

# Conventional Mechanical Ventilation of Neonates - Columbia Way -

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- Often in medicine *less is more*
- Be aware that newer isn't always better
- Don't believe everything you read

“The vast majority  
of lung injury is  
man made.”

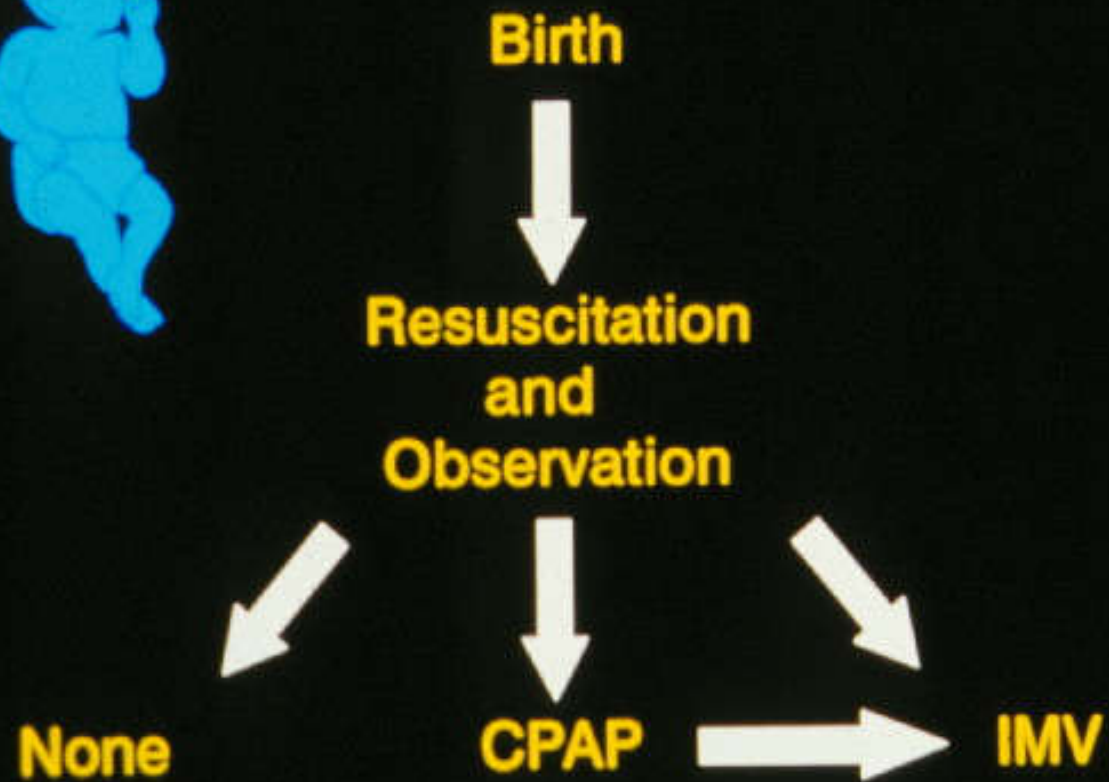
- Dr. Theodor Kolobow

**K** e e p

**I** t

**S** i m p l e &

**S** t u p i d ( **S** a f e )



# Mechanical Ventilation

## Indications

1. Marked retractions on CPAP (not due to nasal obstruction)
2. Frequent apnea and bradycardia on CPAP
3.  $\text{PaO}_2 < 50 \text{ mm Hg}$  with  $\text{FiO}_2 > 60\%$
4.  $\text{PaCO}_2 > 70 \text{ mm Hg}$  (except 1<sup>st</sup> ABGS)
5. Intractable metabolic acidosis  
(  $\text{BD} > 10 \text{ meq/L}$  after Rx with  $\text{NaHCO}_3$  )
6. Others (Cardiovascular collapse, Neuromuscular disorder, Congenital diaphragmatic hernia, or for Surgery, MRI, Cardiac catheterization, etc.)

# Mechanical Ventilation

## Conventional

- **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/H<sub>2</sub>O/L  
( $\gg$  tidal volume 6 ml/kg)

## **Pressure Controlled Ventilation**

- When the preset PIP has been reached, it is maintained for the duration of inspiratory cycle
- Delivered VT is less affected by ET leakage
- The actual VT delivery is dependent on patient mechanical resistance, compliance & patient effort
- Has a simple and reliable mechanical design. Widely available in nearly all ventilators
- Clinicians are most experienced with this mode

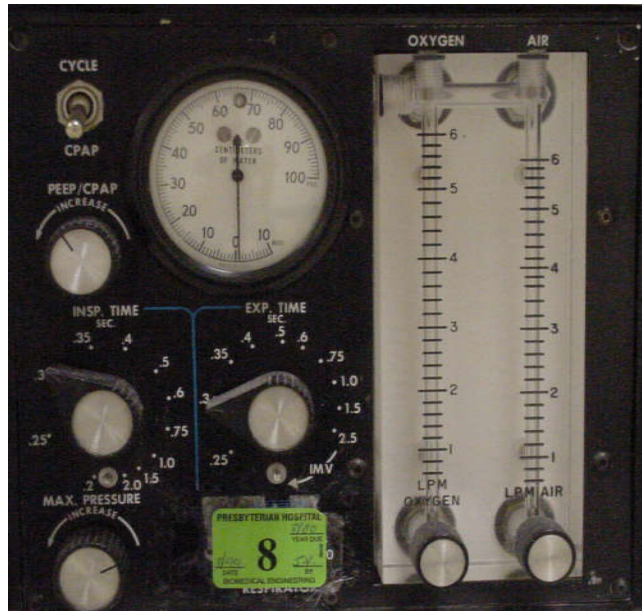
## **Volume Controlled Ventilation**

- Minute ventilation remains constant as lung mechanics change
- Gas compression in the circuit and variable ET leakage & small TV makes accurate control of delivered VT very difficult

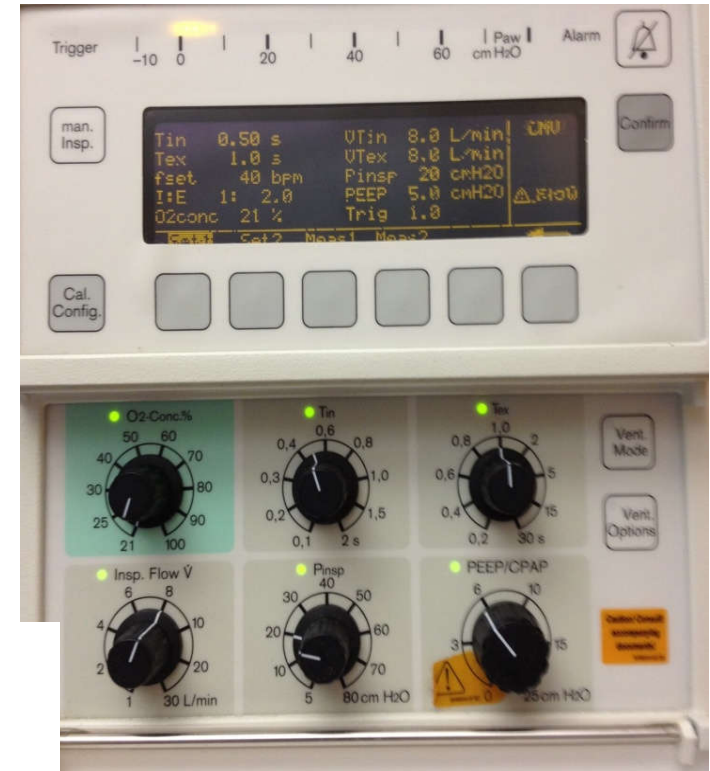
# Infant Ventilators

- 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
- Servo 300
- Draeger Babylog 8000, Servo i
- Servo n, Servo u, Babylog VN500, Avea,  
Puritan Bennett 840

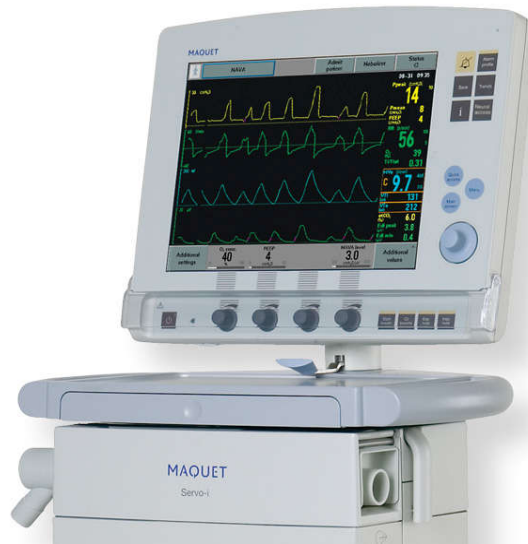
# MVP-10



# Babylog 8000



# Servo i

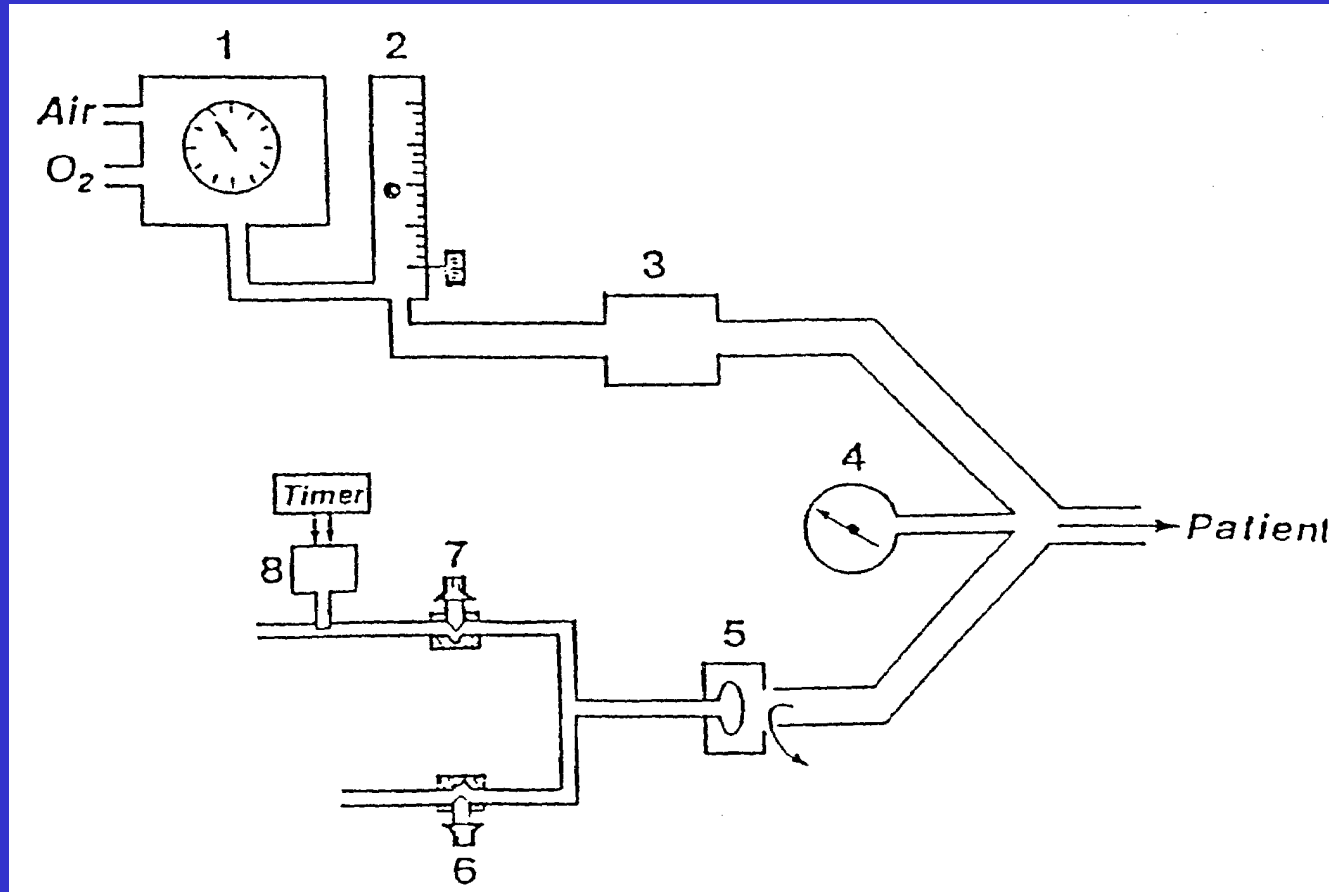


# Servo n



# Infant Ventilator

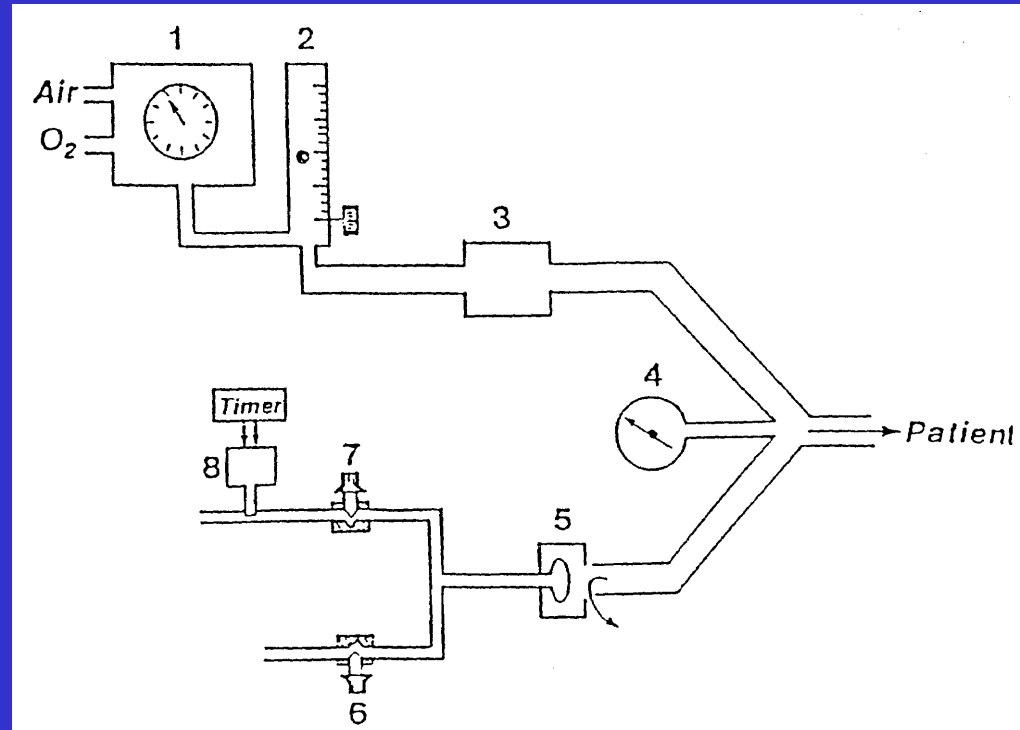
## Basic Simplified Schematic



1. O<sub>2</sub> 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 ( $T_i$ )
- Peak Inspiratory Pressure (PIP)
- Positive end expiratory Pressure (PEEP)



# Mechanical Ventilation

## Complications associated with endotracheal intubation

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. Acquired 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

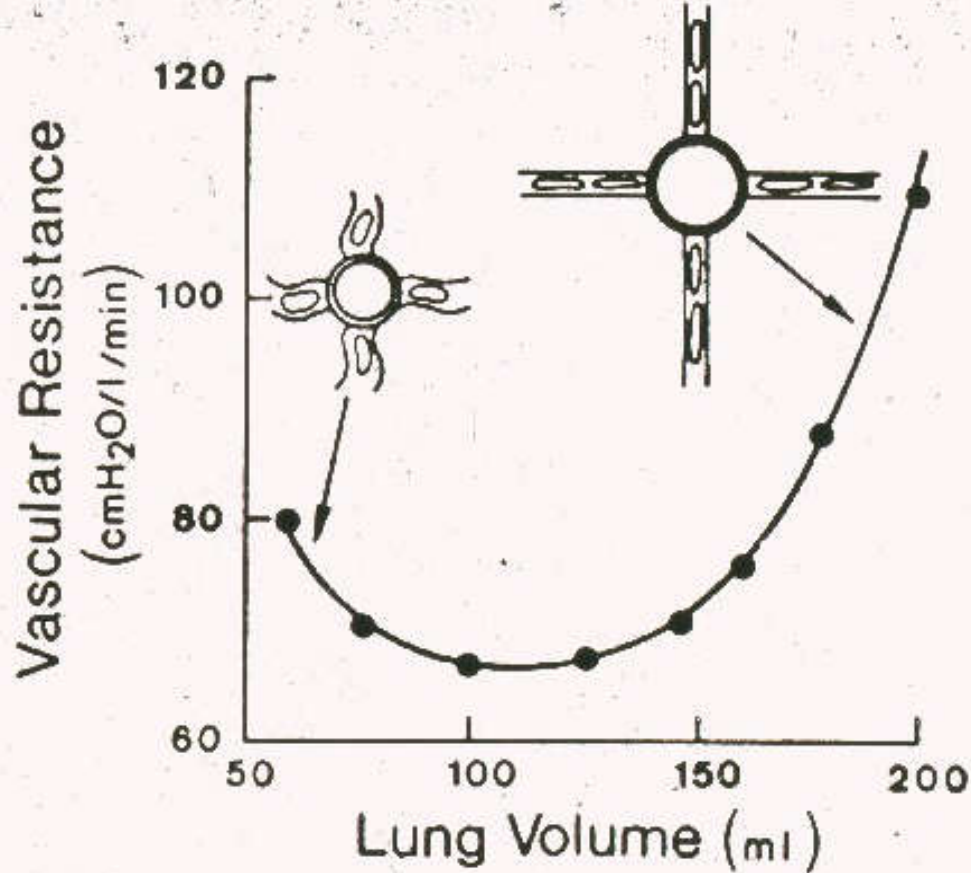
### F. Neurologic; PV-IVH, PVL, Sensorineural hearing loss

### G. Pulmonary Hypertension

### H. Chronic Lung Disease (BPD)

### I. Cor Pulmonary

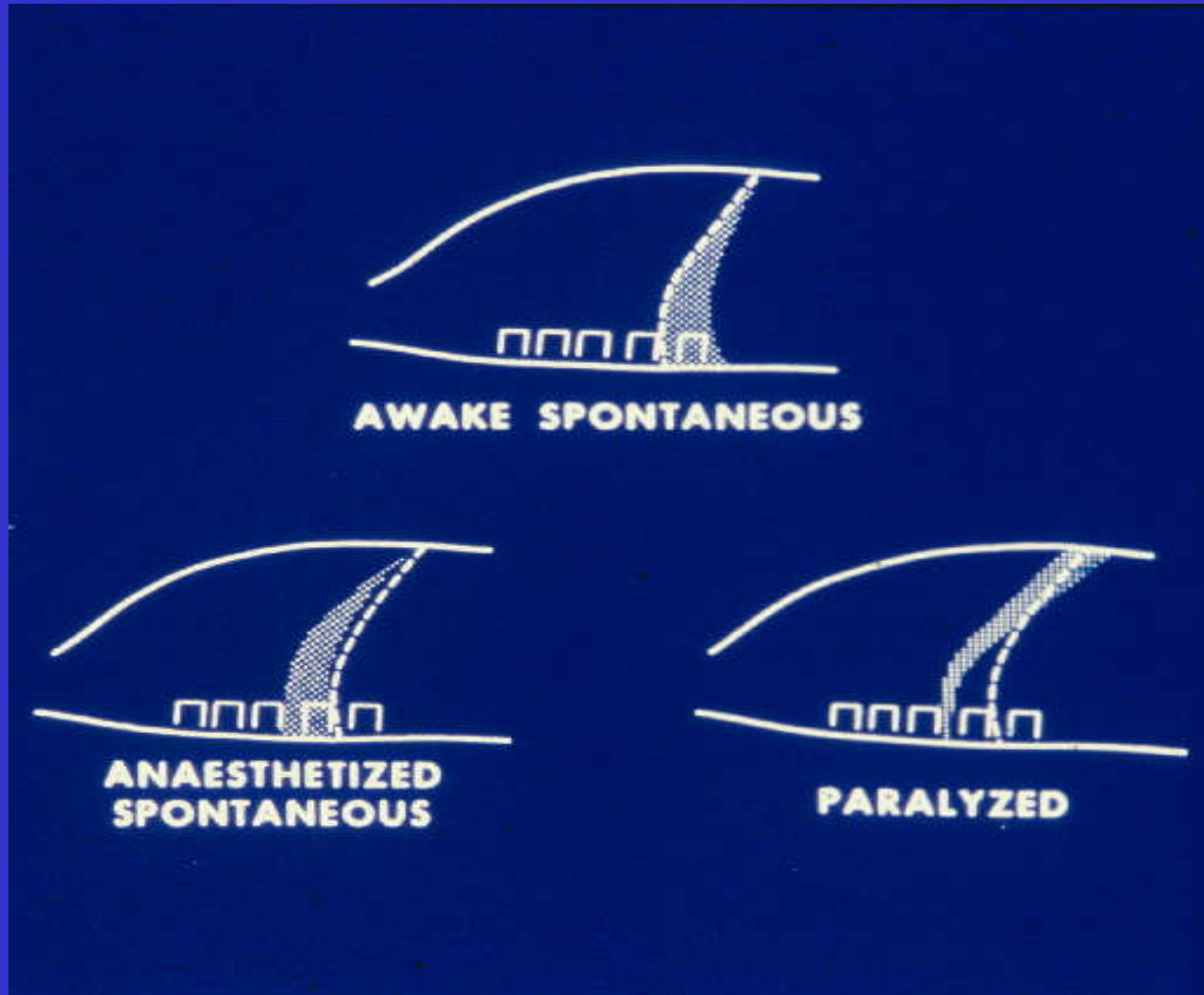
### J. VAP (ventilator associated pneumonia)



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.

