



# Small Volume, Big Concern

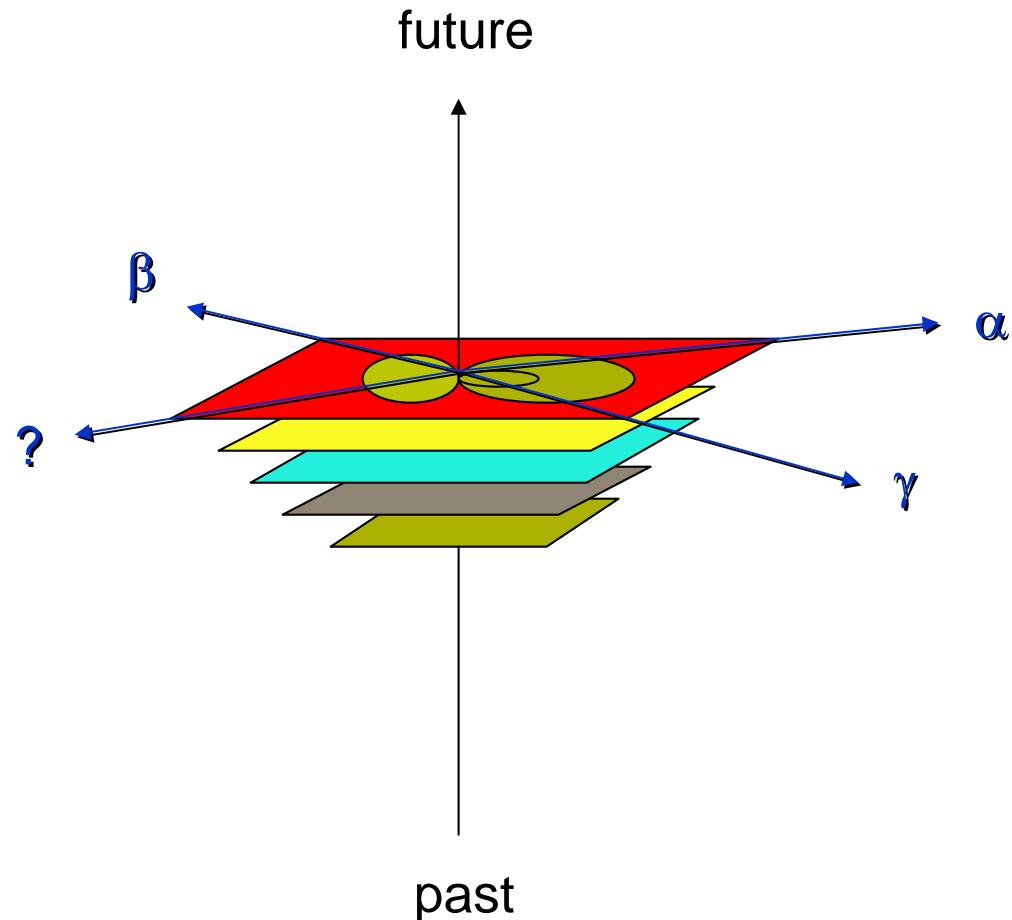
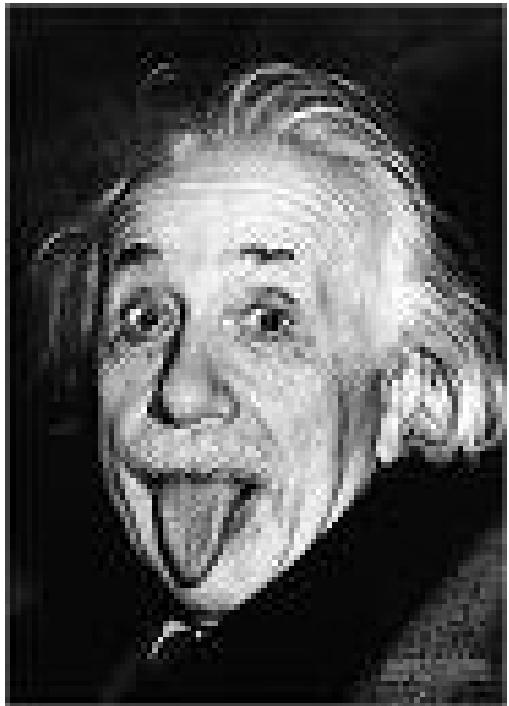


