10
30
cm
H2O
-10

Paw
25
cmH2O
5 s
Flow
5
L/min
-5
5 s
Vol
15
mL
5 s
CMV
Ppeak cmH2O
20
Pmean cmH2O
10
PEEP cmH2O
5
Waveforms
Start

- A large body of evidence indicates that physiologic rhythms are characterized by spontaneous variability. Heart rate, respiratory rate, and blood pressure amplitude are all variable and clearly affect each other.
- In fact, therapeutic interventions with life-support systems diminish or eliminate spontaneous physiologic rhythms. Elimination of these inherent spontaneous rhythms may be detrimental and contribute to the morbidity and mortality associated with such life-support systems.
- Specifically, mechanical ventilation may be improved if normal physiologic variation is reproduced.
- Using a computer-controller, the onset, duration, rate and volume of the ventilator inspiratory cycle could be varied and influence alveolar recruitment and thereby produce better oxygenation

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Biologically Variable or Naturally Noise Mechanical Ventilation Recruits Atelectatic Lung

W.Alan, C. Mutch,et. al

Am J Respir Crit Care Med 2000; 162: 319-23

Stochastic resonance -The addition of noise to input signal (variable PIP) to amplify output (PaO_2) in a nonlinear system

	PaO2	PaCO2	Shunt%	Crs	MAP	Vt ml/kg
Vbv	502	35	9.7	1.15	15.7	14.7
Vc	381	48	14.6	0.79	18.8	13.2
Vs	309	50	22.9	0.77	18.9	

Vbv: biologically variable MV,

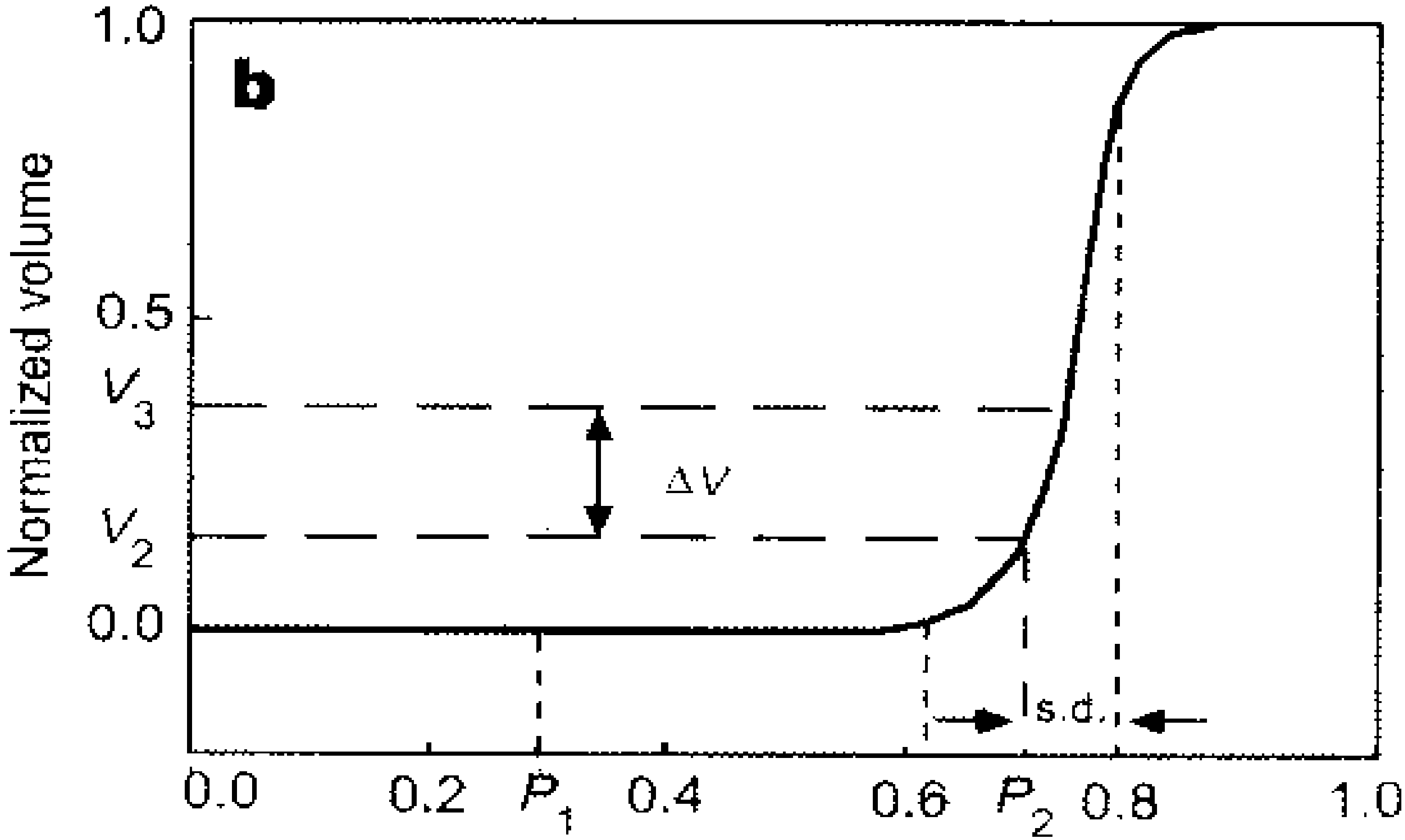
Vc: monotonously control MV,

Vs: Vc plus sigh

Stochastic Resonance

is most simply described as
the addition of noise to an input signal
to enhance output in a nonlinear system

Stachastic Resonance



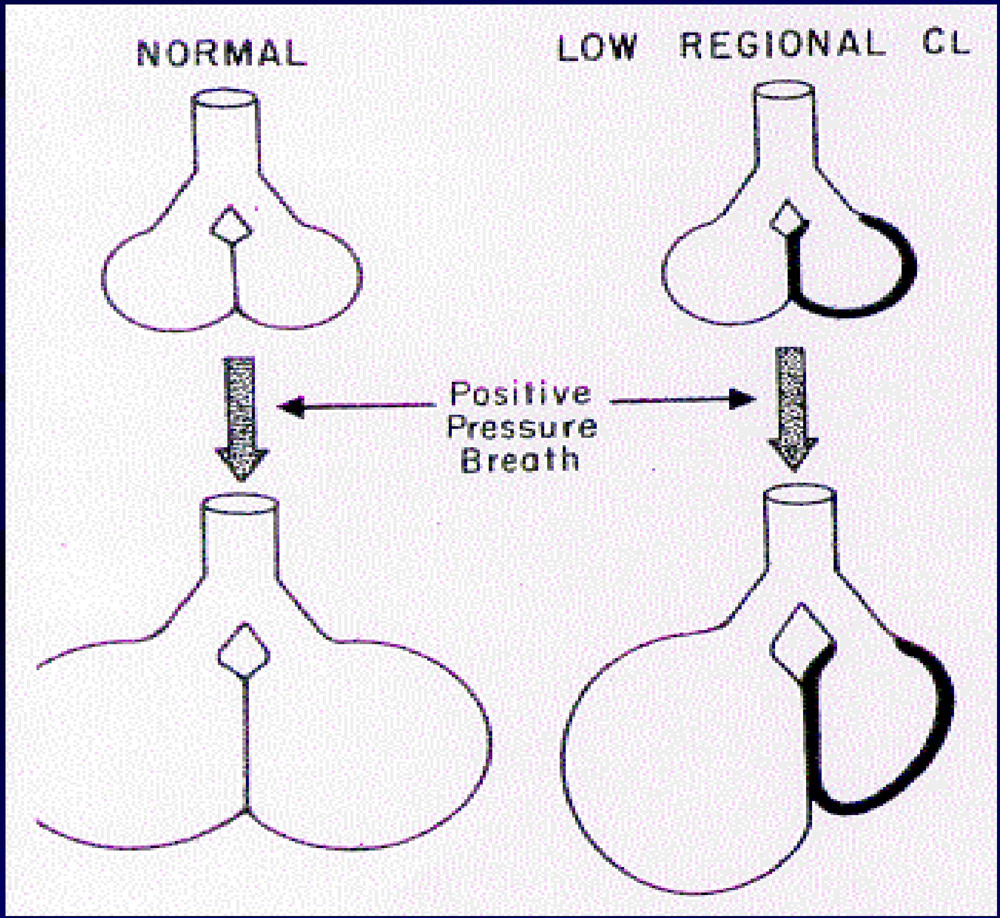
Biologically Variable Ventilation

- Improves lung mechanics, gas exchange, inflammatory mediators, and histological evidence of lung injury in ARDS.
- Recruits atelectatic and poorly areated lung regions.

Graham M.R. et al, Crit Care Med 2011;39:1721-1730

Overdistention may be regional

Even a “normal” VT can create regional overdistention

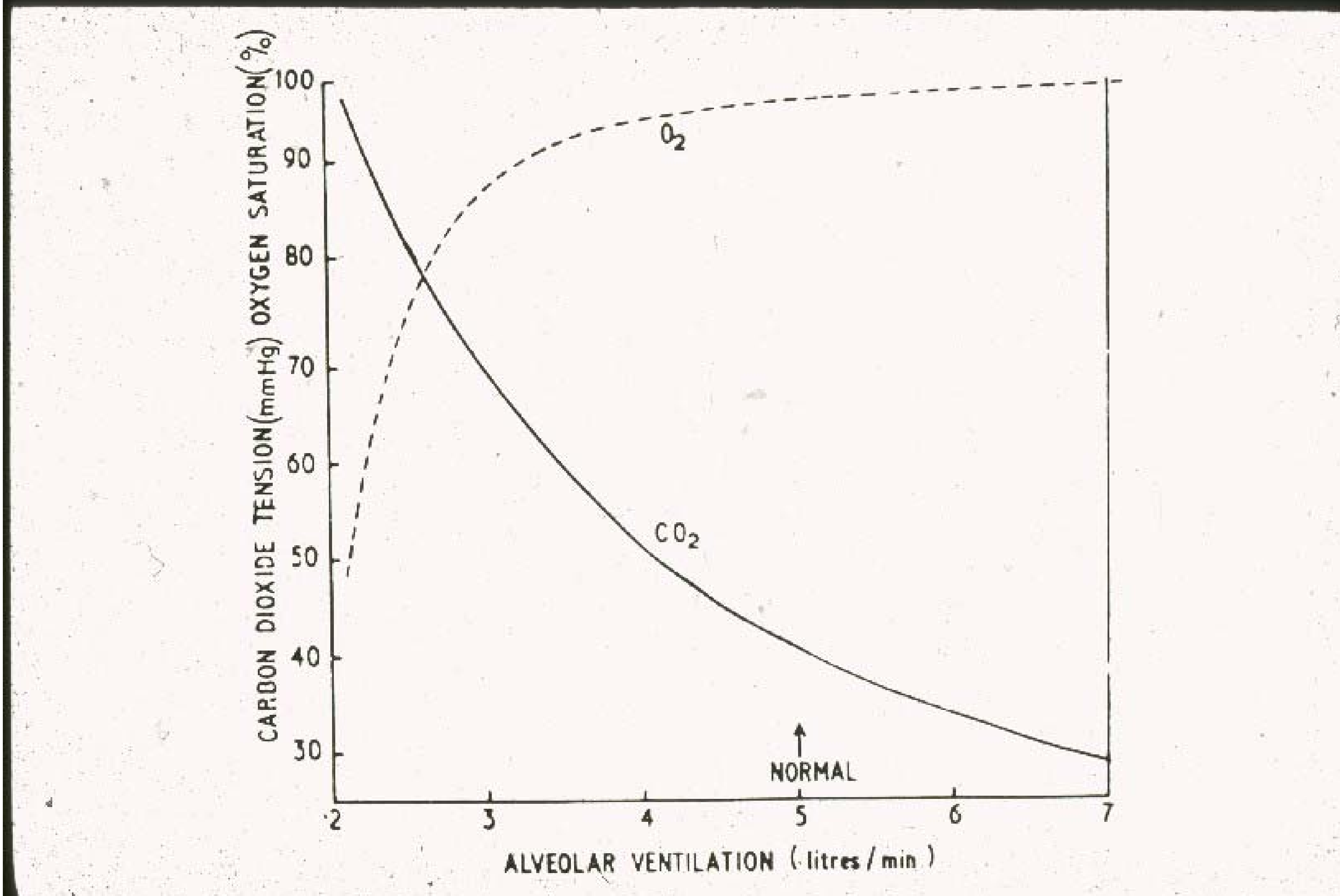


Mechanical Ventilation
Aim

- To maintain adequate gas exchange (oxygenation and CO_2 elimination)
- To avoid excessive work of breathings
- To provide time for resolution of the underlying disorder without further adding injury
  - To minimize cardiovascular depression
  - To minimize injury of lung and airway

Mechanical Ventilation

- Preservation of spontaneous breathings
- Tolerable oxygenation
- Permissive hypercarbia



CARBON DIOXIDE TENSION (mmHg) OXYGEN SATURATION (%)
100
90
80
70
60
50
40
30
O_2
CO_2
NORMAL
·2
3
4
5
6
7
ALVEOLAR VENTILATION (litres / min)

Permissive Hypercarbia

1) For patients having severe lung disease with high Vd/Vt, achieving a $PaCO_2$ in the 40's (sometimes impossible) requires high ventilator settings that result in further lung injury. In this situation, a higher $PaCO_2$ is permissible so that ventilator settings can be lowered to decrease lung damage and cardiovascular compromise, especially if spontaneous breathing is preserved.

2) Allowing a higher $PaCO_2$ can also facilitate extubation, thus avoiding complications from endotracheal intubation and mechanical ventilation

3) Hypercapnic acidosis as an adjunct therapeutic strategy to prevent ongoing lung injury..

Protective effects of hypercapnic acidosis on ventilator-induced lung injury. Am J Respir Crit Care Med 2001;164:802-806 Broccard AF et al

Therapeutic hypercarbia reduces pulmonary and systemic injury following in vivo lung reperfusion. Am J Respir Crit Care Med 2000;162:2287-2294 Laffey JG et al

Hypercapnic acidosis ($PaCO_2$ 80-100 mmHg) is protective in an in vivo model of ventilator-induced lung injury. Am J Respir Crit Care Med 2002;166;403-408 Sinclair SE et.al

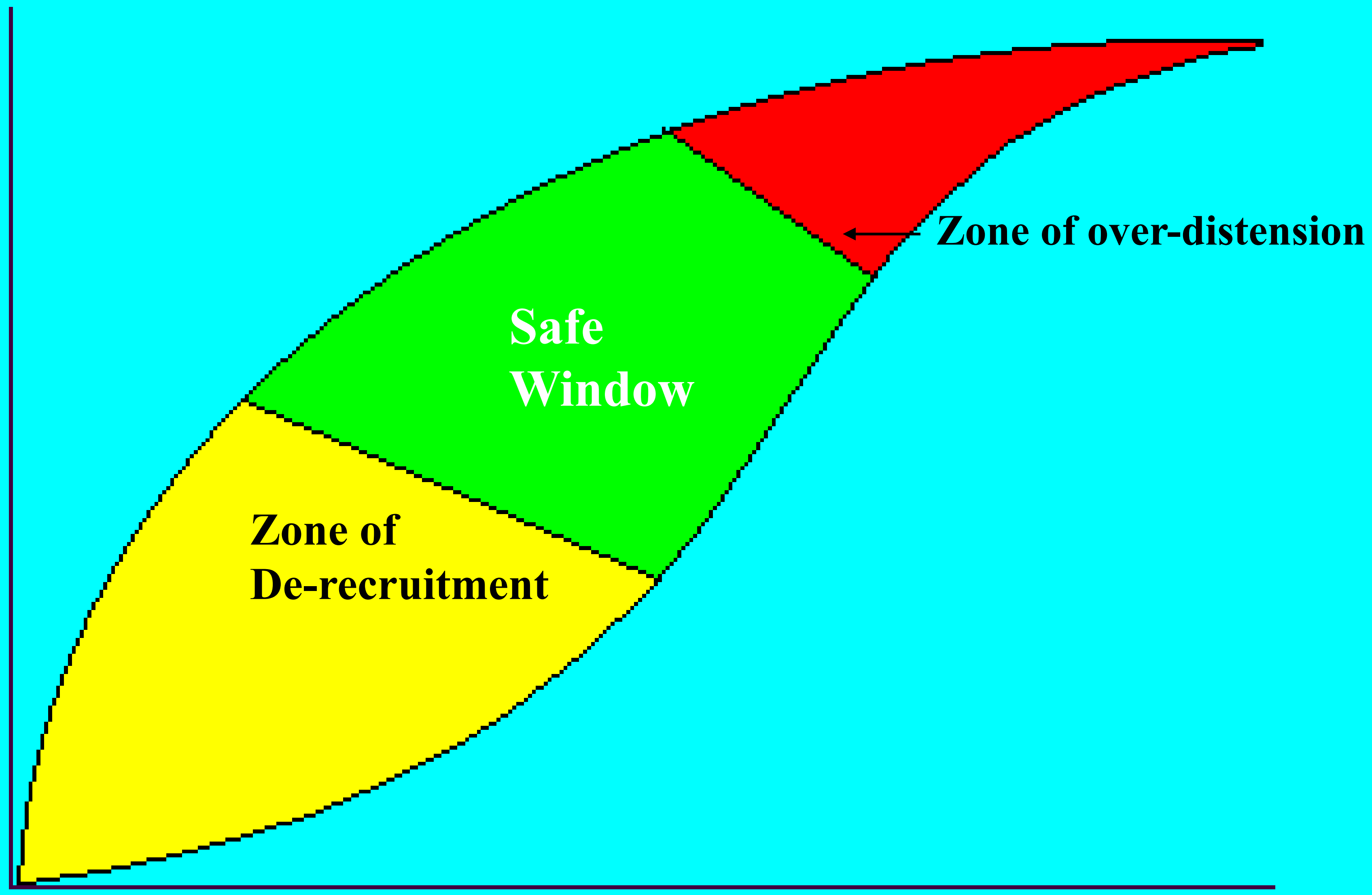
Hypercapnic Acidosis Is Protective in an In Vivo Model of Ventilator-induced Lung Injury.

- 12 anesthetized, paralyzed rabbits, Vt: 25 cc/kg, Rate:32/min, PEEP 0 for 4 hours.
- 6 rabbit receive either an $FiCO_2$ to achieve:
1) **$PaCO_2$ 40 mm Hg**; or 2) **$PaCO_2$ 80–100 mm Hg**.
- Injury was assessed by respiratory mechanics, gas exchange, wet:dry weight, bronchoalveolar lavage fluid protein concentration and cell count, and injury score.
- Conclusion: hypercapnic acidosis is protective against ventilator-induced lung injury in this model

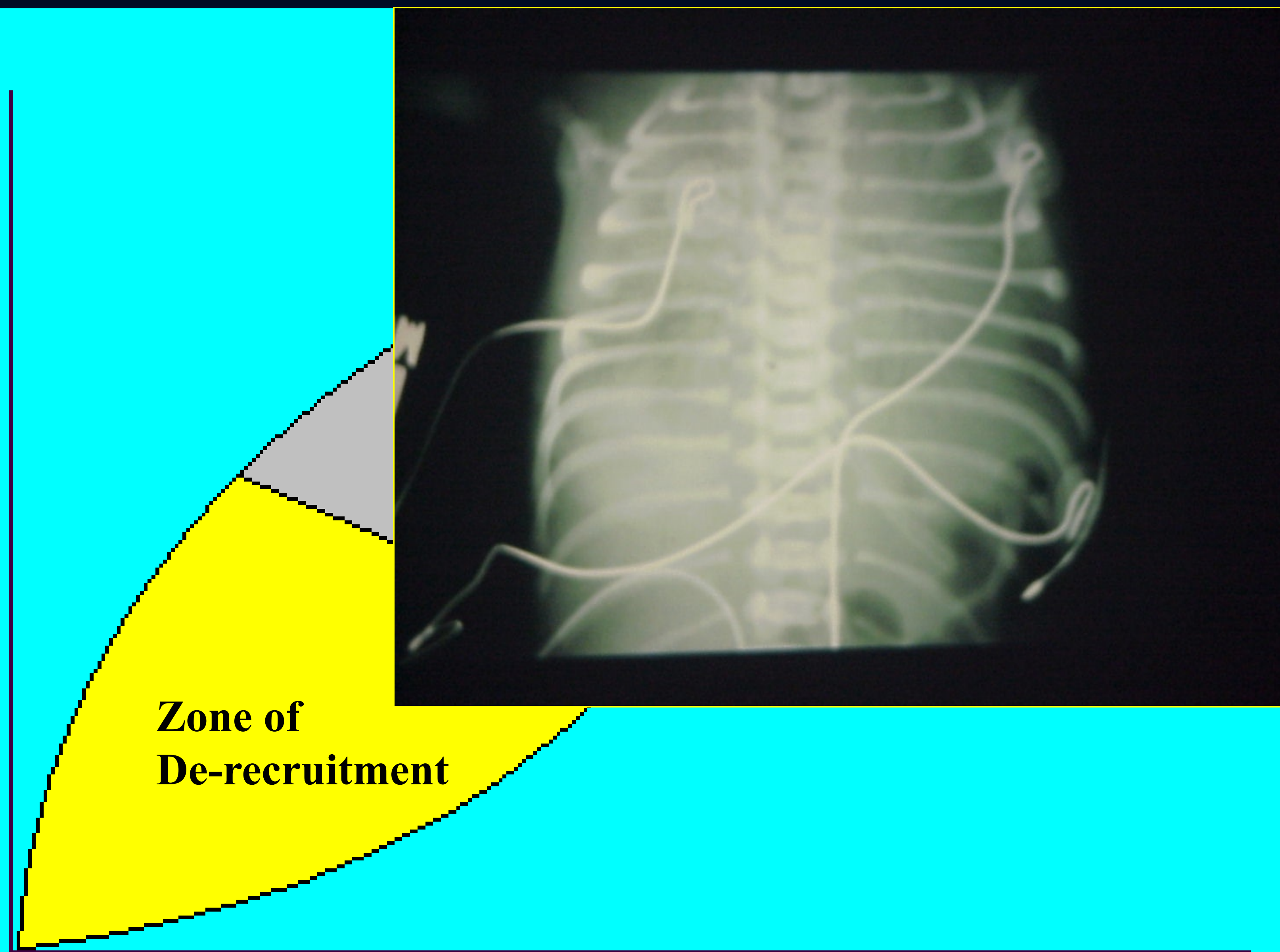
Managing Infants with Respiratory Distress

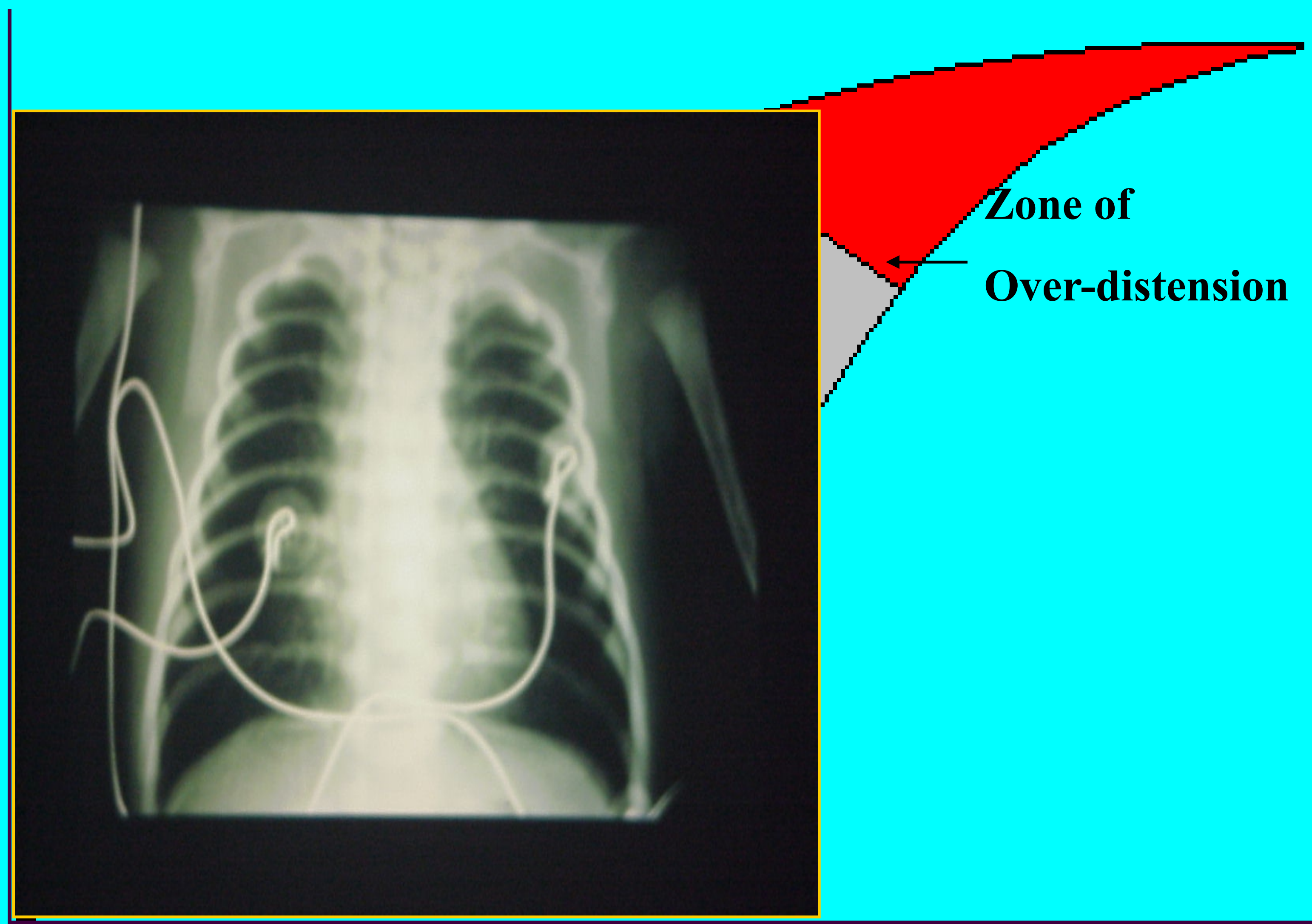
Mechanical Ventilation using infant respirator:

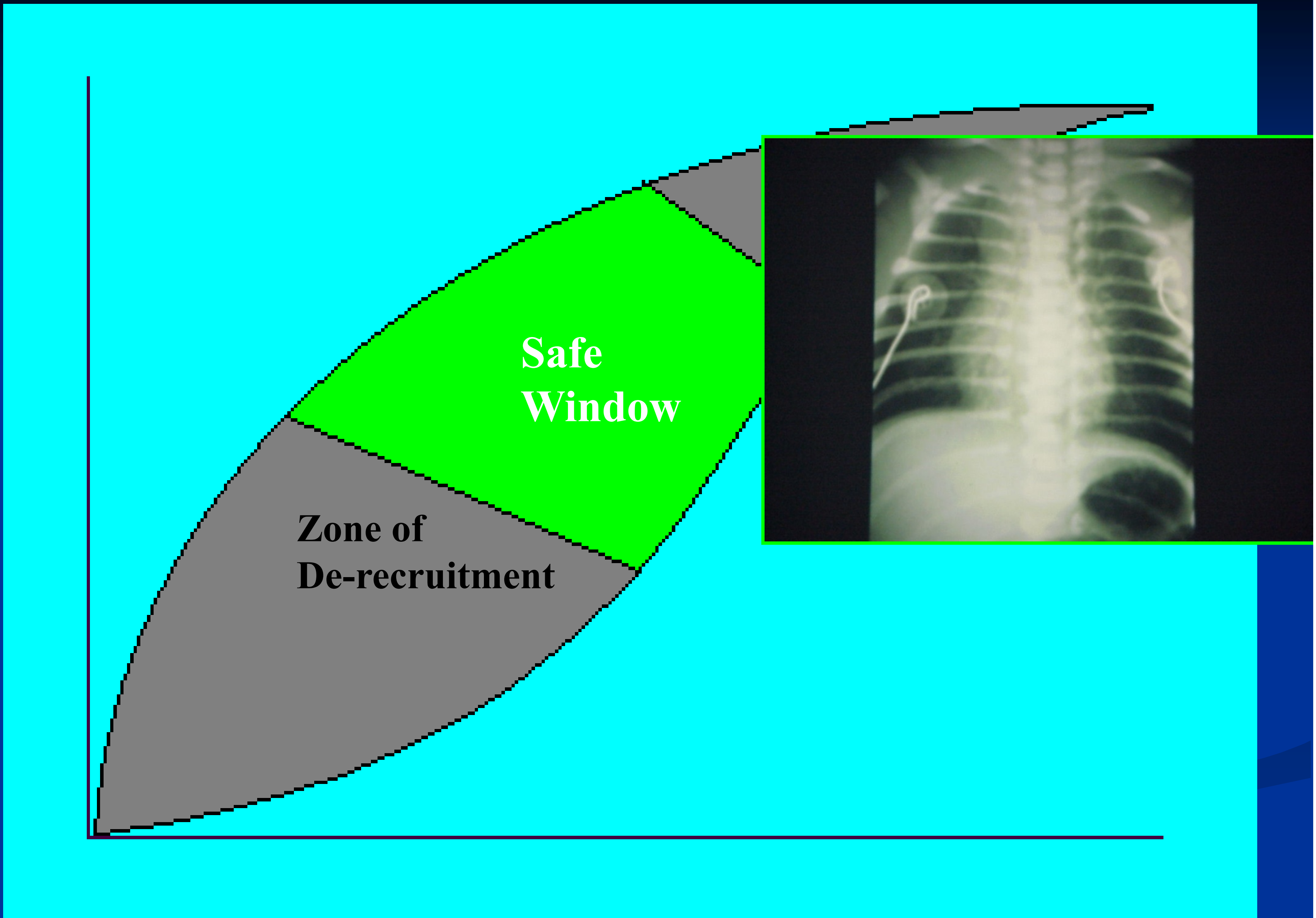
- Allow spontaneous breathing to continue.
- Ventilatory settings are graded according to degree of respiratory failure.
- Consider strategies that balance the tradeoffs between gas exchange and lung protection.
- Wean aggressively and early extubation



Froese, Crit Care Med 1997, 25:906


Zone of
De-recruitment


Zone of
Over-distension


Safe
Window
Zone of
De-recruitment

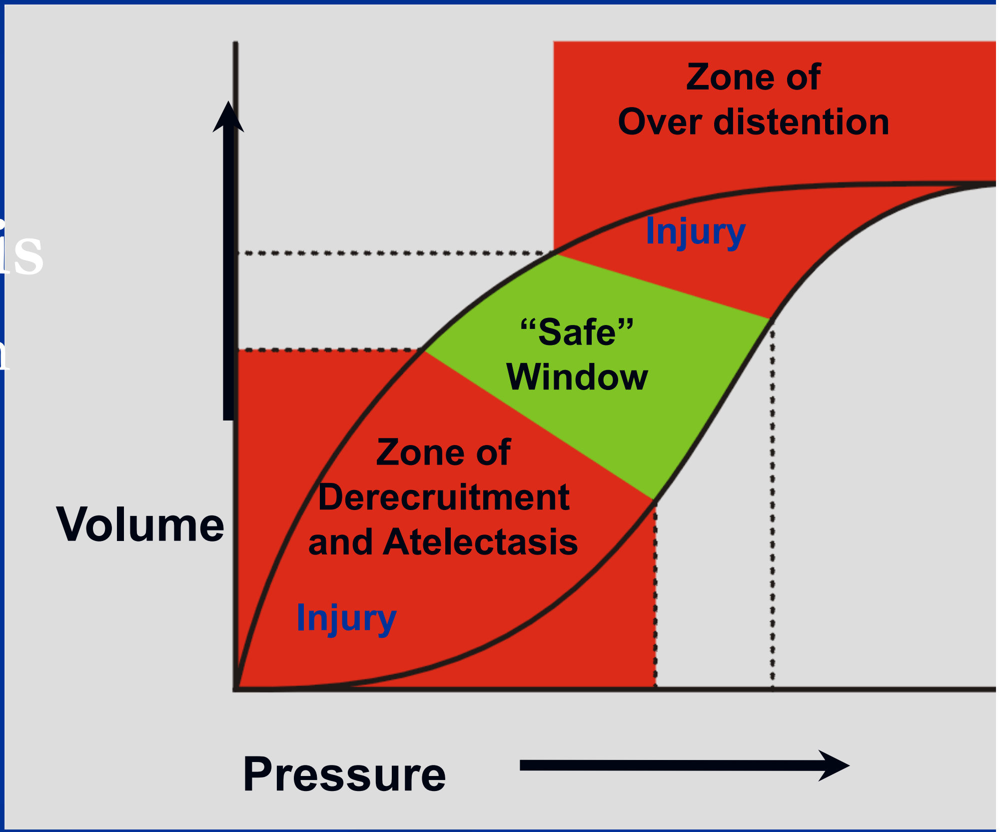
Optimized Lung Volume "Safe Window"

Over distension

- Edema fluid accumulation
- Surfactant degradation
- High oxygen exposure
- Mechanical disruption

Derecruitment, Atelectasis

- Repeated closure / re-expansion
- Stimulation of inflammatory response
- Inhibition of surfactant
- Local hypoxemia
- Compensatory overexpansion



Mechanical Ventilation Using Conventional Infant Ventilators

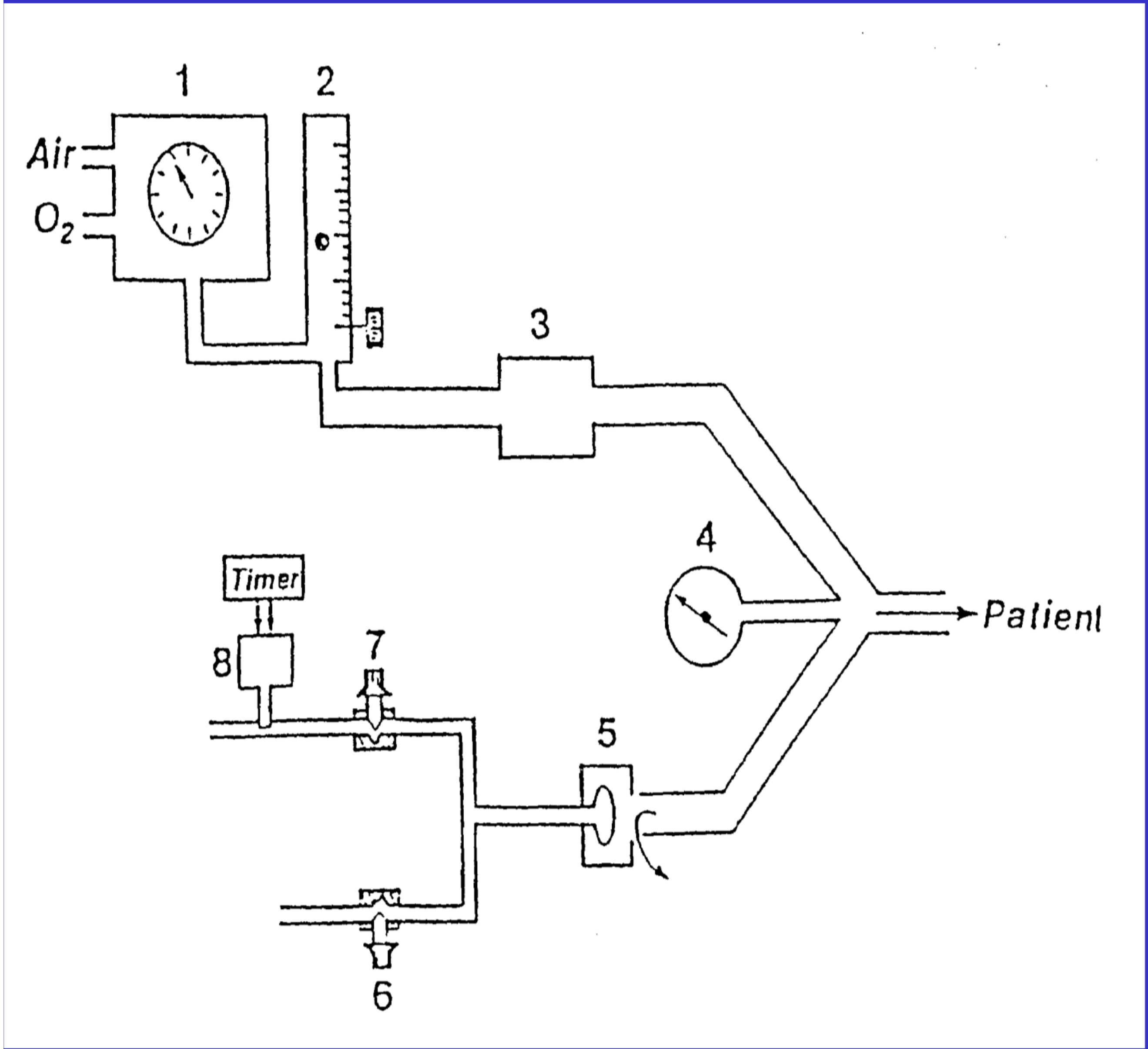
Four Techniques

1. Conventional technique (IMV < 41/min.)

2. High Frequency Positive Pressure Ventilation (HFPPV)

3. Prolonged inspiratory time with inspiratory pressure plateau (reverse I/E ratio)

4. Synchronization (IMV rate between 40 and 100/min to synchronize with patient's spontaneous respiration)



Parameter

- FiO_2 (1)
- Flow rate (2)
- IMV rate (8)
- Ti (8)
- PIP (7)
- PEEP (6)

Conventional Ventilation
FiO_2

To keep PaO_2 50 – 70 mmHg

Acceptable O_2 Saturation around 90% (85 – 95%)

Conventional Ventilation
Flow

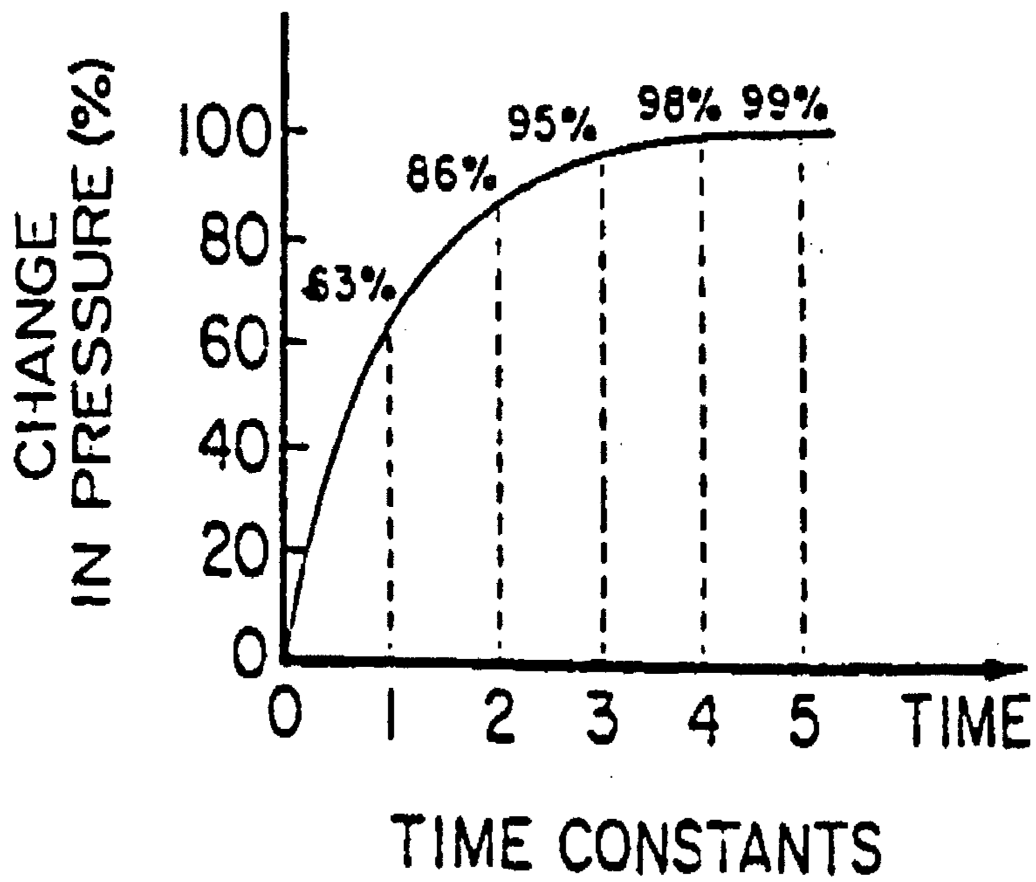
- Usually 5 – 8 lpm
- Enough to reach PIP within Ti
- Minimum flowrate to prevent rebreathing CO_2 : minute ventilation (200ml/kg) × 2.5 plus air leak

Conventional Ventilation(<40/min)
IMV Rate

- Usually start at 20 – 40/min
- To keep $PaCO_2$ 40 – 70 mmHg
- To avoid excessive labored spontaneous breathings

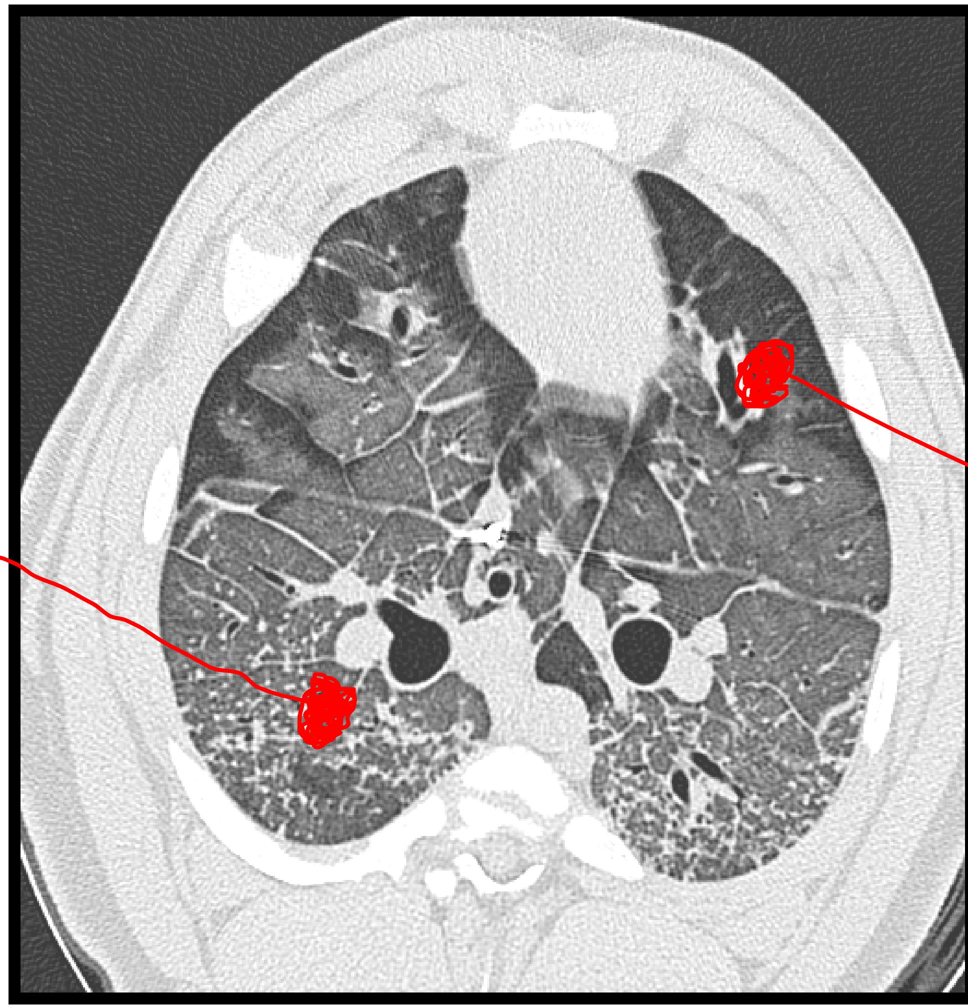
Conventional Ventilation(<40/min)
Ti

- Usually 0.5 seconds (about 2 time constant, T.C. = C x R)



Tc =C x R

Tc = c× R



Tc=C× R

Conventional Ventilation(<40/min) PIP

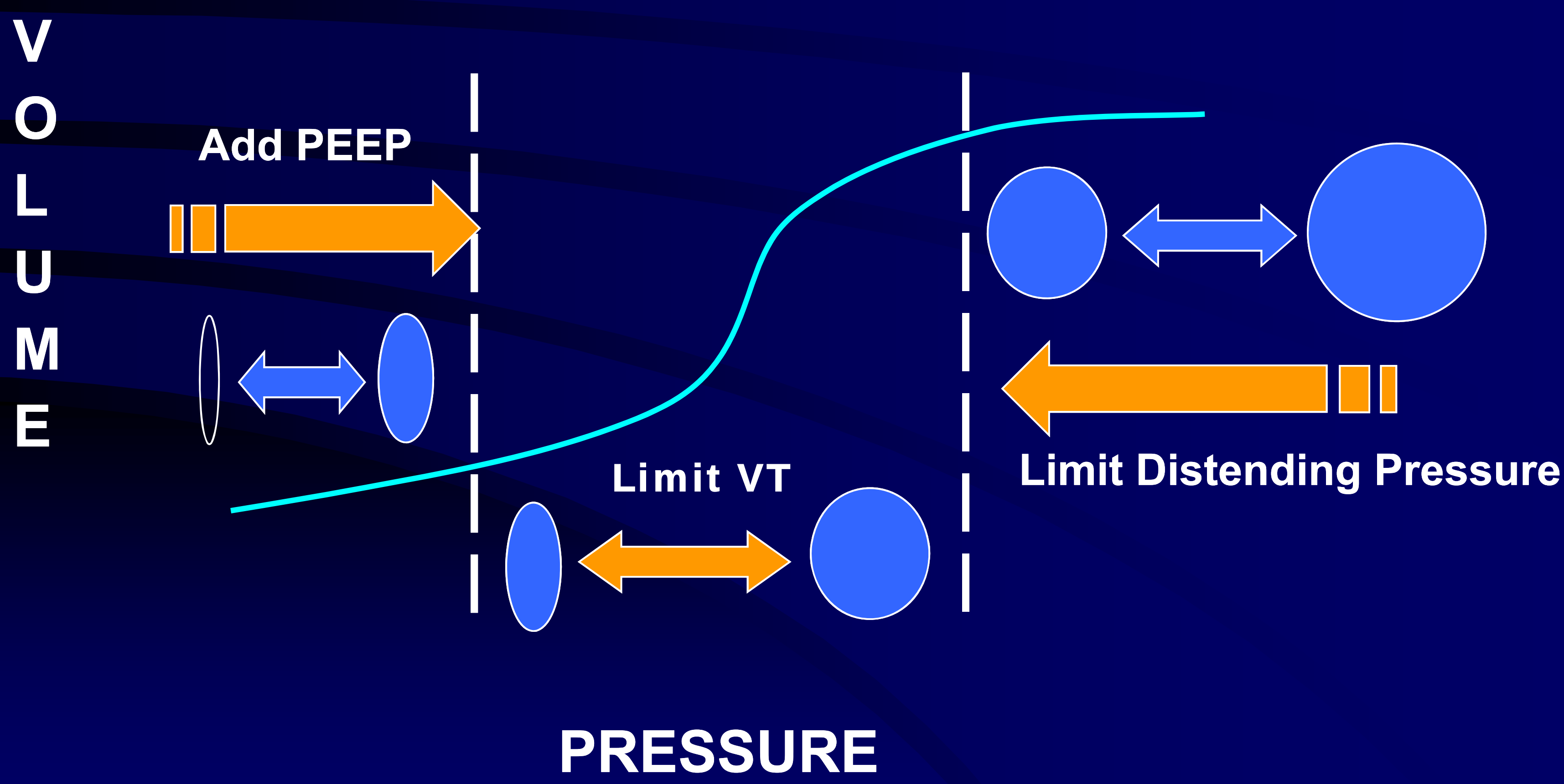
- Usually start at 20 cmH_2O (15 cmH_2O for preemie)
- To have adequate chest and/or abdominal excursion

Conventional Ventilation(<40/min)
PEEP

- Usually 5 cmH_2O
- To increase for deep inspiratory retraction due to low FRC
- To decrease for lung hyperinflation

Preventing Overdistention and Under-Recruitment Injury

"Lung Protective" Ventilation



Conventional Technique

Settings

1. Flow rate 5 - 8 LPM
2. FiO_2 to keep PaO_2 50-70 mmHg
3. IMV rate
    - Usually started at 20-40/min.
    - Avoid excessive labored breathing
    - Maintain $PaCO_2$ 40-70 mmHg
4. Inspiration time (Ti) 0.5 seconds
5. Peak inspiratory pressure (PIP)
    - Adequate chest excursions
    - Usually started at 20 cmH_2O for term infant and 15 cm H_2O for preemie
6. PEEP 5 cmH_2O

Conventional Technique
Improvement

- Decrease IMV rate by 2-5/min for $PaCO_2$ <50 mmHg
- Decrease PIP by 2-5cmH_2O for excessive chest excursion
- Decrease FiO_2 by 1/10 for PaO_2>60mmHg
- Usually no change for flow rate, Ti or PEEP