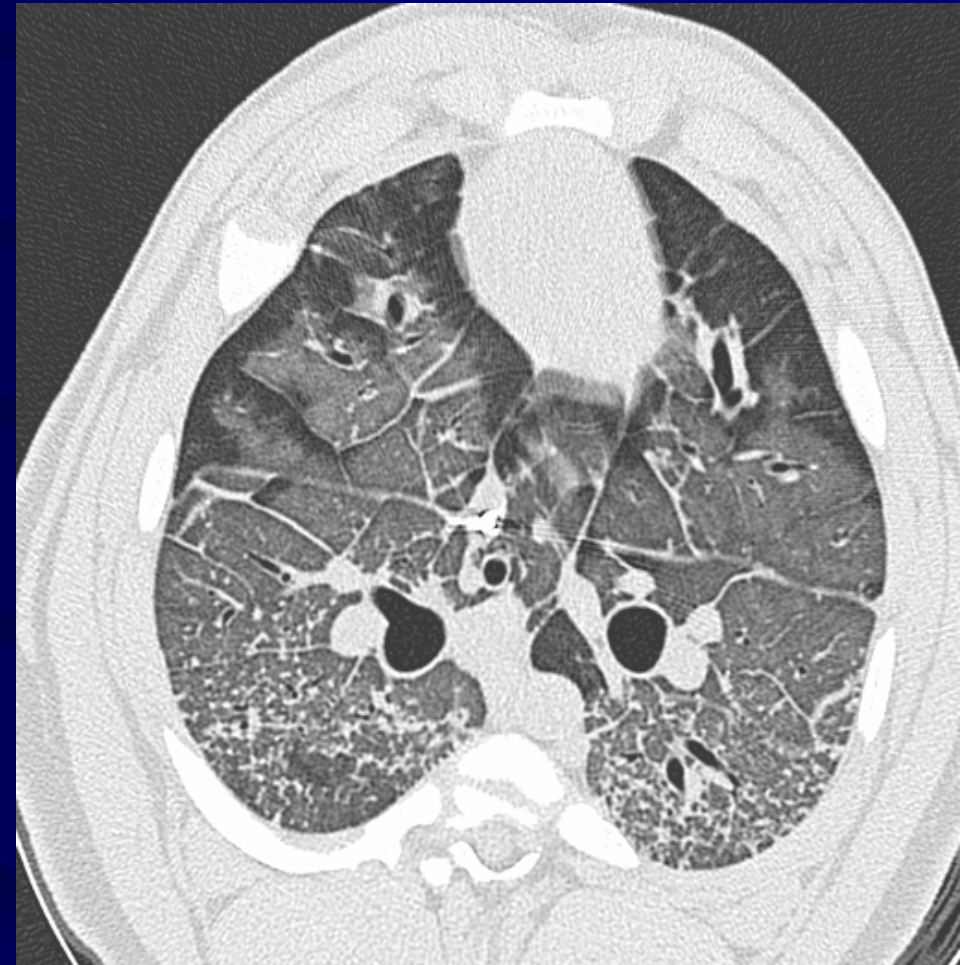
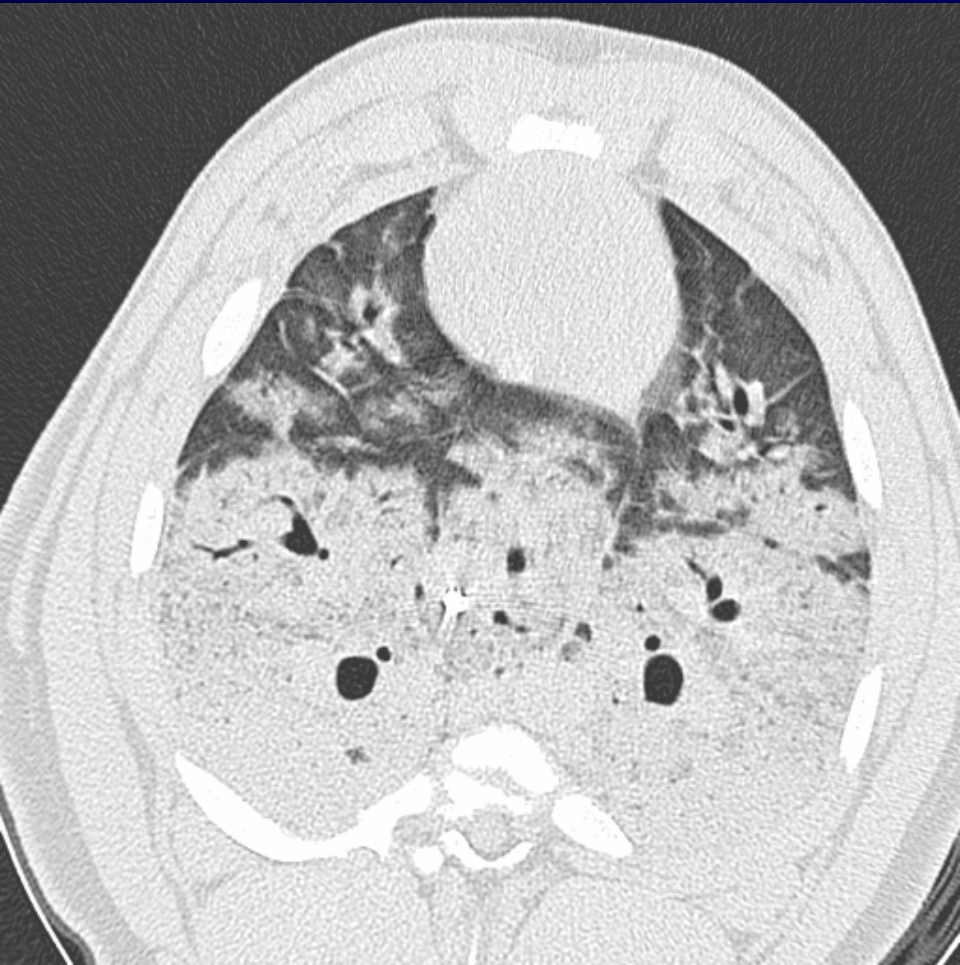
**At high volumes**, the capillaries become stretched as the caliber is reduced.

# Paralyzing the diaphragm is asking for trouble!



Froese, et al., Anesthesiology, 1974

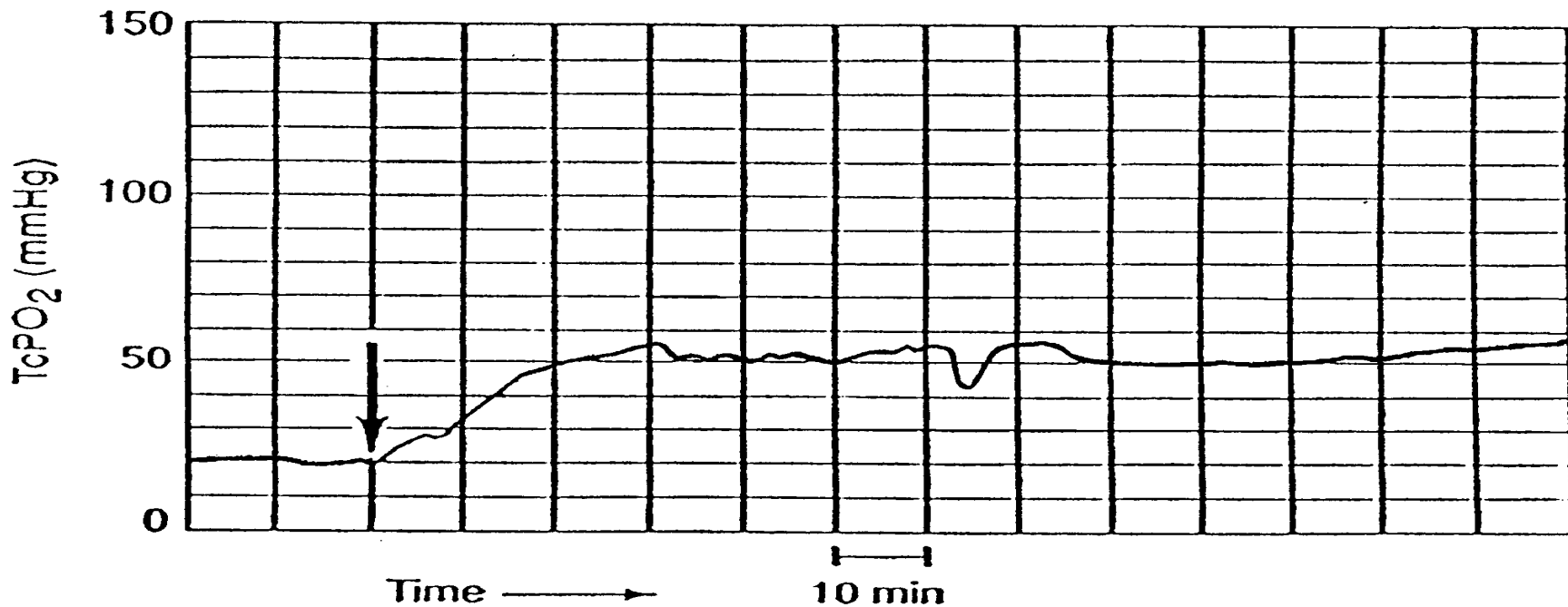
It is not good to spend all day  
laying on your back!



Gattinoni, et al., Critical Care Medicine, 1991

The Best Mode of Ventilation is

**Spontaneous Breathing**

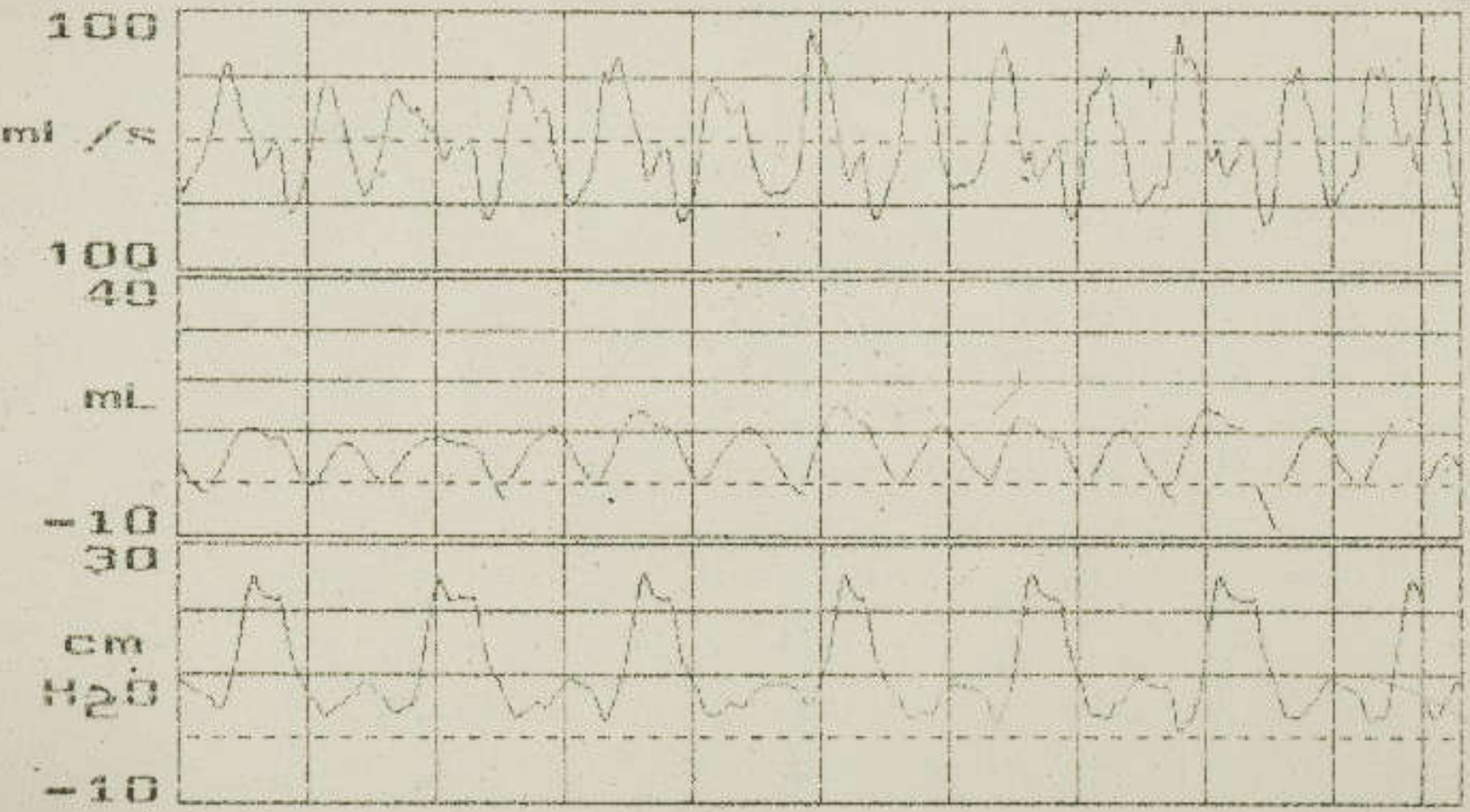


	IMV	Ti	PIP	PEEP	FiO <sub>2</sub>	pH	PaCO <sub>2</sub>	PaO <sub>2</sub>
Before transfer	80	0.4	35	5	1.0	7.41	44	33
After transfer	40	0.6	30	5	1.0	7.30	55	31
After reversal*	25	0.6	30	5	1.0	7.34	53	68

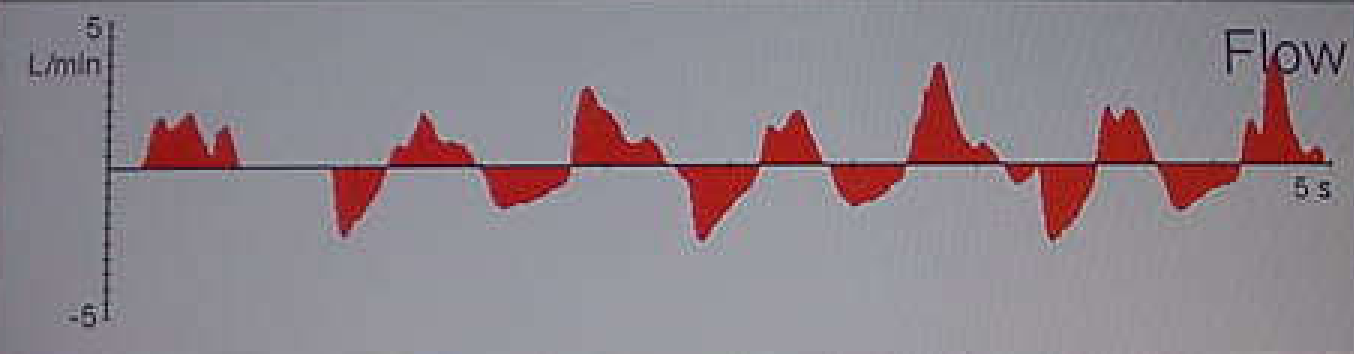
\*TcPO<sub>2</sub> rises (arrow) with spontaneous breathing after pavulon reversal

Breath Interval: 10

$FIO_2$  1, IMV 40  $T_i$  0.5 PIP 25 PEEP 5



U  
UT  
P  
W  
A  
B



CMV

P<sub>peak</sub> cmH2O  
20

P<sub>mean</sub> cmH2O  
10

PEEP cmH2O  
5

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.

# 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 ( $\text{PaO}_2$ ) in a nonlinear system

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

	PaO <sub>2</sub>	PaCO <sub>2</sub>	Shunt%	Crs	MAP	Vt ml/kg
<b>Vbv</b>	502	35	9.7	1.15	15.7	14.7
<b>Vc</b>	381	48	14.6	0.79	18.8	13.2
<b>Vs</b>	309	50	22.9	0.77	18.9	

**Vbv**: biologically variable MV,

**Vc**: monotonously control MV,

**Vs**: Vc plus sigh

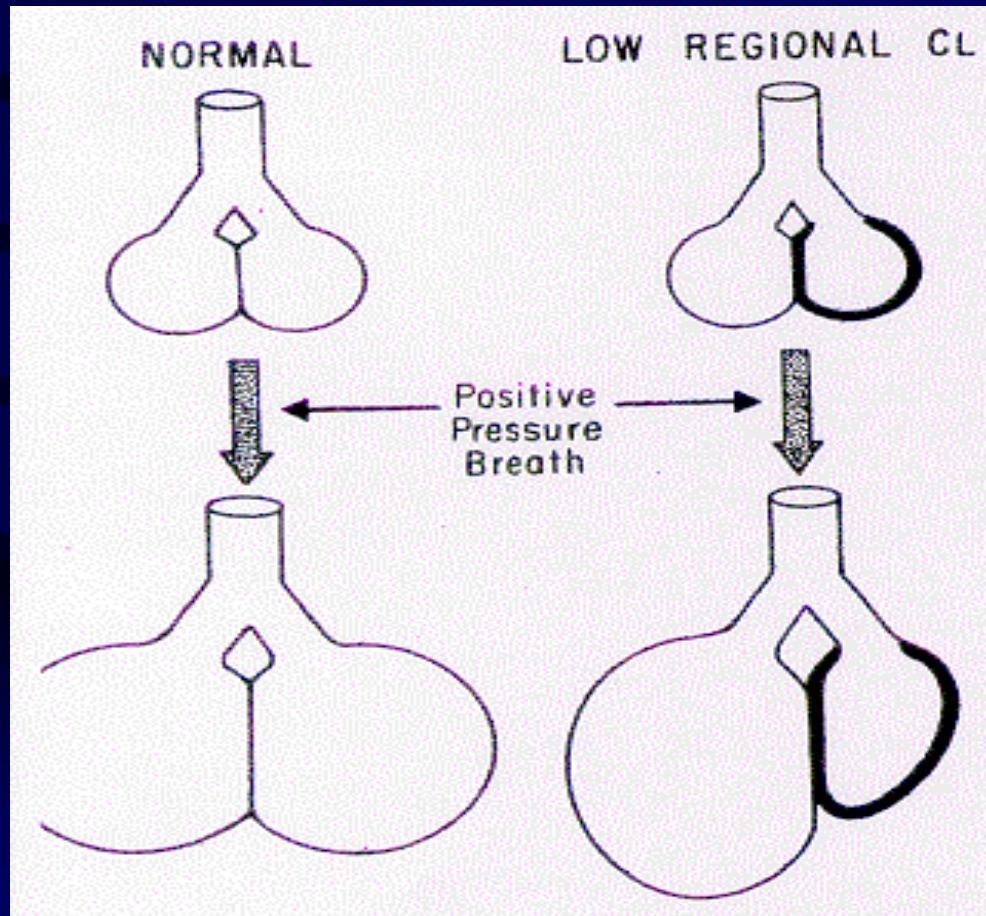
# Biologically Variable Ventilation

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

In the healthcare profession,  
It is a well known fact that  
the **best interventions** are  
those that **interfere least** with  
**nature's own mechanisms**

# Overdistention may be regional

Even a “normal” VT can create regional overdistention



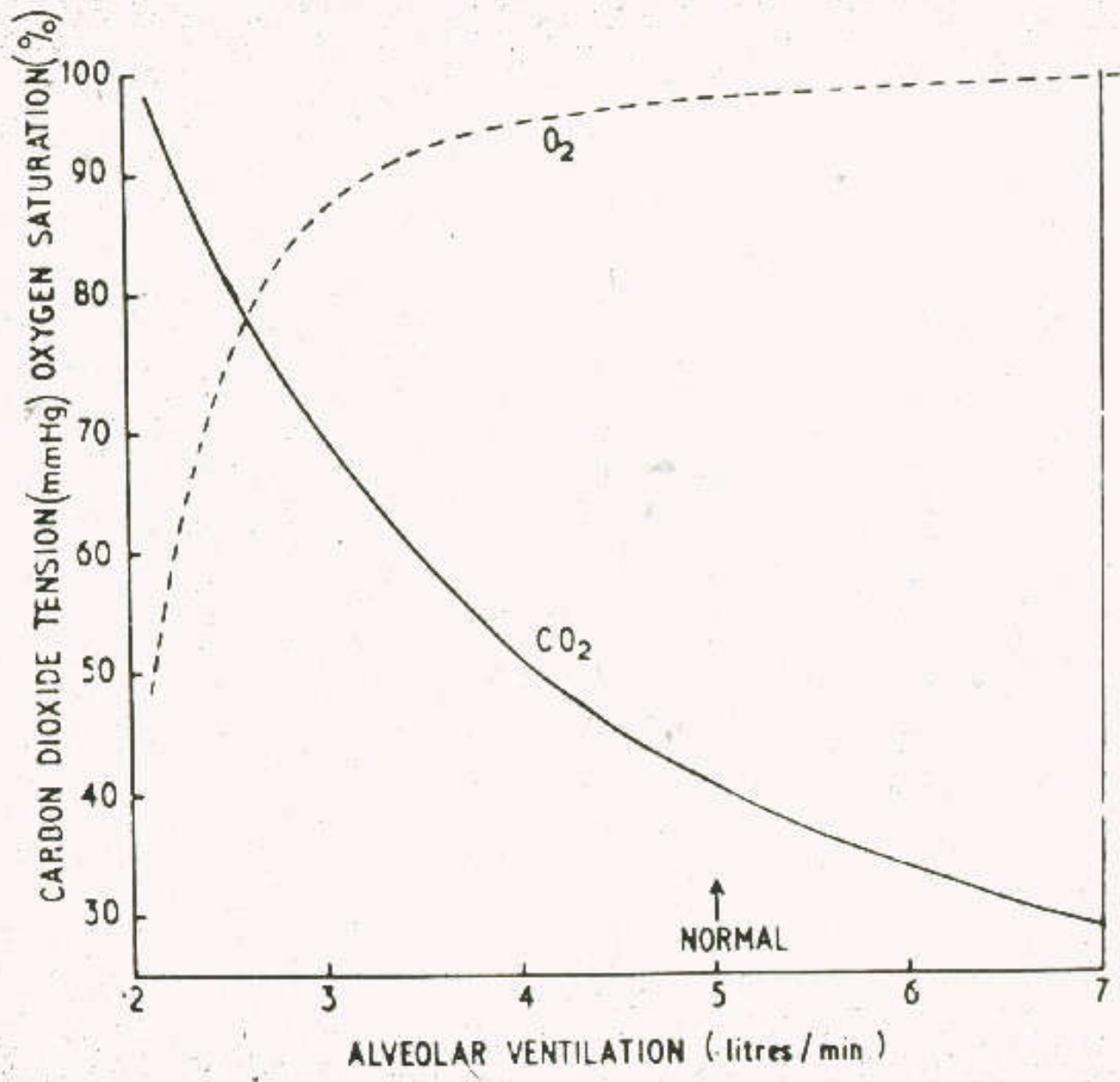
# Mechanical Ventilation

## Aim

- To maintain adequate gas exchange (oxygenation and CO<sub>2</sub> 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



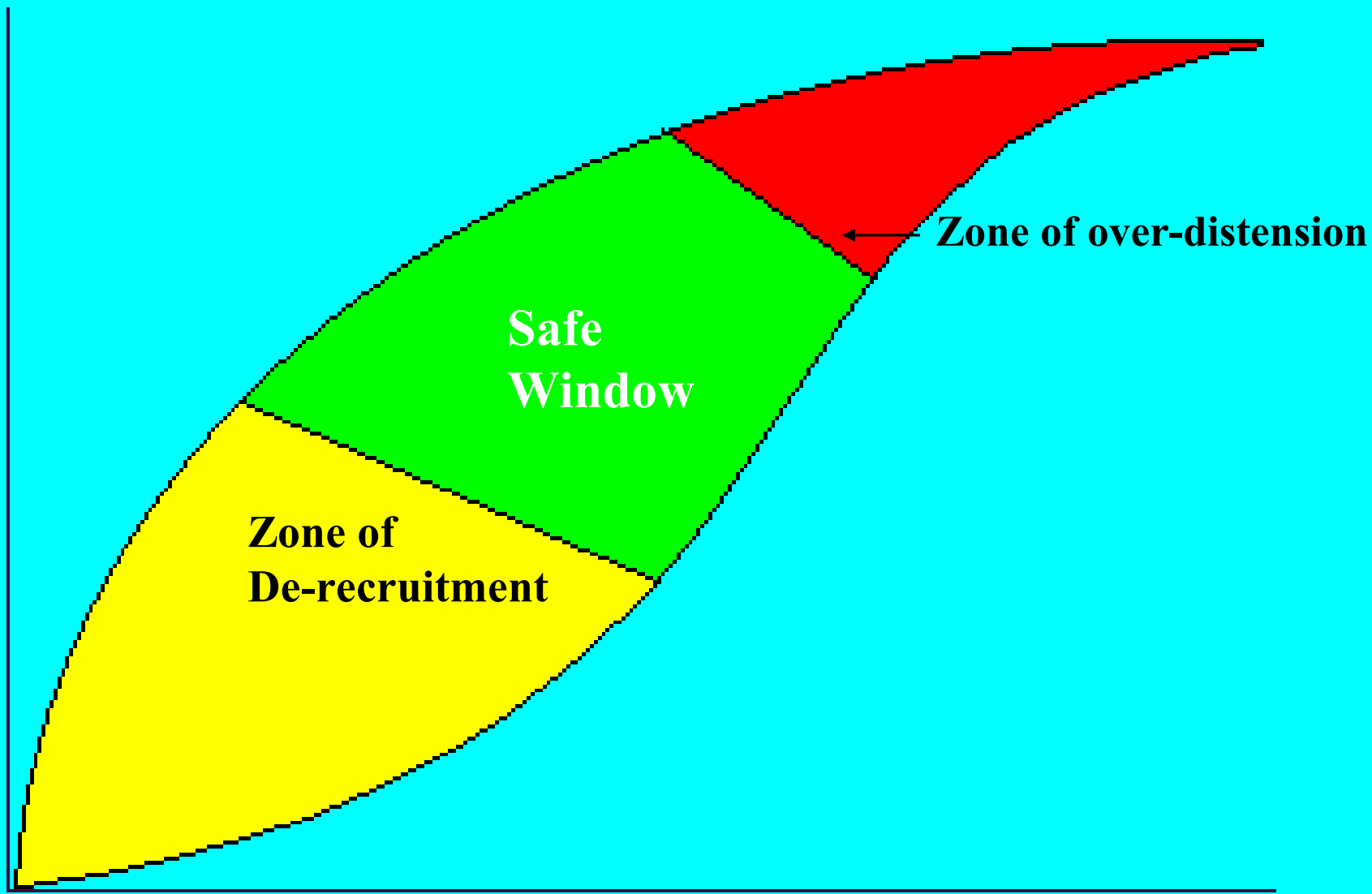
# Hypercapnic Acidosis Is Protective in an In Vivo Model of Ventilator-induced Lung Injury.