Dirk Danschutter, CCNS, CCP, MSc

AAP/Researcher Faculty of Medicine VUB

Resultaten 1 - 10 van circa **862.000** voor **acute lung injury pediatric**  
Resultaten 1 - 10 van circa **1.030.000** voor **acute lung injury child** Resultaten 1 - 10 van circa **1.100.000** voor **acute lung injury children** Resultaten 1 - 10 van circa **654.000** voor **acute lung injury children mechanical support** Resultaten 1 - 10 van circa **135.000** voor **ventilator induced lung injury children**  
Resultaten 1 - 10 van circa **338.000** voor **acute lung injury children mechanical ventilation** Resultaten 1 - 10 van circa **238.000** voor **acute lung injury pediatric mechanical ventilation** Resultaten 1 - 10 van circa **386.000** voor **acute lung injury pediatric ventilatory support** Resultaten 1 - 10 van circa **599.000** voor **acute lung injury child ventilatory support** Resultaten 1 - 10 van circa **598.000** voor **acute lung injury children ventilatory support**  
Resultaten 1 - 10 van circa **1.080.000** voor **ards children ventilatory support**  
Resultaten 1 - 10 van circa **1.210.000** voor **ards children mechanical support**  
Resultaten 1 - 10 van circa **432.000** voor **ards pediatric mechanical support**  
Resultaten 1 - 10 van circa **191.000** voor **ards pediatric mechanical ventilation** Resultaten 1 - 10 van circa **14.300** voor **Lung-protective Ventilation Pediatrics** Resultaten 1 - 10 van circa **14.400** voor **Lung-protective Ventilation child** Resultaten 1 - 10 van circa **13.000** voor **Lung-protective Ventilation child AND children** Resultaten 1 - 10 van circa **14.400** voor **Lung-protective Ventilation child OR children** Resultaten 1 - 10 van circa **970.000** voor **acute respiratory distress syndrome child OR children** Resultaten 1 - 10 van circa **14.600** voor **Open lung tool Ventilation Pediatrics ...**

# The Relativity of Evidence



31 Gehasi aber ging vor ihnen hin und legte den Stab dem Knaben aufs Antlitz: da war aber keine Stimme und kein Empfinden. Und er ging zurück Elisa entgegen und sagte ihm: Der Knabe ist nicht aufgewacht.

32 Und als Elisa ins Haus kam, siehe, da lag der Knabe tot auf seinem Bett.

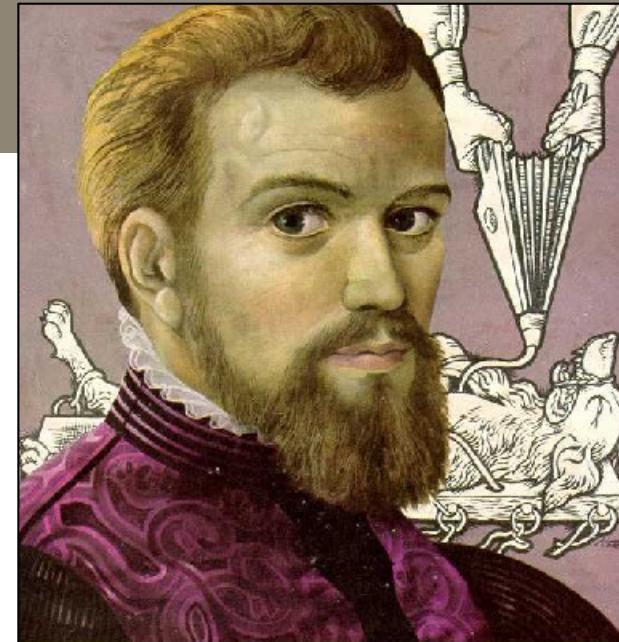
33 Und er ging hinein und schloß die Tür hinter sich zu und betete zu dem HERRN