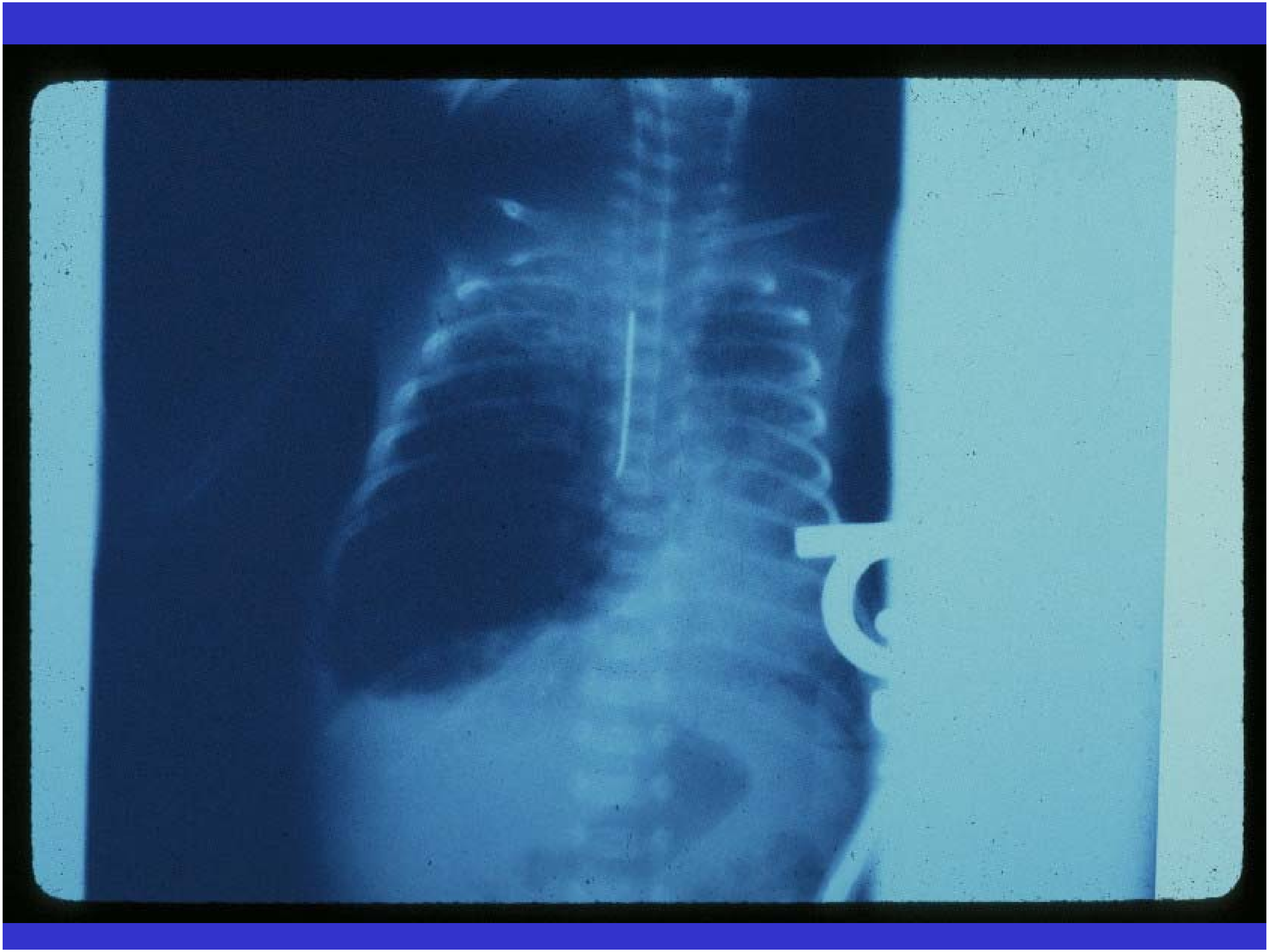
Conventional Technique

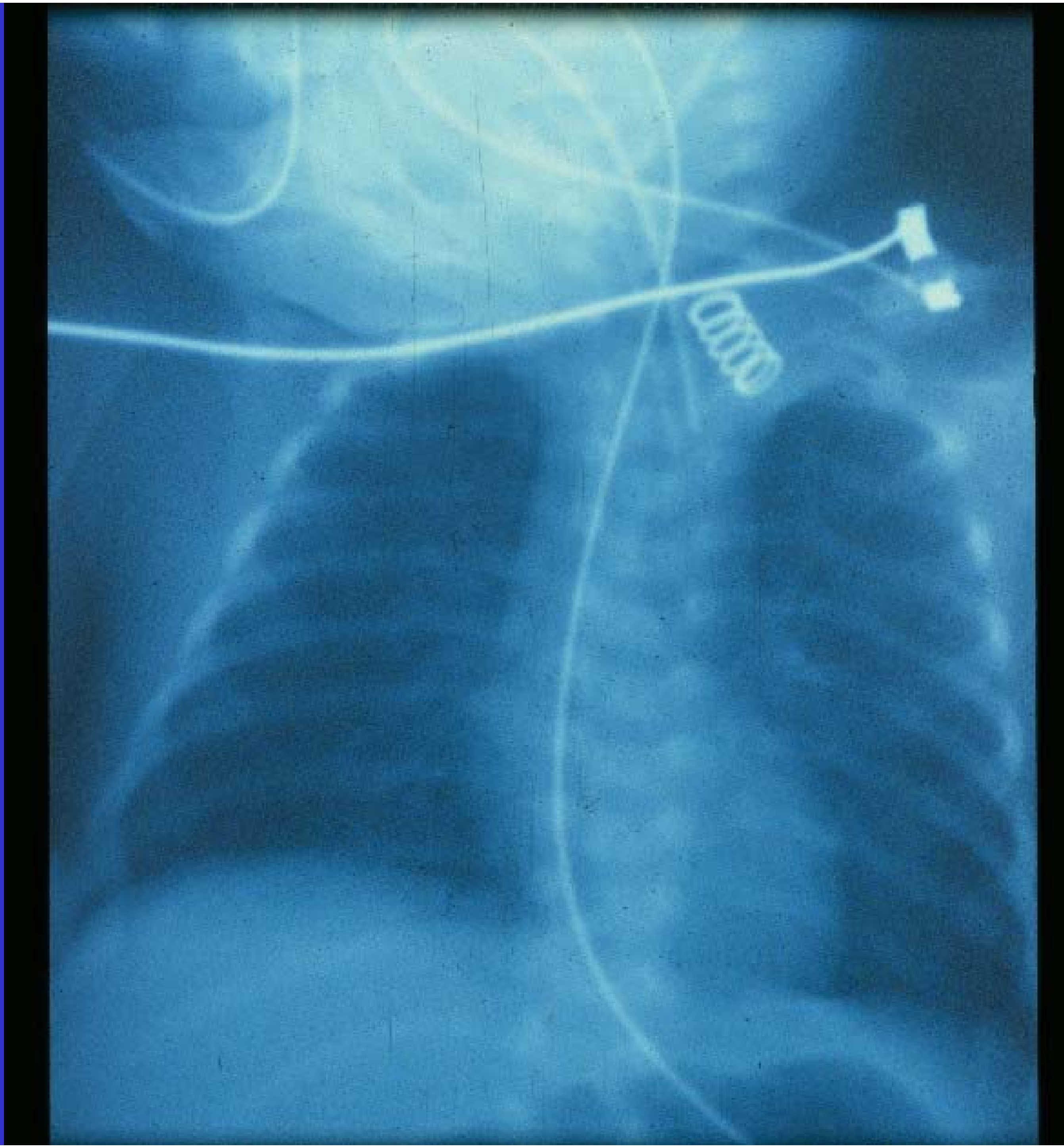
Deterioration

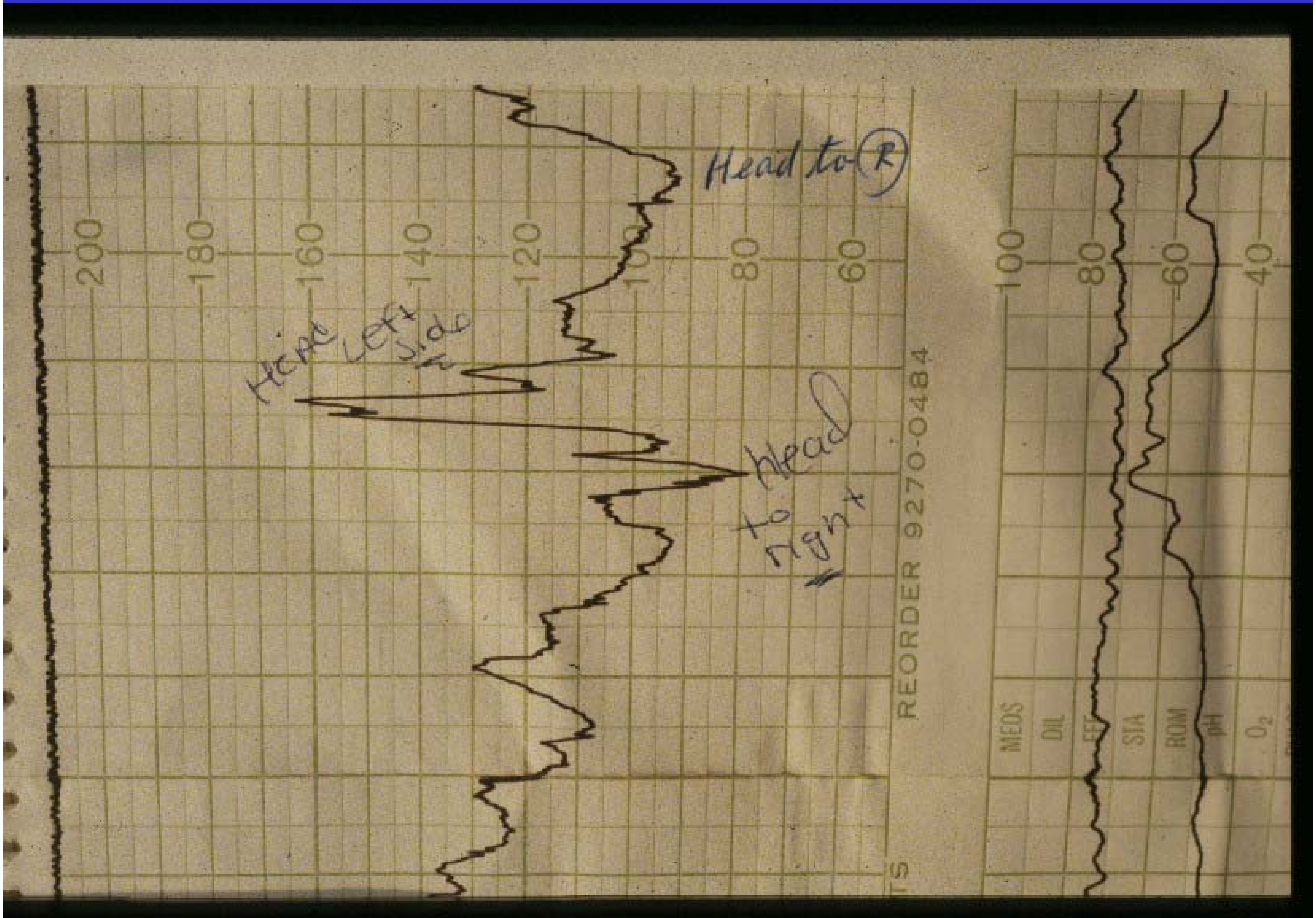
- R/O ET tube obstruction, pneumothorax, underventilation, overventilation, etc.

- For $PaCO_2$>70mmHg or excessive labored breathings, increase IMV rate (up to 40/min)

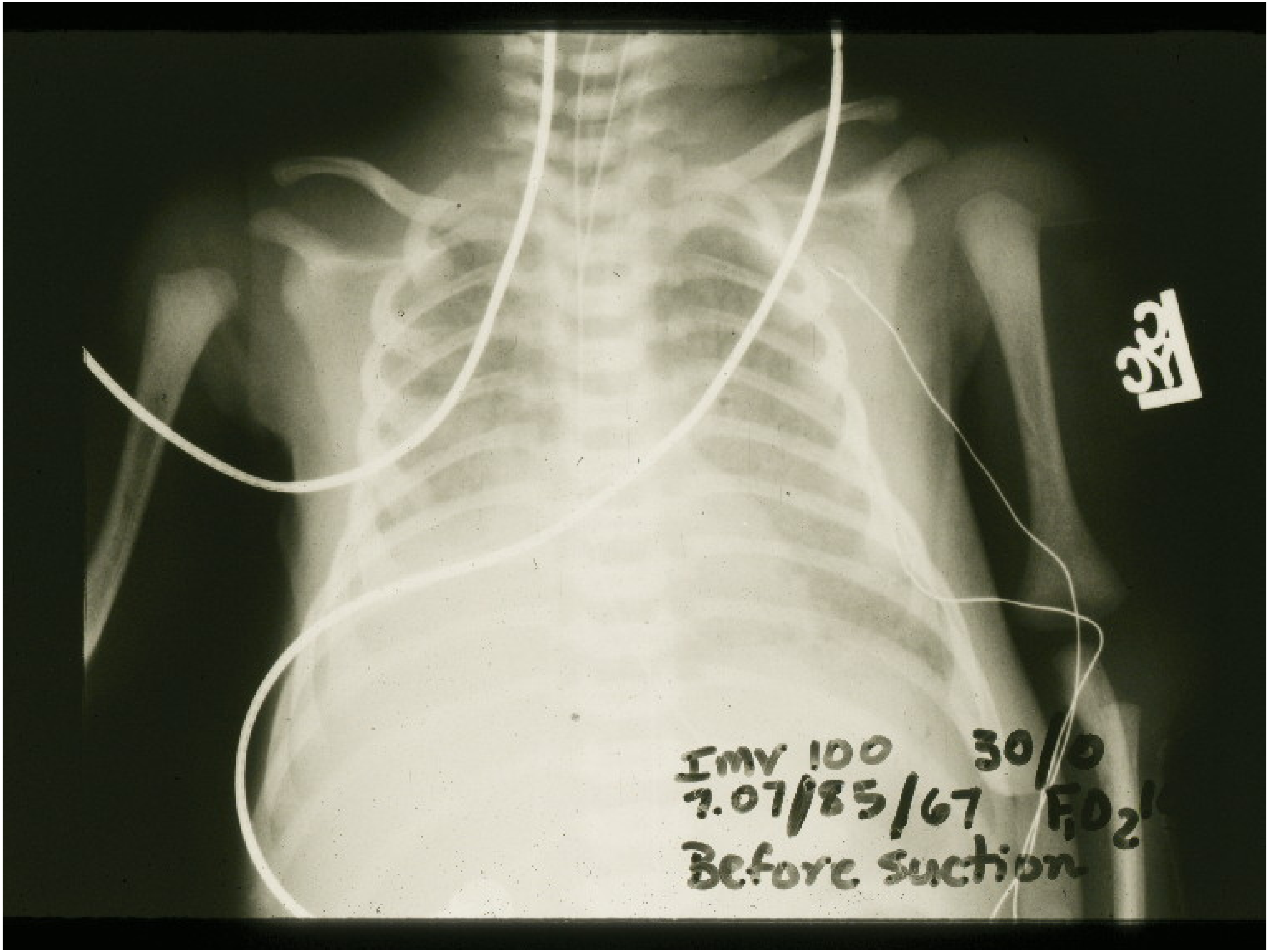
- For hypoxemia,
  - Increase PIP if chest excursion is inadequate
  - Increase PEEP for severe inspiratory retractions
  - Increase FiO_2



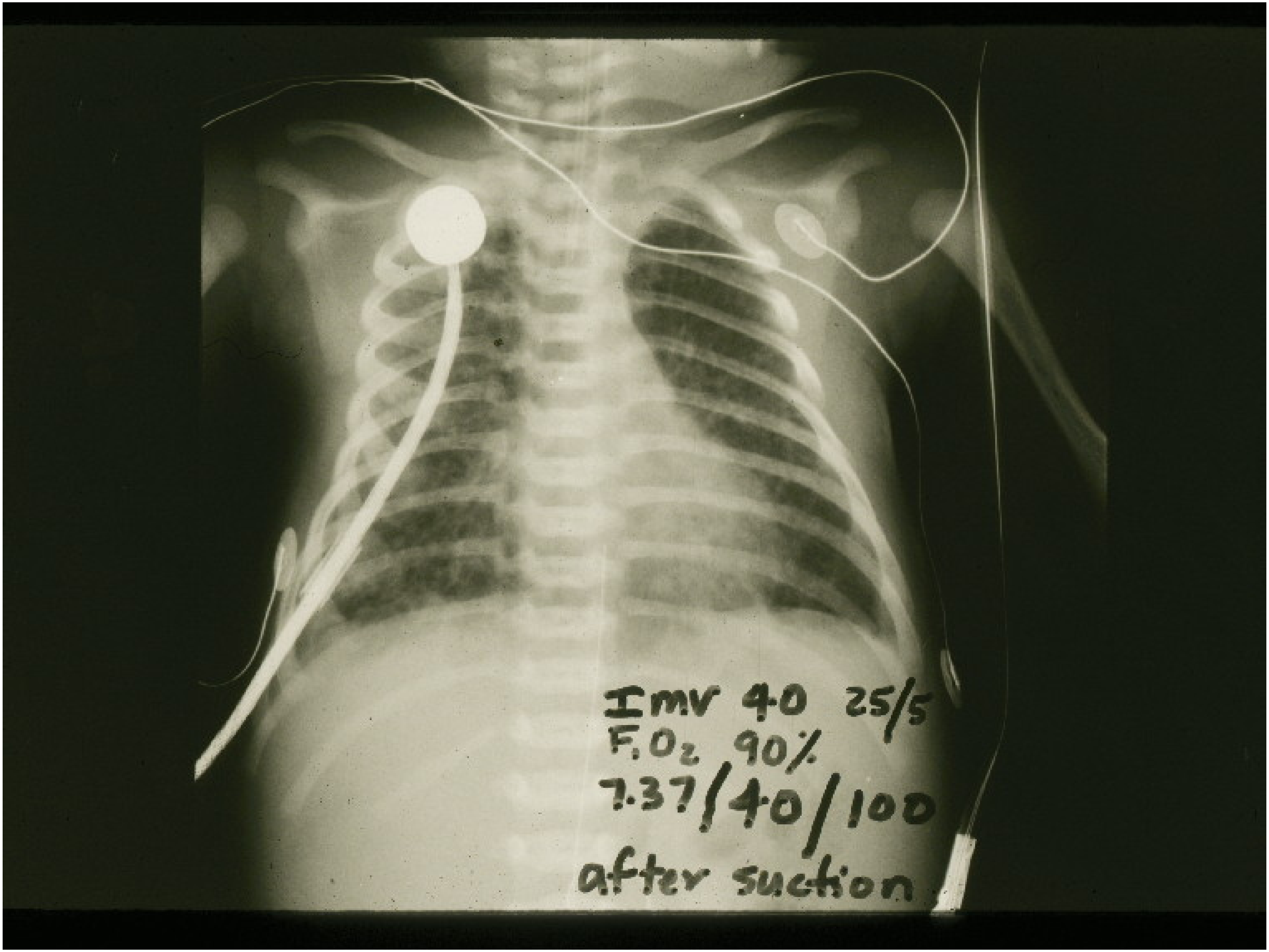




200
180
160
140
120
100
80
60
Head to R
Here Left side
Head to right
REORDER 9270-0484
100
80
60
40
MEDS
DIL
EFF
STA
ROM
pH
O_2



Imv 100 30/0
7.07/85/67 FiO2
Before suction


Imv 40 25/5
F.O2 90%
7.37/40/100
after suction


TRACH MATE
4.9 OD
ORAL / NASAL
ID 3.5

Indications for a Trial of HFPPV

On Conventional Technique:

1. PaO_2 < 50 mm Hg with an FiO_2 100%

2. PaO_2 is very labile

3. PIP > 30 cm H_2O to achieve visible chest excursions

4. $PaCO_2$ > 70 mm Hg or excessive labored spontaneous breathing with IMV rate up to 40/min.

5. Pulmonary interstital emphysema (P.I.E.)

High Frequency Positive Pressure Ventilation (HFPPV)

Setting

1. IMV 100/min.
2. Ti 0.3 sec. (Te 0.3 sec)
3. Flow rate (>6 LPM)
4. PIP is usually the same as conventional settings
5. PEEP 1 (to prevent intrinsic high PEEP)

Mechanical Ventilation Using Conventional Infant Ventilators

Four Techniques

3. Prolonged inspiratory time with inspiratory pressure plateau (called reverse I/E ratio in the past)

- Inspiration time (Ti): 0.5 -1.0 seconds
- For infants with severe parenchymal lung disease, e.g. severe RDS, congenital pneumonia, etc.
- Replaced by HFO

Mechanical Ventilation Using Conventional Infant Ventilators

Four Techniques

4. Synchronization

- IMV rate between 40 and 100/min to synchronize with patient's spontaneous respiration
- Ti: 0.5 seconds or I:E ratio = 1, whichever is shorter
- Replaced by patient triggered ventilation (SIMV, A/C, PS or NAVA)

Mechanical Ventilation

Weaning

	FiO2	Flow	IMV	Ti	PIP	PEEP
Conventional	↓		↓		↓	
HFPPV	↓				↓	
Prolonged Ti	↓		↓	↓	↓	
Synchronized	↓		↓	↑	↓	

“Agitation”
“Fighting with respirator”

Patient is telling us something is wrong

“Agitation”
“Fighting with respirator”

- Looking for the cause
- Suctioning of the endotracheal tube
- Nasotracheal intubation
- Mild sedation if necessary
- Best sedation is a clear airway and television set

Ramsay Sedation Scale

1. Agitated, anxious, restless
2. Cooperative, oriented, tranquil
3. Drowsy, respond to commend
4. Sleepy, easy arousal
5. Sleepy, difficult arousal
6. Sleepy, not arousal

Ramsay et al Br Med J 1974;2:656-9

Sedation Analgesia

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Amnesia Hypnosis Anxiolysis

Selective α2 adrenoreceptor agonist

Dexmedetomidine (precedex)

Loading :1 ug/kg over 10-20 minutes

Maintenance: 0.2 – 0.7 ug/kg/hr (max. 24 hours)

Tolerance,withdrawal, and physical dependence of children in PICU after long-term sedation and analgesia

Joseph P. Tobias

Crit Care Med 2000; 28: 2122-32

Neuromuscular blocking agents

Undesirable side effects

1. Loss of spontaneous respiration and increase of respirator settings which cause barotrauma and volotrauma
2. V/Q mismatch
3. suppression of cough reflex resulting in secretion retention and atelectasis
4. Immobility leading to peripheral edema, peripheral nerve injuring, muscle atrophy, contractures, skin breakdown/stasis ulcer, deep vein thrombosis and pulmonary embolism
5. Inability or limitation of doing a thorough neurological examination
6. Autonomic and cardiovascular changes
7. Inappropriate use of sedatives and analgesics
8. Prolonged paralysis or weakness
9. Myopathy, particularly if corticosteroids are concurrently used.

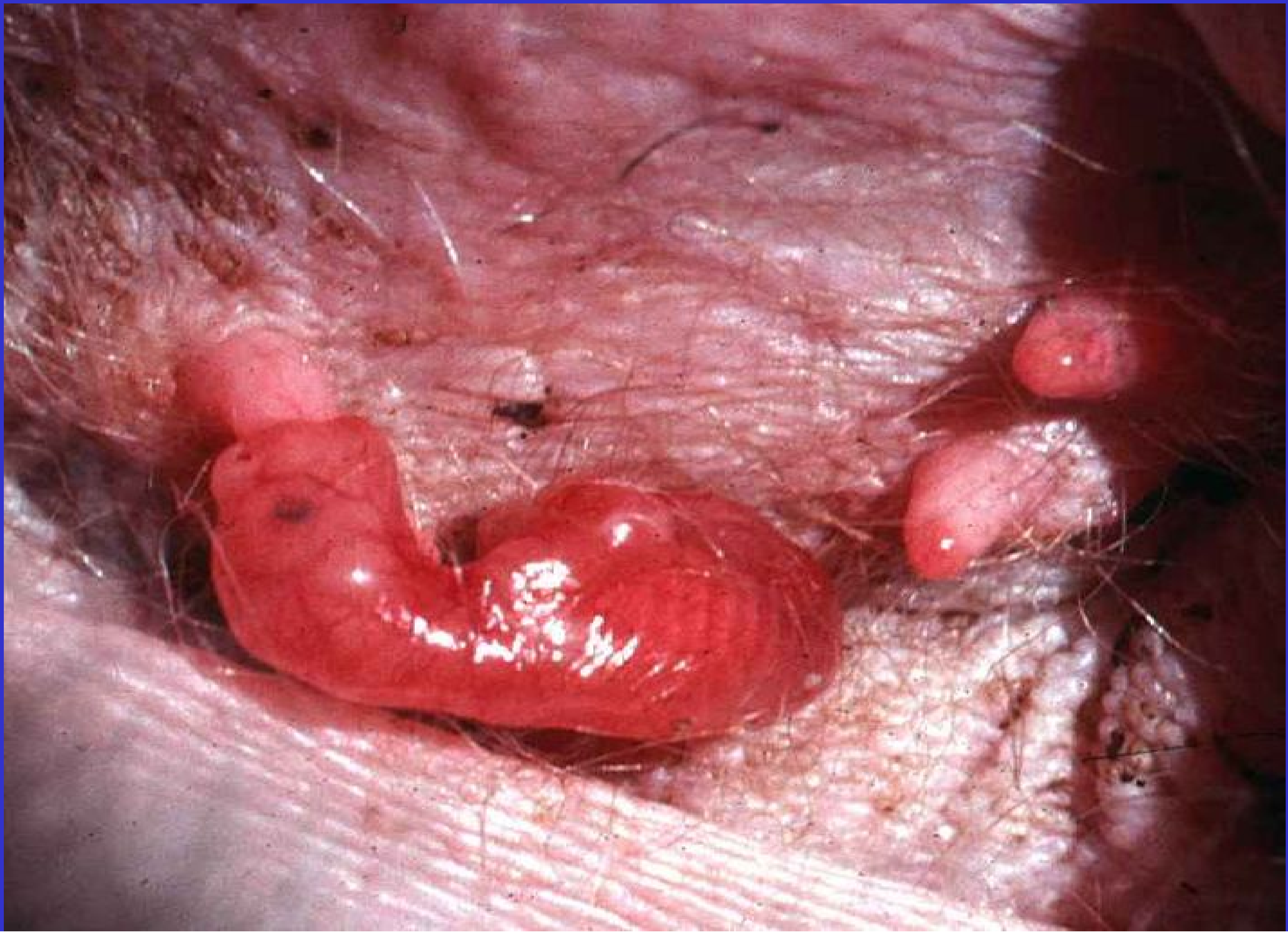
Mechanical Ventilation

Extubation

Condition is improved and stable

- IMV rate $\leq$20/min
- Flip-flopped $PaCO_2$ due to ET tube obstruction from retention of secretions or tube bevel against tracheal wall, otherwise, patient is active.

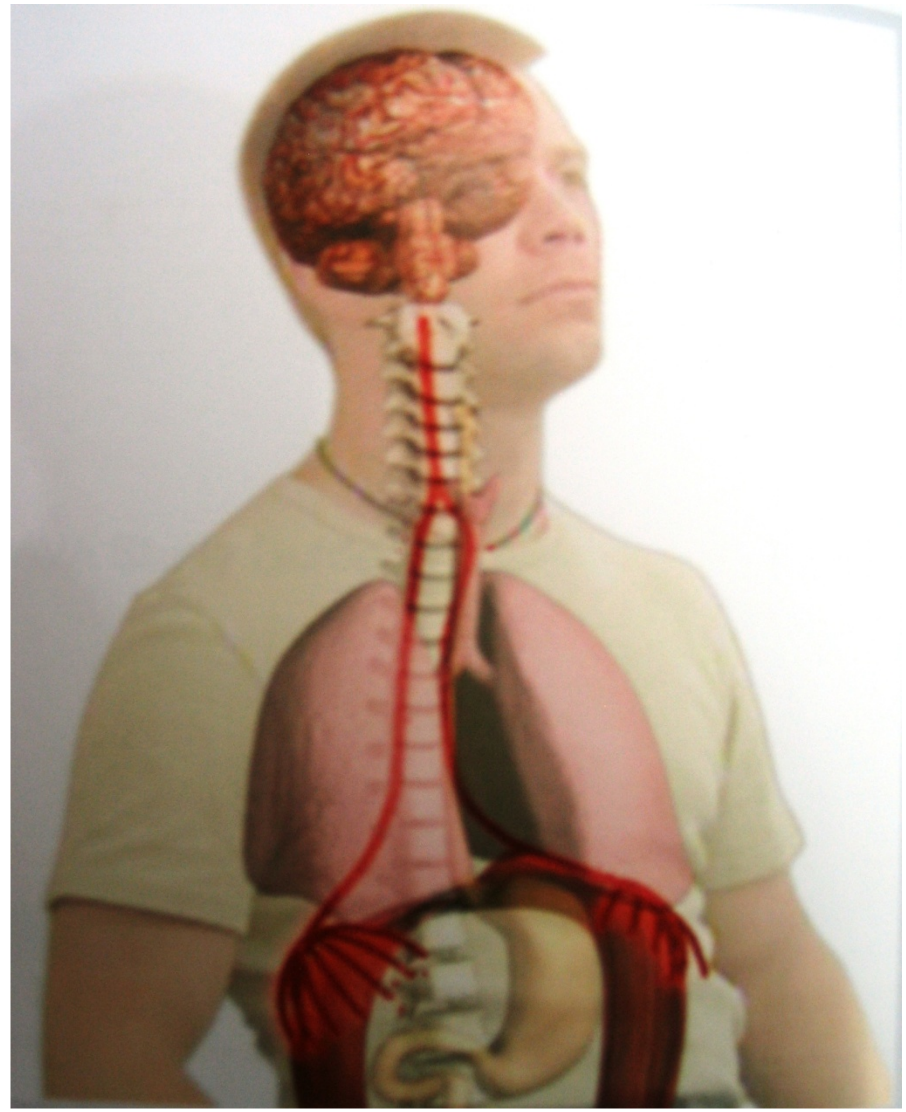
KANGAROO NEWBORN



Sequence of Steps for Extubation of Very-Low-Birth-Weight Infants

- Endotracheal tube Suctioning
- Direct laryngoscopy
- Paint larynx with vaponephrine
- Place on Nasal CPAP
- No prophylactic caffeine given

The act of breathing depends on rhythmic discharge from the respiratory center of the brain. This discharge travels along the phrenic nerve, excites the diaphragm muscle cells, leading to muscle contraction and decent of the diaphragm dome. As a result, the pressure in the airway drops, causing an inflow of air into the lungs



Central nervous system

↓

Phrenic nerve

↓

Diaphragm excitation

↓

Diaphragm contraction

↓

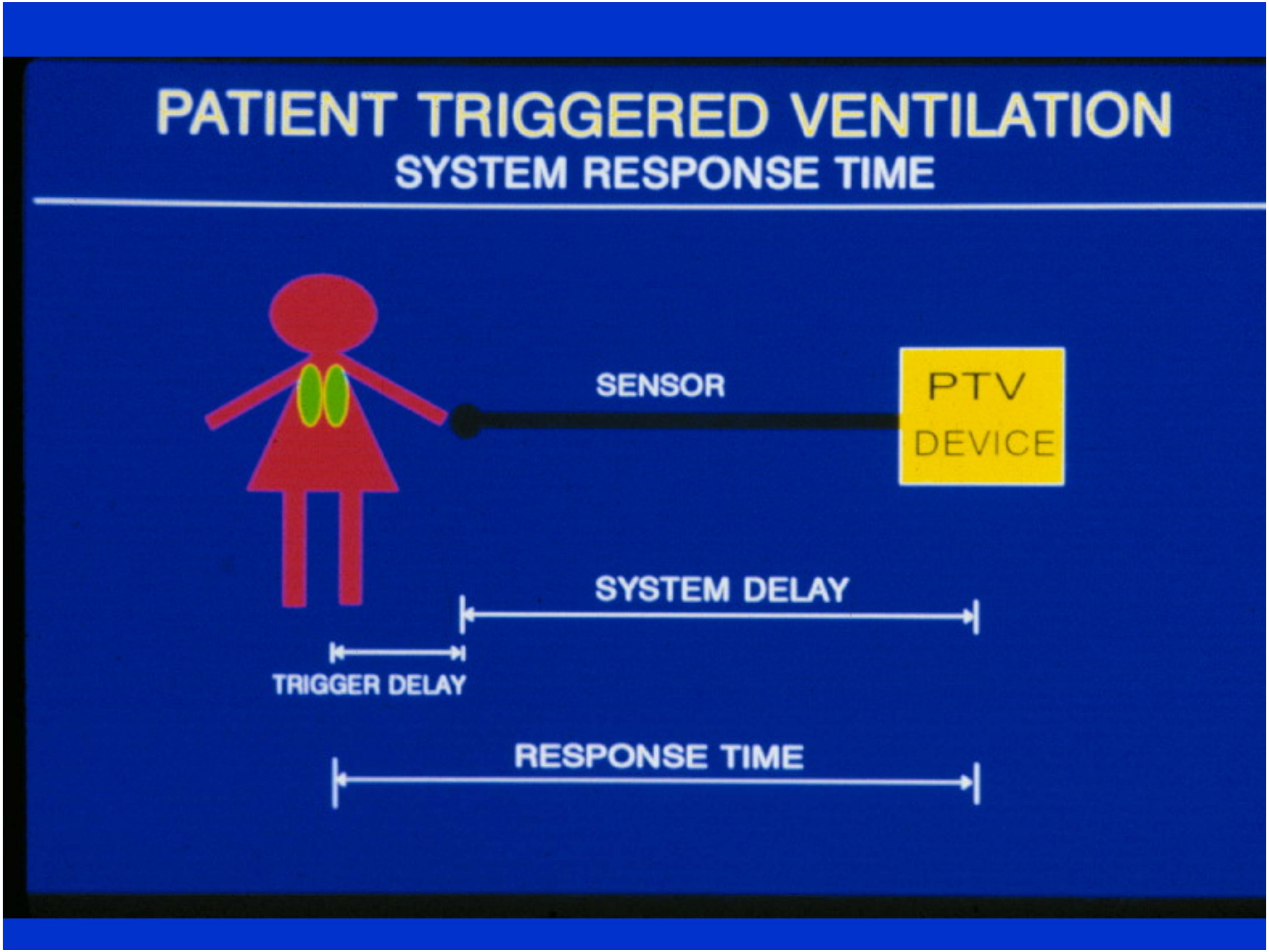
Chest wall and lung expansion

↓

Airway pressure drop, flow reversal --⟶ PTV

Patient Triggered Ventilation (PTV)