- 12 anesthetized, paralyzed rabbits,  $V_t$ : 25 cc/kg, Rate: 32/min, PEEP 0 for 4 hours.
- 6 rabbits receive either an  $F_iCO_2$  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

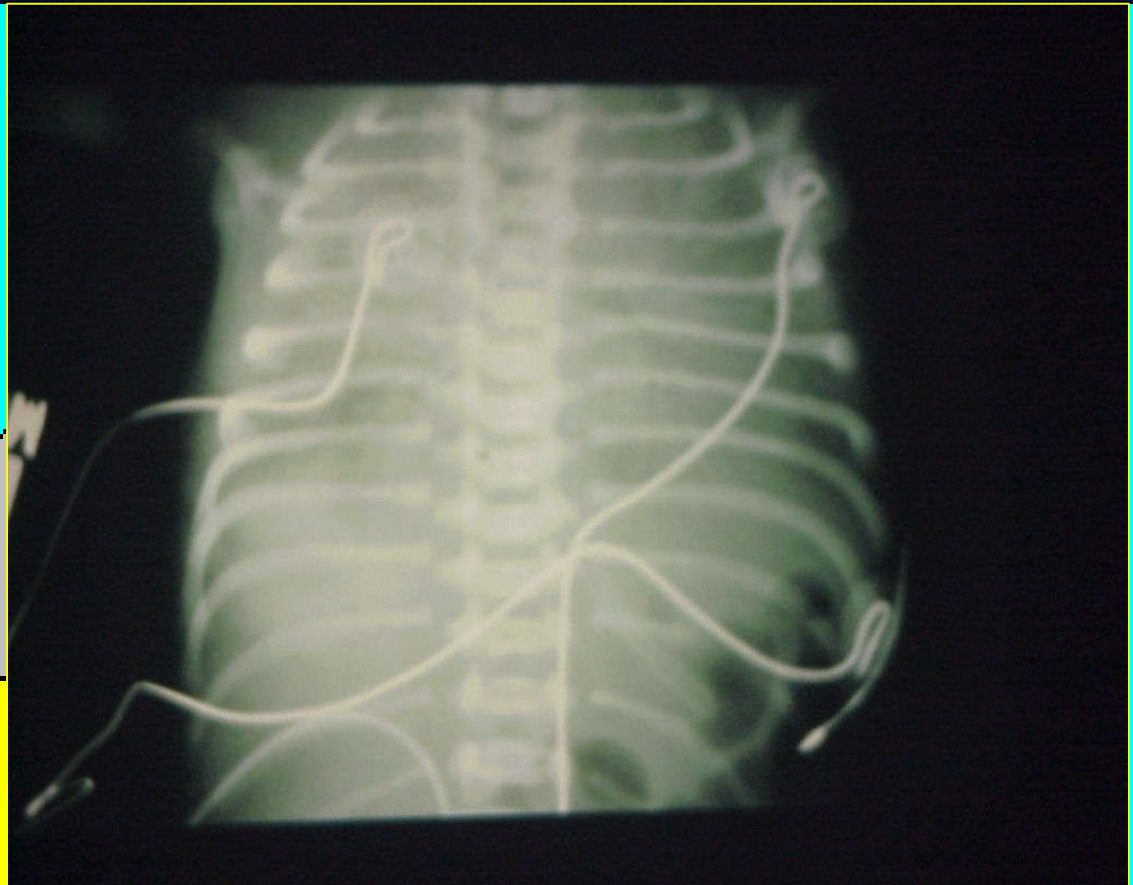
# Managing Infants with Respiratory Distress

## Mechanical Ventilation using infant respirator:

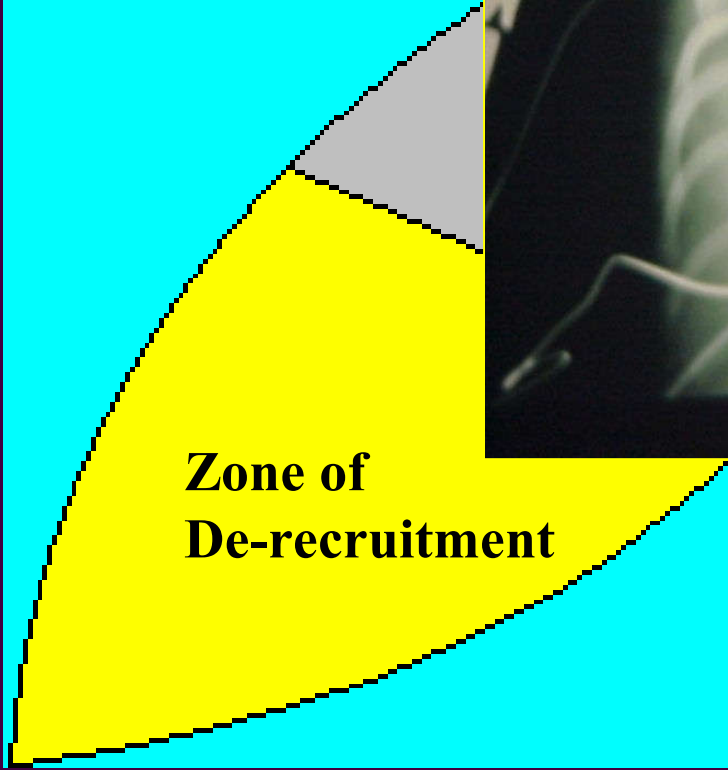
- Allow spontaneous breathing to continue.
- Ventilatory settings are graded according to degree of respiratory failure.
- Consider strategies that balance the tradeoffs between gas exchange and lung protection.
- Wean aggressively and early extubation

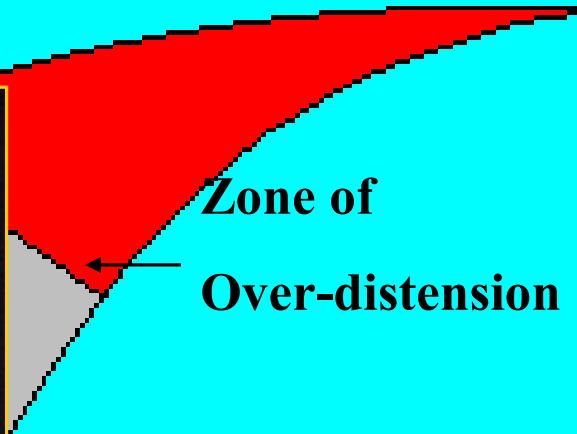
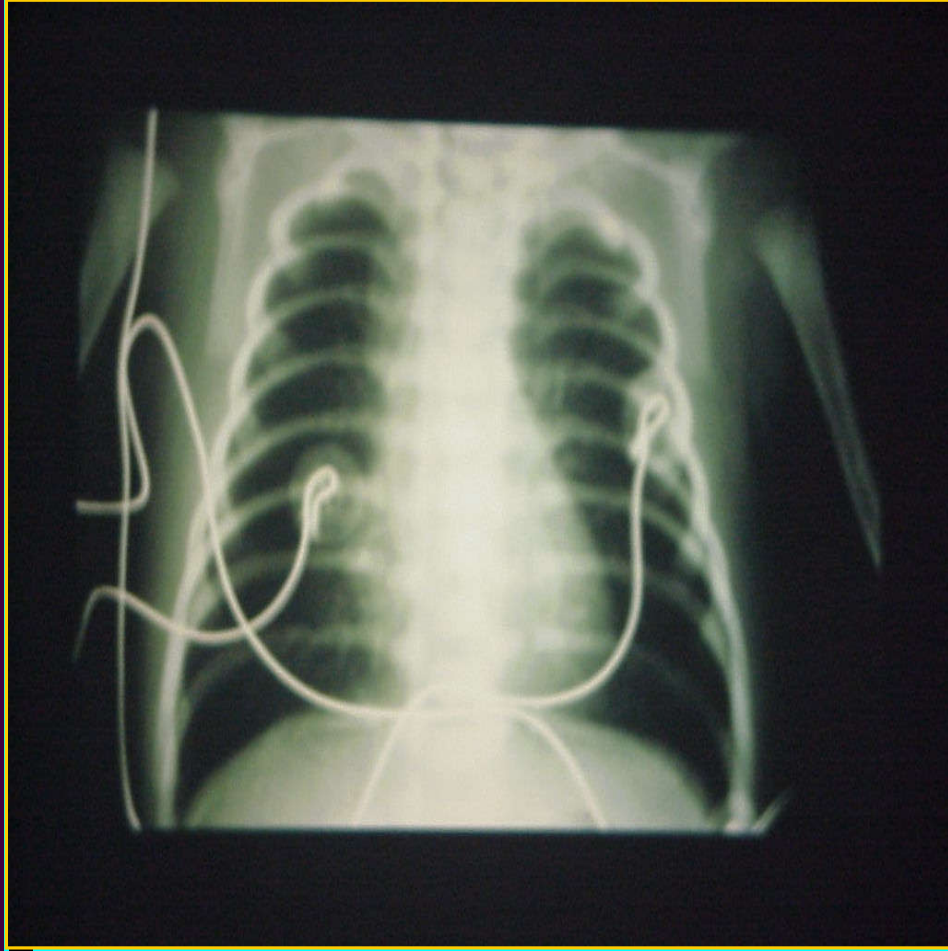


Froese, Crit Care Med 1997, 25:906

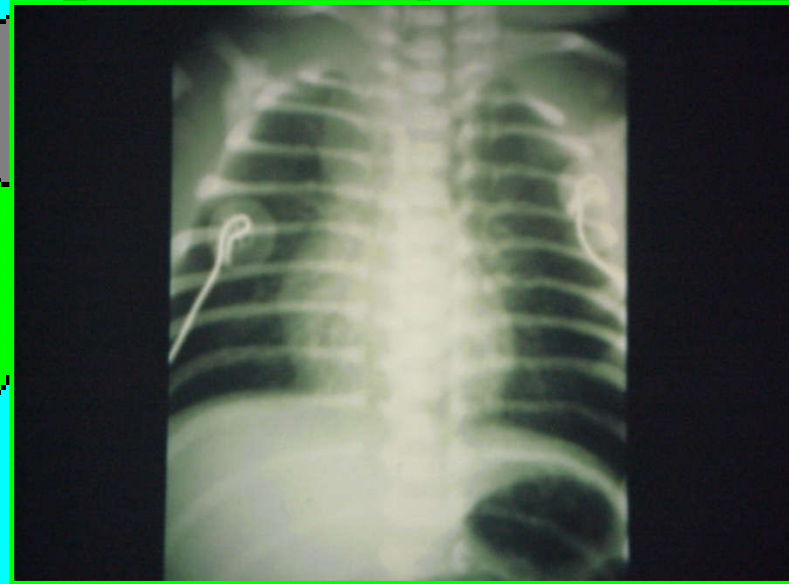
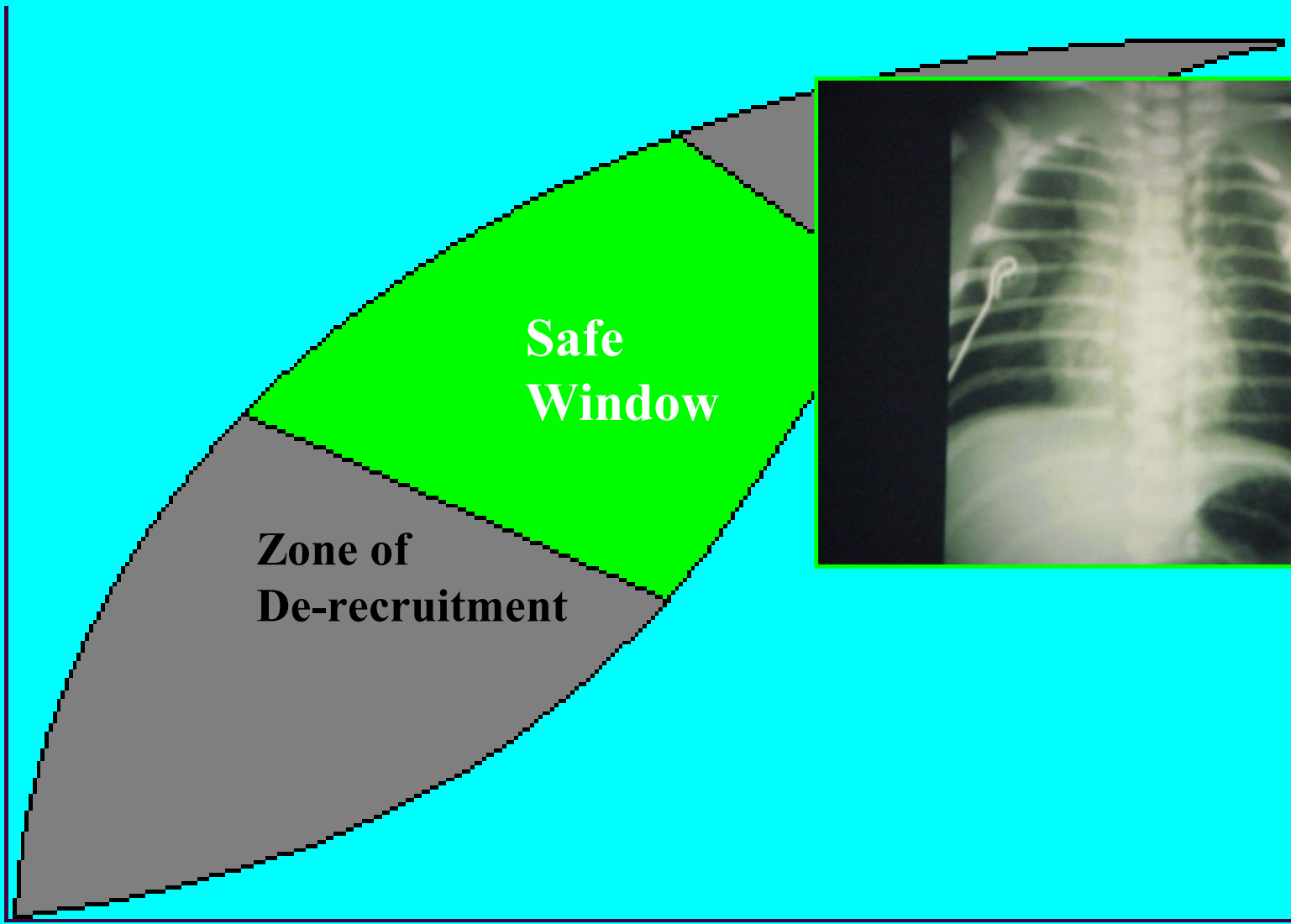


**Zone of  
De-recruitment**





**Zone of  
Over-distension**



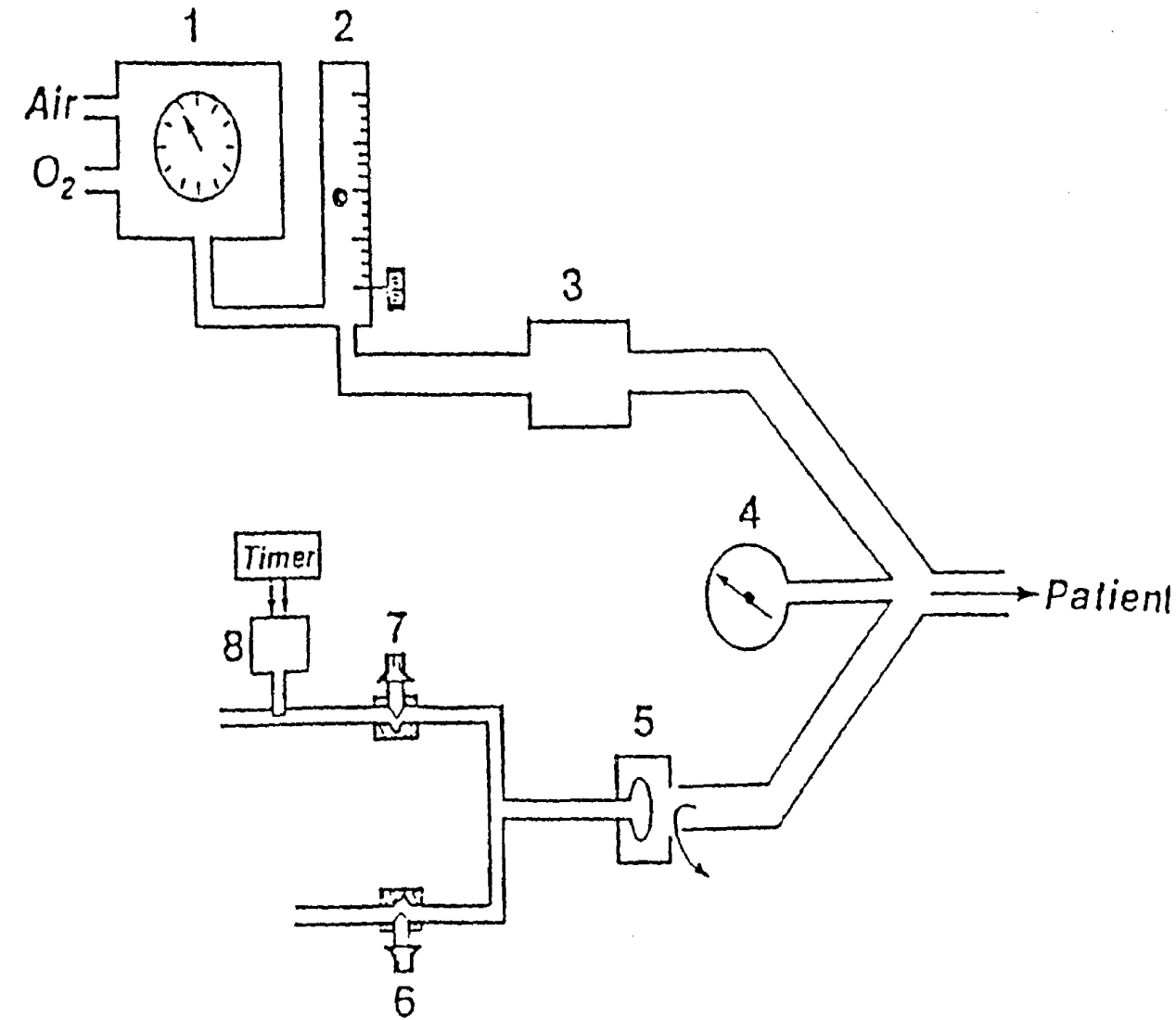
# Mechanical Ventilation Using Conventional Infant Ventilators

## 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%

(Alarm limit 85 – 95%)

# Conventional Ventilation

## Flow

- Usually 5 – 8 lpm
- Enough to reach PIP within  $T_i$
- Minimum flowrate to prevent rebreathing  $\text{CO}_2$  :  
minute ventilation (200ml/kg)  $\times$  2.5 plus air leak

# Conventional Ventilation(<40/min)

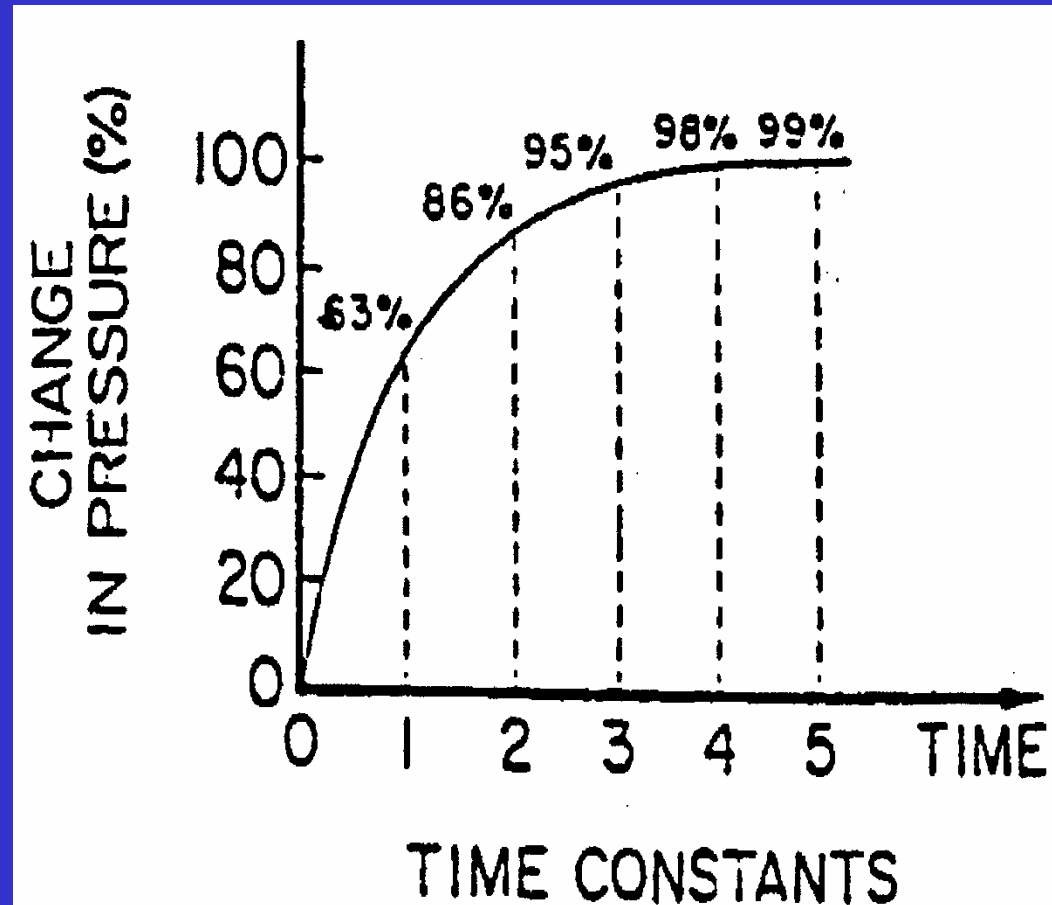
## IMV Rate

- Usually start at 20 – 40/min
- To keep PaCO<sub>2</sub> 40 – 70 mmHg
- To avoid excessive labored spontaneous breathings

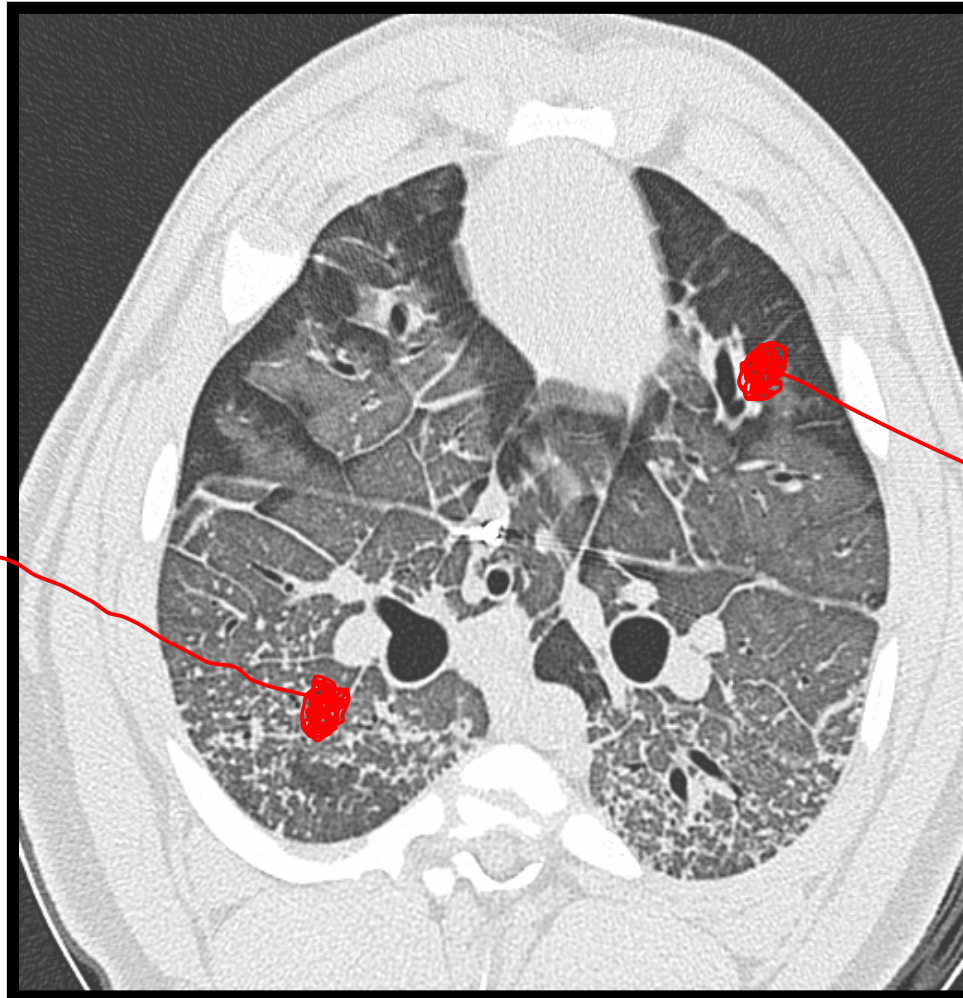
# Conventional Ventilation(<40/min)