34 und stieg aufs Bett und legte sich auf das Kind und legte seinen Mund auf

## Book of Kings 5 - 18



« ...The force applied should be limited to as much as a man can bear... (1745) »



“... One shall make an opening in the trachea wherein a small tube or hollow sheer is placed. Then one shall blow air in the tube and hence the lung will expand again and the heart will become stronger again...”

*Humani Corporis fabrica Lib. VII  
(1555)*

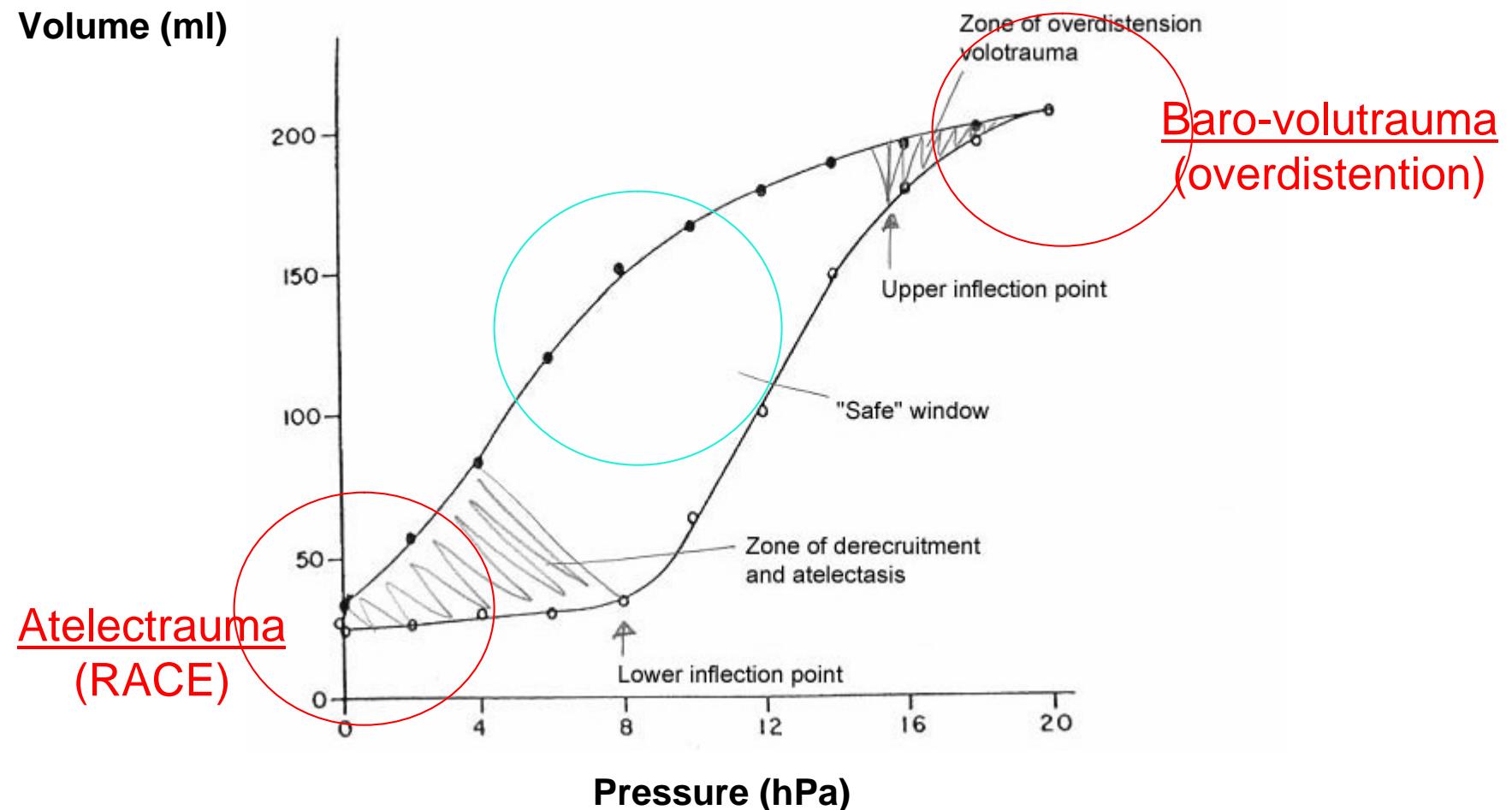


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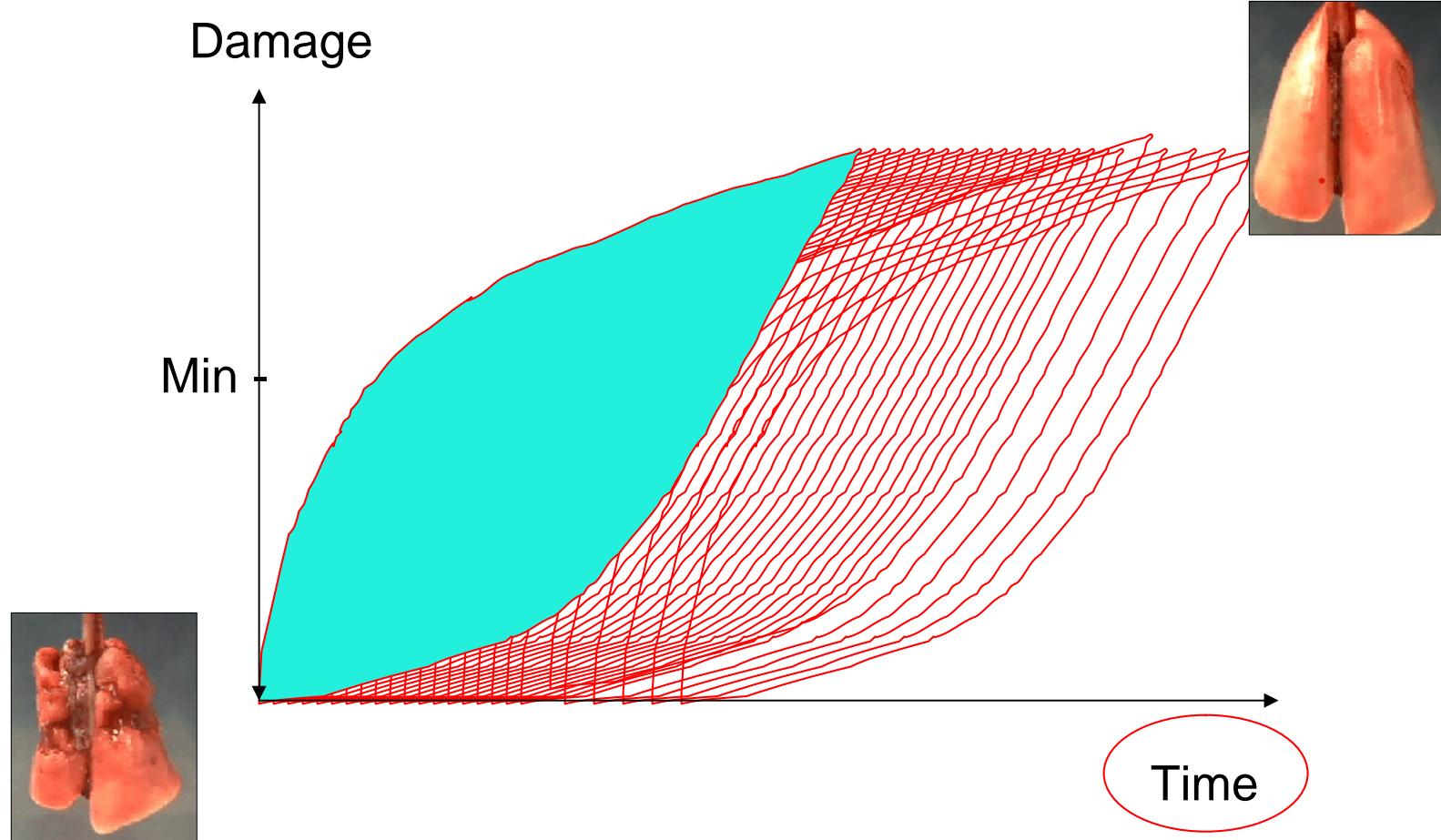
## A few current concepts about VILI:

- ☞ **Not VILI but Operator Induced Lung Injury**
- ☞ **Baro-, volutrauma & Atelectrauma**
- ☞ **Repetitive opening & closing lung (RACE)**
- ☞ **Biotrauma**
- ☞ **Cell death or repair**
- ☞ **Angry cells & pro-inflammatory substances**
- ☞ **Secondary (remote) organ failure**
- ☞ **Role of central nervous system**

## ☞ Baro- & volutrauma & Atelectrauma



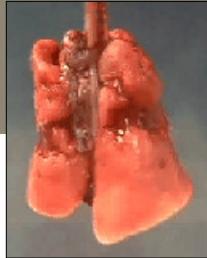
## ☞ Repetitive Alveolar Collapse & Expansion (RACE)



**Slutsky AS ea. AM Respir Crit Care Med 1998; 157:1721-1725**



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## ☞ Atelectrauma

- ☞ PEEP (low)
- ☞ Derecruitment (open suctioning, closed suctioning VC...)?
- ☞ Asynchronous ventilation, controlled ventilation?
- ☞ Non-proportional ventilation?
- ☞ FBAO (plug, thickening, mucus, lavage...)
- ☞ Heating & humidification gasses < 44 mg/L?
- ☞ Positioning ET & air leakage
- ☞ Intrinsic & environmental causes (supine position?  
Anesthesia? Curarisation?...)

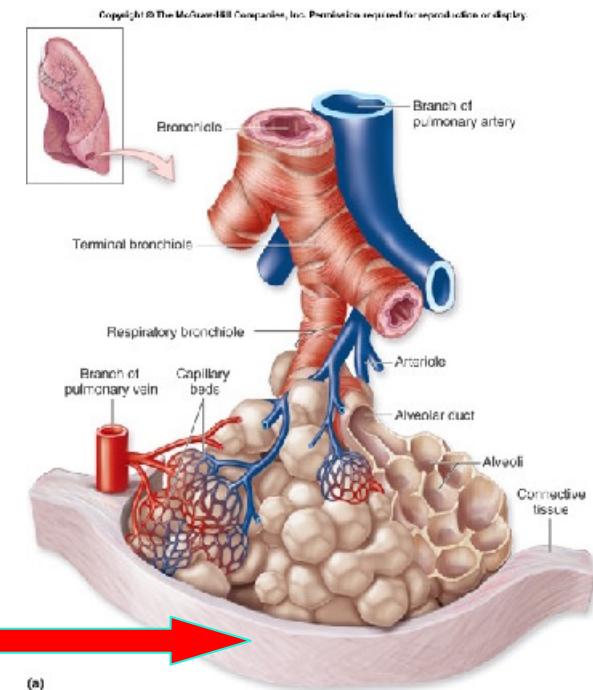
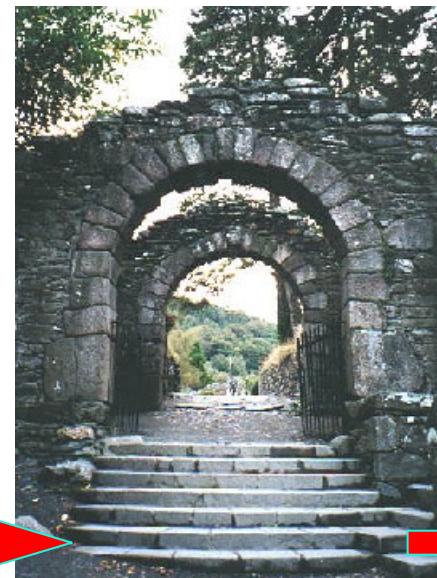