- A method of Mechanical ventilation that are triggered by the patient's inspiratory effort
- The patient's spontaneous breathing effort leads to change of signal (i.e. pressure, flow or impedance, etc)


PATIENT TRIGGERED VENTILATION
SYSTEM RESPONSE TIME
SENSOR
PTV
DEVICE
SYSTEM DELAY
TRIGGER DELAY
RESPONSE TIME

PATIENT TRIGGERED VENTILATION
Triggering mechanisms

- **Pressure**
  - Esophageal pressure
  - Airway pressure (SLE HV 2000)
- **Airflow**
  - Flow transducer (Servo i, Avea Comprehensive Ventilator)
  - Pneumotachograph (VIP Bird)
  - Hot-wire anemometer (Babylog 8000, Evita XL)
- **Thoracic impedance pneumograph** (Sechrist IV 200 SAVI)
- **Graseby pneumatic capsule** (Infant Star Sync)

Patient Triggered Ventilation (PTV)
Requisites PTV System

- Adequate sensitivity to detect signals
- Not too sensitive to cause auto-cycling
- Early detection of signal - during first 25% of inspiratory effort (ideally within 10%, neonatal inspiratory time is 250 - 300 msec)
- Consistent detection of signal
- Consistent rapid response time (60 - 80 msec)
- Minimum increase of dead space and/or resistance

Patient Triggered Ventilation (PTV)

Particular problems in infants

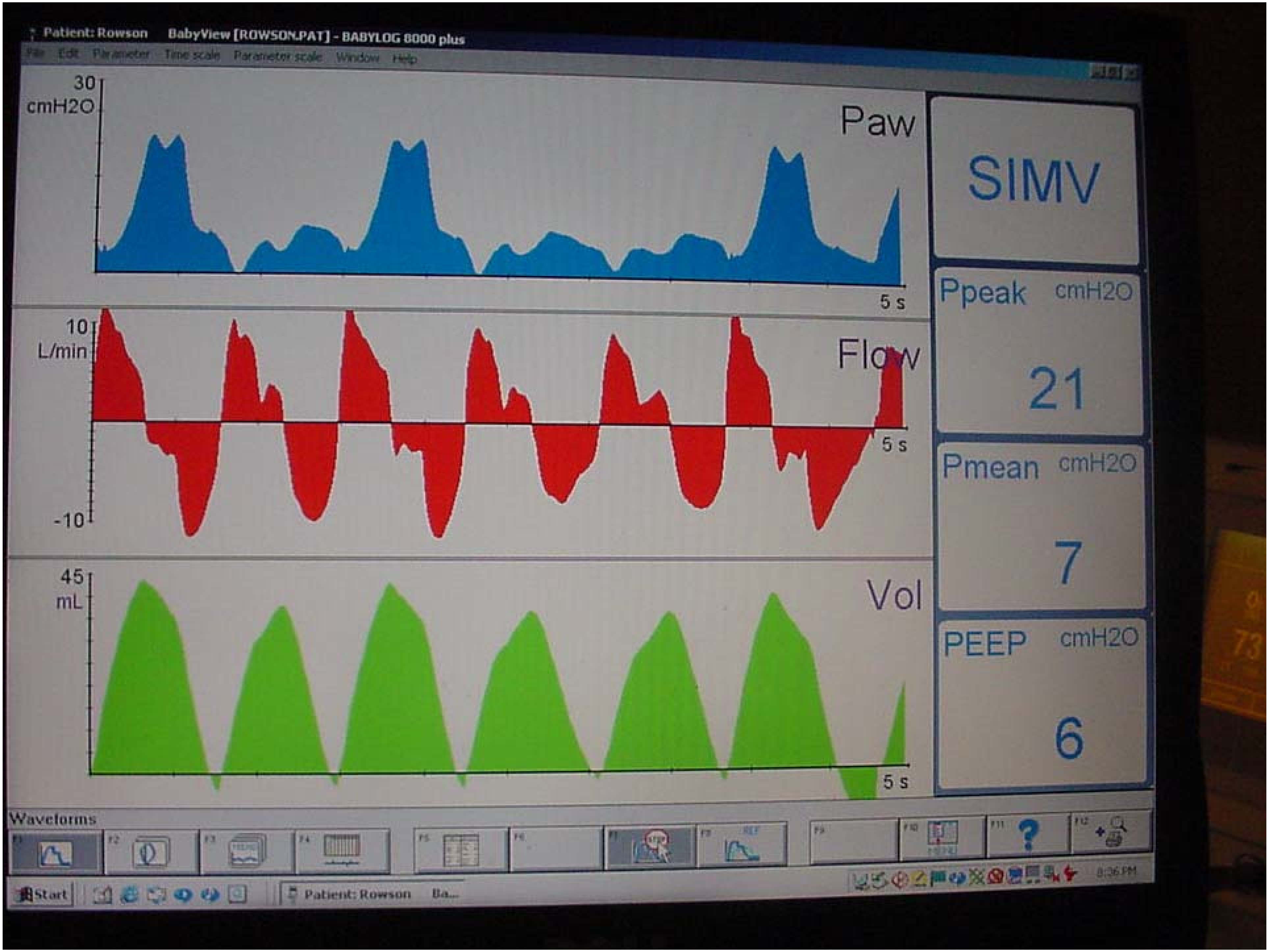
- High respiration rate, short inspiration time, irregular respiratory frequency
- Variability in inspiratory effort
- Asynchronous chest wall movement
- Frequent apnea
- Airleak around ET tube or chest tube
- Frequent motion artifact

Patient Triggered Ventilation
Beware of

- :Sensor: It may not working properly and need calibration.Watch sensitivity level. Avoid autocycling due to water condensation.
- Tidal volume: Part from spontaneous breathing and part from respirator. Pay attention to airleakage and hypoplastic lung.
- A/C mode: May need to adjust Ti. May not synchronized with high respiration rate.
- Narcotic and sedative suppress respiratory effort

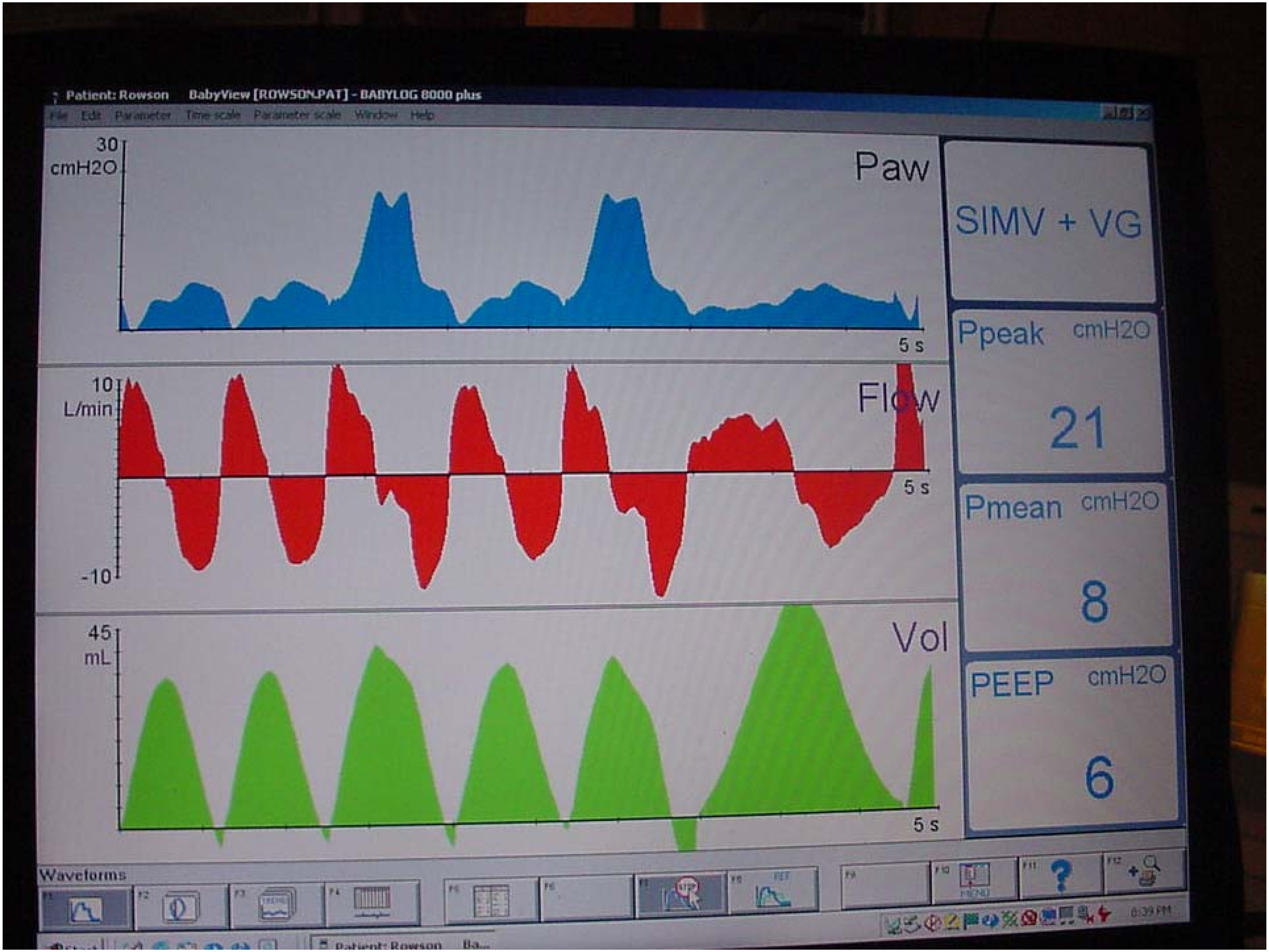
IMV	SIMV	A/C	PS
Flowrate	Flowrate	Flowrate	Flowrate
FiO2	FiO2	FiO2	FiO2
IMV rate	SIMV rate	Patient, Backup rate	Patient, Backup rate
Ti	Ti	Ti	Insp. cycle off
PIP	PIP	PIP	Support P.
PEEP	PEEP	PEEP	PEEP
	Sensitivity	Sensitivity	Sensitivity
	Sync.	Synchronization	Sync.
		Readjust Ti and PEEP	Readjust PEEP


25
cmH2O
Paw
5 s
5
L/min
Flow
-5
5 s
15
mL
Vol
5 s
CMV
Ppeak cmH2O
20
Pmean cmH2O
10
PEEP cmH2O
5
Waveforms
Start



Patient: Rowson
BabyView [ROWSON.PAT] - BABYLOG 8000 plus
File Edit Parameter Time scale Parameter scale Window Help
30
cmH2O
Paw
5 s
10
L/min
Flow
-10
5 s
45
mL
Vol
5 s
SIMV
Ppeak cmH2O
21
Pmean cmH2O
7
PEEP cmH2O
6
Waveforms
Start
Patient: Rowson

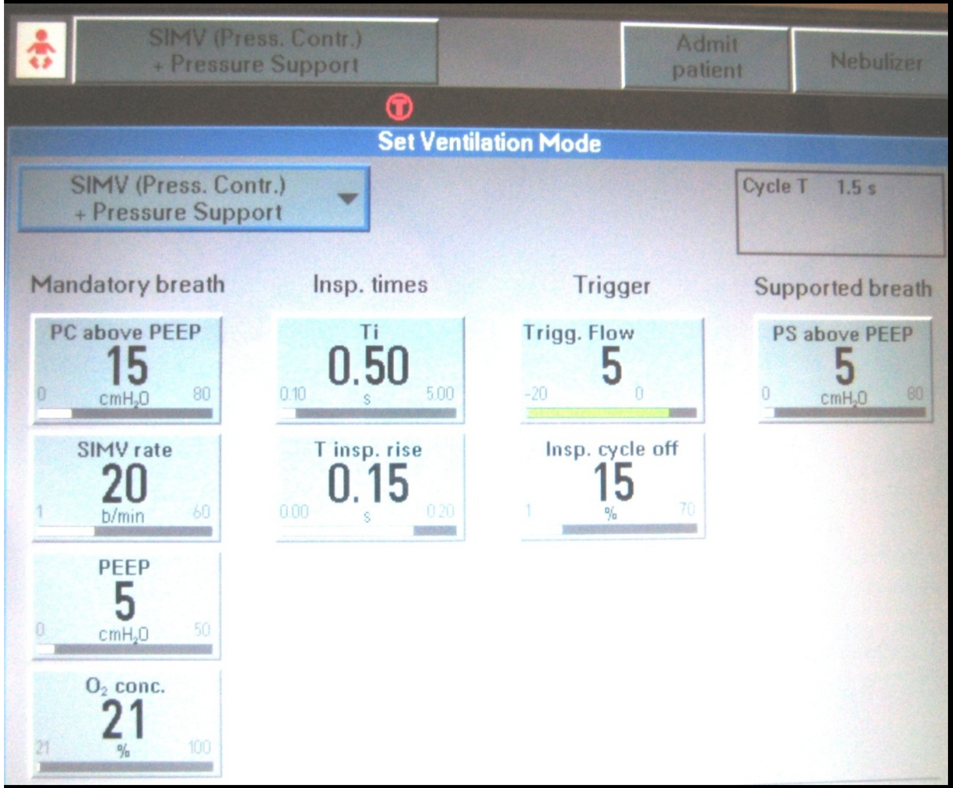
Patient: Rowson BabyView [ROWSON.PAT] - BABYLOG 8000 plus
30
cmH2O
Paw
5 s
10
L/min
Flow
-10
45
mL
Vol
5 s
SIMV + VG
Ppeak cmH2O
20
Pmean cmH2O
9
PEEP cmH2O
6
Waveforms
Start
Patient: Rowson Ba...

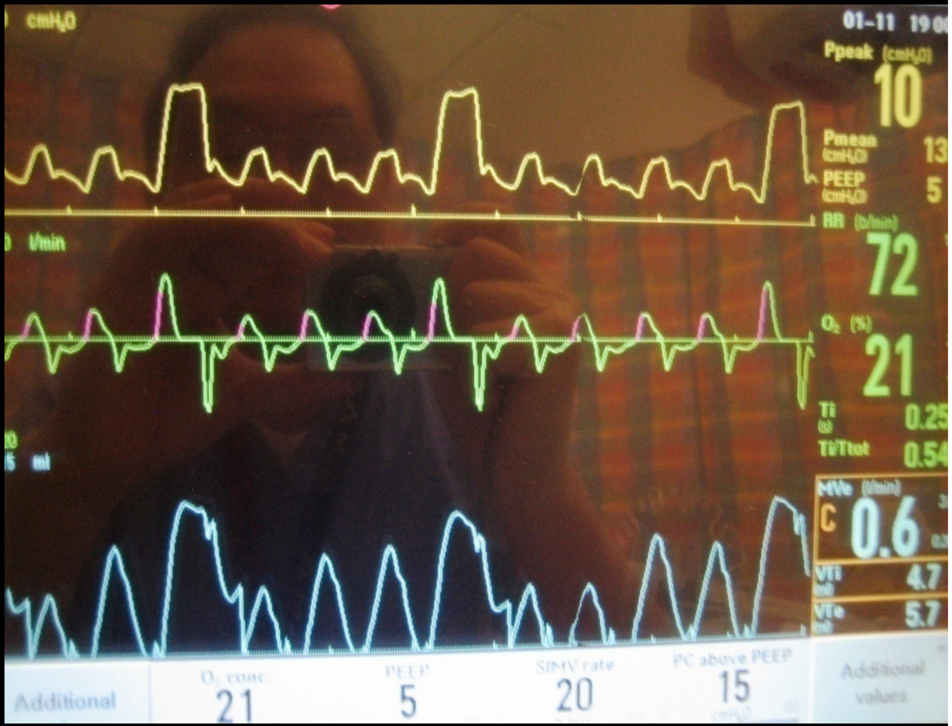

Patient: Rowson BabyView [ROWSON.PAT] - BABYLOG 8000 plus
File Edit Parameter Time scale Parameter scale Window Help
30
cmH2O
Paw
5 s
10
L/min
Flow
-10
5 s
45
mL
Vol
5 s
SIMV + VG
Ppeak cmH2O
21
Pmean cmH2O
8
PEEP cmH2O
6
Waveforms

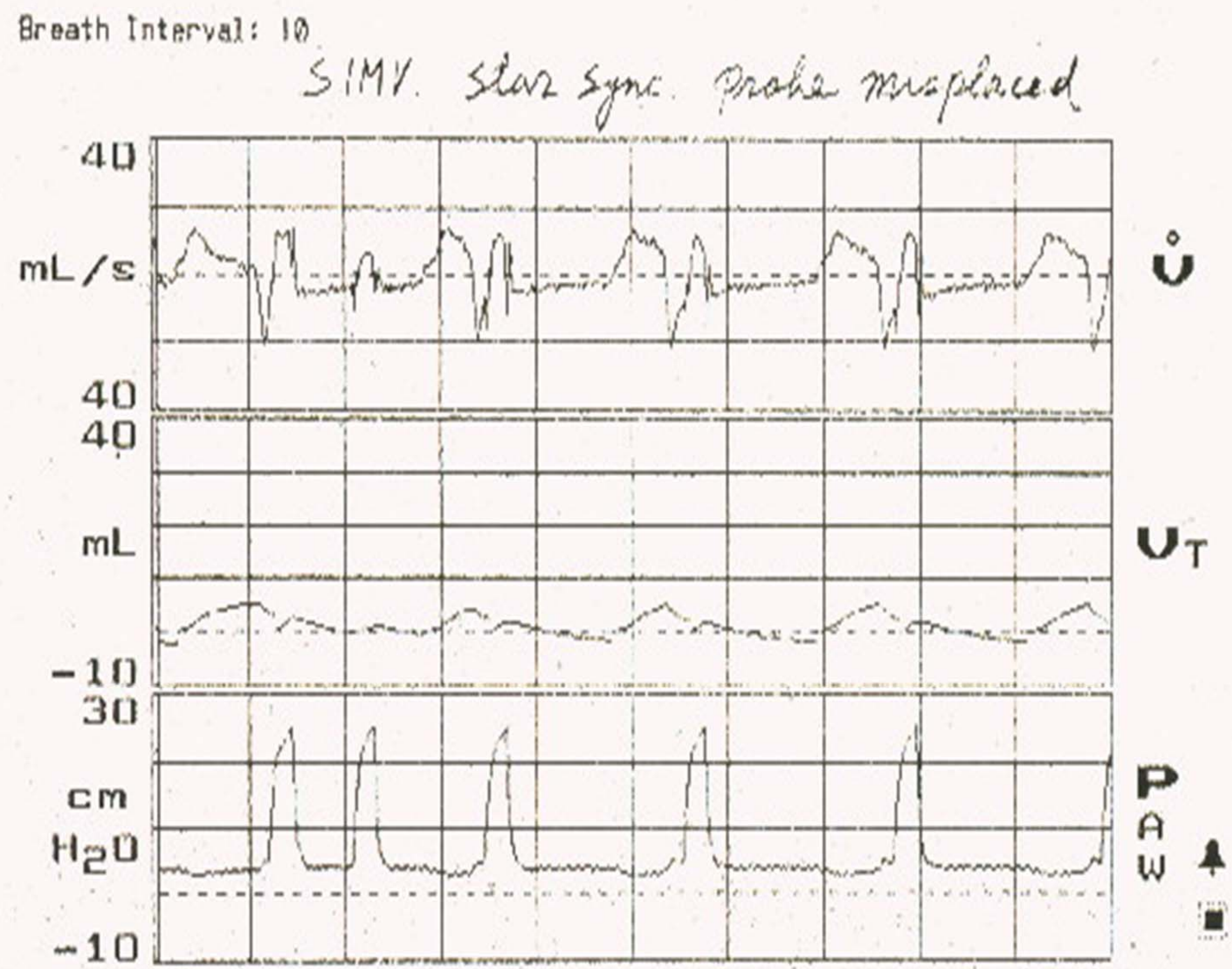
Patient: Rivera
BabyView [RIERA.PAT] - BABYLOG 8000 plus
25
cmH2O
Paw
5 s
5
L/min
Flow
-5
5 s
15
mL
Vol
5 s
A/C
Ppeak cmH2O
20
Pmean cmH2O
10
PEEP cmH2O
5
Waveforms
Start
Patient: Rivera
Bab...
Printers Folder
DELL

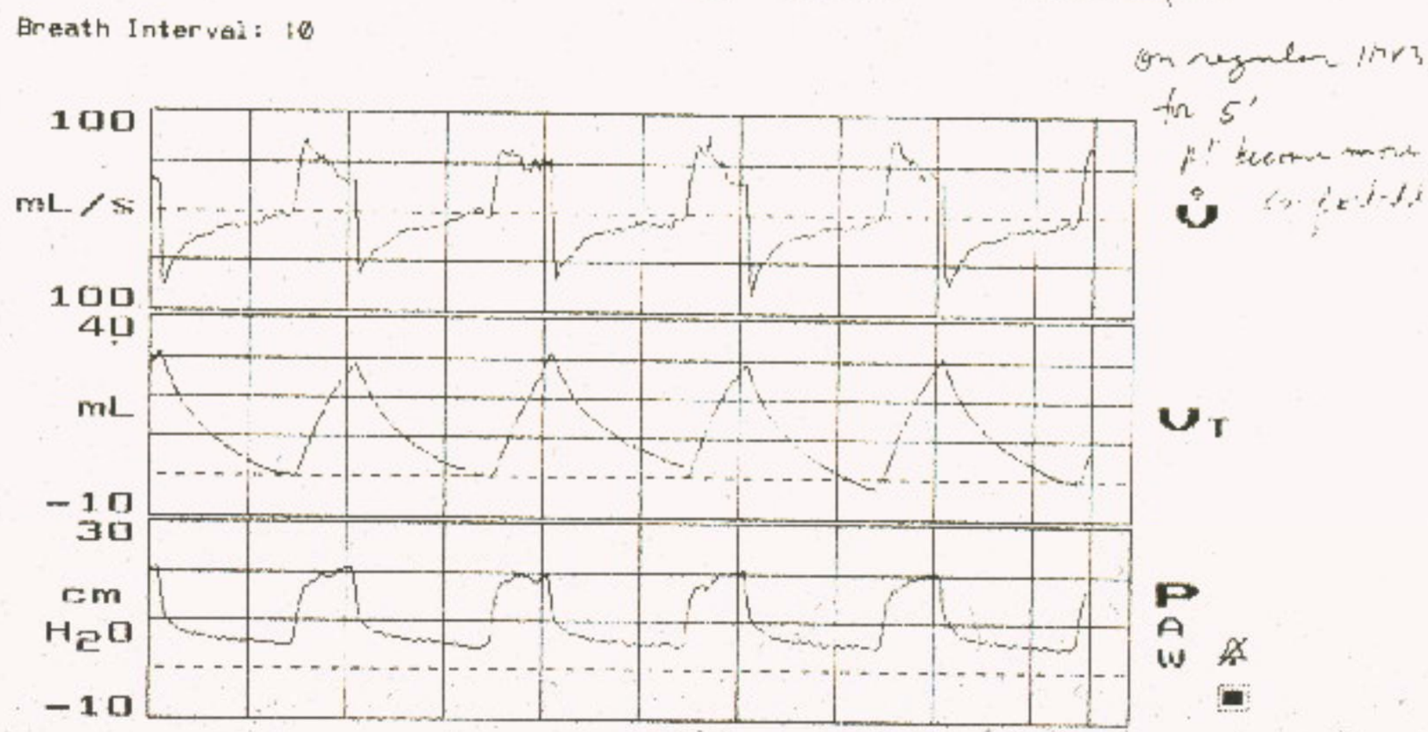
Patient: Hassan
BabyView [HASSAN.PAT] - BABYLOG 8000 plus
Paw
35
cmH2O
5 s
Flow
5
L/min
-5
5 s
Vol
45
mL
5 s
A/C
Ppeak cmH2O
30
Pmean cmH2O
21
PEEP cmH2O
5
Waveforms
Start
Patient: Hassan
DELL

SIMV + PS

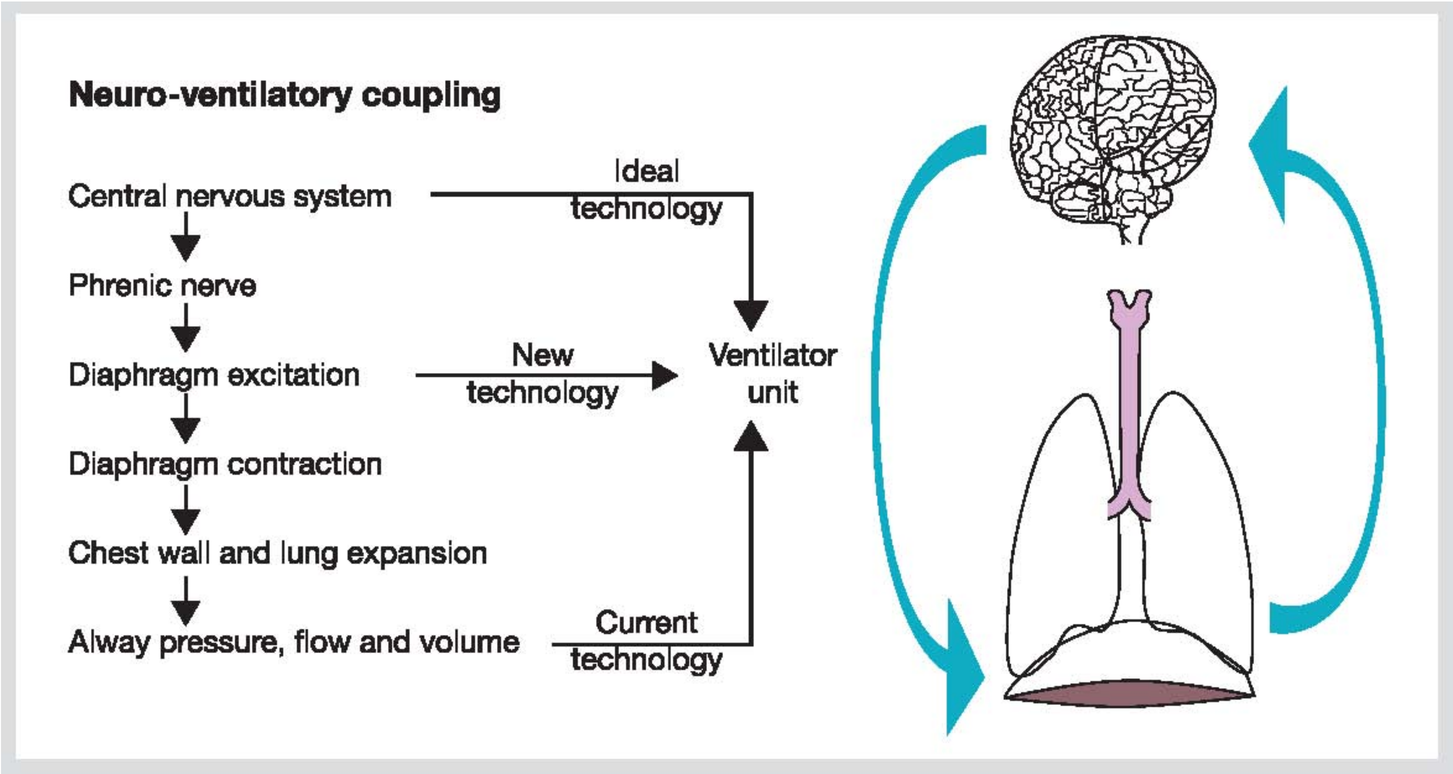

SIMV (Press. Contr.)
+ Pressure Support
Admit patient
Nebulizer
Set Ventilation Mode
SIMV (Press. Contr.)
+ Pressure Support
Cycle T 1.5 s
Mandatory breath
Insp. times
Trigger
Supported breath
PC above PEEP
15
cmH2O
Ti
0.50
s
Trigg. Flow
5
PS above PEEP
5
cmH2O
SIMV rate
20
b/min
T insp. rise
0.15
s
Insp. cycle off
15
%
PEEP
5
cmH2O
O2 conc.
21
%