$T_i$

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



$$T_c = C \times R$$



$$T_c = C \times R$$

$$T_c = C \times R$$

# Conventional Ventilation(<40/min)

## PIP

- Usually start at 20 cmH<sub>2</sub>O (15 cmH<sub>2</sub>O for preemie)
- To have adequate chest and/or abdominal excursion

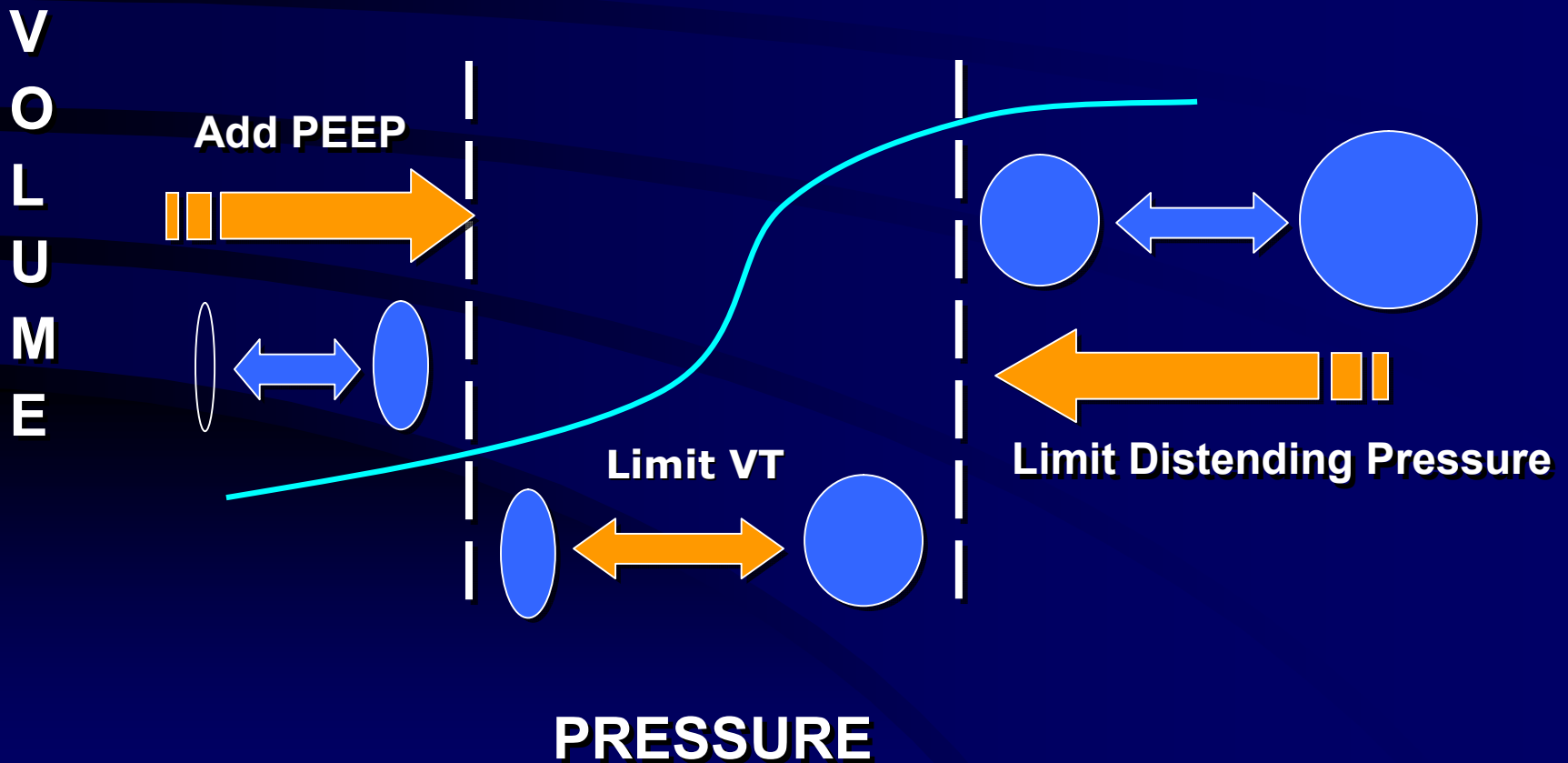
# Conventional Ventilation(<40/min)

## PEEP

- Usually 5 cmH<sub>2</sub>O
- 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.  $\text{FiO}_2$  to keep  $\text{PaO}_2$  50-70 mmHg
3. IMV rate
  - Usually started at 20-40/min.
  - Avoid excessive labored breathing
  - Maintain  $\text{PaCO}_2$  40-70 mmHg
4. Inspiration time ( $T_i$ ) 0.5 seconds
5. Peak inspiratory pressure (PIP)
  - Adequate chest excursions
  - Usually started at 20  $\text{cmH}_2\text{O}$  for term infant and 15  $\text{cmH}_2\text{O}$  for preemie
6. PEEP 5  $\text{cmH}_2\text{O}$

# Conventional Technique

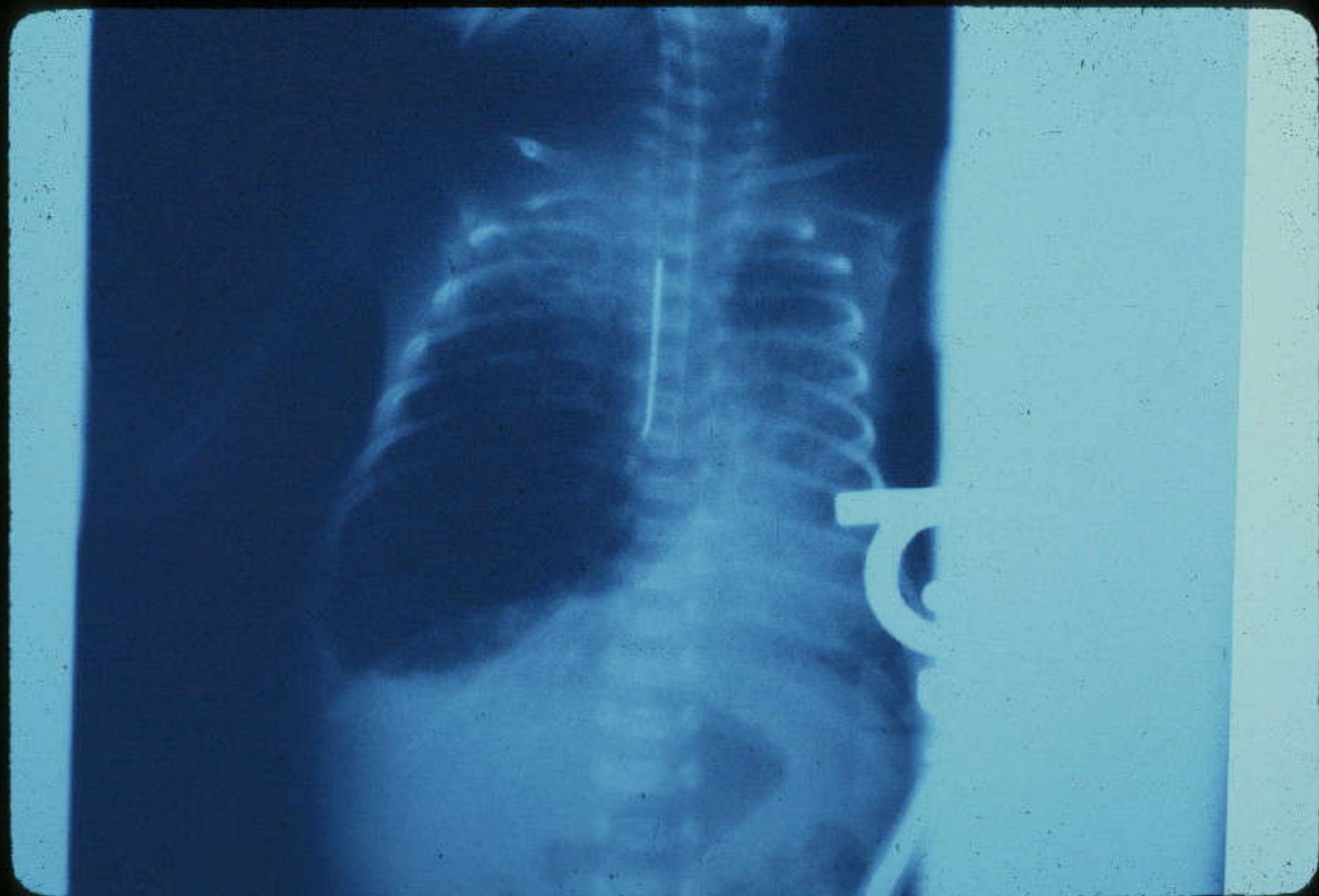
## Improvement

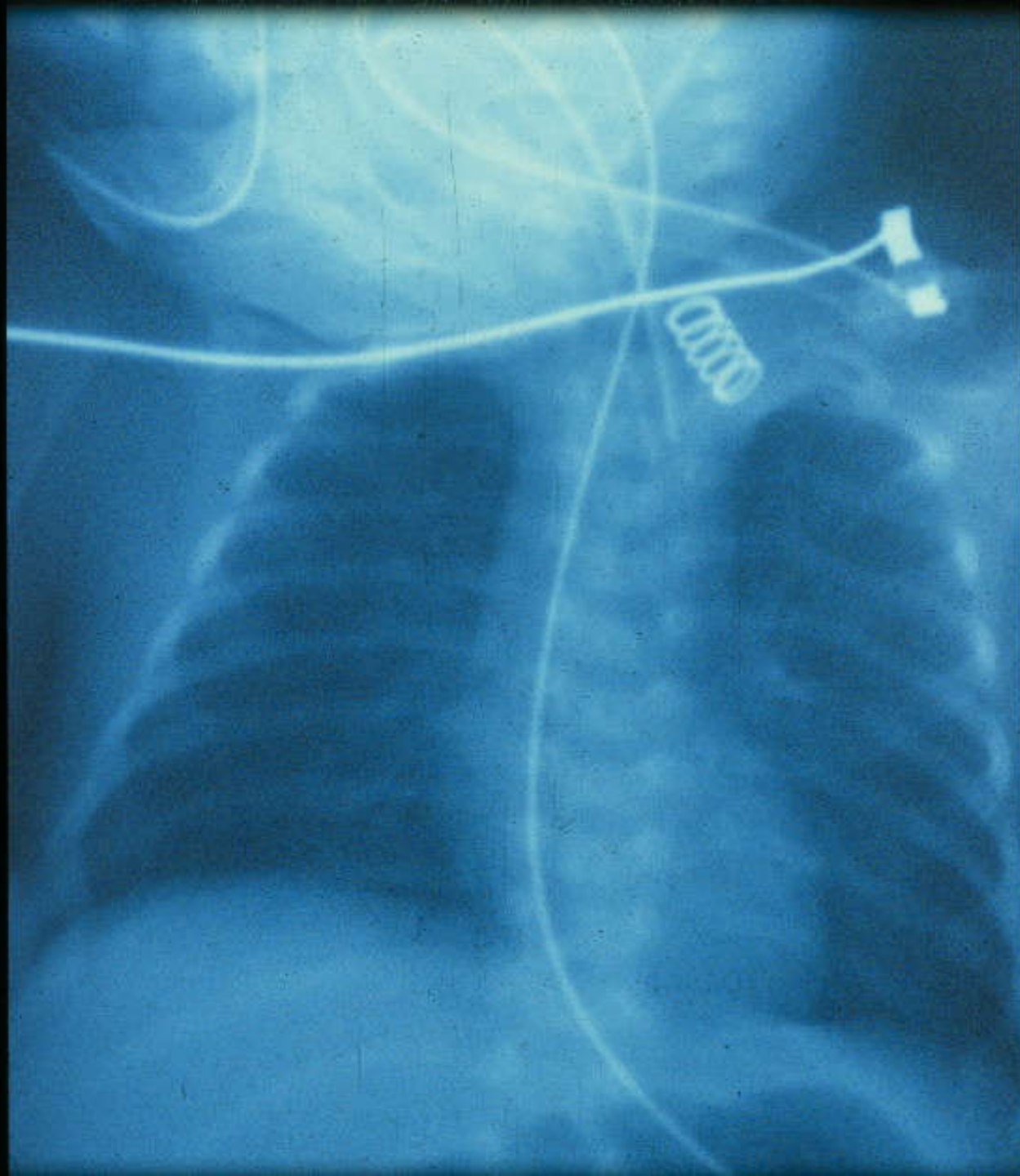
- Decrease IMV rate by 2-5/min for  $\text{PaCO}_2 < 50$  mmHg
- Decrease PIP by 2-5cmH<sub>2</sub>O for excessive chest excursion
- Decrease  $\text{FiO}_2$  by 1/10 for  $\text{PaO}_2 > 60$ mmHg
- Usually no change for flow rate,  $T_i$  or PEEP

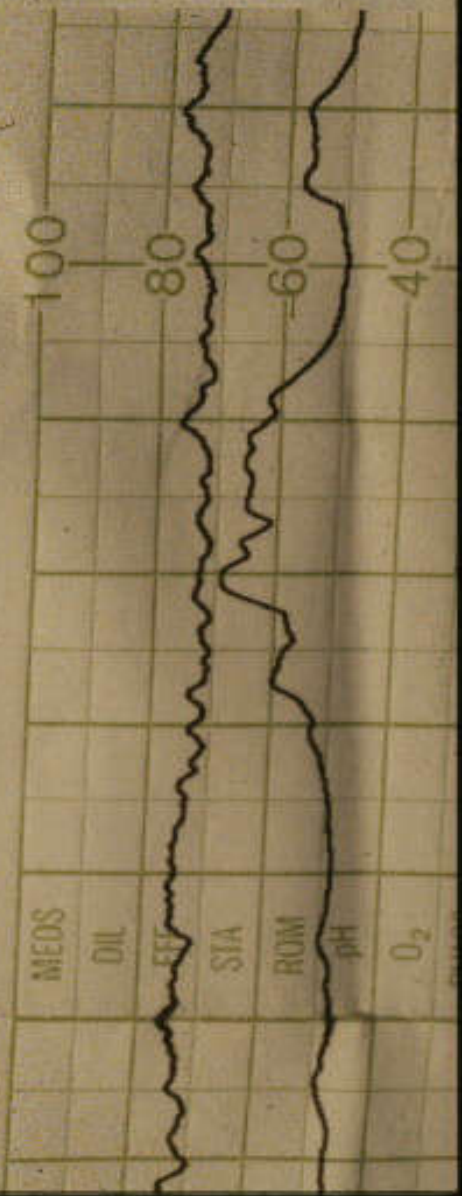
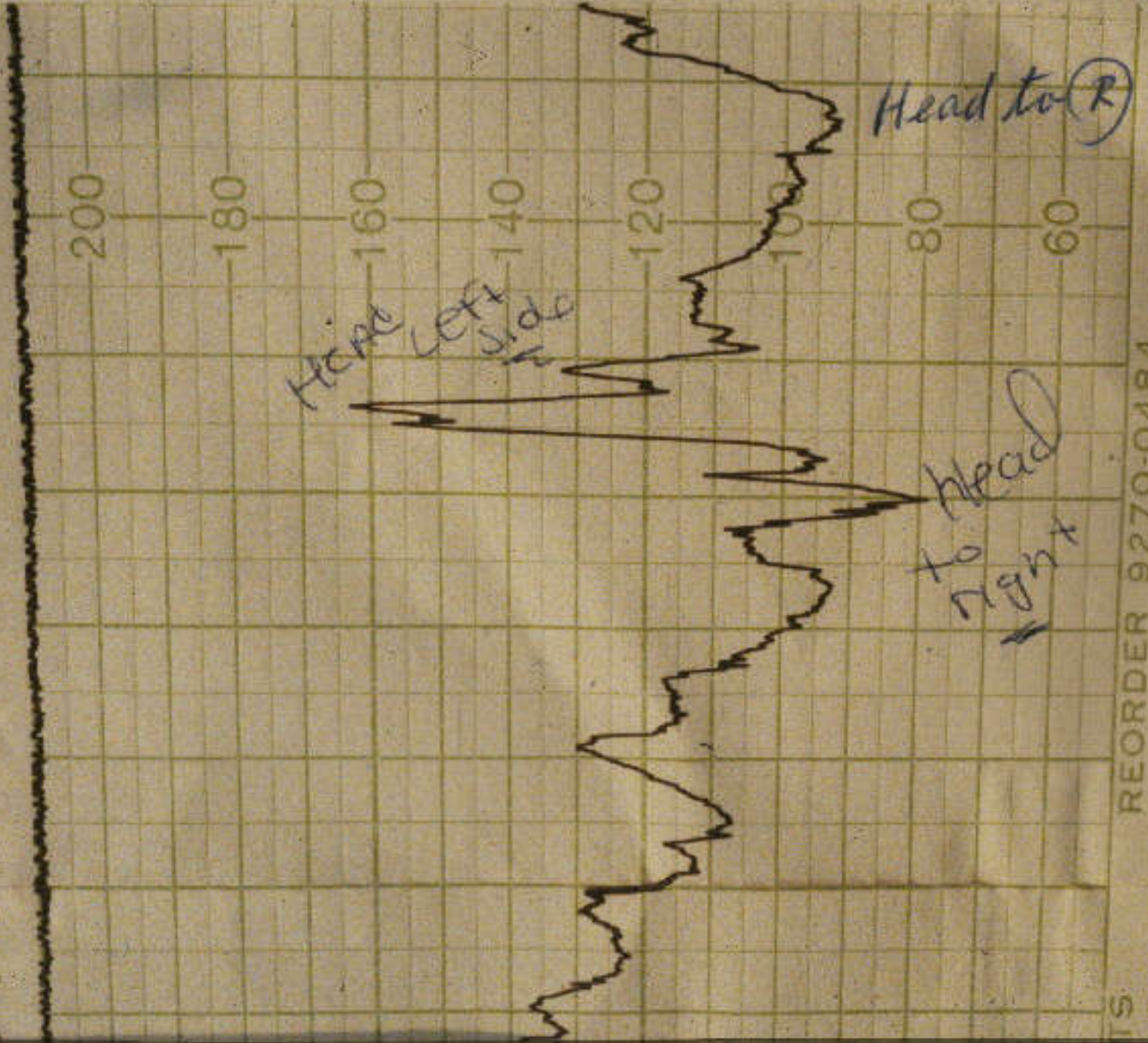
# Conventional Technique

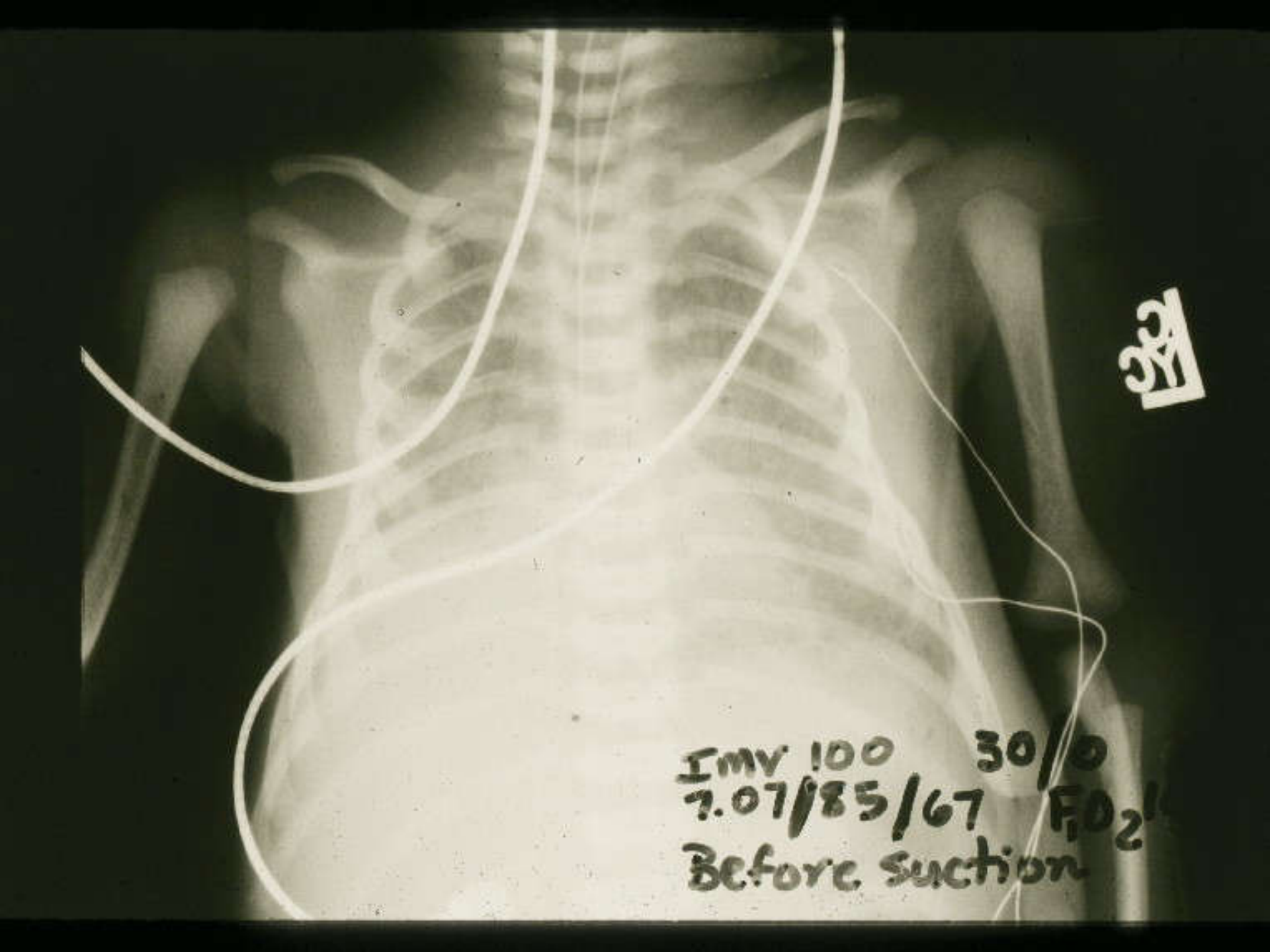
## Deterioration

- R/O ET tube obstruction, pneumothorax, underventilation, overventilation, etc.
- For  $\text{PaCO}_2 > 70 \text{ mmHg}$  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  $\text{FiO}_2$