## ☞ Baro- & volutrauma

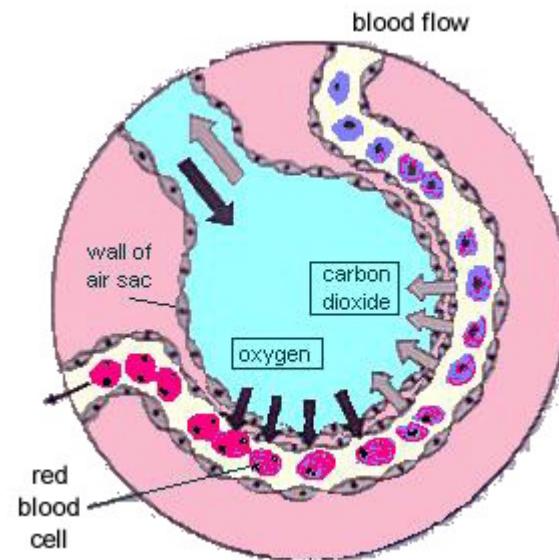
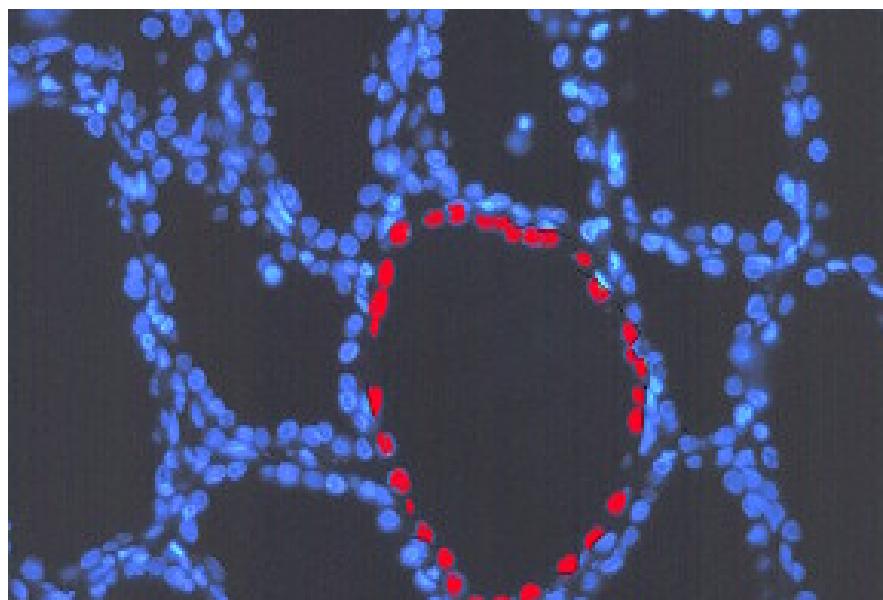
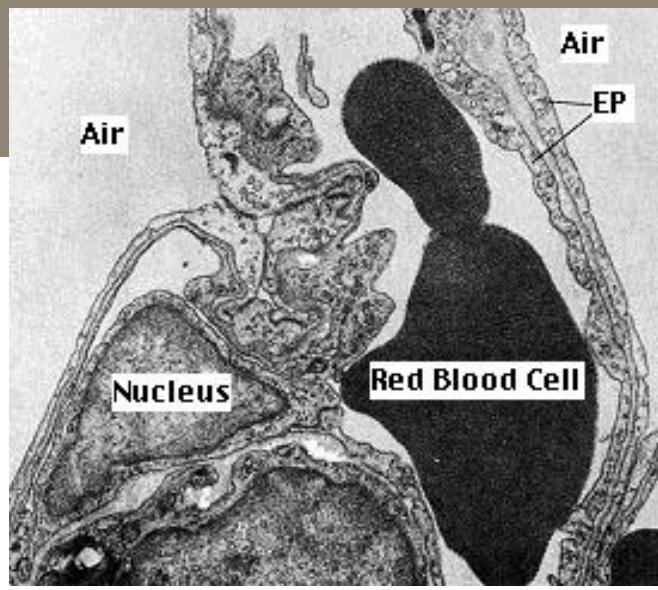
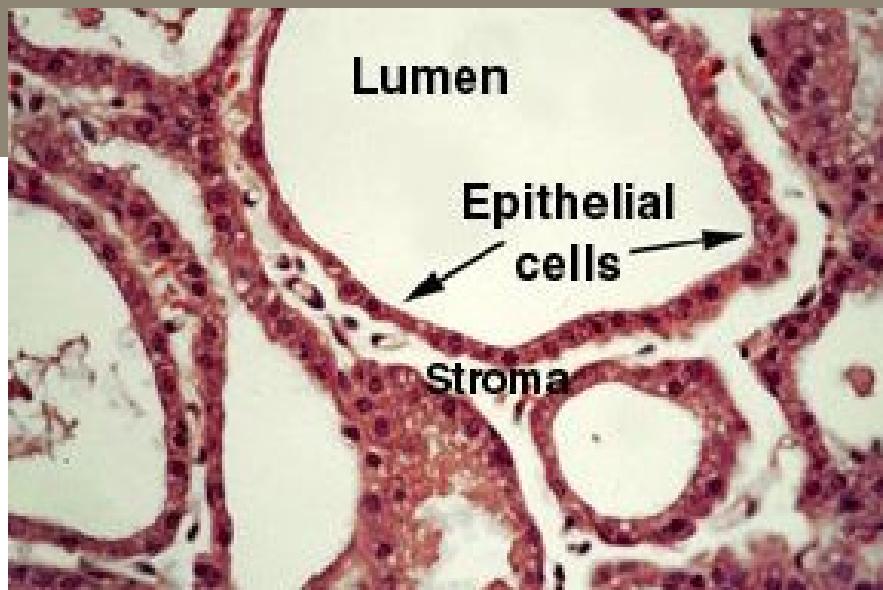
- ☞ High lung volumes ( $V_t > 6.3 \text{ ml/kg}$ )
- ☞ Bagging (manual ventilation episodes, resuscitation...)
- ☞ Ventilation modus
- ☞ Invasive diagnostics/therapeutics (fiberoptic)
- ☞ Mucus recruiting manouvers
- ☞ Impairment of venous return & LEF (CO)