Ppeak (cmH2O)
10
Pmean
PEEP
5
RR (b/min)
72
O2 (%)
21
Ti
Ti/Ttot
MVe (l/min)
0.6
VTi
4.7
VTe
5.7
Additional
O2 conc.
21
PEEP
5
SIMV rate
20
PC above PEEP
15
Additional values

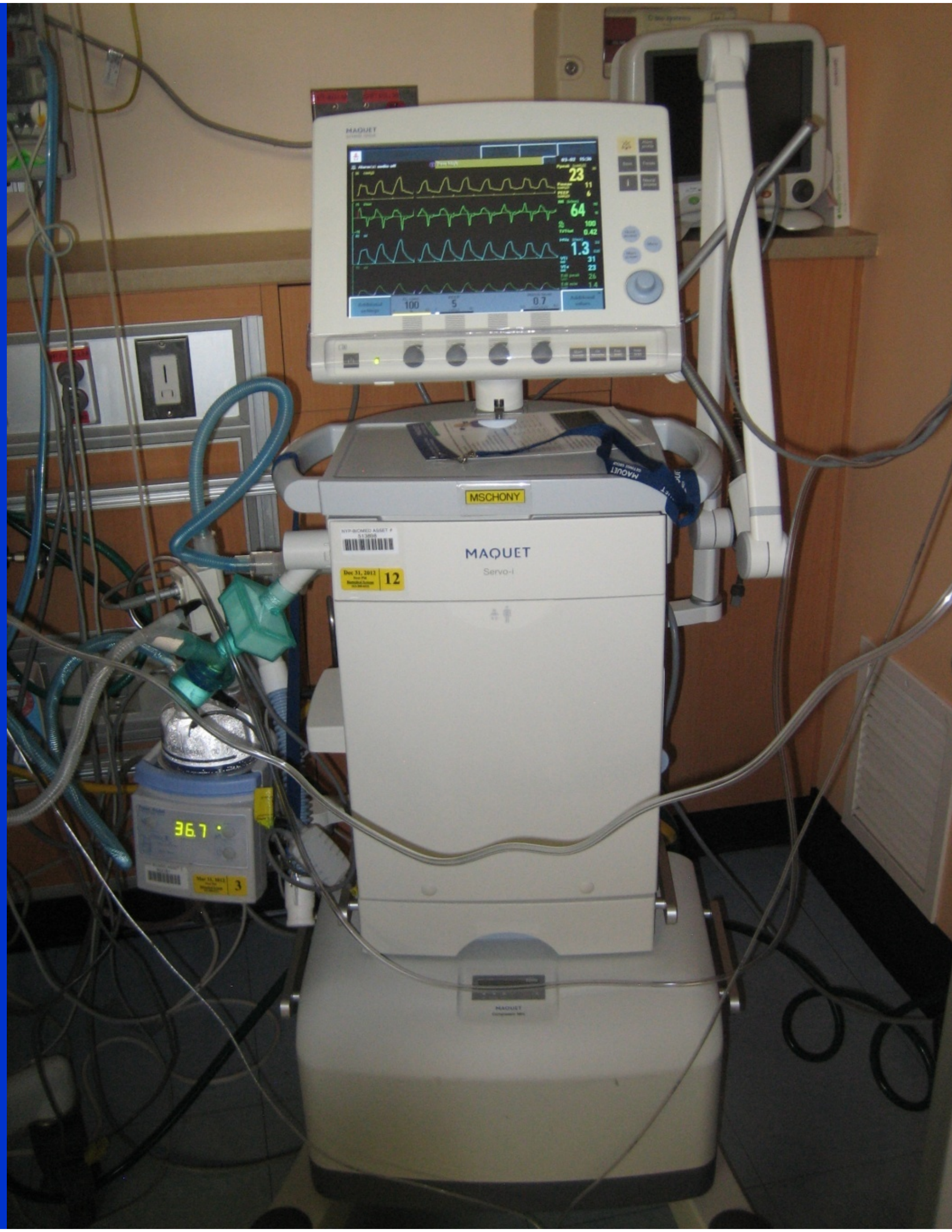

Breath Interval: 10
SIMV. Star Sync. Probe misplaced
40
mL/s
40
40
mL
-10
30
cm
H2O
-10
V̊
VT
P
A
W


Breath Interval: 10
100
mL/s
100
40
mL
-10
30
cm
H_2O
-10
V̇
V_T
P
A
W

Patient Ventilator Interaction



Nature 1999


MSCHONY
MAQUET
Servo-i
36.7
12
3

Central nervous system

↓

Phrenic nerve

↓

Diaphragm excitation --→ NAVA

↓

Diaphragm contraction

↓

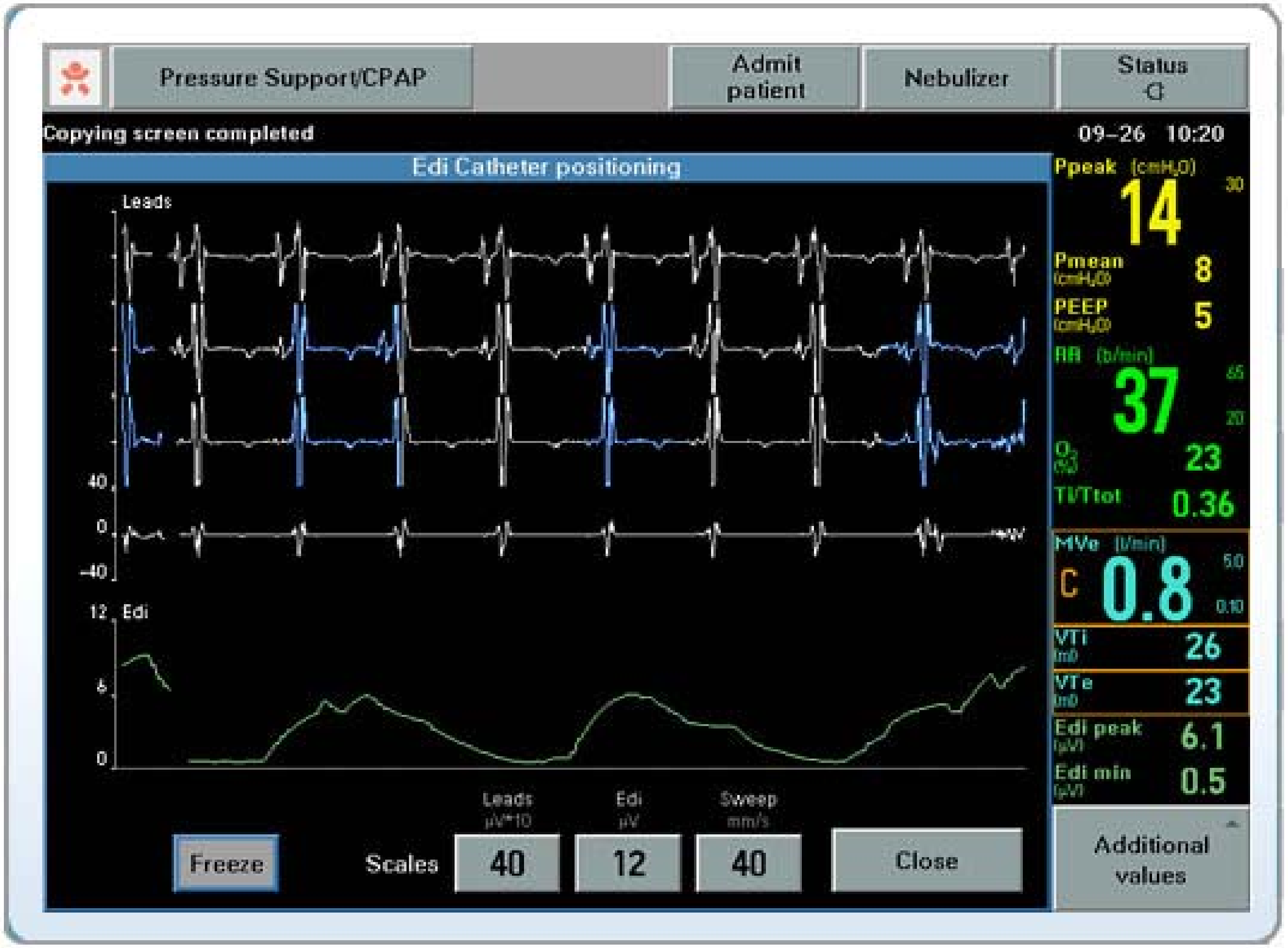
Chest wall and lung expansion

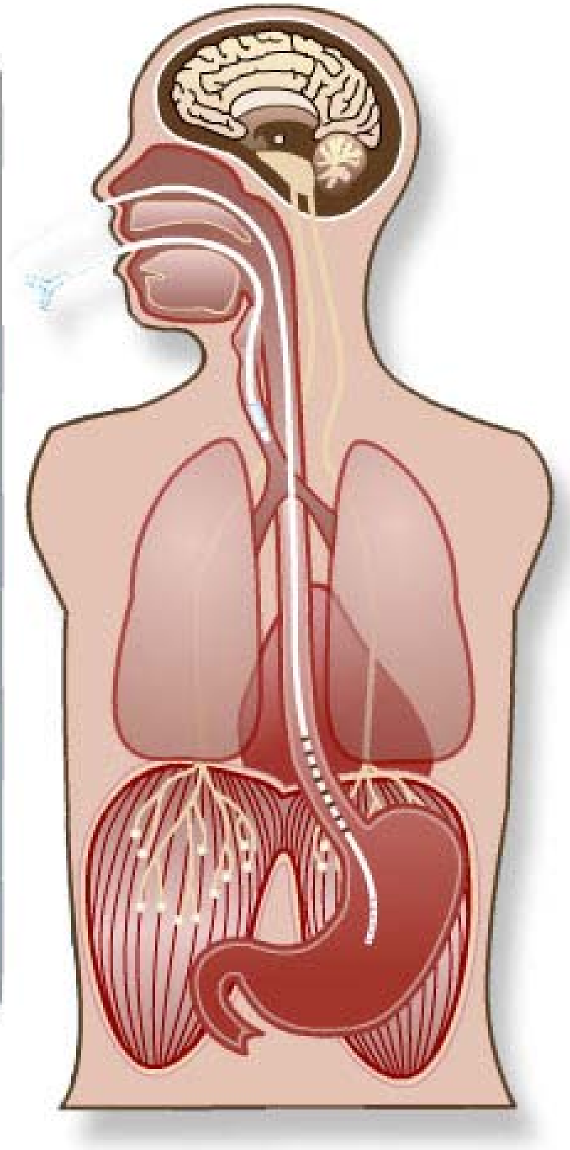
↓

Airway pressure drop, flow reversal --→ PTV

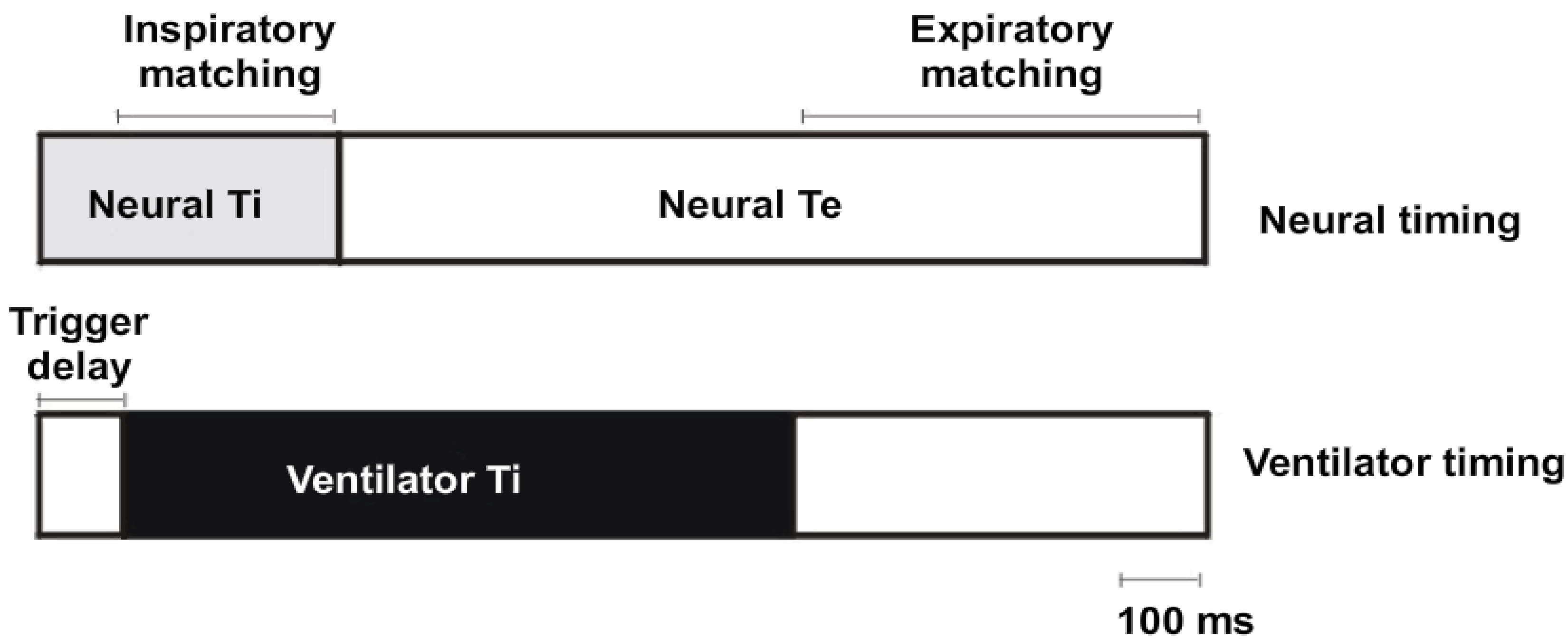
NAVA (Neurally Adjusted Ventilatory Assist)

Edi Catheter positioning procedure
Position and Edi signal





Asynchrony



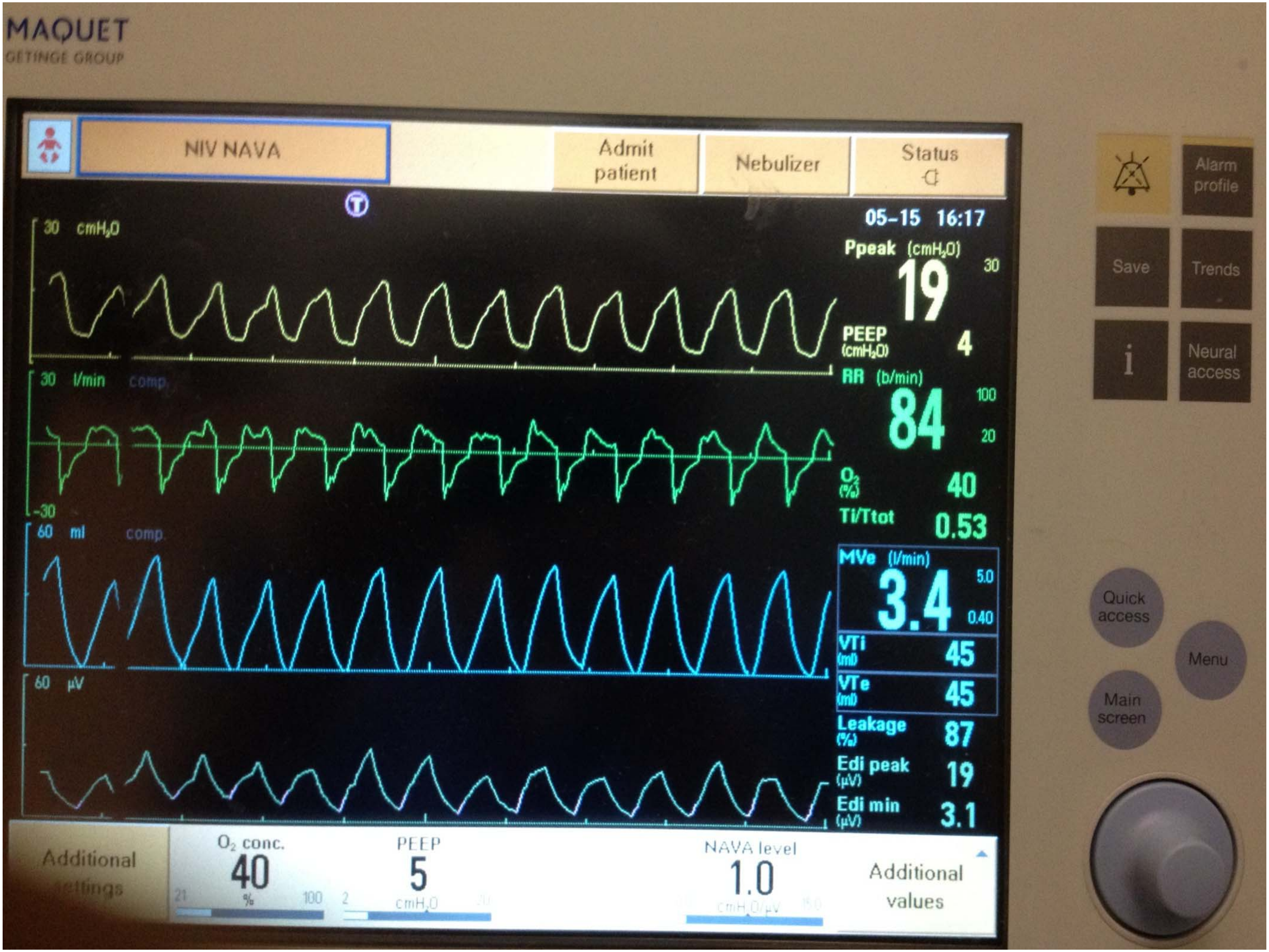
Even with current technology the most sensitive triggers will exhibit lag time = Asynchrony.

Formula for estimating peak pressures during NAVA:

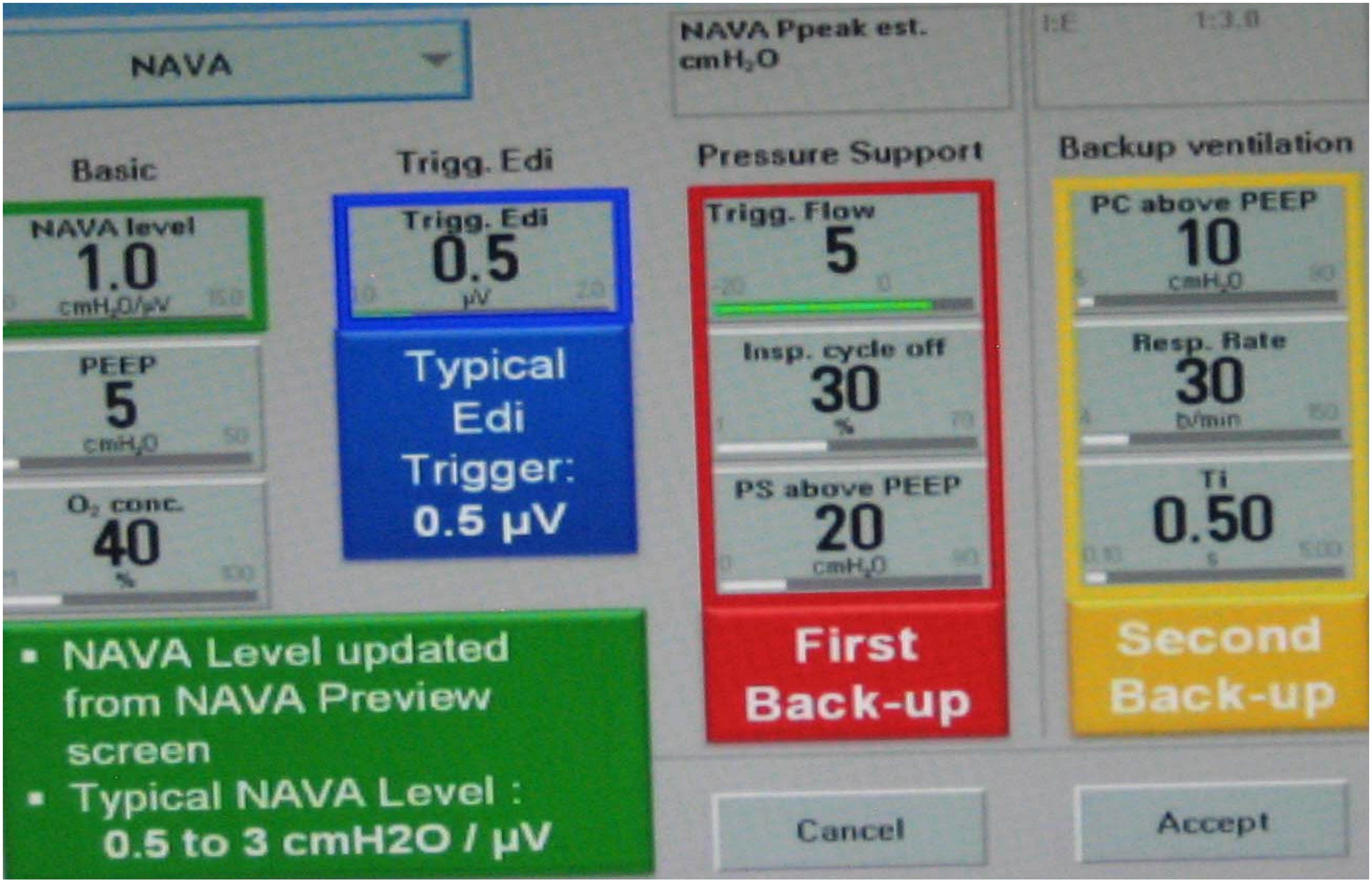
P_{peak} est.=NAVA level X (Edi_{peak} – Edi_{min}) +PEEP

* NAVA level is the factor by which the Edi signal is multiplied to adjust the amount of assist delivered to the patient


NAVA
Admit patient
Nebulizer
Status
08-10 13 19
Ppeak (cmH2O)
13
Pmean (cmH2O) 8
PEEP (cmH2O) 5
RR (b/min)
35
O2 (%) 28
Ti/Ttot 0.39
MVe (l/min)
2.9
VTi (ml) 77
VTe (ml) 86
etCO2 (%) 4.8
Edi peak (µV) 5.5
Edi min (µV) 0.3
25 cmH2O
Pressure
40 l/min
Flow
-40
150 ml
Volume
12 µV
Micro-volts: µV
Additional settings
O2 conc. 28 %
PEEP 5 cmH2O
NAVA level 1.3 cmH2O/µV
Additional values


MAQUET
GETINGE GROUP
NIV NAVA
Admit patient
Nebulizer
Status
05-15 16:17
30 cmH2O
Ppeak (cmH2O)
19
PEEP (cmH2O)
4
30 l/min comp.
RR (b/min)
84
O2 (%)
40
Ti/Ttot
0.53
60 ml comp.
MVe (l/min)
3.4
VTi (ml)
45
VTe (ml)
45
60 μV
Leakage (%)
87
Edi peak (μV)
19
Edi min (μV)
3.1
O2 conc.
40
%
PEEP
5
cmH2O
NAVA level
1.0
cmH2O/μV
Additional values
Alarm profile
Save
Trends
Neural access
Quick access
Menu
Main screen

Implement NAVA Mode



High Frequency Ventilation

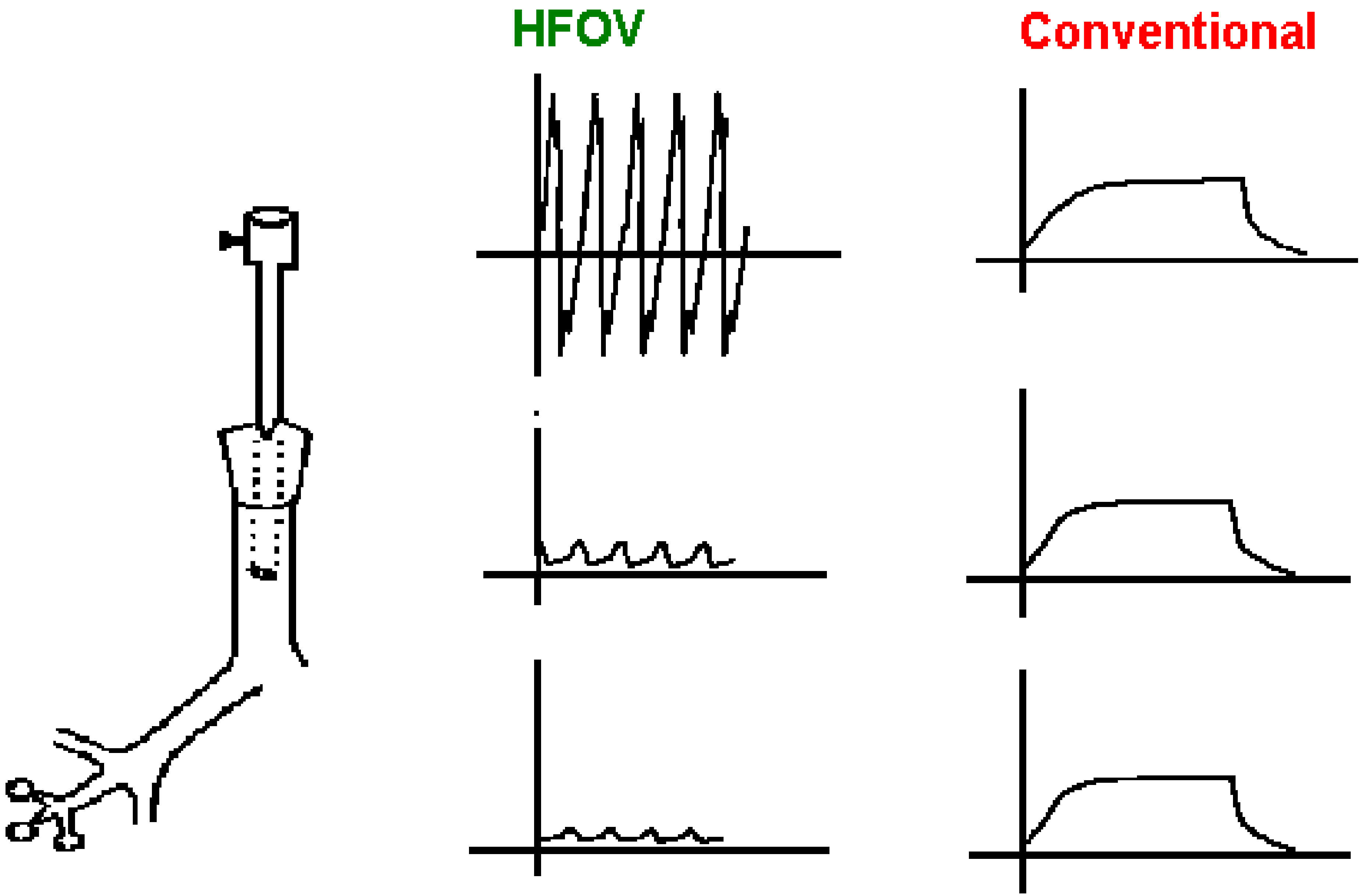
- Defined by FDA as a ventilator that delivers more than 150 breaths/min.
- Delivers a small tidal volume, usually less than or equal to anatomical dead space volume.
- While HFV's are frequently described by their delivery method, they are usually classified by their exhalation mechanism (active or passive).