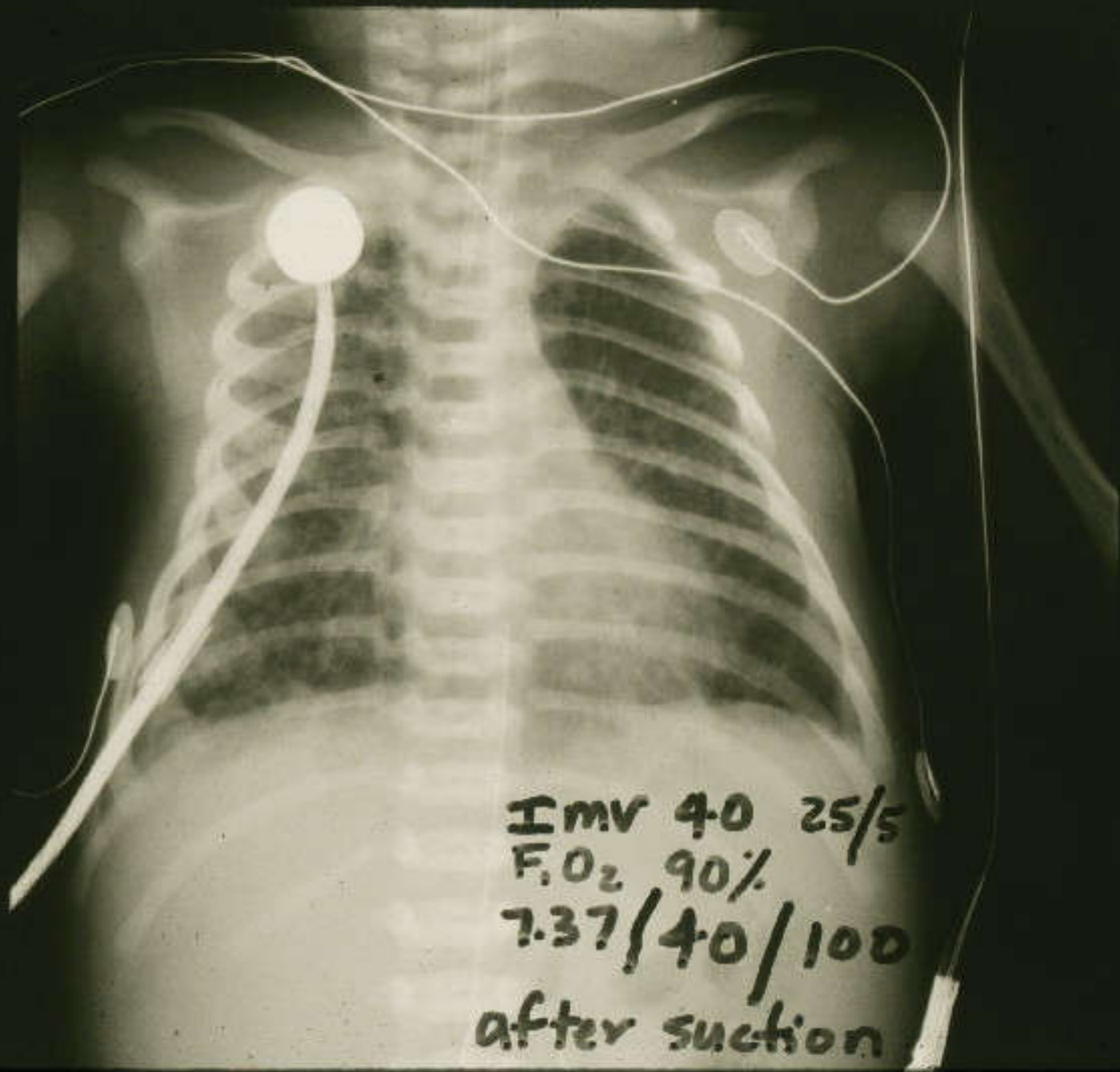




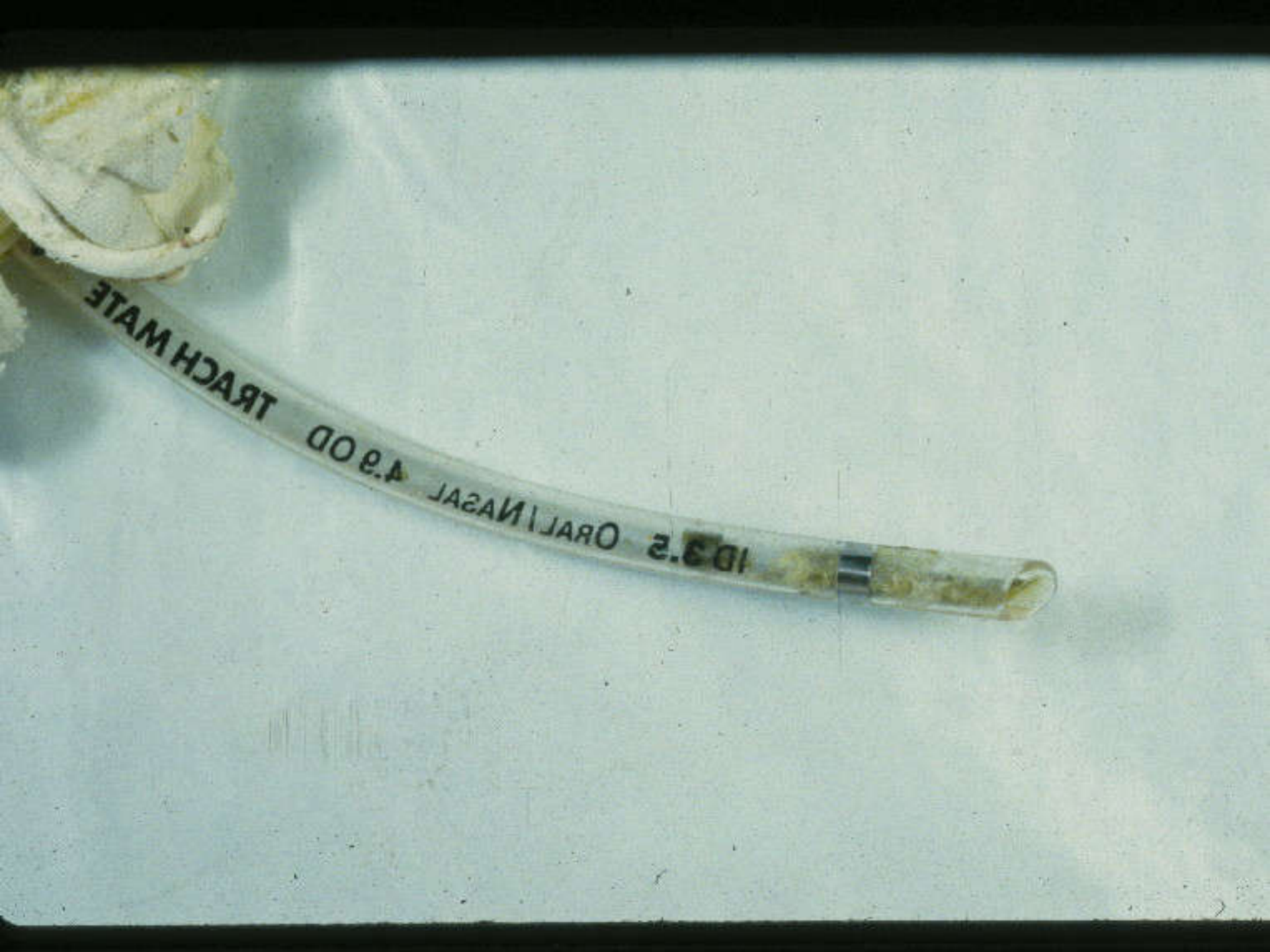
IMV 100 30/0  
7.07/85/67 F<sub>1</sub>O<sub>2</sub>  
Before suction

A chest X-ray showing the ribcage and spine. Two white tubes are visible, one on each side, curving around the chest. The image is somewhat faded and has a dark background.

322



IMV 4.0 25/5  
F.O<sub>2</sub> 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.  $\text{PaO}_2 < 50$  mm Hg with an  $\text{FiO}_2$  100%
2.  $\text{PaO}_2$  is very labile
3.  $\text{PIP} > 30$  cm  $\text{H}_2\text{O}$  to achieve visible chest excursions
4.  $\text{PaCO}_2 > 70$  mm Hg or excessive labored spontaneous breathing with IMV rate up to 40/min.
5. Pulmonary interstitial 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)



Pressure Control

Automode

Admit patient

Nebulizer

Status

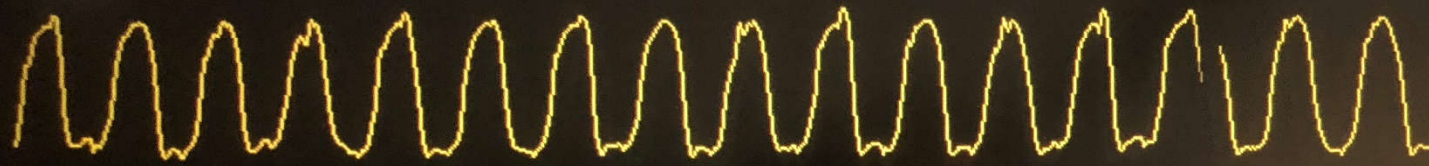
Check battery status

Respiratory Rate: High



1:46

30 cmH<sub>2</sub>O



Ppeak (cmH<sub>2</sub>O)

18

28

Pmean (cmH<sub>2</sub>O)

11

PEEP (cmH<sub>2</sub>O)

6

20 l/min BTPS



RR (b/min)

100

80

20

O<sub>2</sub> (%)

26

30

20

I:E

1.0:1

50 ml BTPS



MVe (l/min)

3.0

3.2

0.5

VTi (ml)

31

VTe (ml)

30

Additional settings

O<sub>2</sub> conc.

25

21 % 100 0

PEEP

1

cmH<sub>2</sub>O 50 4

Resp. Rate

100

b/min 150 0

PC above PEEP

18

cmH<sub>2</sub>O 80

Additional values

# 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 ( $T_i$ ): 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
- $T_i$ : 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	↓		↓	↑	↓	

Volume Control

SIMV (Press. Contr.)  
+ Pressure Support

Pressure Control

SIMV (PRVC)  
+ Pressure Support

PRVC

PS/CPAP

Volume Support

SIMV (Vol. Contr.)  
+ Pressure Support

# Set Ventilation Mode

SIMV (Press. Contr.)  
+ Pressure Support

Cycle T 1.5 s

Mandatory breath

Insp. times

Trigger

Supported breath

PC above PEEP

15

cmH<sub>2</sub>O

Ti

0.50

s

Trigg. Flow

5

PS above PEEP

5

cmH<sub>2</sub>O

SIMV rate

10

b/min

T insp. rise

0.15

s

Insp. cycle off

30

%

PEEP

6

cmH<sub>2</sub>O

O<sub>2</sub> conc.

35

%

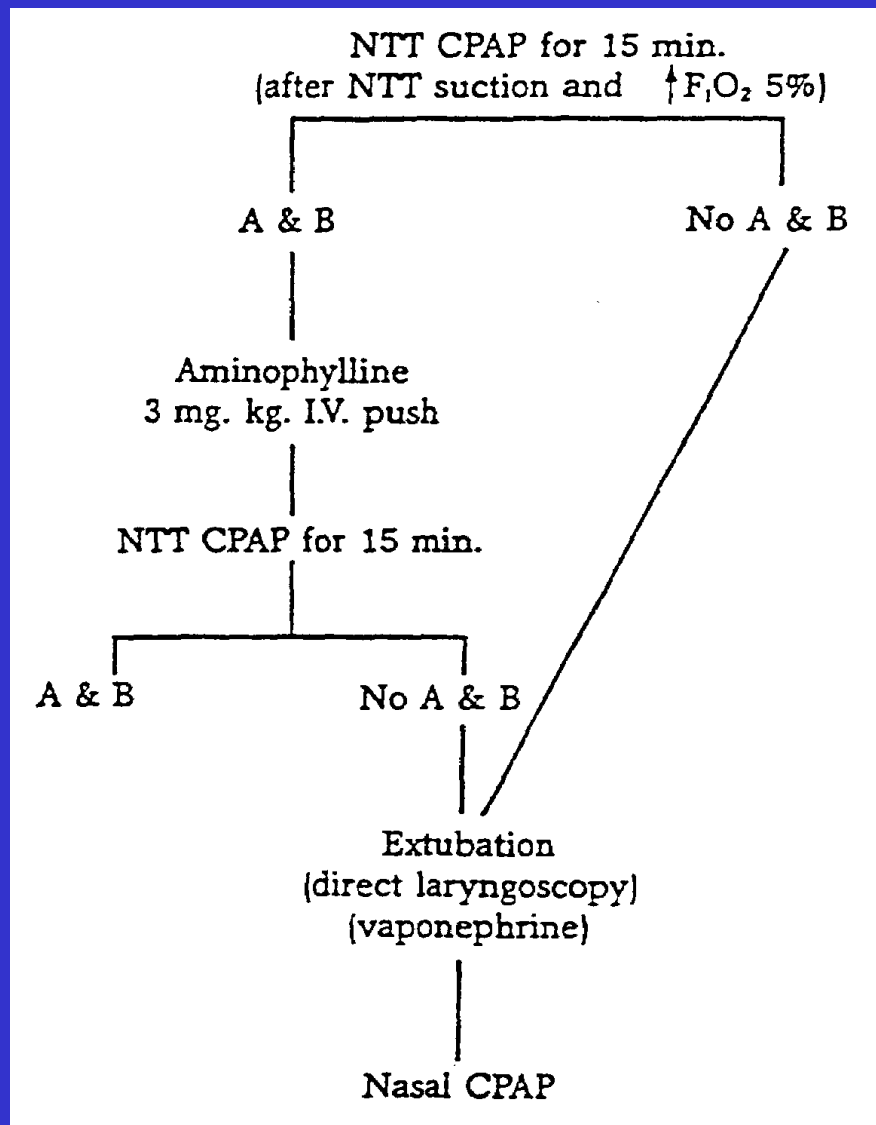
# Mechanical Ventilation

## Extubation

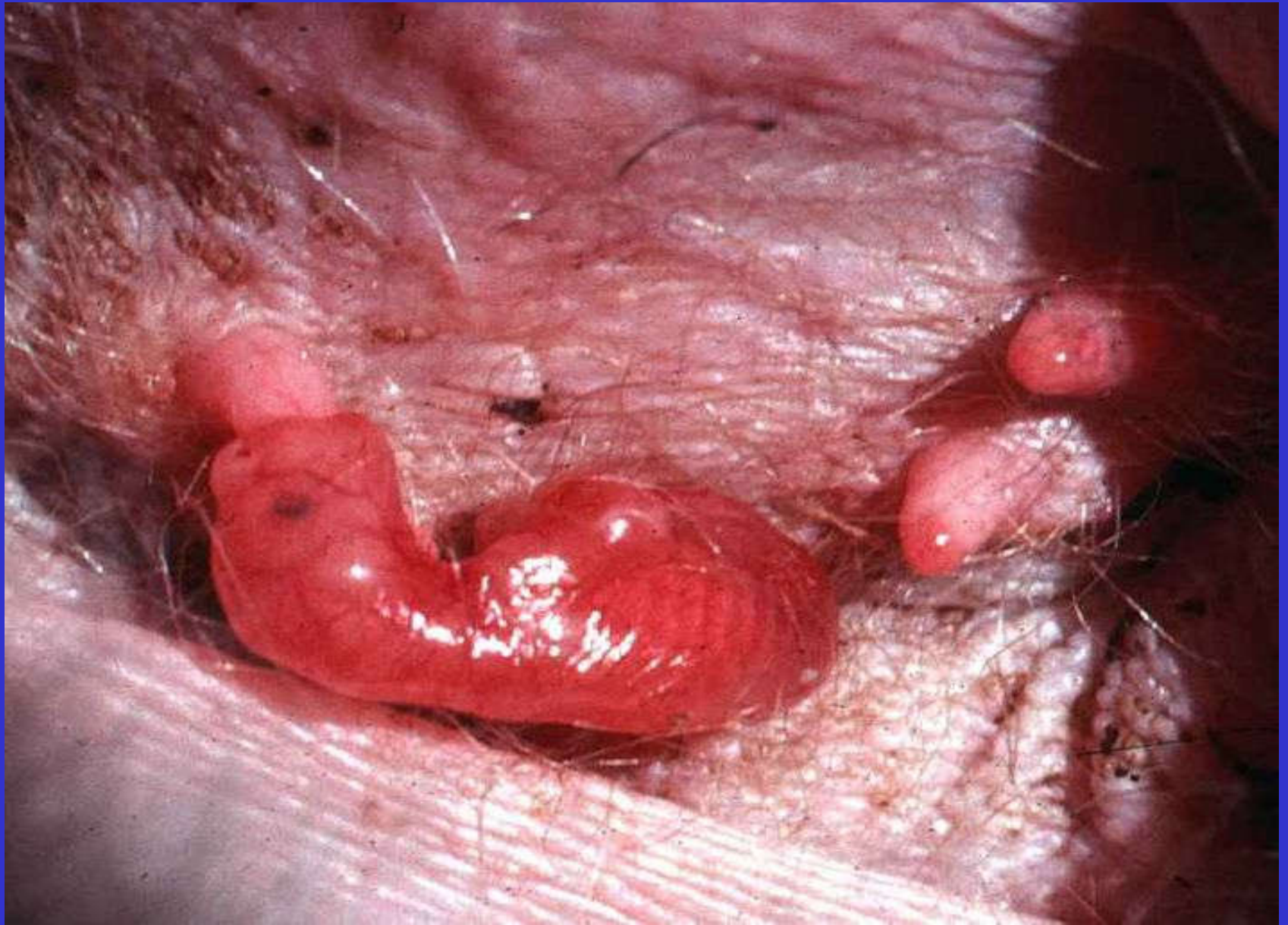
Condition is improved and stable

- IMV rate  $\leq 20/\text{min}$
- Flip-flopped PaCO<sub>2</sub> due to ET tube obstruction from retention of secretions or tube bevel against tracheal wall, otherwise, patient is active.

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



# KANGAROO NEWBORN



“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

---

Amnesia Hypnosis Anxiolysis

---

Selective  $\alpha_2$  adrenoreceptor agonist

Dexmedetomidine (precedex)

Loading :1 ug/kg over 10-20 minutes

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

# Extubation of neonates on ECMO

## Can we learn from the Adults?



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

Joseph P. Tobias

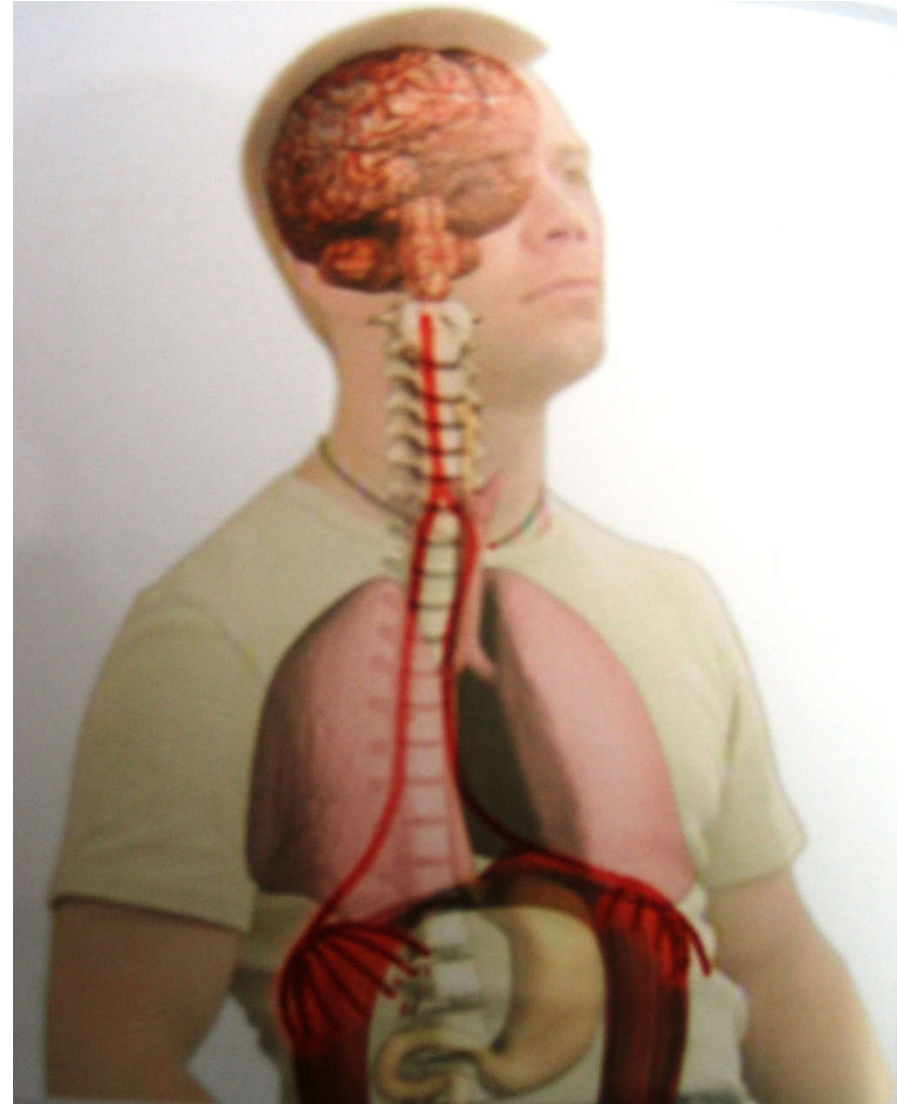
Crit Care Med 2000; 28: 2122-32

# 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.

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 descent 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 --> NAVA



Diaphragm contraction



Chest wall and lung expansion



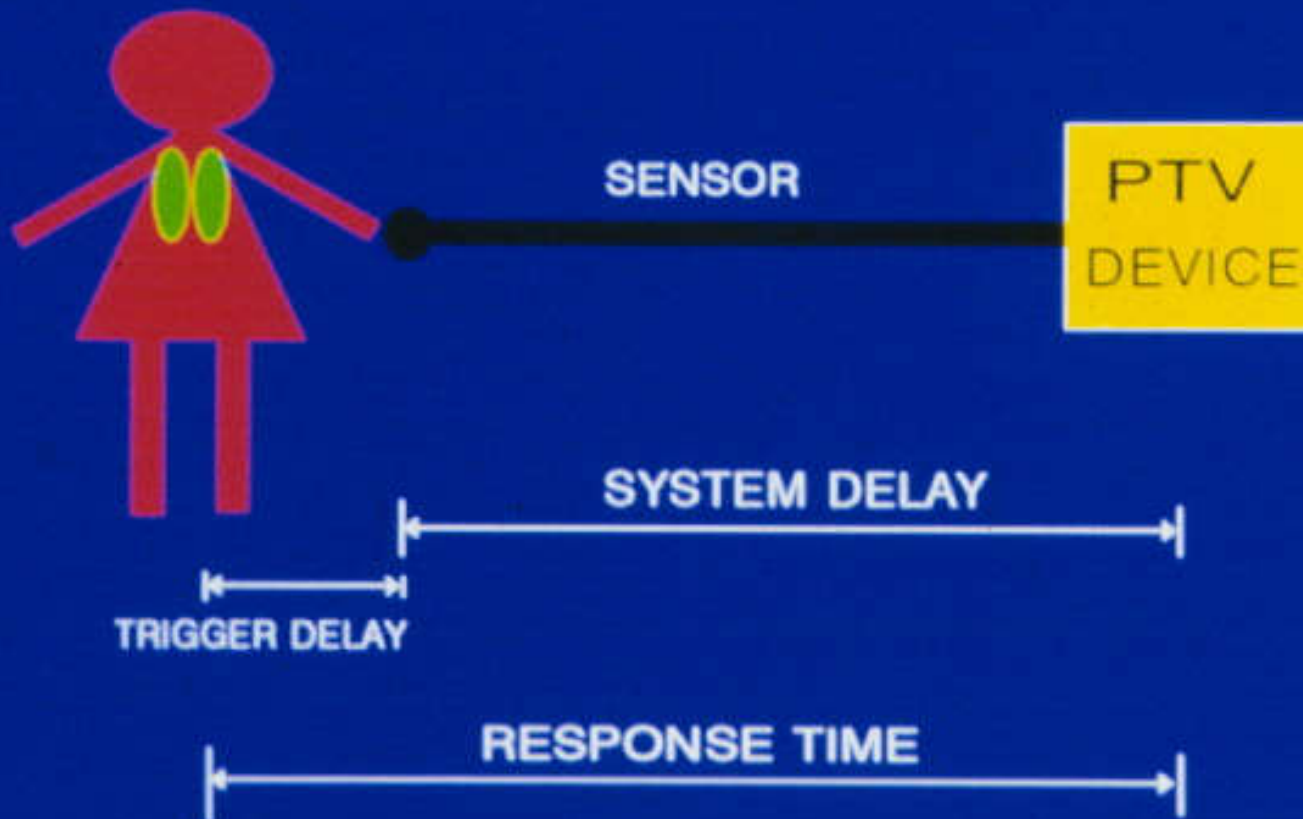
Airway pressure drop, flow reversal --> PTV

NAVA (Neurally Adjusted Ventilatory Assist)

# 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



# 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

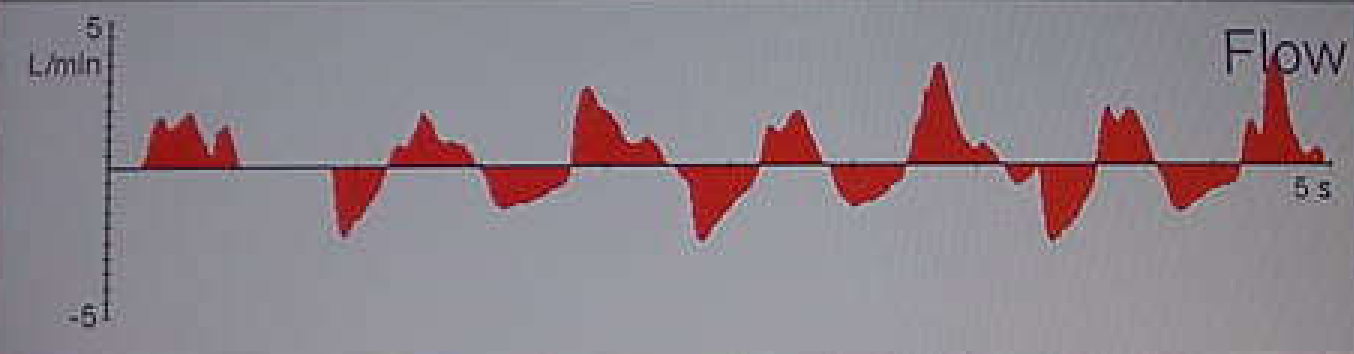
- High respiration rate, short inspiration time, irregular respiratory frequency
- Variability in inspiratory effort
- Asynchronous chest wall movement
- Frequent apnea
- Airleak around ET tube or chest tube
- Frequent motion artifact

# Patient Triggered Ventilation

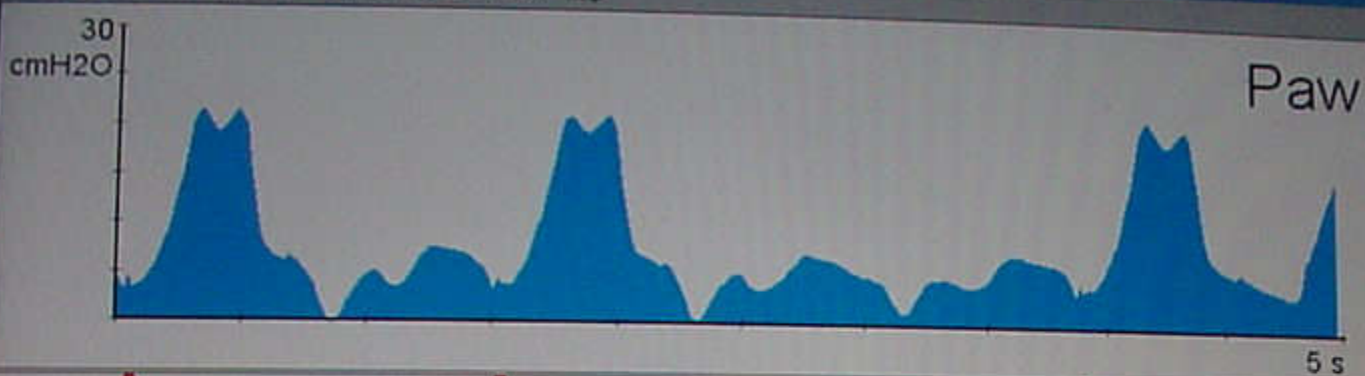
## Beware of

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

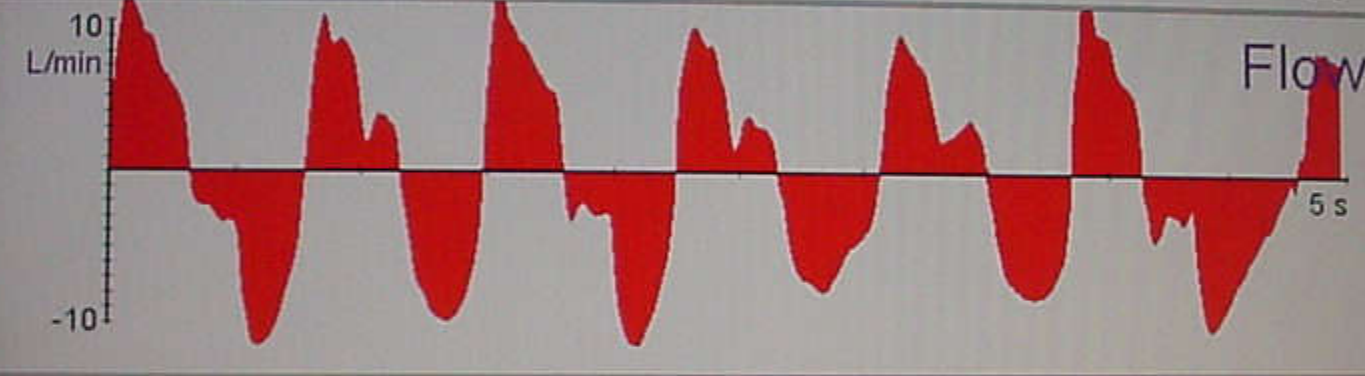
<b>IMV</b>	<b>SIMV</b>	<b>A/C</b>	<b>PS</b>
Flowrate	Flowrate	Flowrate	Flowrate
FiO2	FiO2	FiO2	FiO2
IMV rate	SIMV rate	Patient, <b>Backup rate</b>	Patient, <b>Backup rate</b>
Ti	Ti	Ti	Insp. cycle off
PIP	PIP	PIP	Support P.
PEEP	PEEP	PEEP	PEEP
	Sensitivity	Sensitivity	Sensitivity
	Sync.	Synchronization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



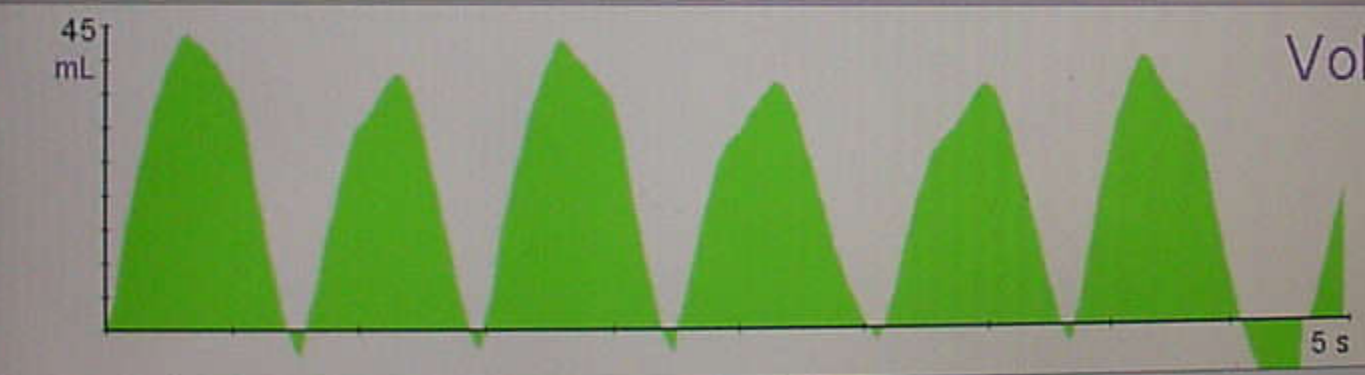
CMV	
P <sub>peak</sub> cmH <sub>2</sub> O	20
P <sub>mean</sub> cmH <sub>2</sub> O	10
PEEP cmH <sub>2</sub> O	5



SIMV



Ppeak cmH2O  
21



Pmean cmH2O  
7

PEEP cmH2O  
6

Waveforms

F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12

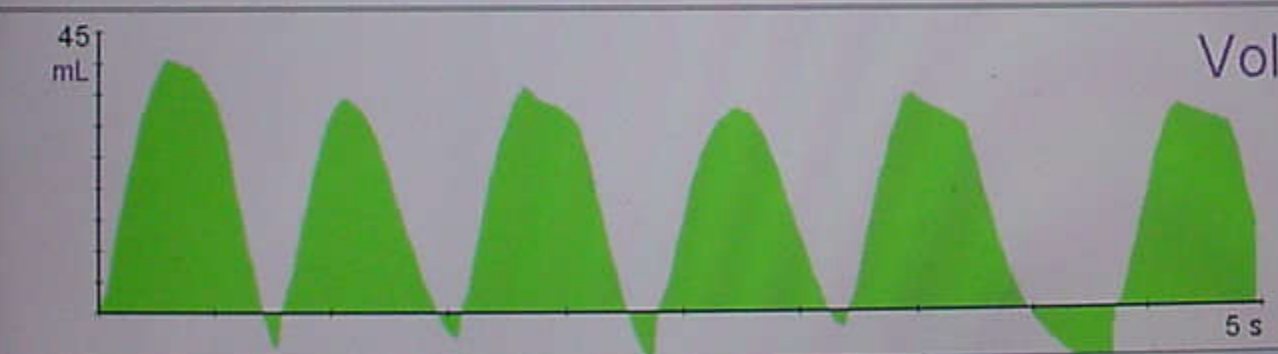
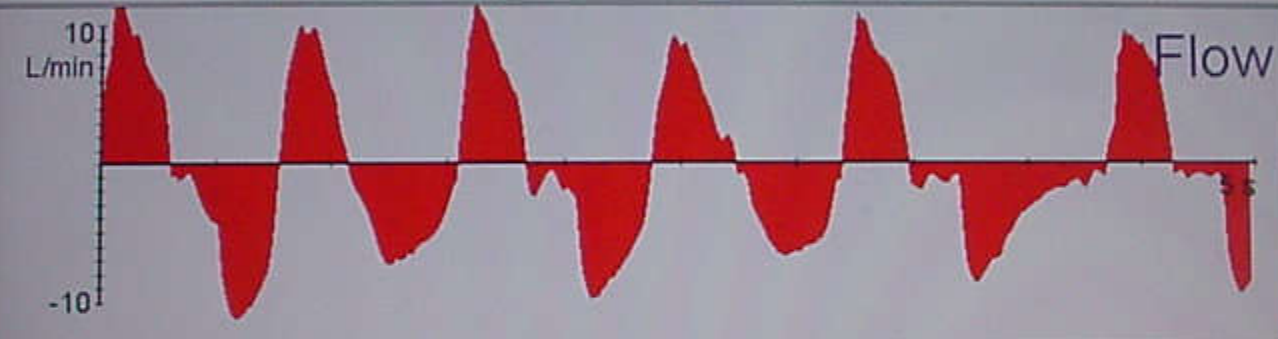


SIMV + VG

Ppeak cmH<sub>2</sub>O  
20

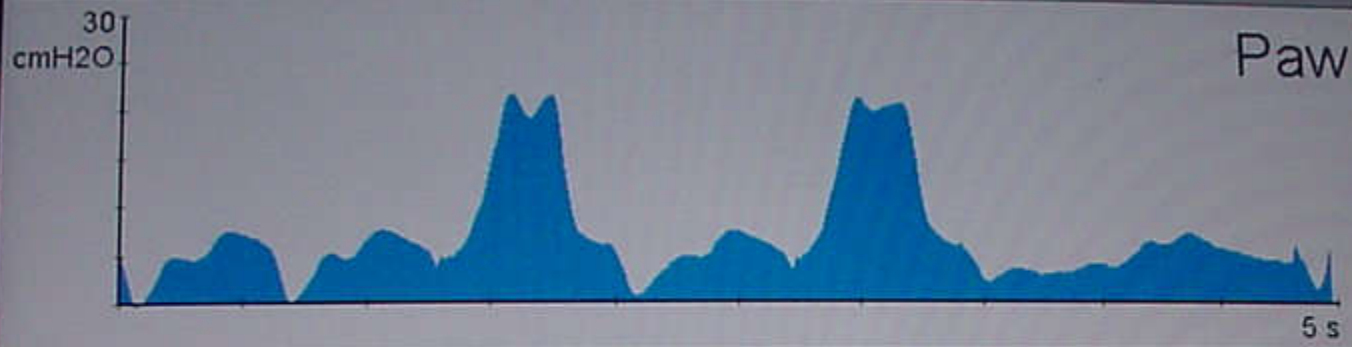
Pmean cmH<sub>2</sub>O  
9

PEEP cmH<sub>2</sub>O  
6

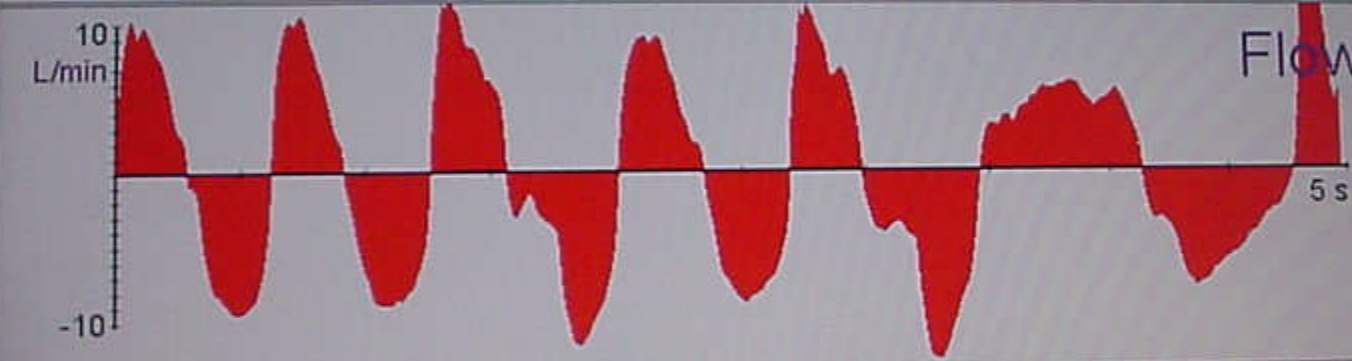


Waveforms

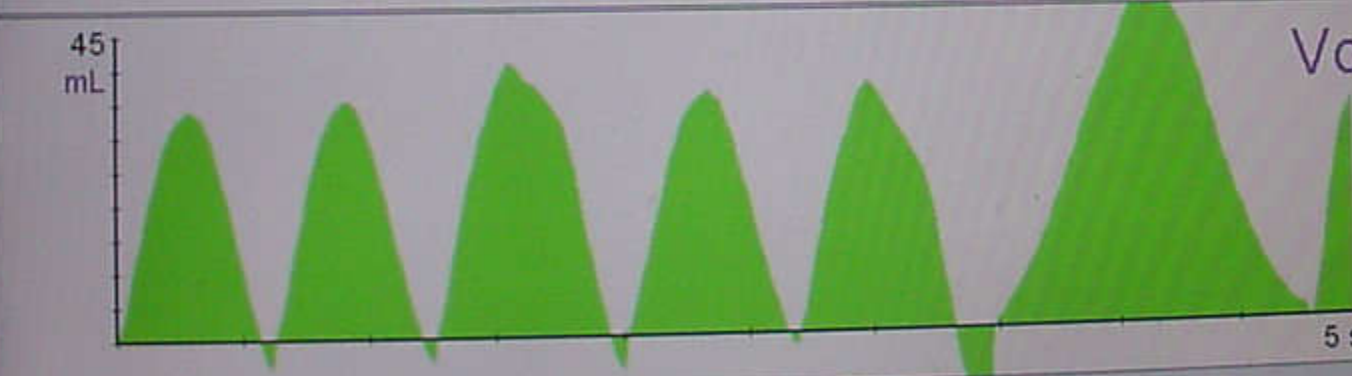
Navigation icons for various waveforms and settings: P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12.



SIMV + VG



Ppeak cmH2O  
21



Pmean cmH2O  
8

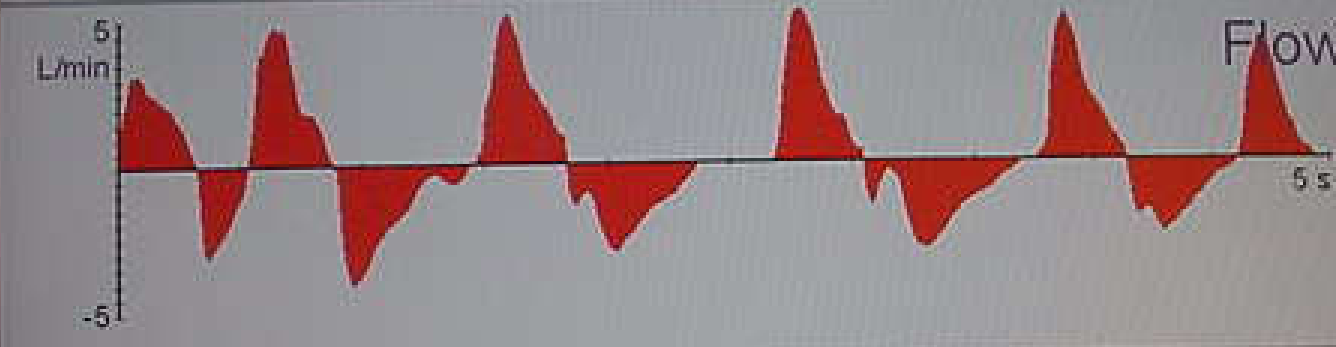
PEEP cmH2O  
6

Waveforms

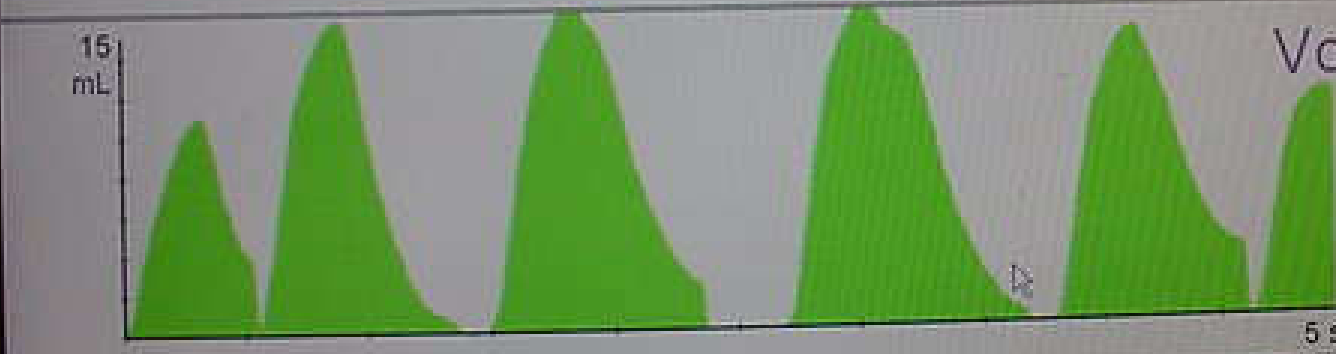
Navigation icons for various parameters: P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12. Includes a help icon (?) and a search icon (+). A system tray at the bottom right shows the time 8:29 PM.



A/C



Ppeak cmH2O  
20



Pmean cmH2O  
10

PEEP cmH2O  
5

Waveforms

Navigation icons for various monitoring and control functions.