HIGH FREQUENCY VENTILATION

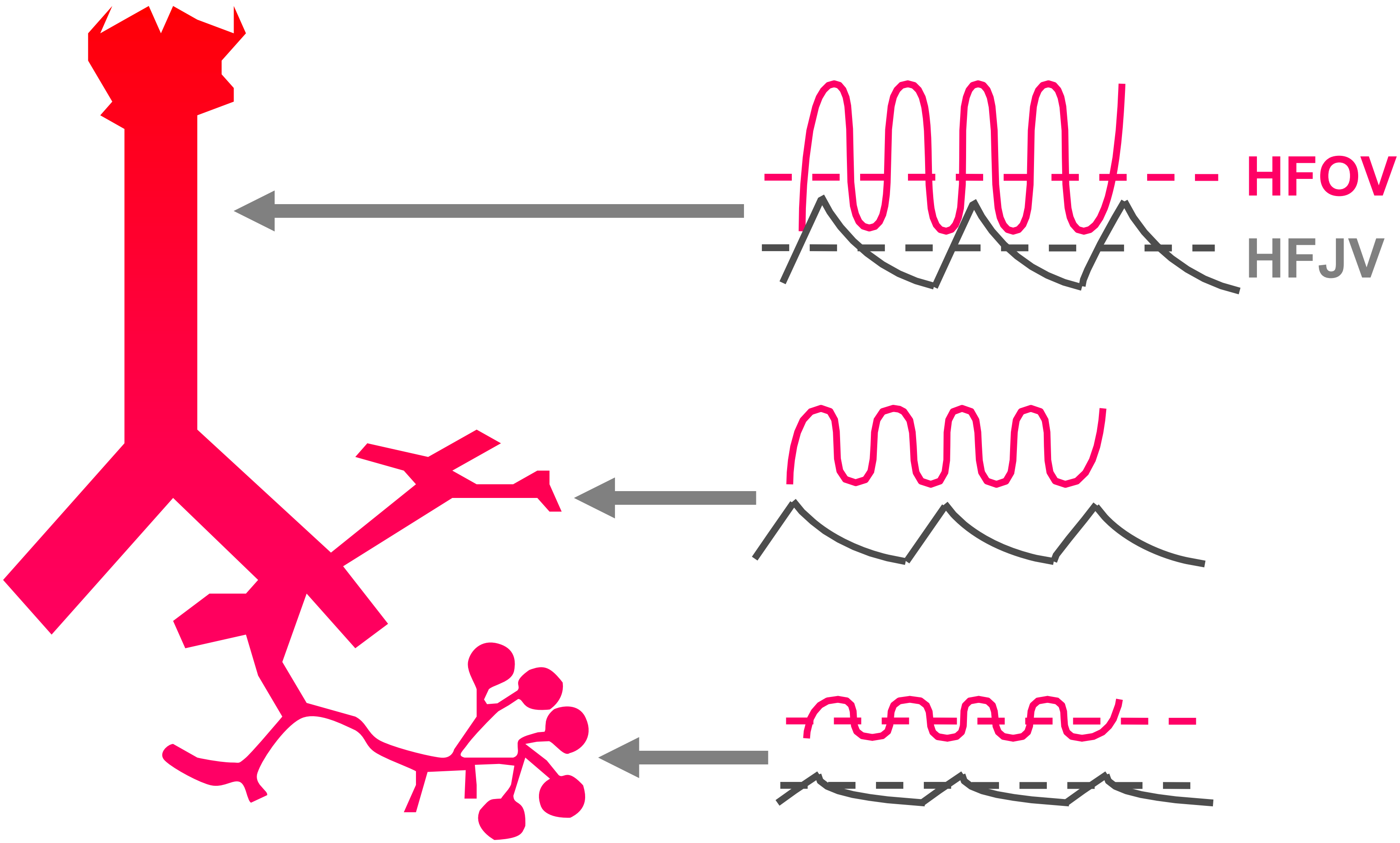
Types of Ventilators

- HFPPV (High Frequency Positive Pressure Ventilation, infant respirator, rate 60 - 150)
- HFFI (High Frequency Flow Interrupter, Infant Star, rate ~ 22 Hz)
- HFJV (High Frequency Jet Ventilator, Bunnell Life Pulse, 7 Hz)
- HFO (High Frequency Oscillatory Ventilator, SensorMedics 3100A, rate ~ 15 Hz)
- HFCWO (High Frequency Chest Wall Oscillator)

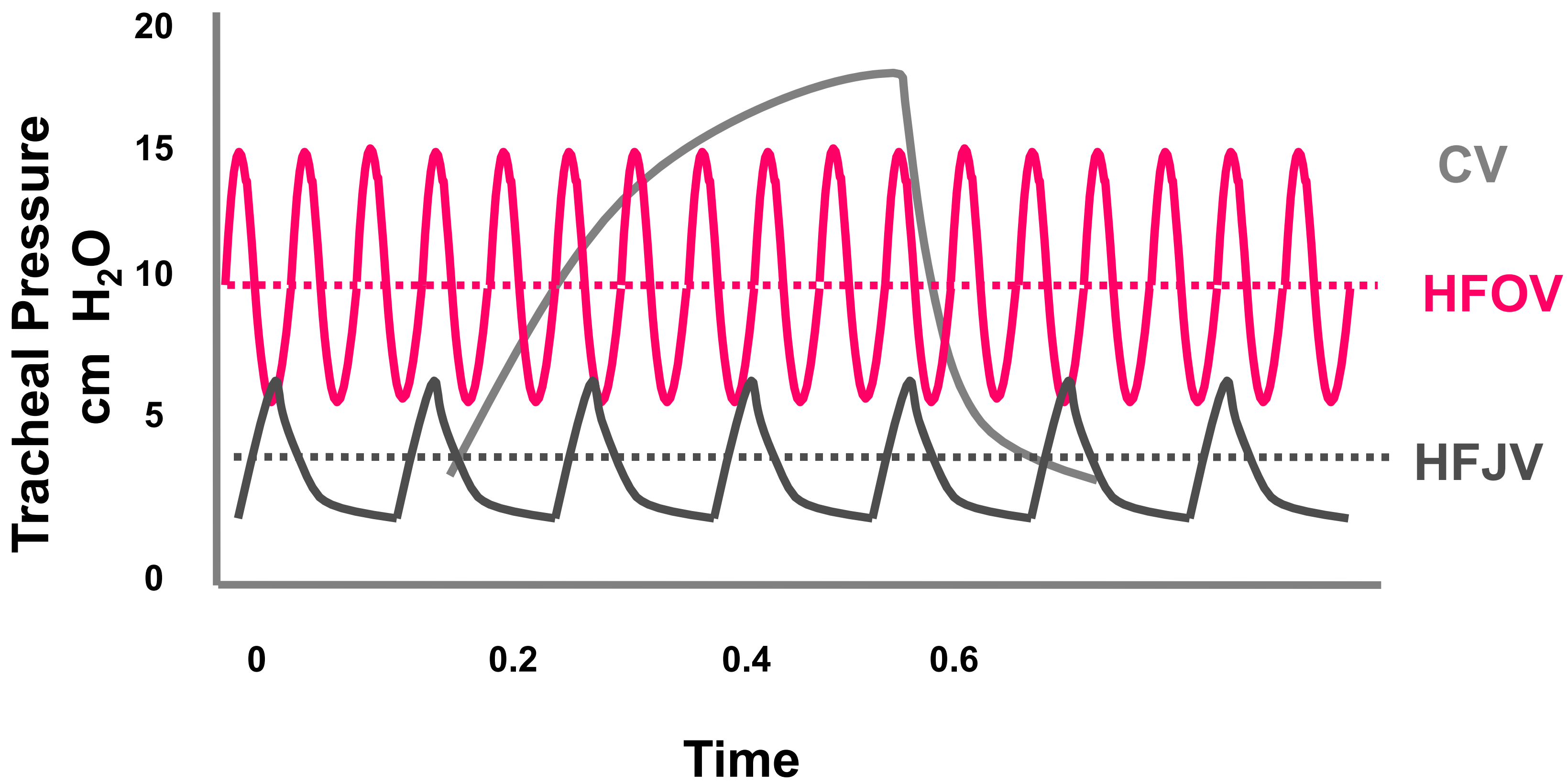
Airway Pressure Waveforms



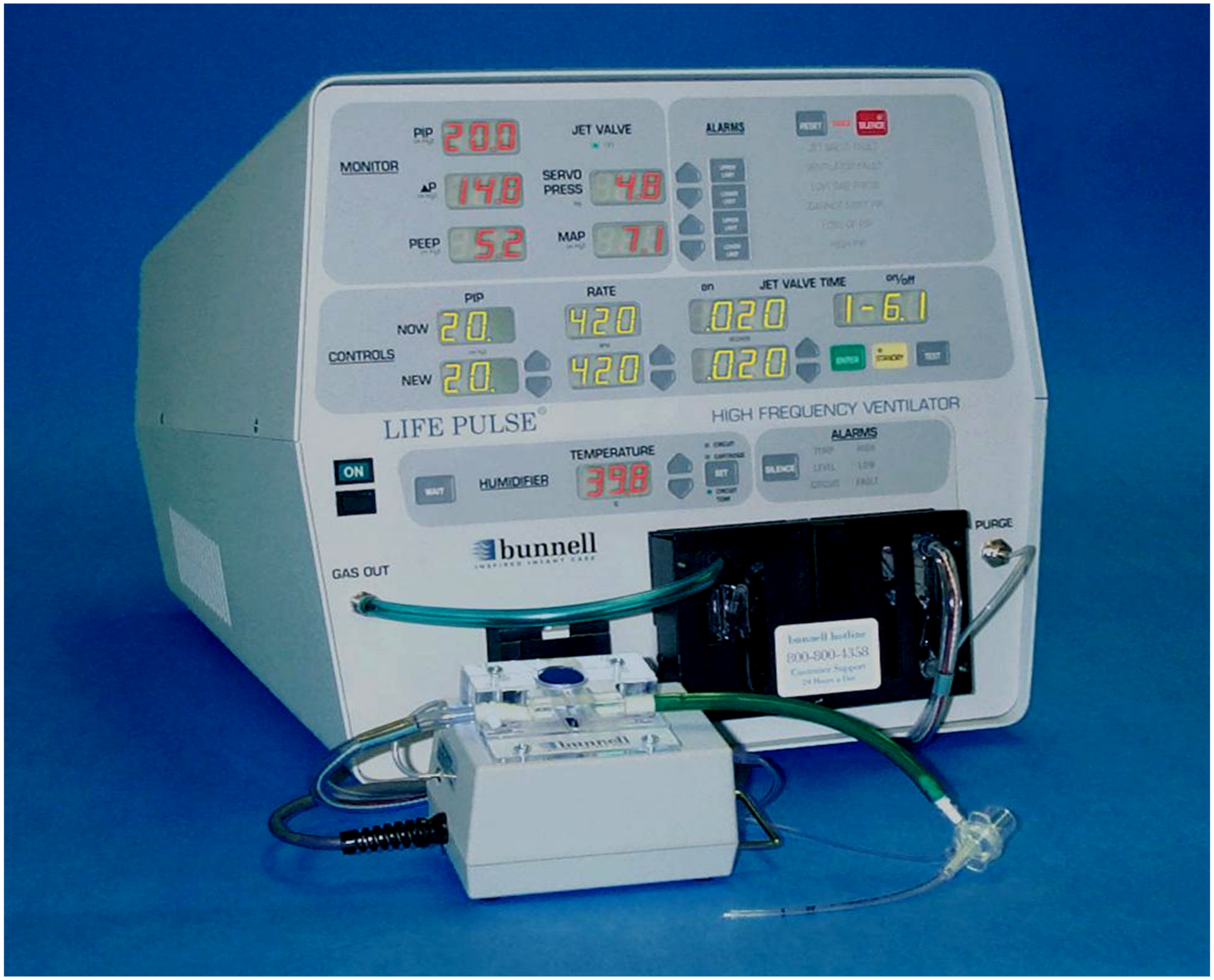
AIRWAY PRESSURE WAVEFORMS



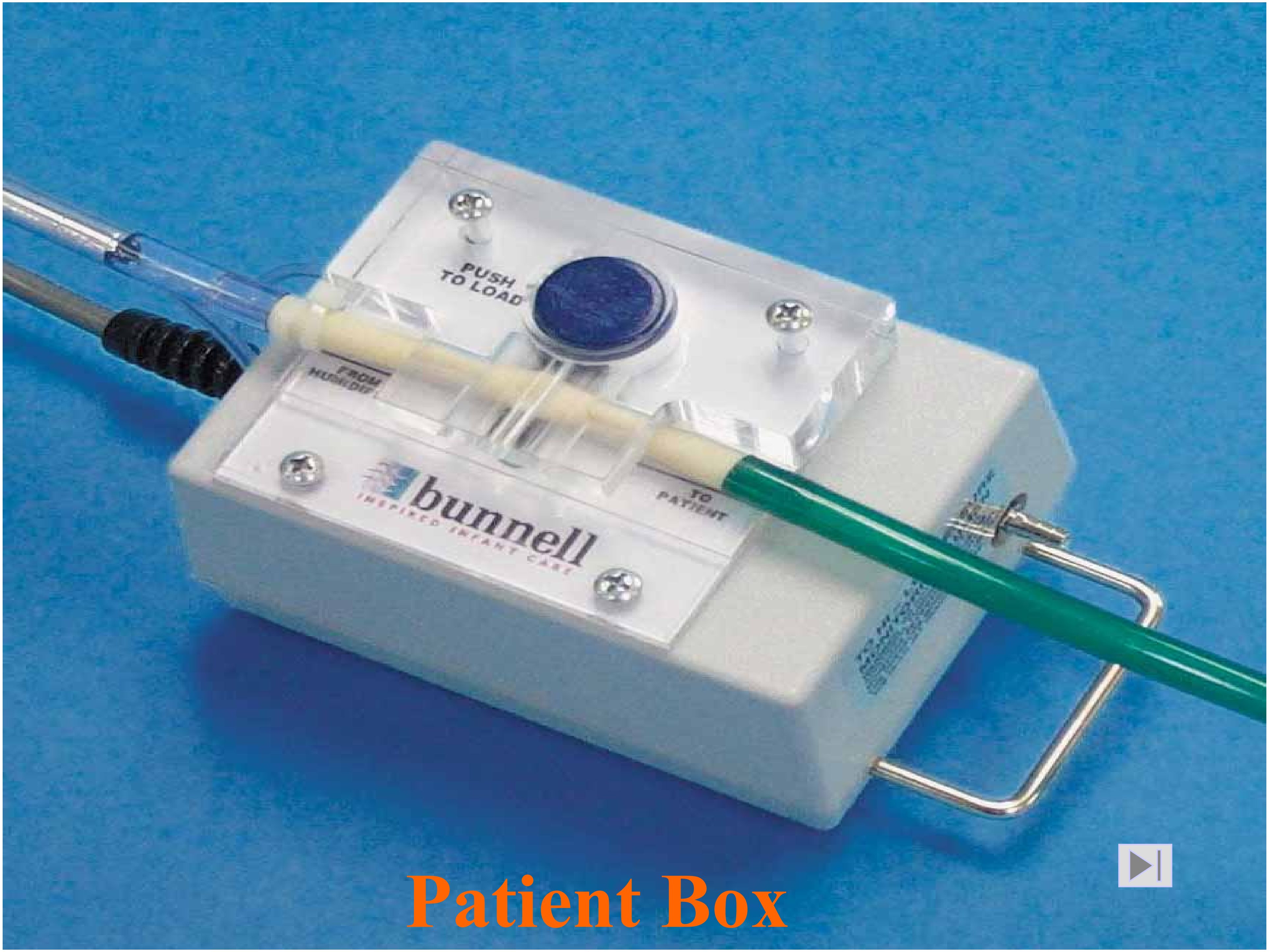
PRESSURE WAVEFORM COMPARISON



HFJV
Bunnell Life Pulse

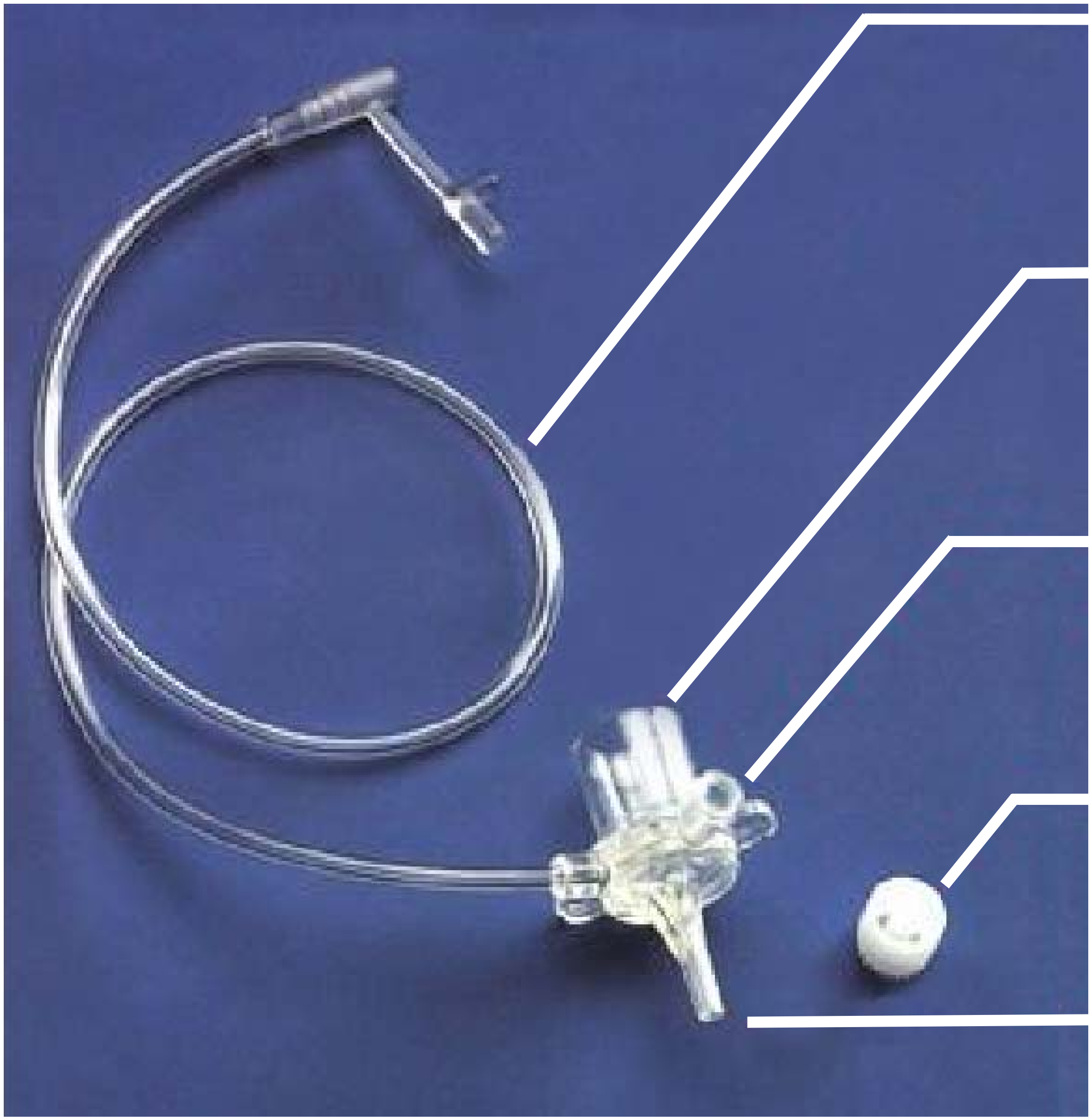


Operating instructions: www.bunl.com



Patient Box

LifePort ET tube adapter



Pressure Monitoring Line

15-mm Connector

Jet Injection Port

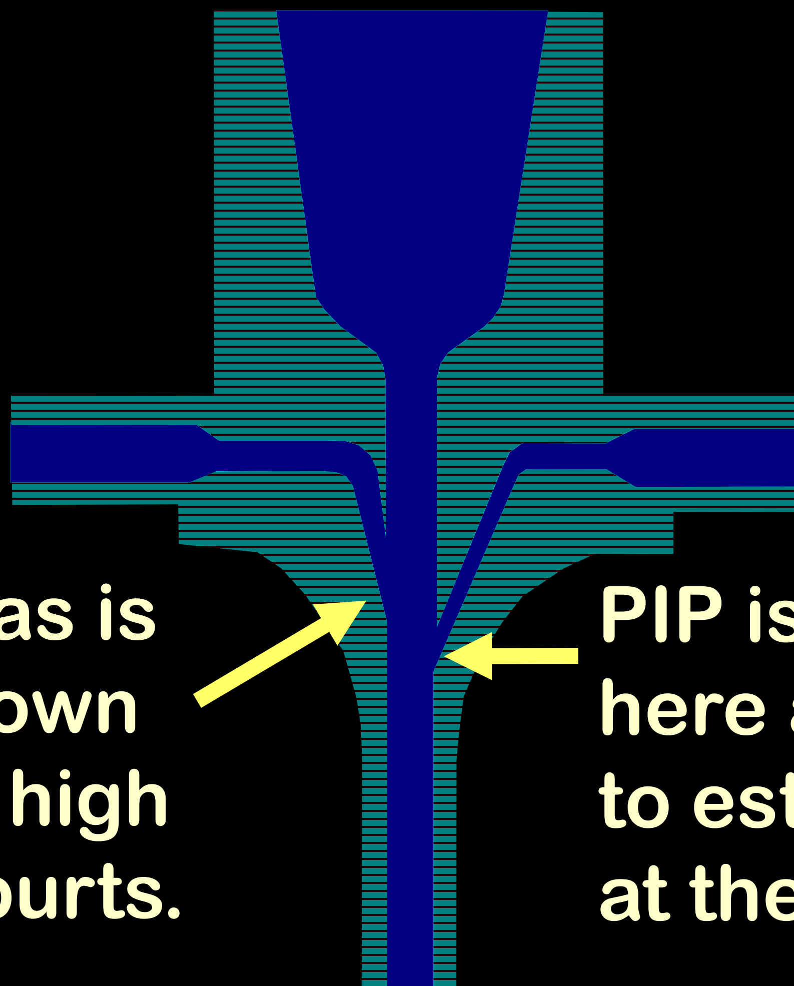
Jet Port Cap

ET Tube Connector

LifePort Adapter

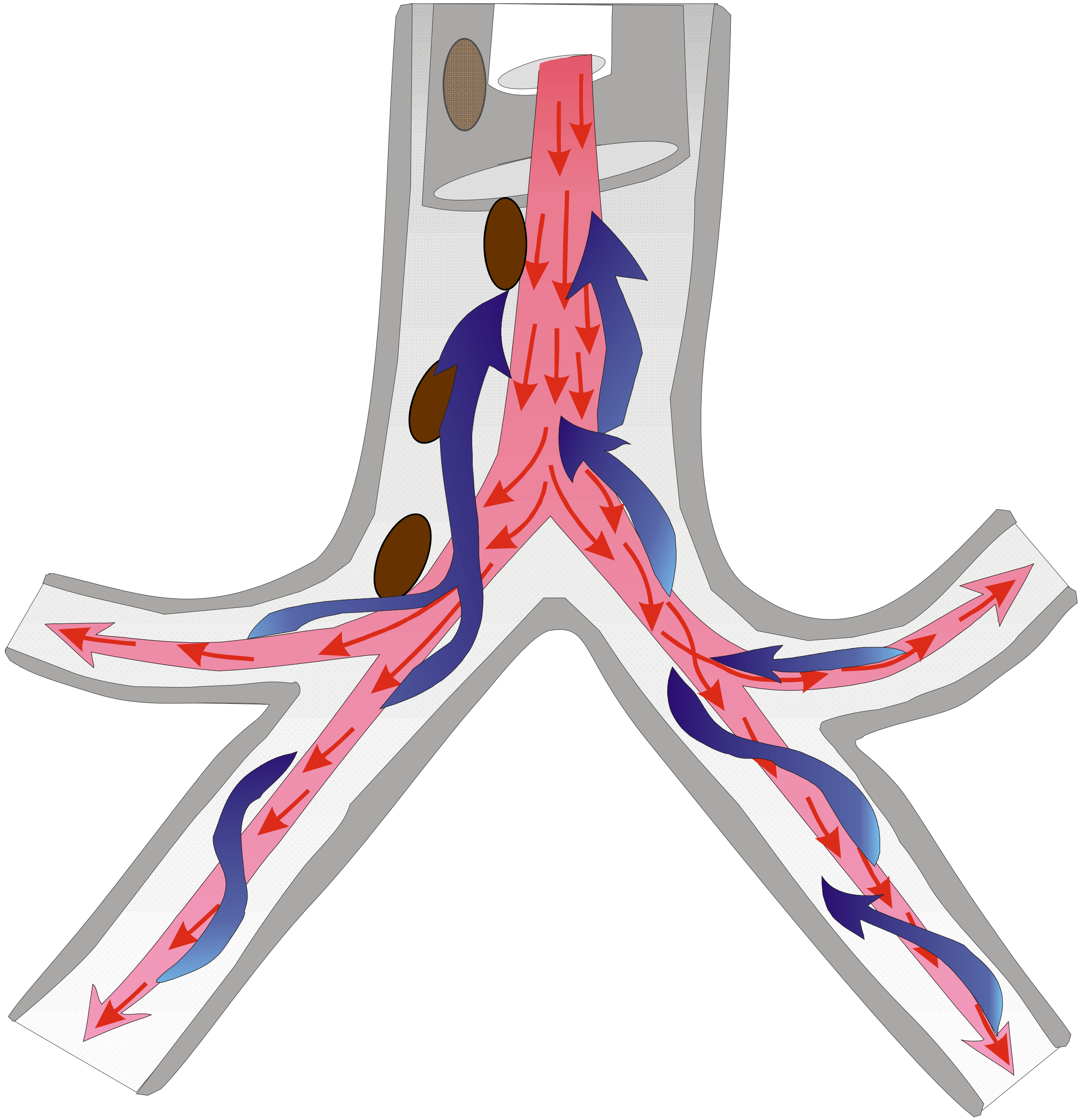
Jet Port

Pressure Monitoring Port



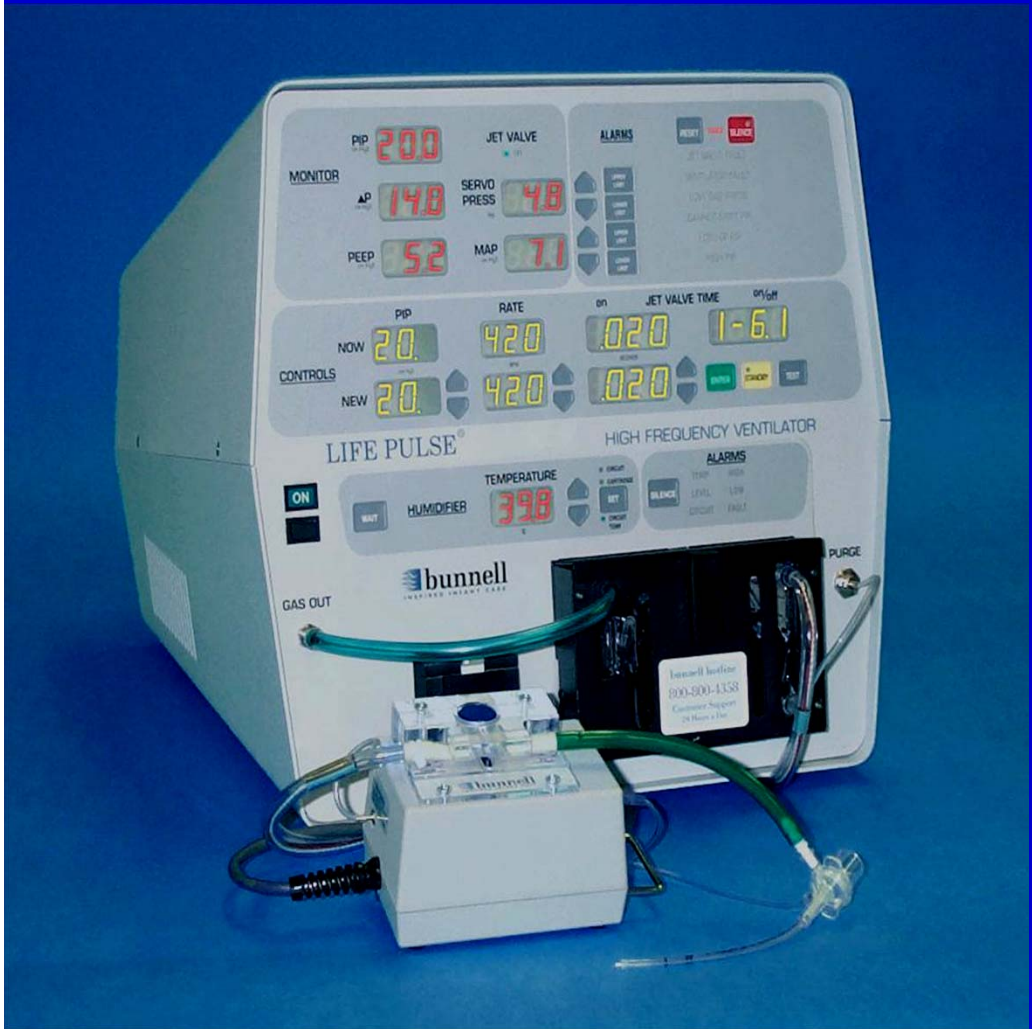
Inspired gas is injected down the ETT in high velocity spurts.