# SIMV + PS

SIMV (Press. Contr.) + Pressure Support

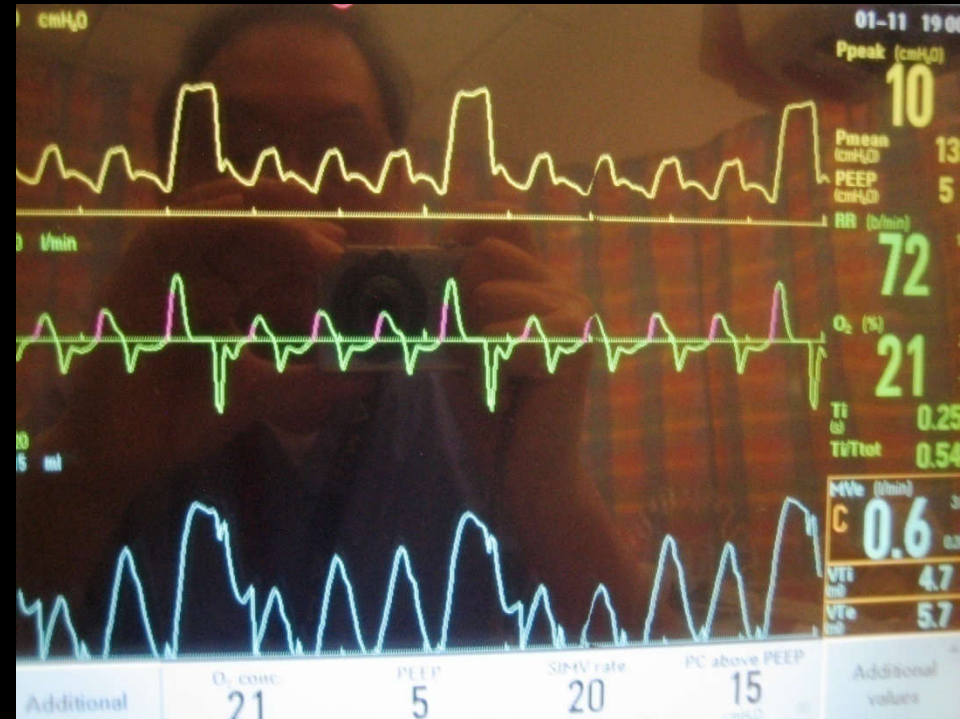
Admit patient    Nebulizer

**Set Ventilation Mode**

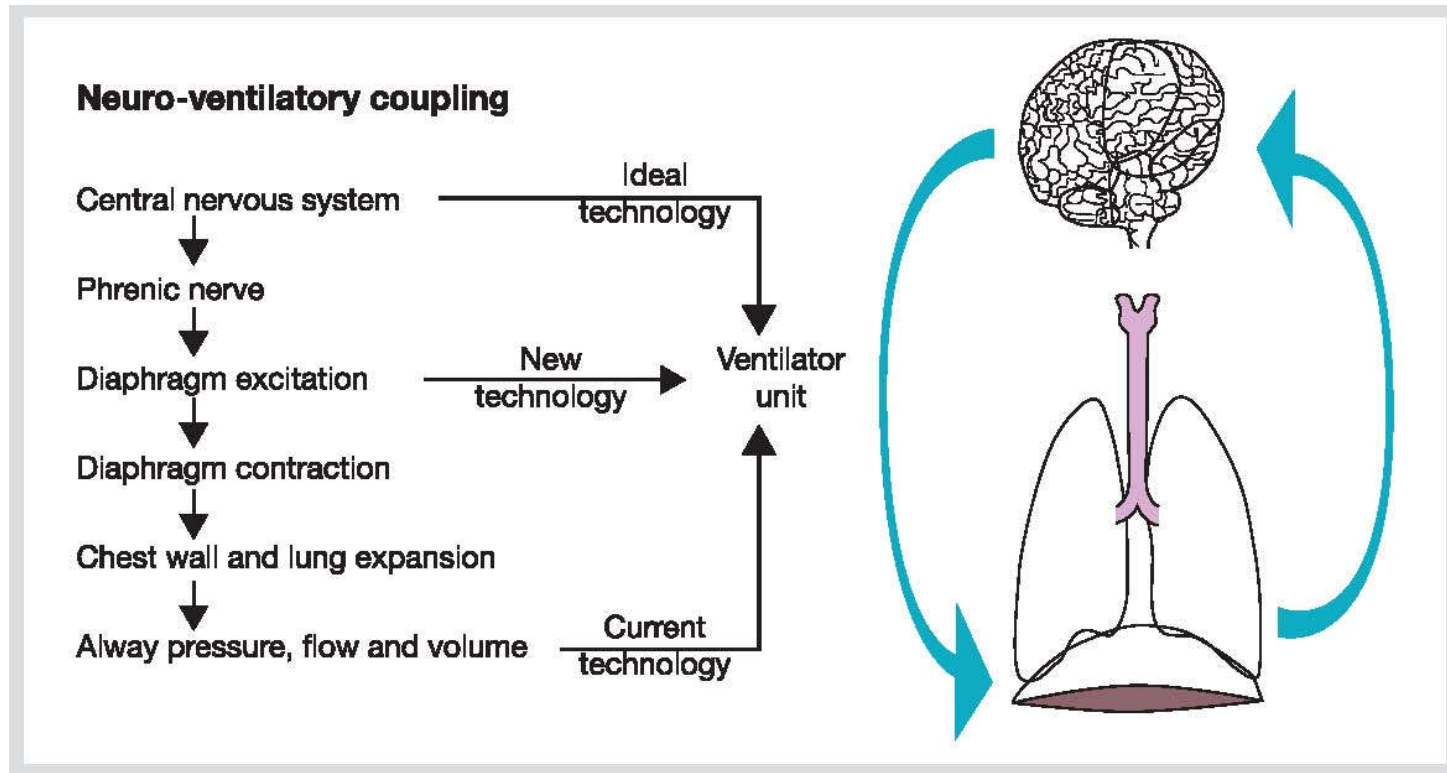
SIMV (Press. Contr.) + Pressure Support

Cycle T 1.5 s

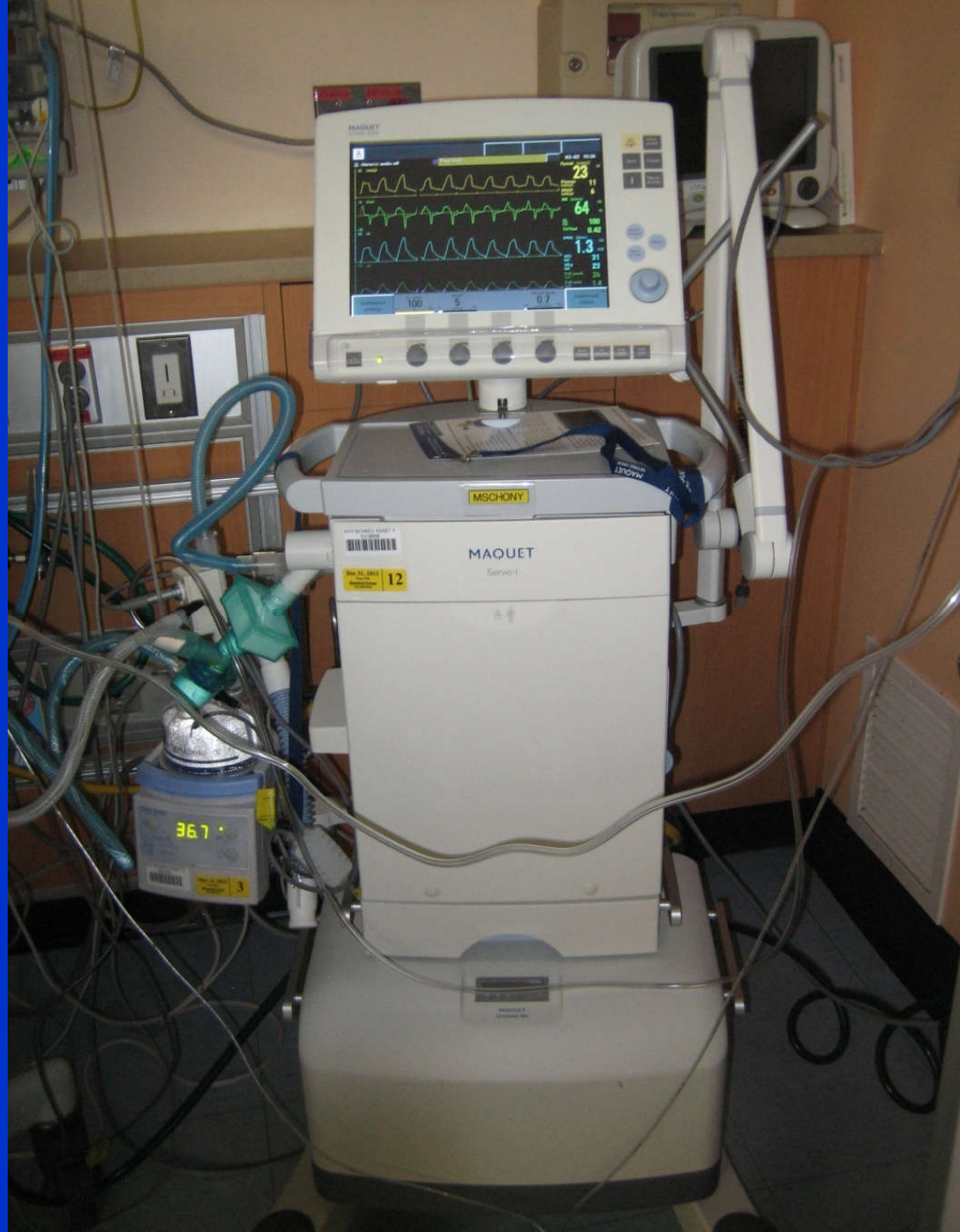
Mandatory breath	Insp. times	Trigger	Supported breath
PC above PEEP <b>15</b> cmH <sub>2</sub> O	Ti <b>0.50</b> s	Trigg. Flow <b>5</b>	PS above PEEP <b>5</b> cmH <sub>2</sub> O
SIMV rate <b>20</b> b/min	T insp. rise <b>0.15</b> s	Insp. cycle off <b>15</b> %	
PEEP <b>5</b> cmH <sub>2</sub> O			
O <sub>2</sub> conc. <b>21</b> %			



# Patient Ventilator Interaction



Nature 1999



Central nervous system



Phrenic nerve



Diaphragm excitation --→ NAVA



Diaphragm contraction



Chest wall and lung expansion

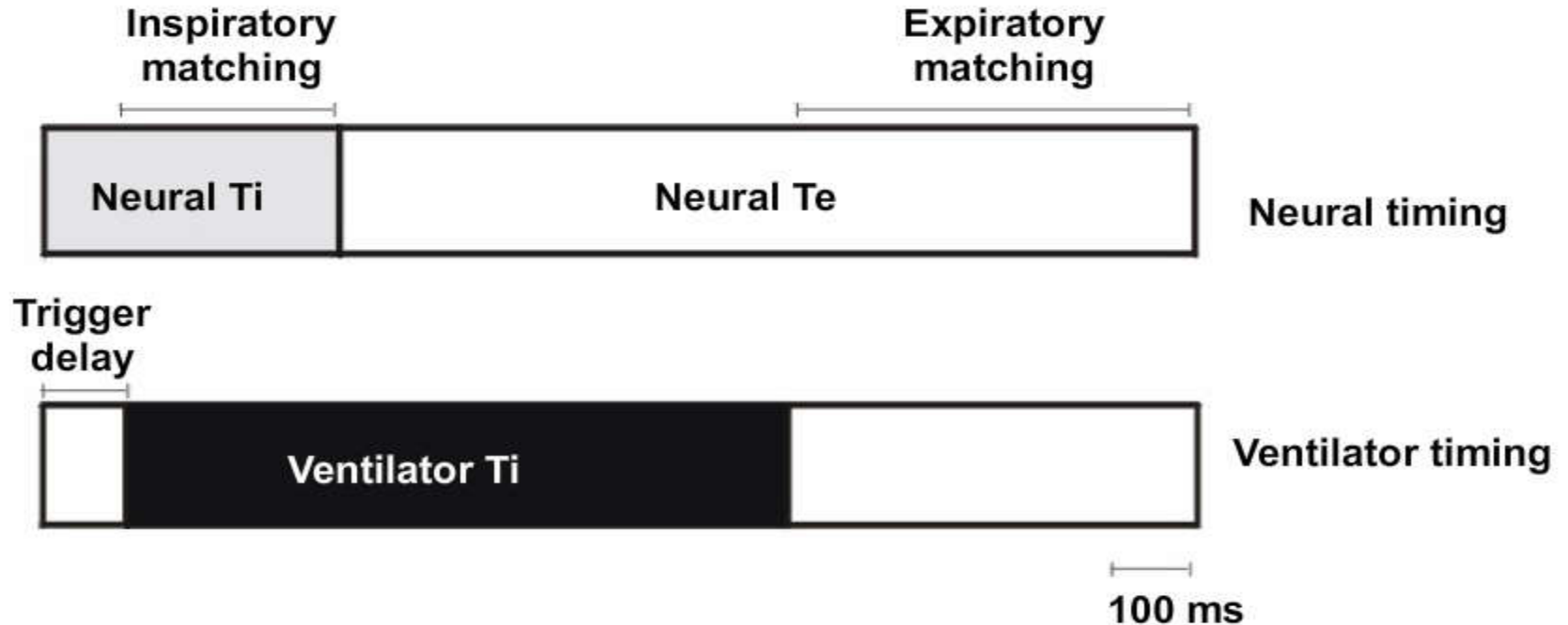


Airway pressure drop, flow reversal --→ PTV

NAVA (Neurally Adjusted Ventilatory Assist)



# Asynchrony



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

# NAVA

Formula for estimating peak pressures:

$$P_{\text{peak est.}} = \text{NAVA level} \times (\text{Edi}_{\text{peak}} - \text{Edi}_{\text{min}}) + \text{PEEP}$$

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



6 FR / 50 NASALLY 21.5 cm



SIMV (Press. Contr.)  
+ Pressure Support

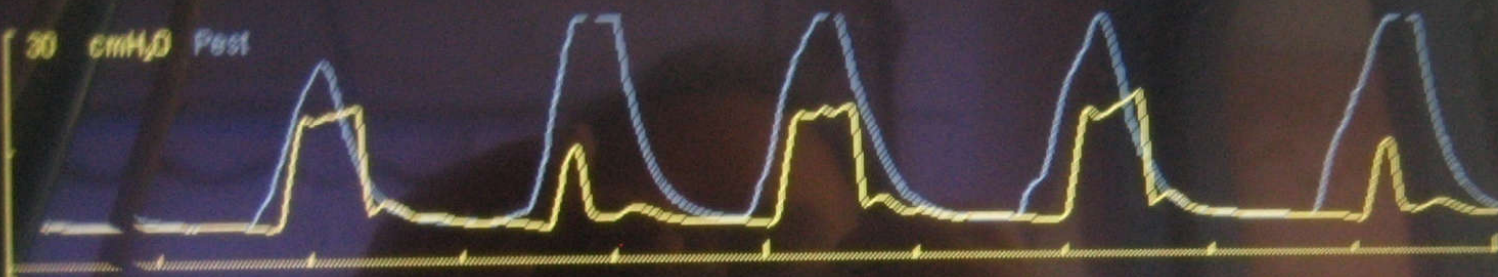
Admit  
patient

Nebulizer

Status  
G

02-09 09:04

30 cmH<sub>2</sub>O P<sub>est</sub>



P<sub>peak</sub> (cmH<sub>2</sub>O)

15

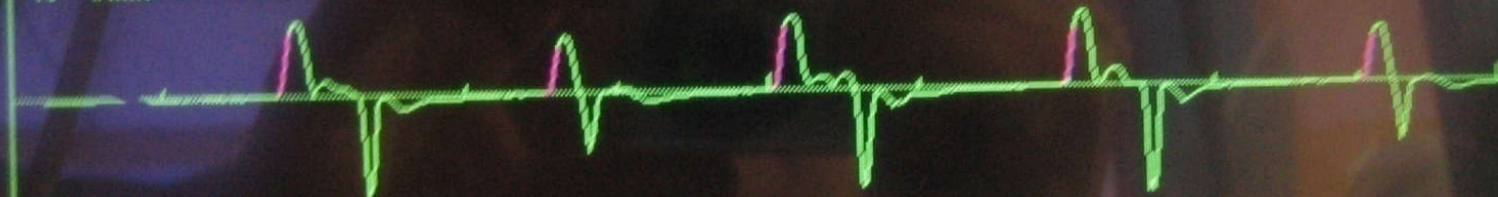
P<sub>mean</sub> (cmH<sub>2</sub>O)

9

PEEP (cmH<sub>2</sub>O)

5

15 l/min



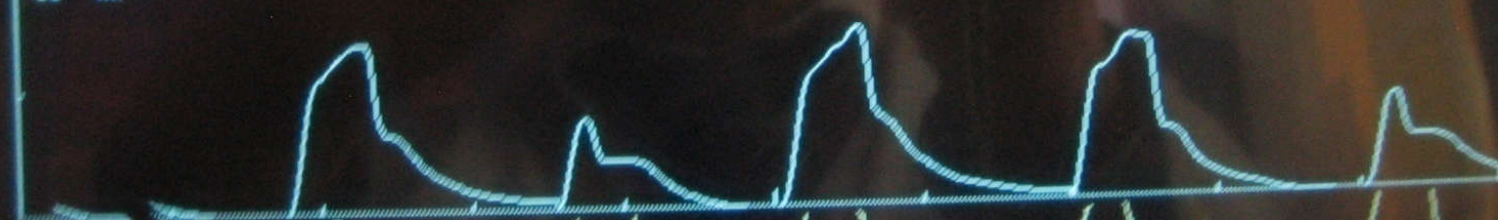
RR (b/min)

31

O<sub>2</sub> %

60

-15 ml



Ti/Tot

0.26

MVe (l/min)

0.5

VTi (ml)

12.0

VTe (ml)

20

70 μV



Edi peak (μV)

116

Edi min (μV)

0.2

O<sub>2</sub> conc

PEEP

SIMV rate

PC above PEEP

15

Additional

NAVA

Admit patient

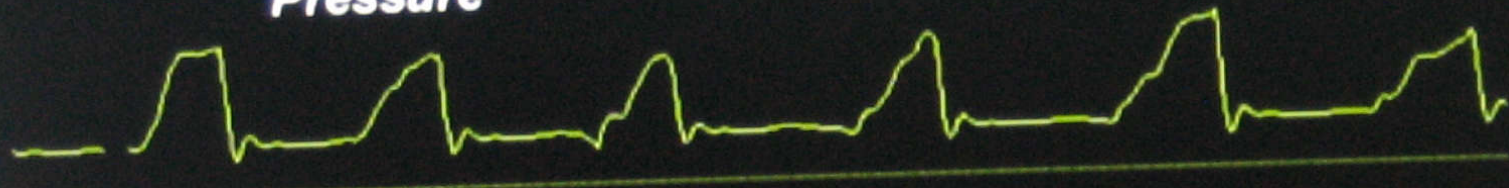
Nebulizer

Status  
G

08-10 13:19

25 cmH<sub>2</sub>O

Pressure



Ppeak (cmH<sub>2</sub>O)

13

Pmean (cmH<sub>2</sub>O)

8

PEEP (cmH<sub>2</sub>O)

5

RR (b/min)

35

O<sub>2</sub> (%)

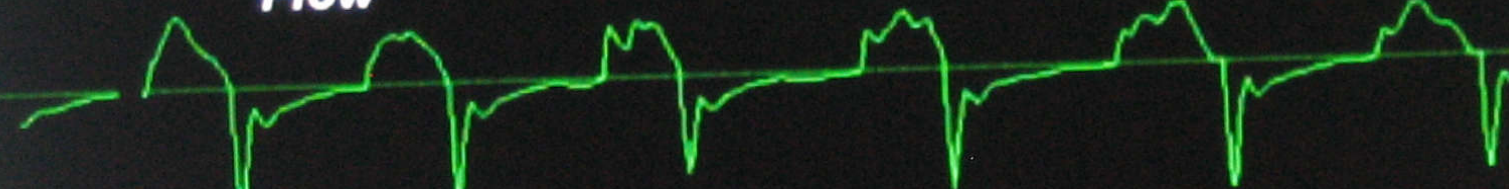
28

Tl/Ttot

0.39

40 l/min

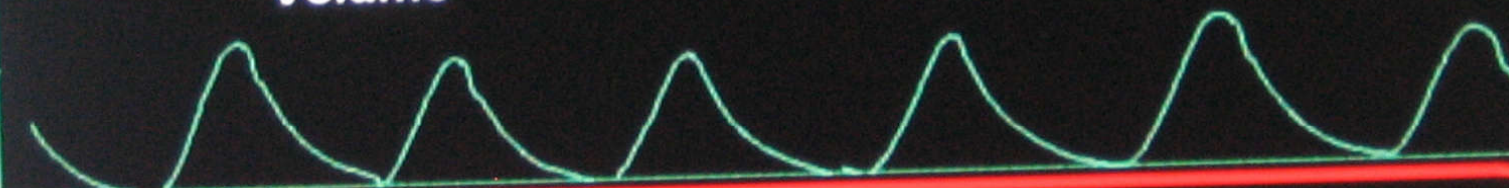
Flow



-40

150 ml

Volume



MVe (l/min)

C 2.9

6.5

10

VTI ml

77

VTe ml

86

etCO<sub>2</sub> (%)

4.8

Edi peak (μV)

5.5

Edi min (μV)

0.3

12 μV

Micro-volts: μV



Additional settings

O<sub>2</sub> conc.

28

%

PEEP

5

cmH<sub>2</sub>O

NAVA level

1.3

cmH<sub>2</sub>O/μV

Additional values



NIV NAVA

Admit patient

Nebulizer

Status



Alarm profile

Save

Trends



Neural access

Quick access

Menu

Main screen



05-15 16:17



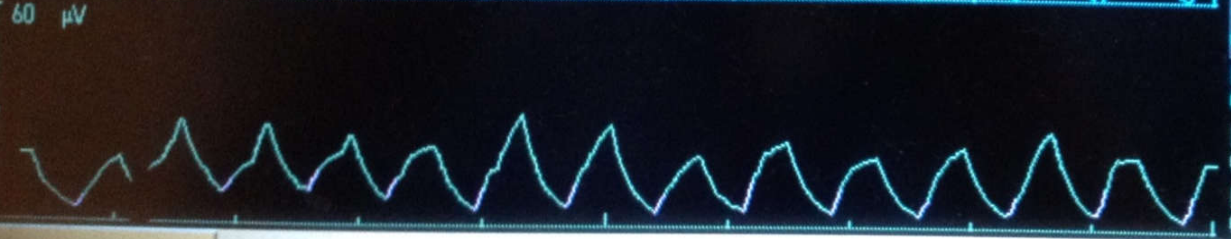
Ppeak (cmH<sub>2</sub>O)  
**19**



PEEP (cmH<sub>2</sub>O) **4**  
RR (b/min) **84**



O<sub>2</sub> (%) **40**  
Ti/Ttot **0.53**



MVe (l/min) **3.4**

VTi (ml) **45**

VTe (ml) **45**

Leakage (%) **87**

Edi peak (µV) **19**

Edi min (µV) **3.1**

Additional settings

O<sub>2</sub> conc. **40**  
21 % 100

PEEP **5**  
cmH<sub>2</sub>O 2 20

NAVA level **1.0**  
cmH<sub>2</sub>O/µV 0.5 15.0

Additional values

# Implement NAVA Mode

NAVA

NAVA Ppeak est. cmH<sub>2</sub>O

I:E 1:3.0

Basic

NAVA level 1.0 cmH<sub>2</sub>O/µV

PEEP 5 cmH<sub>2</sub>O

O<sub>2</sub> CONC. 40 %

Trigg. Edi

Trigg. Edi 0.5 µV

Typical Edi Trigger: 0.5 µV

Pressure Support

Trigg. Flow 5

Insp. cycle off 30 %

PS above PEEP 20 cmH<sub>2</sub>O

First Back-up

Backup ventilation

PC above PEEP 10 cmH<sub>2</sub>O

Resp. Rate 30 b/min

Ti 0.50

Second Back-up

- NAVA Level updated from NAVA Preview screen
- Typical NAVA Level : 0.5 to 3 cmH<sub>2</sub>O / µV

Cancel Accept

# 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

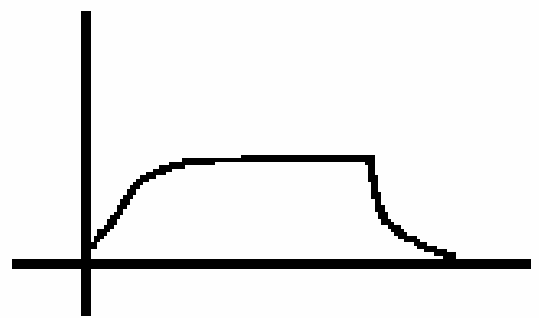
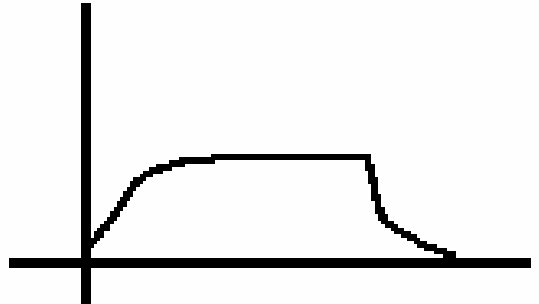
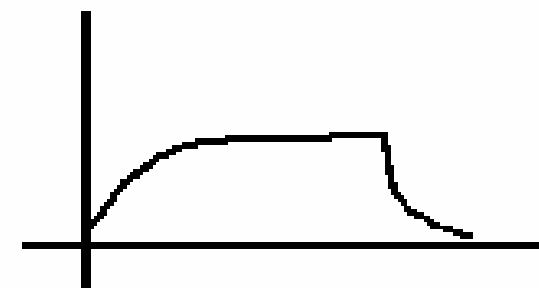
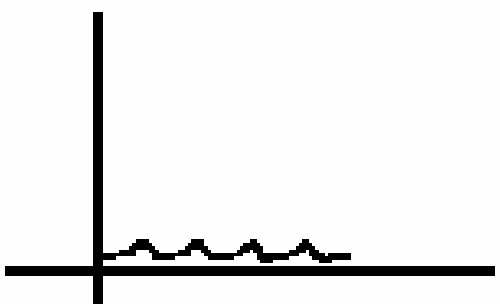
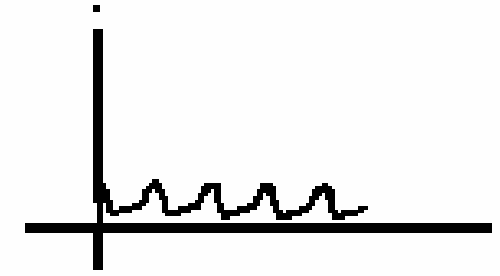
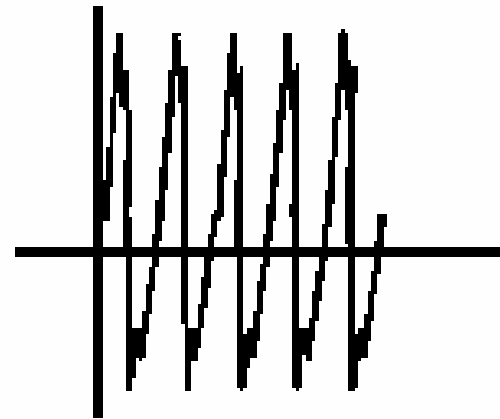
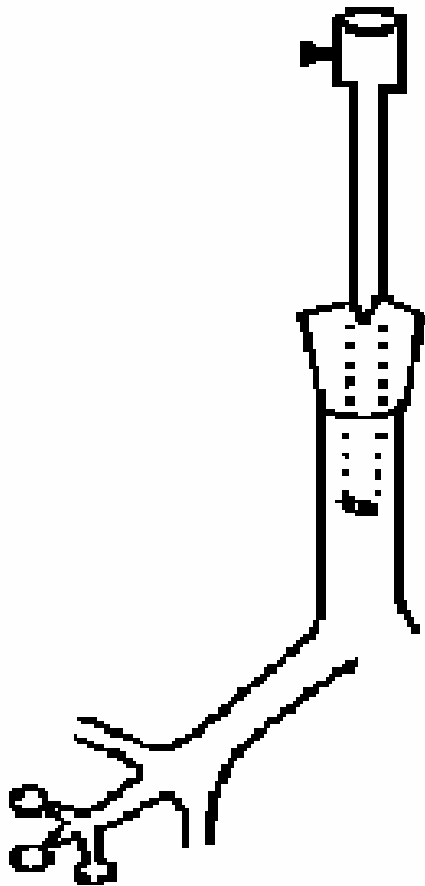
## *Types of Ventilators*

- 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)

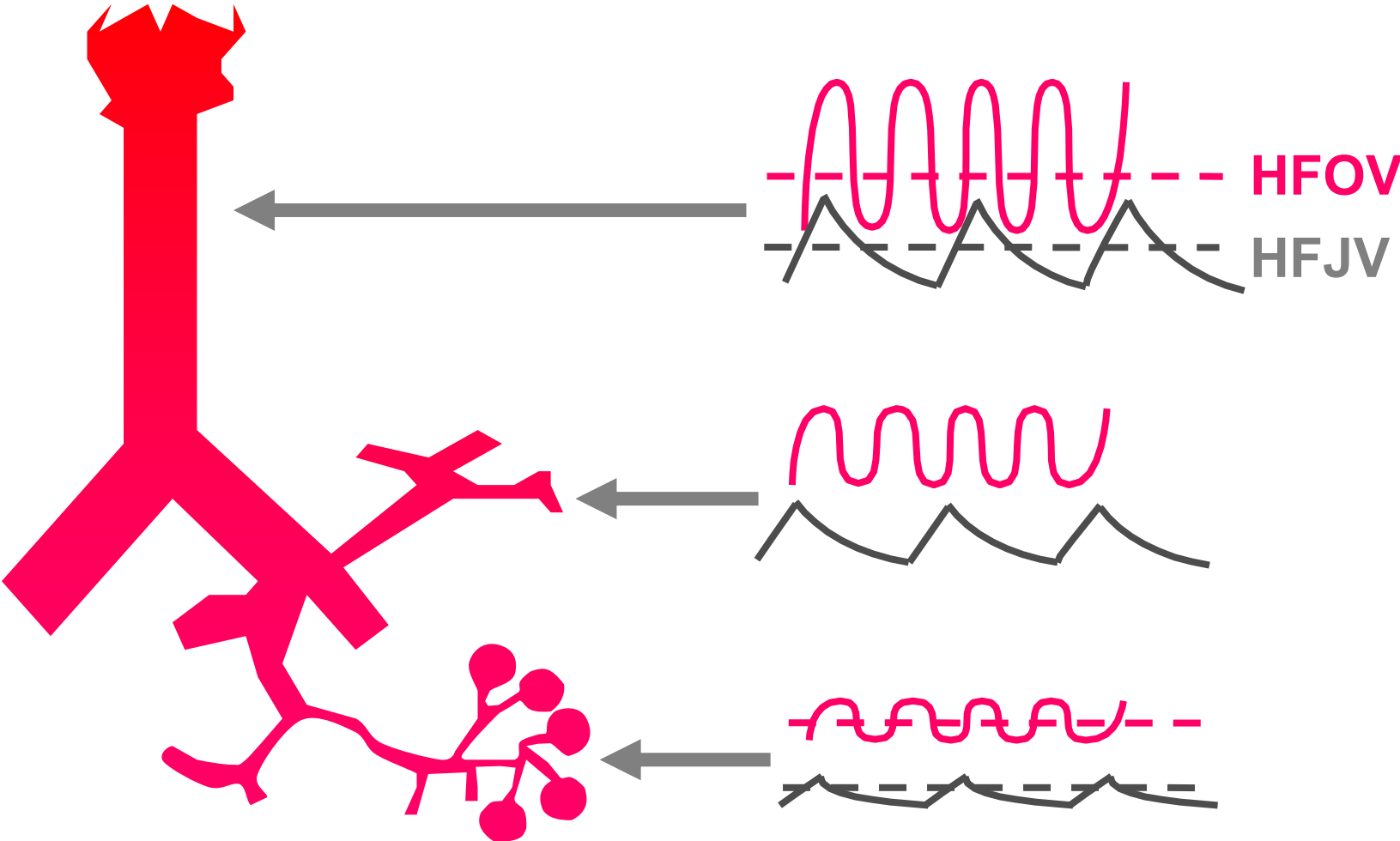
# Airway Pressure Waveforms

HFOV

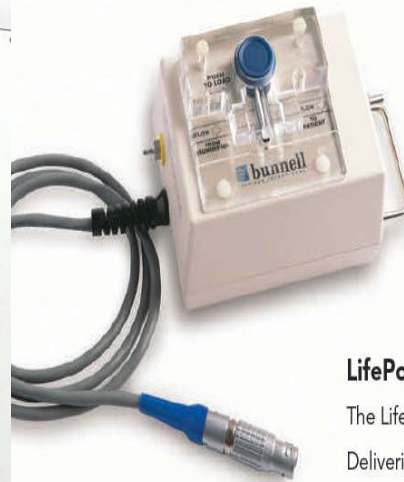
Conventional



# AIRWAY PRESSURE WAVEFORMS



# LifePulse HFJV-Model 204



## WhisperJet™ Patient Box

The WhisperJet Patient Box places the inhalation valve and pressure transducer close to the patient. This proximity allows the small, high-frequency breaths to be effective by traveling through a short length of circuit. Bunnell's superior technology facilitates fast and accurate pressure monitoring so the system can respond quickly, breath to breath.

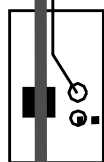
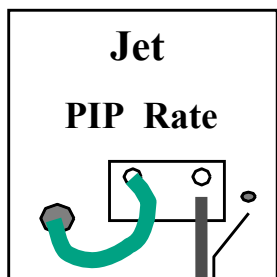
## LifePort™ ETT Adapter

The LifePort ETT Adapter creates the "jet" in high-frequency jet ventilation. Delivering short, high-velocity pulses of gas into the lungs allows the small tidal volumes to be effective. As a result, less peak and mean airway pressure is needed to ventilate and oxygenate the patient.



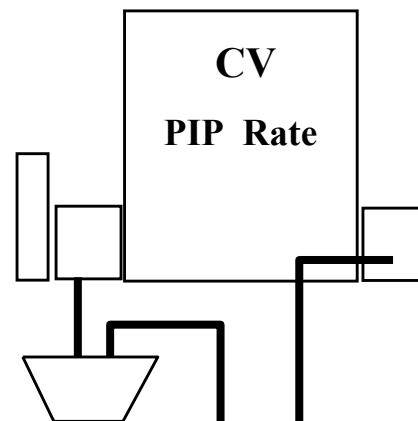
# HFJV in Tandem with CV

## Ventilation



Jet Flow  $\approx 1$  Lpm

## Oxygenation



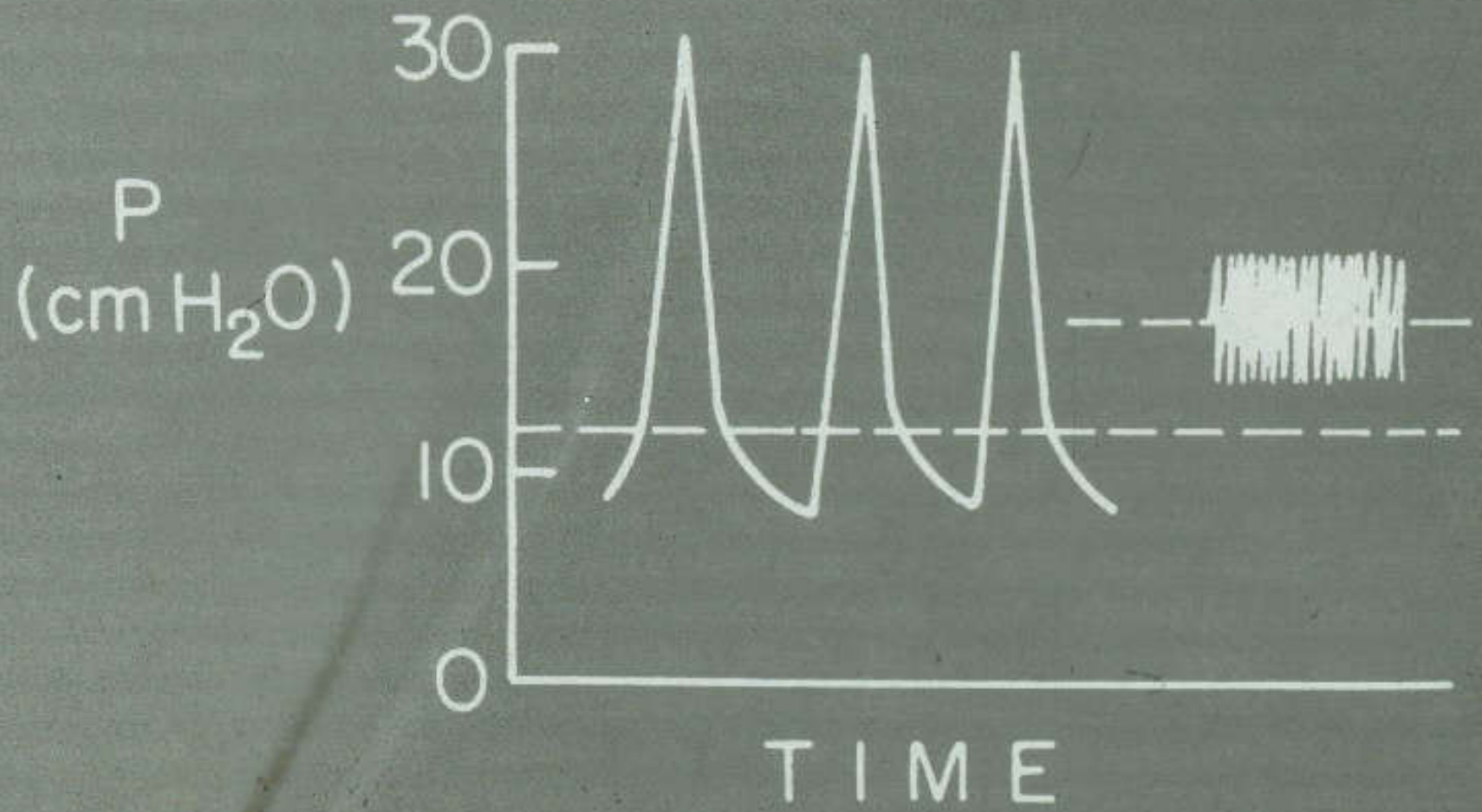
LifePort adapter

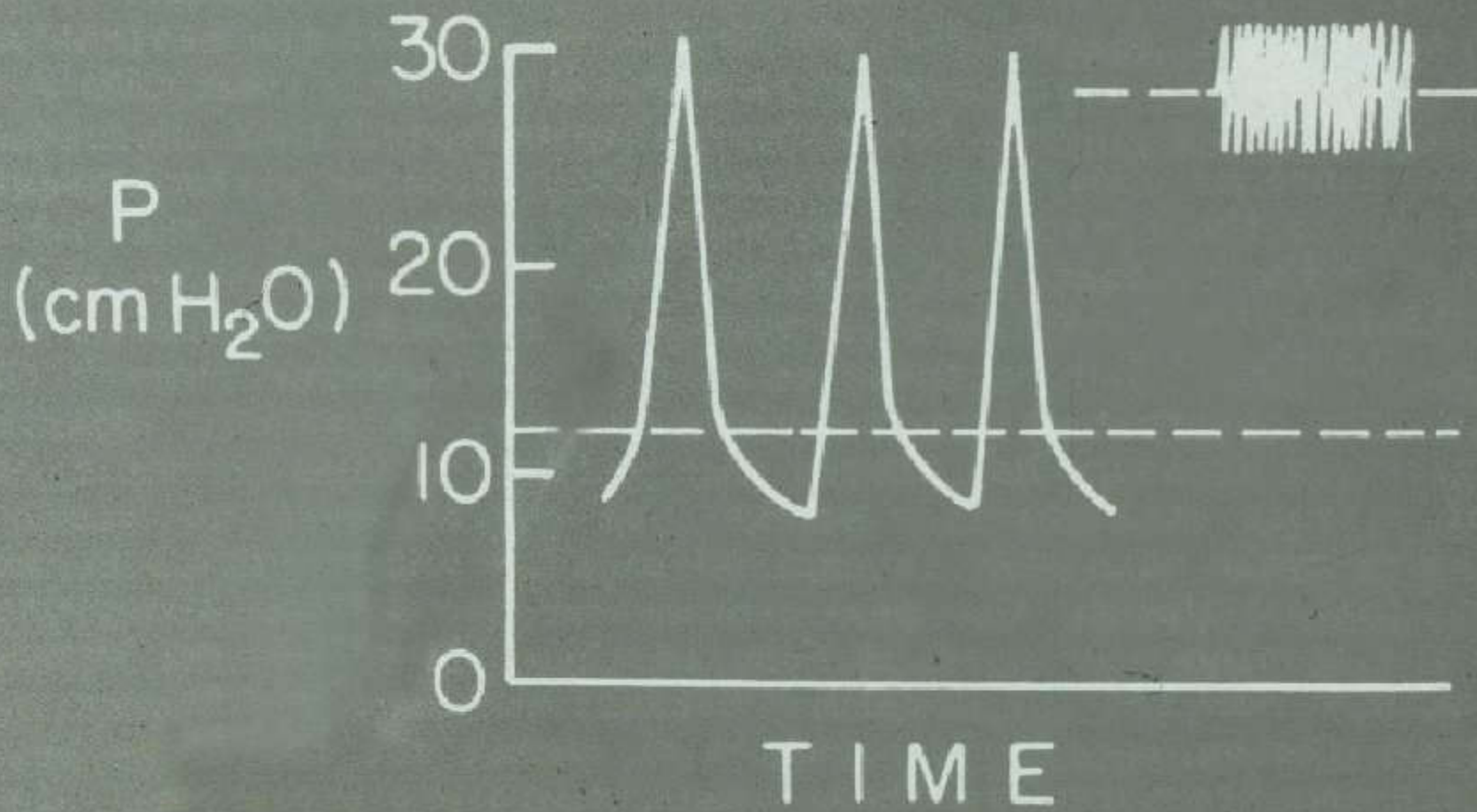


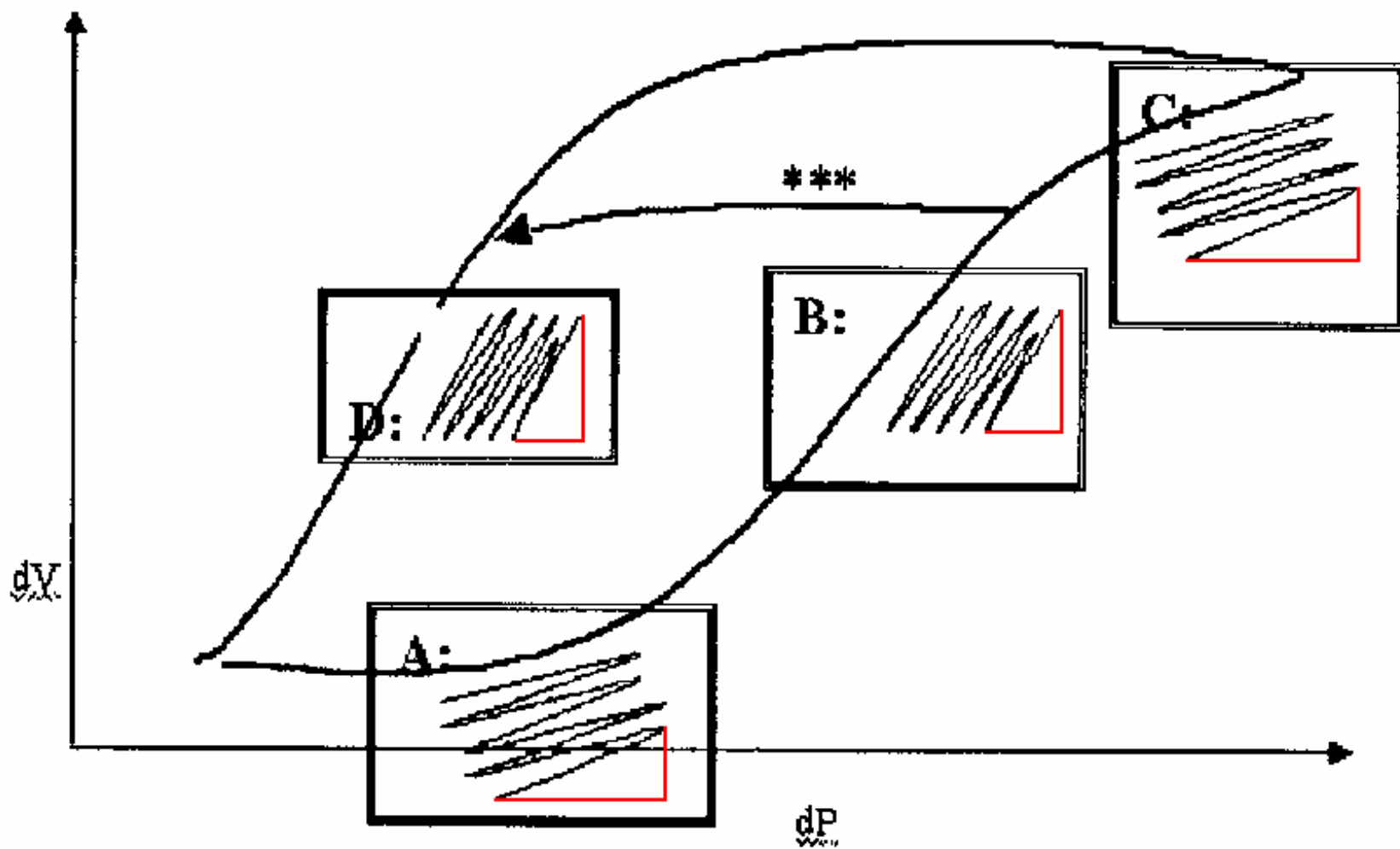
## Operator-selected parameter:

- FREQUENCY (10 – 15 HZ)
- INSPIRATION TIME (33%)
- MEAN AIRWAY PRESSURE (MAP)
- AMPLITUDE
- BIAS FLOW RATE
- PISTON CENTERING
- FIO<sub>2</sub> (ATTACHED OXYGEN BLENDER)









124006 Neo 22 FEB 02 9:46

No alarm recording available

HR Non-paced mode  
**161** PULSE 160  
 SpO<sub>2</sub> 79  
 ABP 48/35 (41)

### Graph Trends

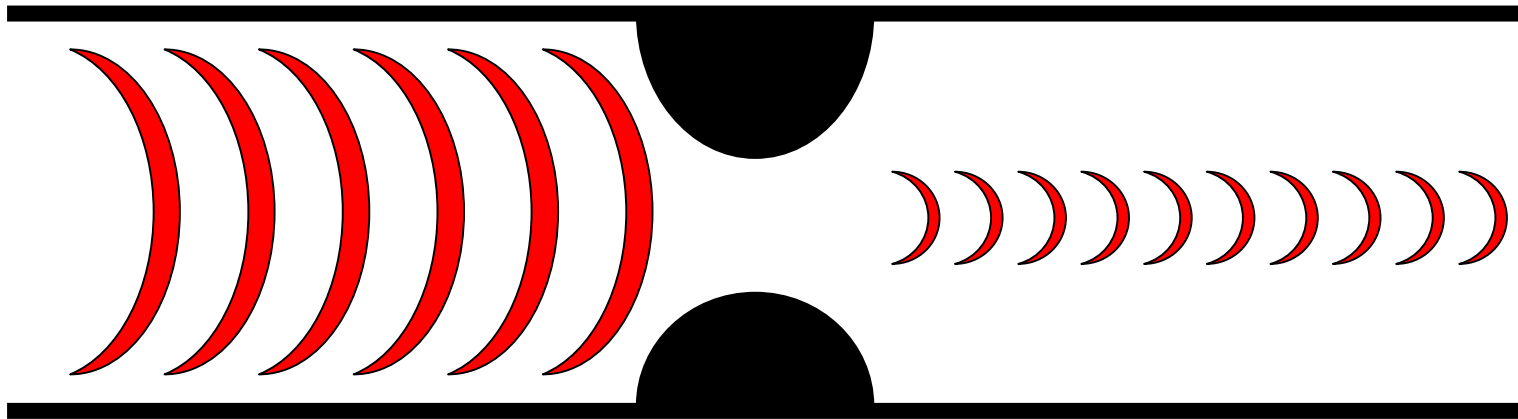


Use the left and right arrow keys to move vertical time bar:

Patient on HFOV. O<sub>2</sub> sat. increase with spontaneous breathings

Next Group	Select Graph	Zoom In	Zoom Out	Change Settings	Print Graphs	Vital Signs
------------	--------------	---------	----------	-----------------	--------------	-------------

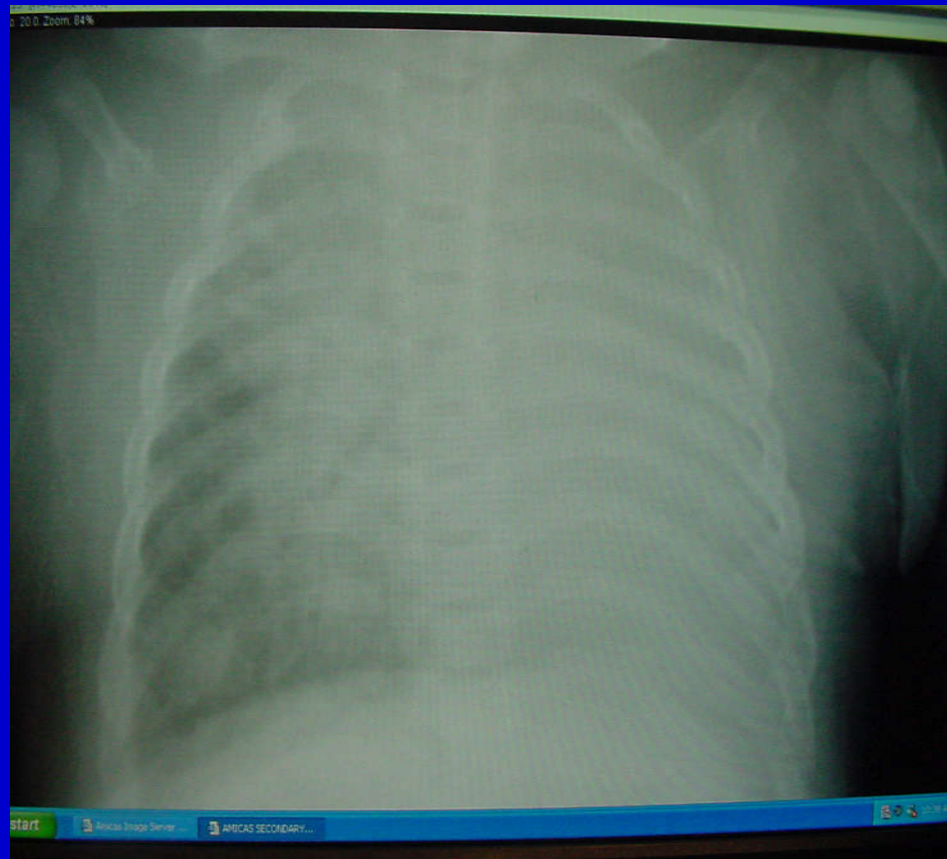
# Shunt Oscillation



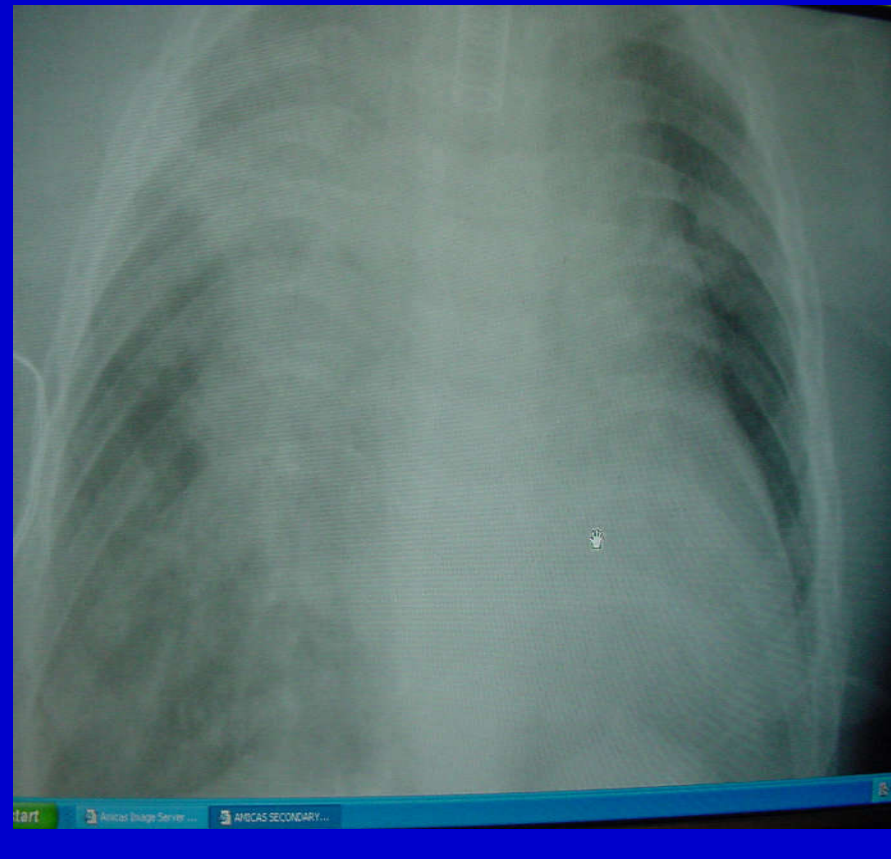
# HFO

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

**Left lung collapsed  
(lower compliance)**



**Left lung opened  
on HFO**



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%