PIP is measured here and *filtered* to estimate PIP at the tip of ETT.



HFJV

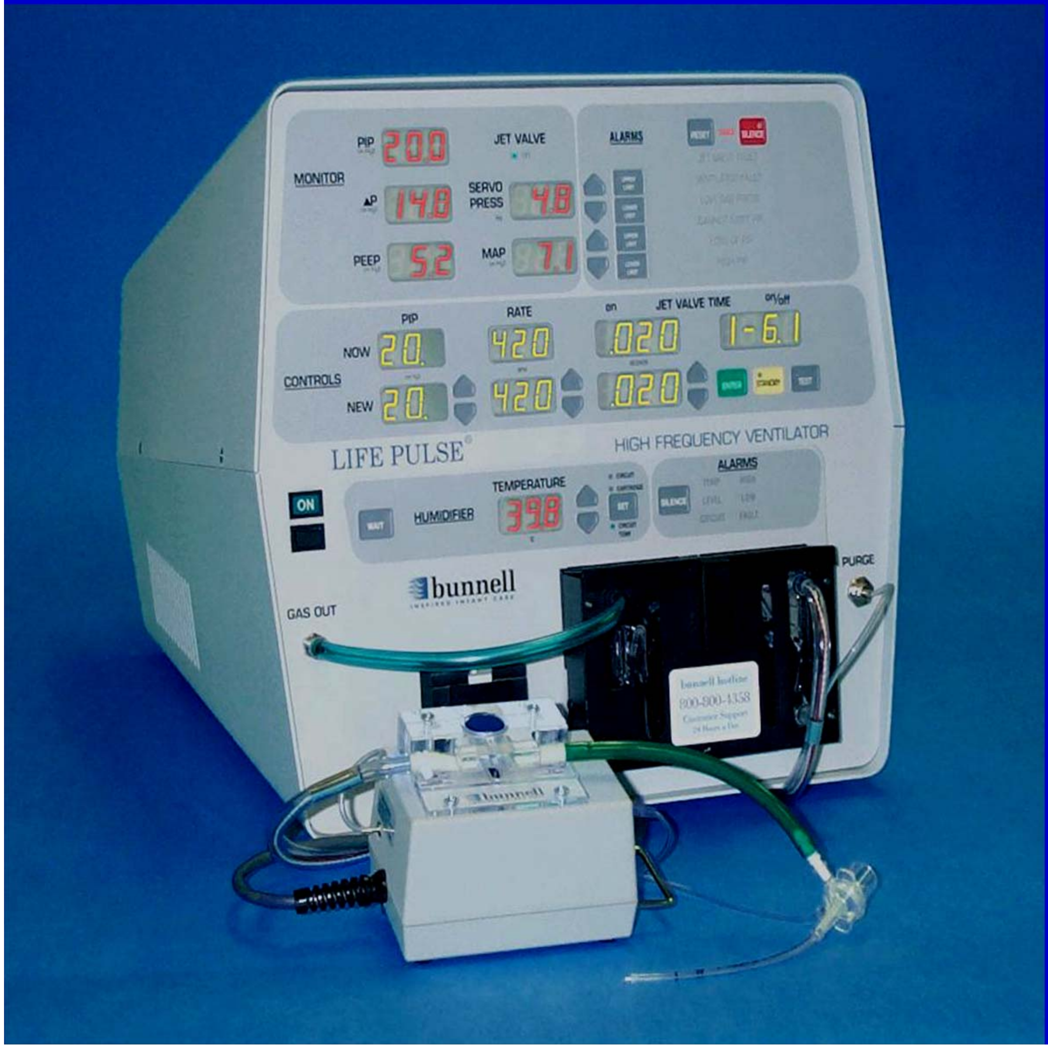
Bunnell Life Pulse- (1)



- Microprocessor – controlled
- Feedback control (peak pressure and gas temperature)
- Patient box contains pressure transducer and pinch valve)
- Lifeport ET tube adaptor

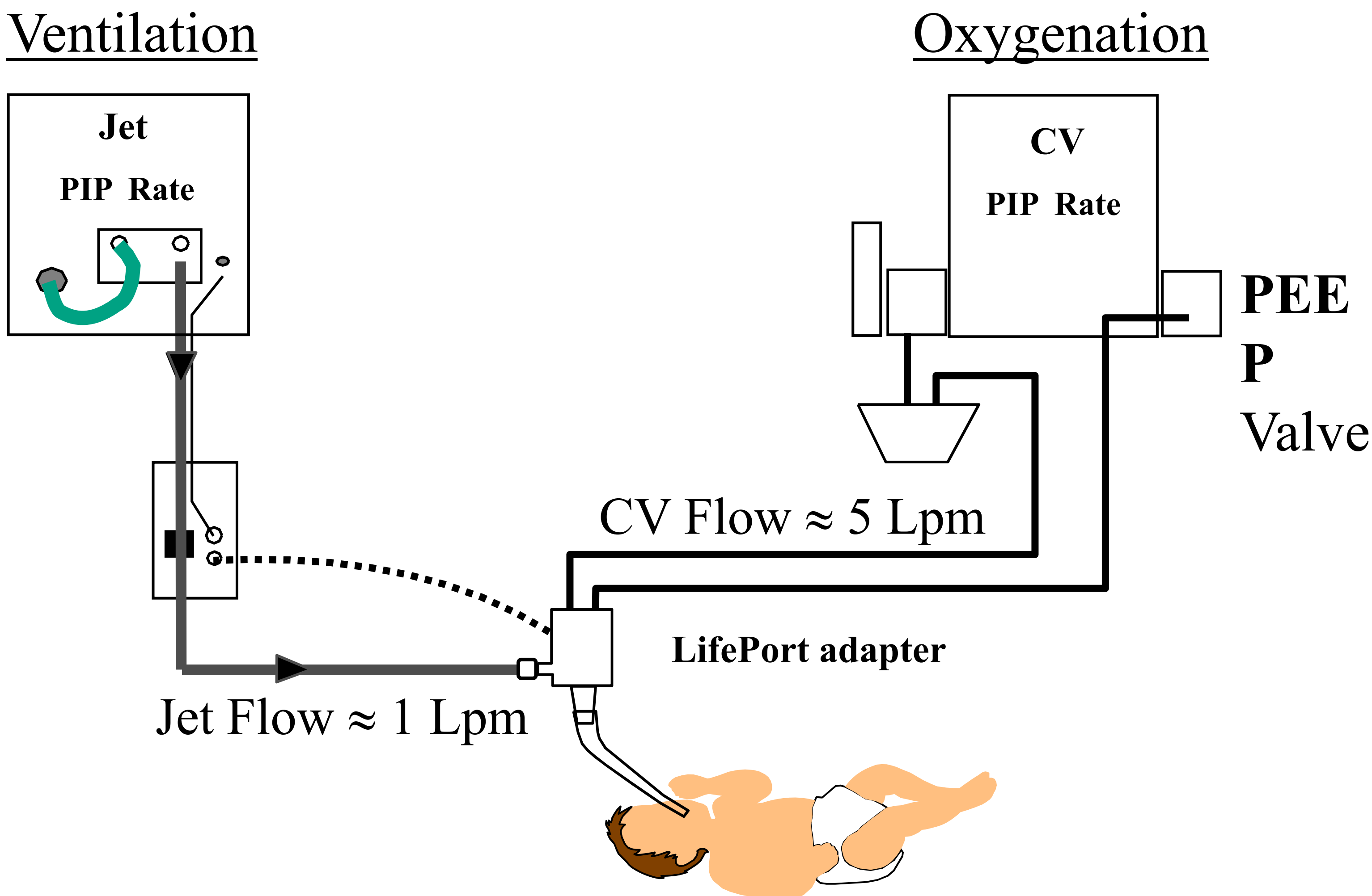
HFJV

Bunnell Life Pulse- (2)



- Rate: 4-11Hz, usually 7 Hz
- Inspiration: active
- Expiration: passive
- A jet is produced by opening and closing of a control valve
- Tidal volume > anatomical deadspace

HFJV in Tandem with CV



HFJV

Bunnell Life Pulse- (3)

Operator-selected parameter:

- Conventional ventilator required for FiO_2, IMV rate (0-10,) PIP and PEEP
- Jet: PIP

  rate 420/min (4 – 11 Hz)

  Ti 0.02 seconds
- Oxygenation: PIP, PEEP, FiO_2
- Ventilation: Jet PIP

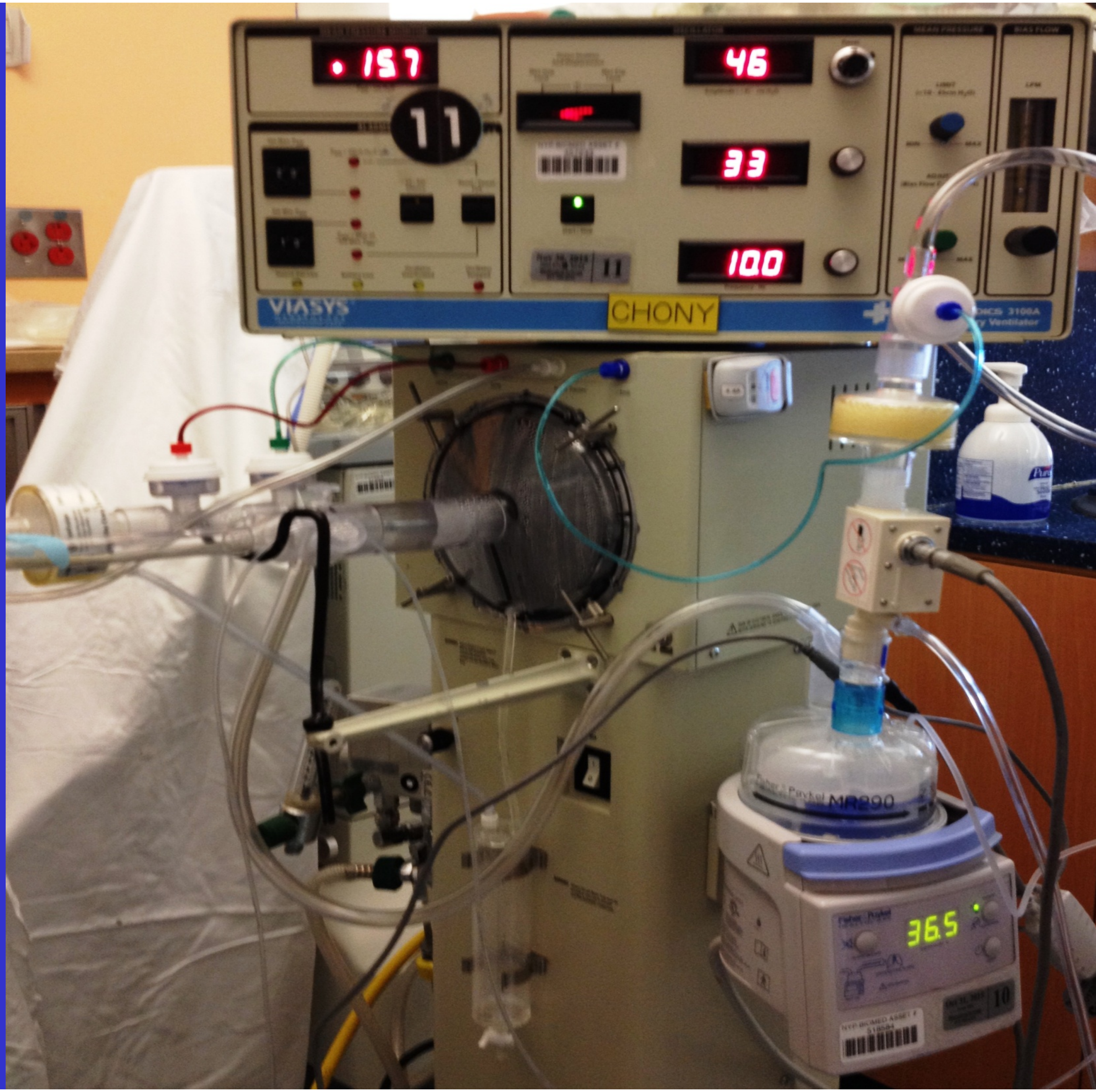
HFJV vs. HFOV

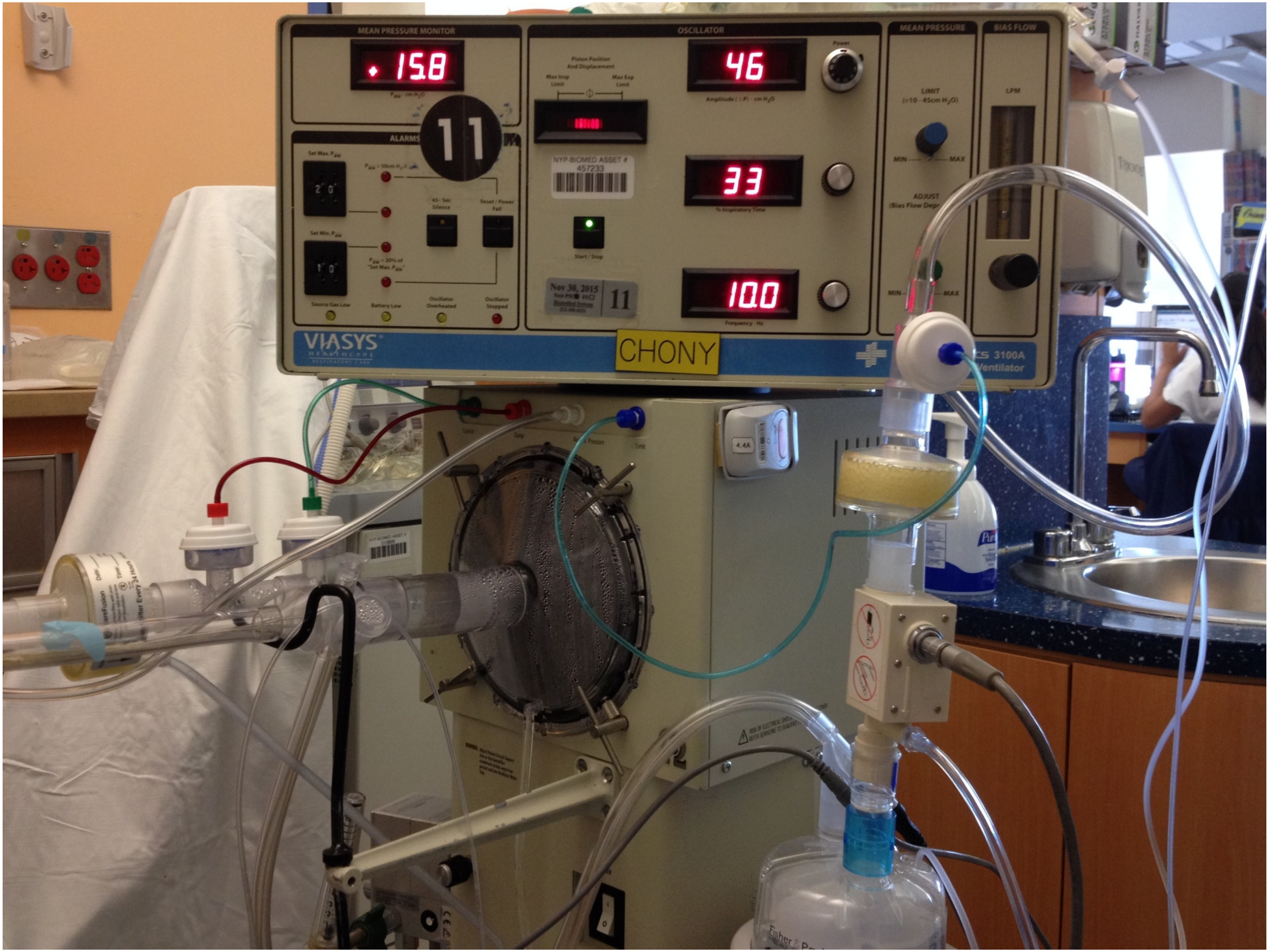
When is the Jet the HFV of choice?

- Air Leak Syndromes
  (e.g., Ptx, PIE)
- Excessive Secretions
  (e.g., pneumonias)
- Hemodynamic Compromise
- When HFOV Fails
  (e.g., non-homogenous lung diseases)

Operator-selected parameter:

- FREQUENCY(10 – 15 HZ)
- INSPIRATION TIME (33%)
- MEAN AIRWAY PRESSURE (MAP)
- AMPLITUDE
- FIO_2 (ATTACHED OXYGEN BLENDER)
- BIAS FLOW RATE
- PISTON CENTERING


VIASYS
CHONY
46
33
10.0
MR290
36.5


MEAN PRESSURE MONITOR
15.8
ALARMS
11
Set Max. Paw
Set Min. Paw
45 - Sec Silence
Reset / Power Fail
Source Gas Low
Battery Low
Oscillator Overheated
Oscillator Stopped
OSCILLATOR
Piston Position And Displacement
Max Insp Limit
Max Exp Limit
NYP-BIOMED ASSET #
457233
Start / Stop
Nov 30, 2015
11
Power
46
33
% Inspiratory Time
10.0
Frequency - Hz
MEAN PRESSURE
LIMIT
MIN
MAX
ADJUST
BIAS FLOW
LPM
VIASYS
CHONY
3100A
Ventilator
4.4A

How to begin!
for infant

- Start with mean airway pressure 0-4 cmH_20 above CMV mean airway pressure(**disease dependent)**
  - ✓ Monitor SaO_2 to maintain SaO_2 to 88 -93%
  - ✓ If SaO_2 does not increase within the first 5 – 10 minutes, increase mean airway pressure by 1-2 cmH_20.
  - Start with the power setting at 2.5 and monitor chest wiggle to **umbilicus.**
  - **Inspiration time 33%**

OXYGENATION:

- **Conventional ventilator:** FiO_2, PIP, PEEP, Ti
- HFO: MAP, FiO_2

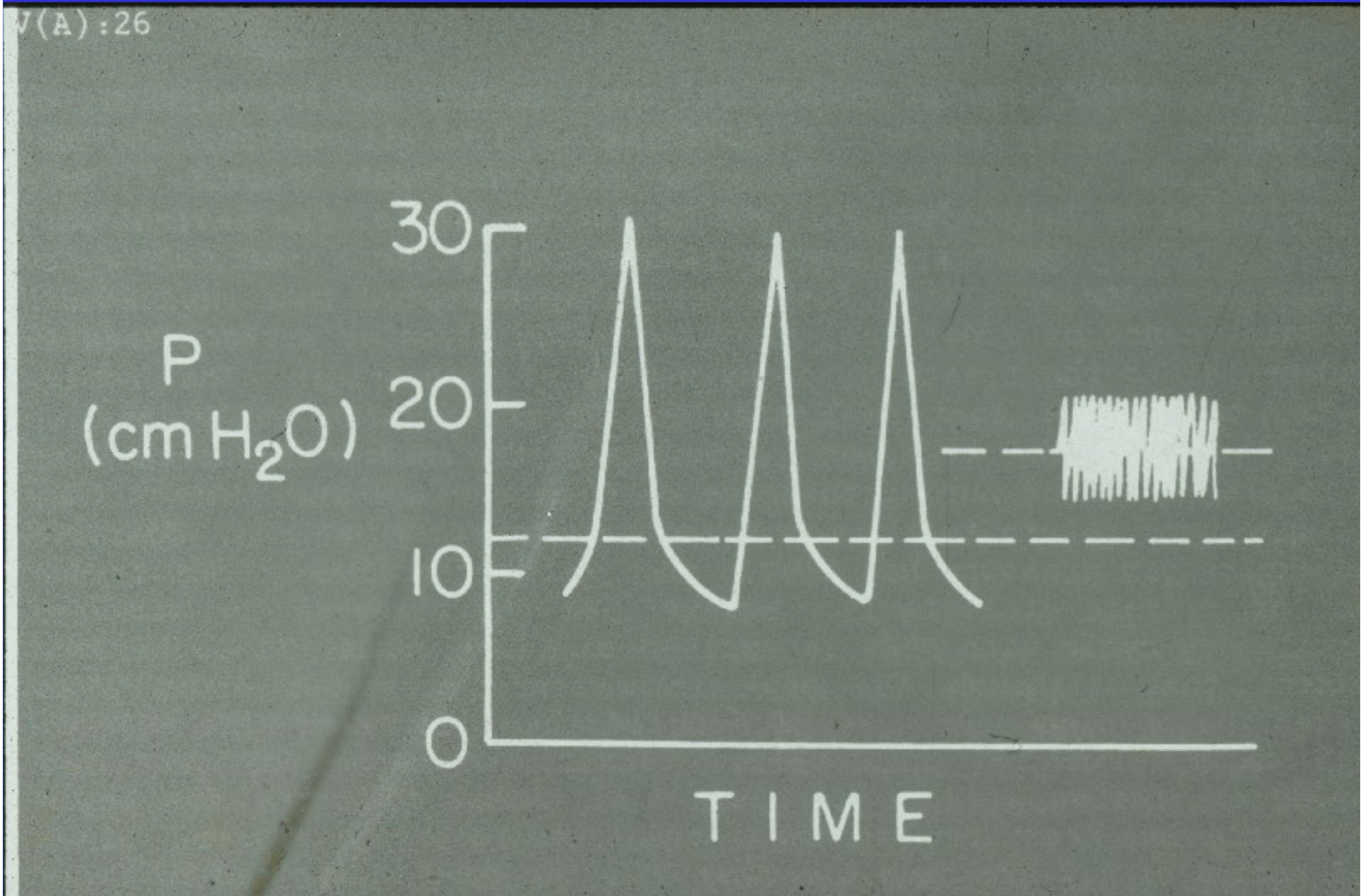
VENTILATION:

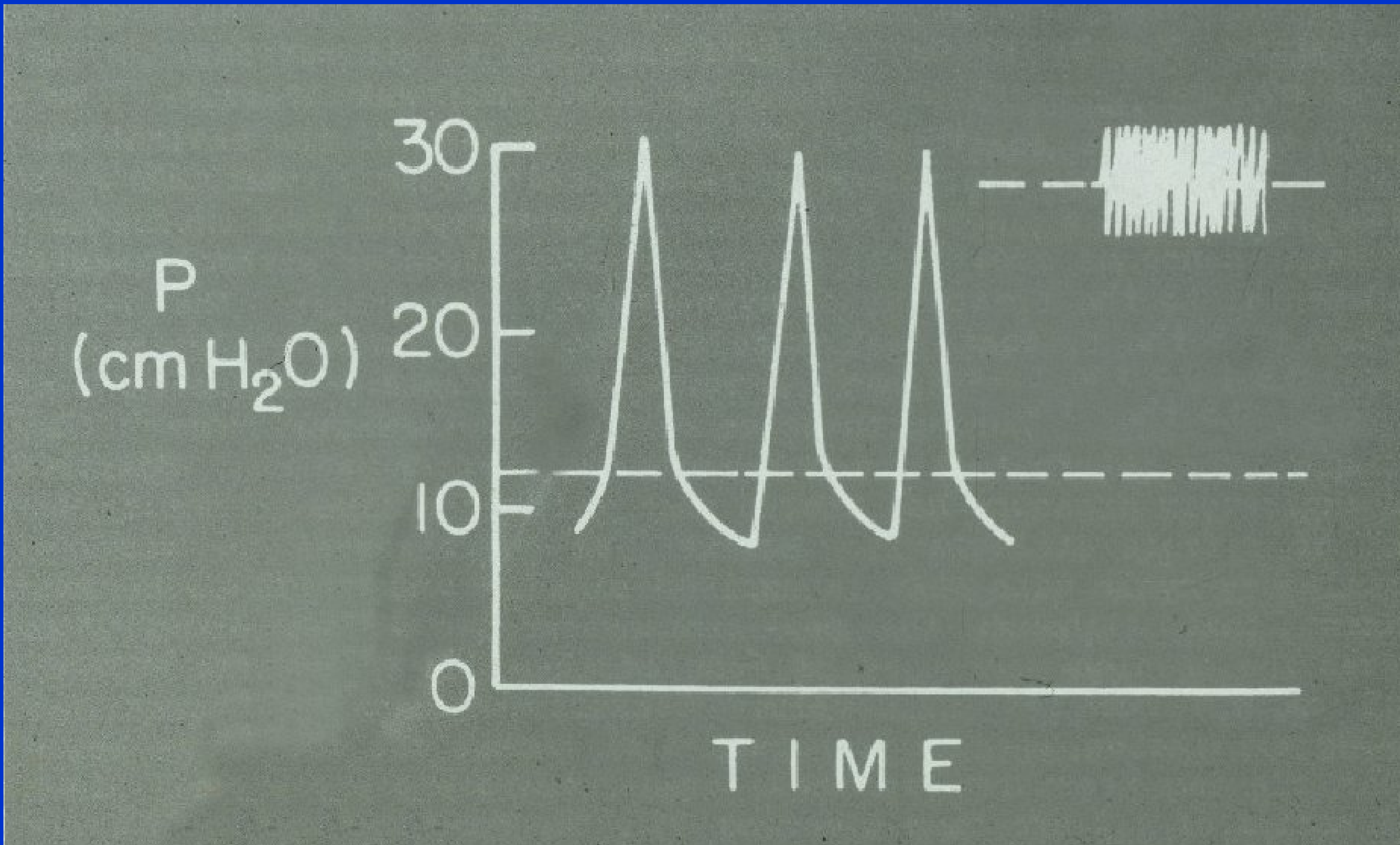
- Conventional ventilator: $MV = Vt \times F$

  where F is IMV rate, Vt is PIP – PEEP
- HFO : $MV = F^a \times Vt^b$

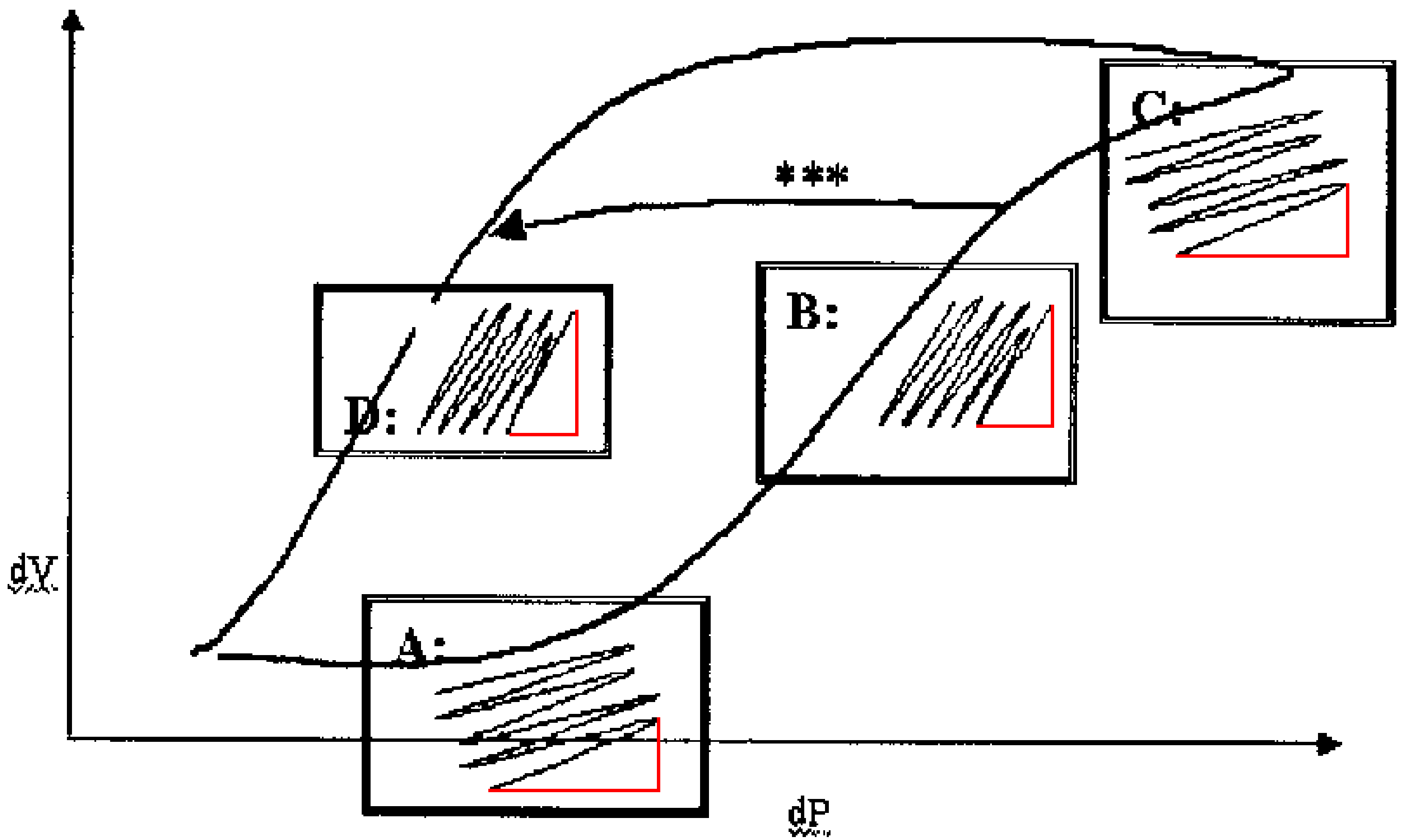
  where a is estimated as 0.75 to 1.24 and b is between 1.5 and 2.2 (About $MV = F \times Vt^2$)

  Vt is related to amplitude


V(A):26
P
(cm H_2O)
30
20
10
0
TIME



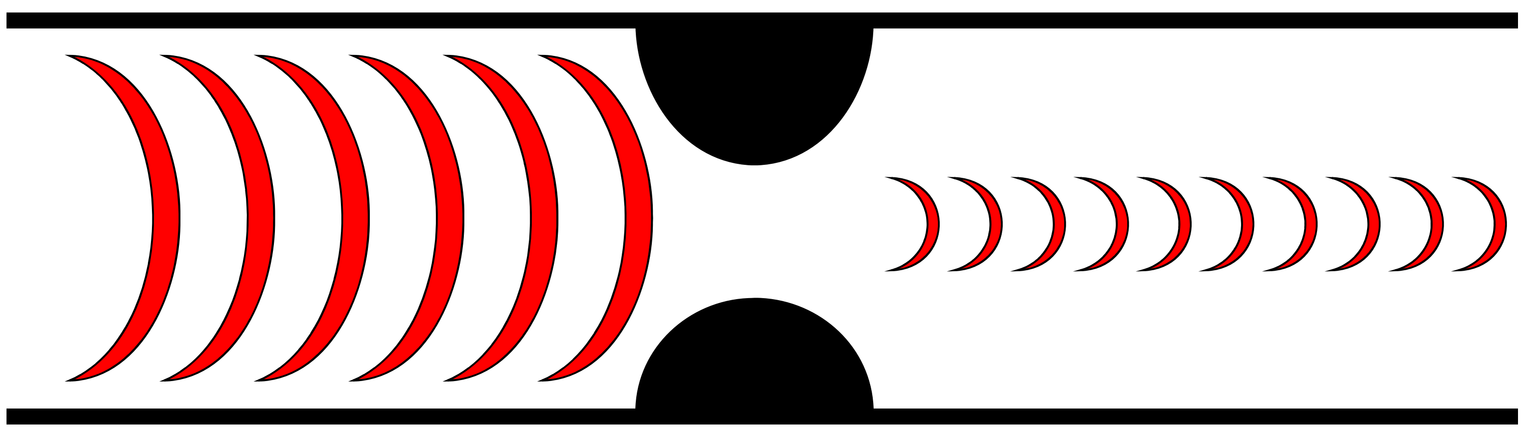
P
(cm H_2O)
30
20
10
0
TIME



C:
***
B:
D:
dV
A:
dP

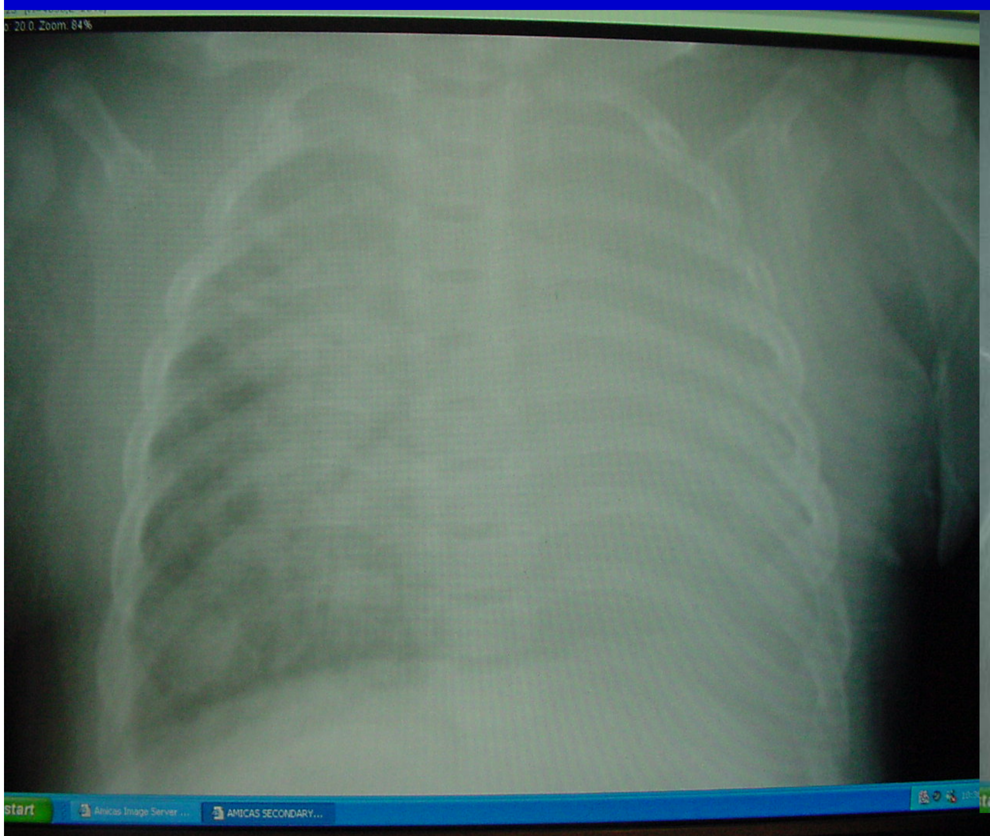
Patient on HFOV. O_2 sat. increase with spontaneous breathings

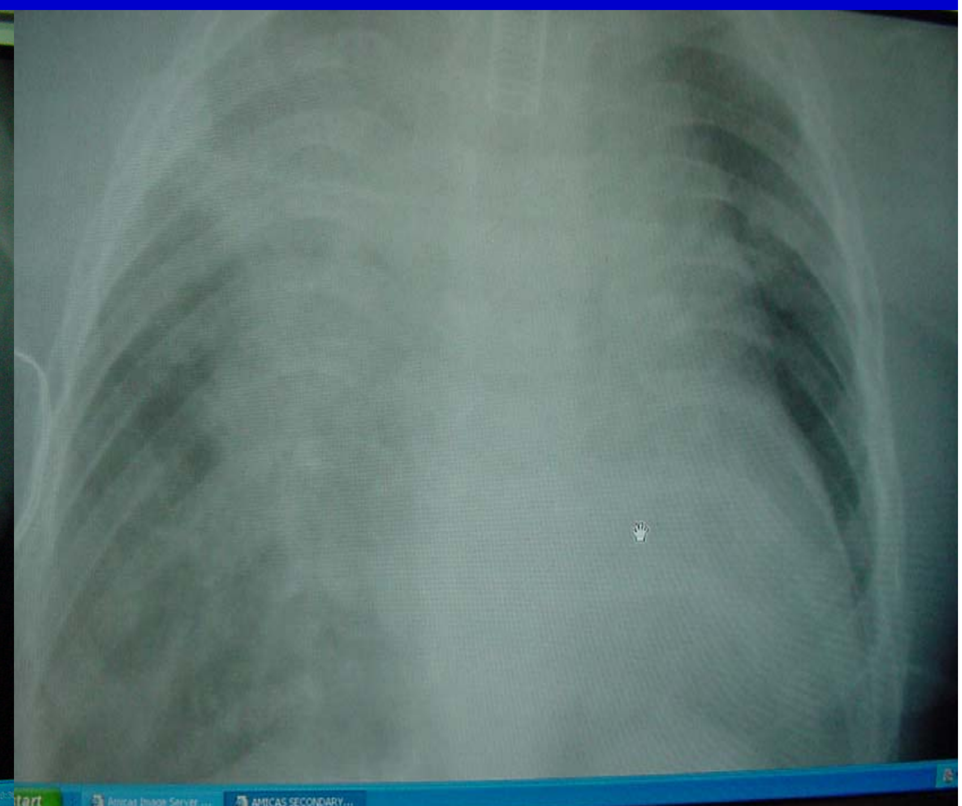
Shunt Oscillation



HFO

- Very sensitive to increase of airway resistance
- Less sensitive to Nonhomogeneous compliance


20.0. Zoom: 84%
start
Amicas Image Server ...
AMICAS SECONDARY...


tart
Amicas Image Server ...
AMICAS SECONDARY...

BIRTH WEIGHT 750-2000 gm

	HFV	CMV
No.	327	346
BPD	40%	41%
MORTALITY	18%	17%
CROSSOVER*	26%	17%
PNEUMOPERITONEUM*	3%	1%
IVH Gr 3 & 4*	26%	18%
PERIVENTRICULAR LEUCOMALACIA *	12%	7%

HFV versus CMV -1

Reference	Device	N	BW(kg)	CLD Rate
Carlo ’87	HFJV	41	1.48	No difference
HIFI ’89	HFOV	673	1.10	No difference
Carlo ’90	HFJV	42	1.42	No difference
Clark ’92	HFOV	83	1.10	30% vs 65% 30d
				10% vs 38% 36w
Ogawa’92	HFOV	92	1.20	No difference
Pardou’93	HFFI	24	1.30	No difference

HFV versus CMV -2

Reference	Device	N	BW(kg)	CLD Rate
Gerstman'96	HFOV	125	1.50	24% vs 44% 30d
Wiswell '96	HFJV	73	0.90	No difference
Keszler '97	HFJV	130	1.00	67% vs 71% 30d 20% vs 40% 36w
Rettwitz-Volk '98	HFOV	96	1.10	No difference
Thome'99	HFFI	284	0.88	No difference

HIGH FREQUENCY VENTILATION

Concern of the trials

- ✓ The results are contradictory
- ✓ Most of these trials have been performed by investigators who have extensive experience in HFV
- ✓ Masking of investigators is not possible
- ✓ A standardized approach for HFV versus a non-standardized approach for CMV
- ✓ Only studies in which there is a relatively high rate of BPD in CMV group have demonstrated a lower incidence of BPD in HFV group

HIGH FREQUENCY VENTILATION

Indication - Prophylactic

- ✓ In animal experiments, HFV cause less lung trauma than conventional ventilation
- ✓ Whether this is also true in human preterm infants is still uncertain
- ✓ The findings of clinical trials are contradictory
- ✓ There remain concerns that HFV may be associated with a high rate of brain injury

HFV as a primary mode of ventilation is not recommended

HIGH FREQUENCY VENTILATION

Indication - Rescue

- ✓ Most of the evidence of benefit is short term and in term babies
- ✓ No clear evidence to support a rescue role in preterm babies
- ✓ Indications should be considered on a case by case basis

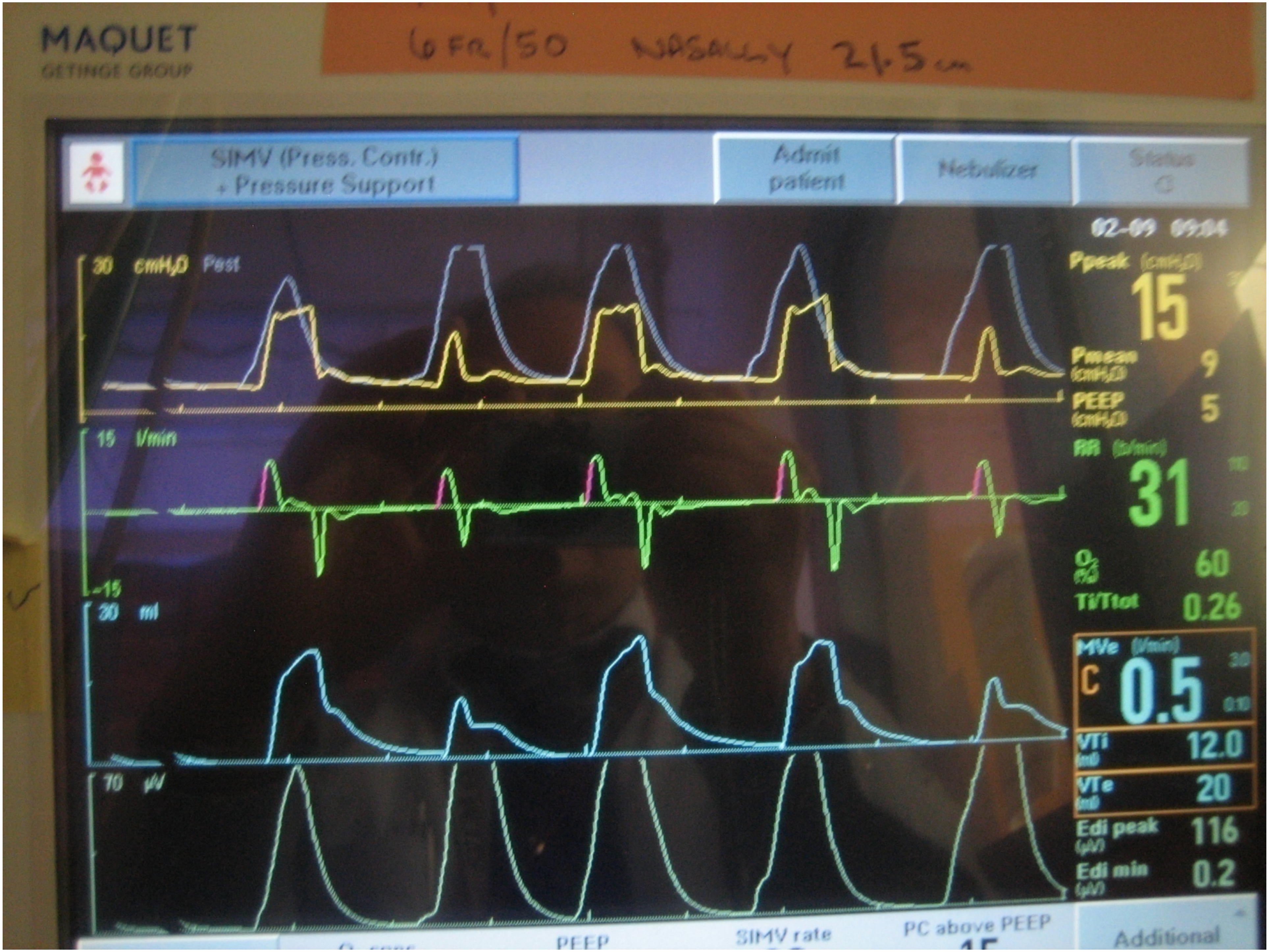
ADVANCES IN MEDICINE

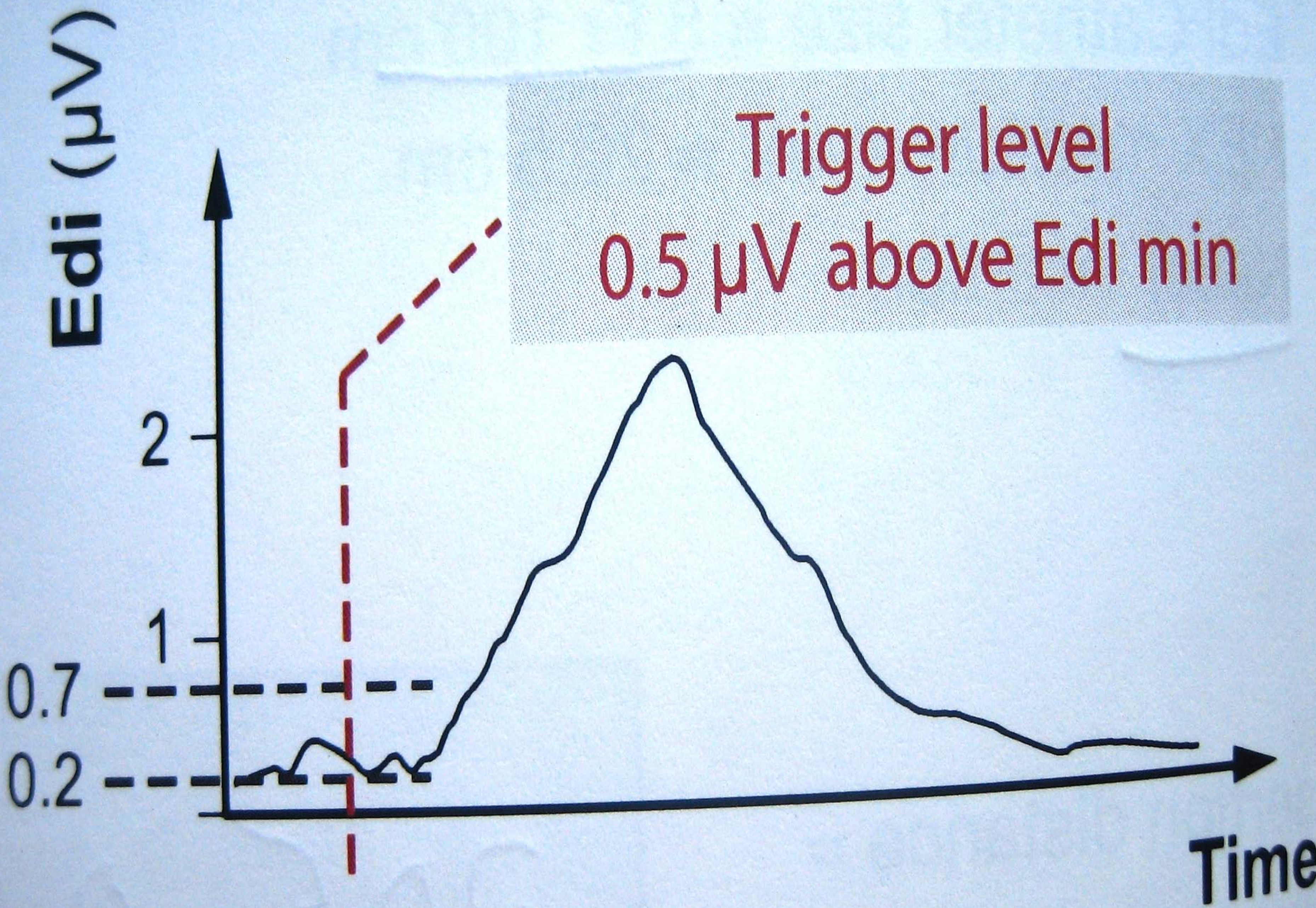
TRADITIONAL MEDICINE

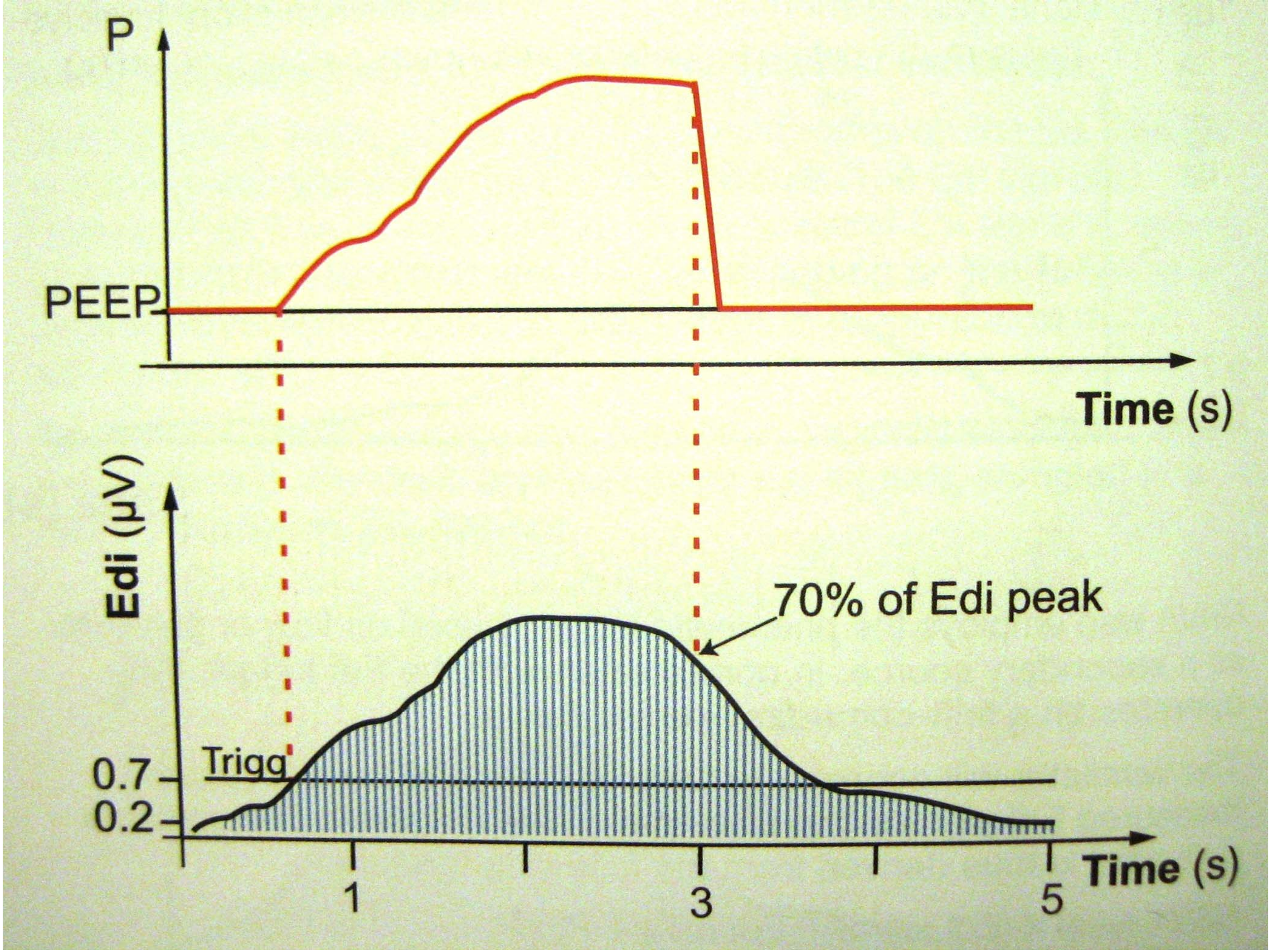
- Doctor amused the patient
- Nature cured the patient

MODERN MEDICINE

- Technology amuses the doctor
- Nature still cures the patient


MAQUET
GETINGE GROUP
6 FR/50 NASALLY 21.5 cm
SIMV (Press. Contr.) + Pressure Support
Admit patient
Nebulizer
Status
02-09 09:04
30 cmH2O Pest
15 l/min
-15
30 ml
70 μV
Ppeak (cmH2O) 15
Pmean (cmH2O) 9
PEEP (cmH2O) 5
RR (b/min) 31
O2 (%) 60
Ti/Ttot 0.26
MVe (l/min) C 0.5
VTi (ml) 12.0
VTe (ml) 20
Edi peak (μV) 116
Edi min (μV) 0.2
PEEP
SIMV rate
PC above PEEP
Additional


Edi (µV)
Trigger level
0.5 µV above Edi min
2
1
0.7
0.2
Time



P
PEEP
Time (s)
Edi (µV)
70% of Edi peak
Trigg
0.7
0.2
1
3
5
Time (s)