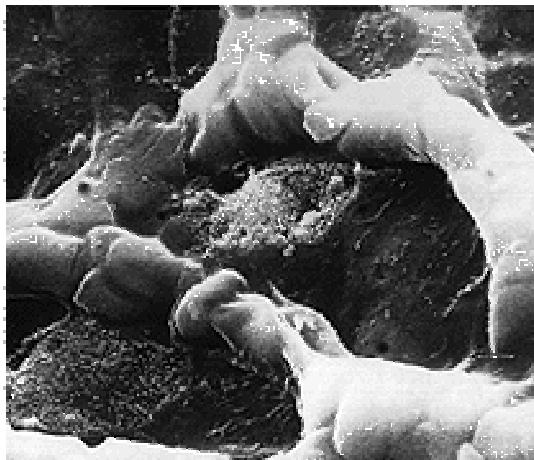
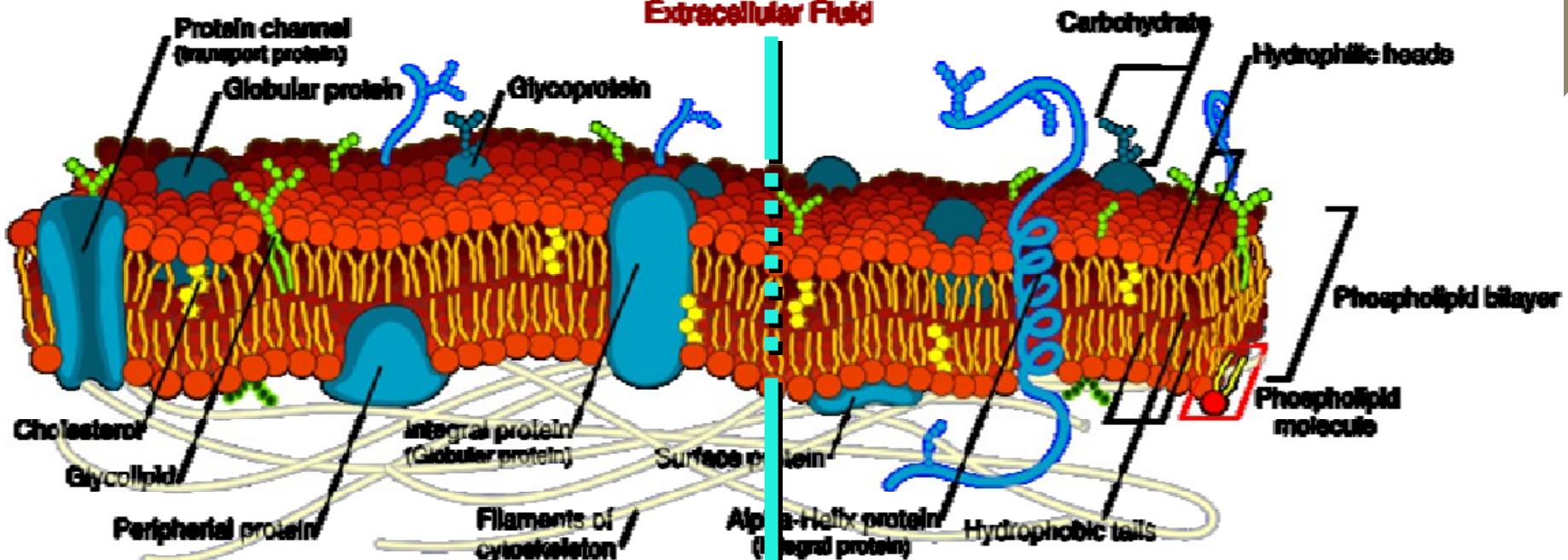
Dreyfuss D ea. Am Rev Respir Dis 1988: 137; 1159-1164

## 👉 Biotrauma

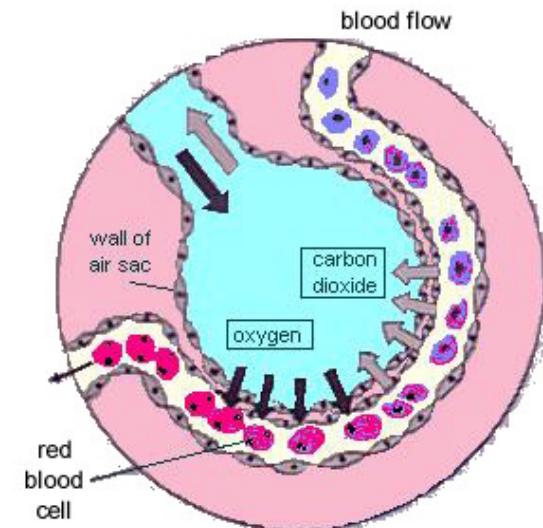
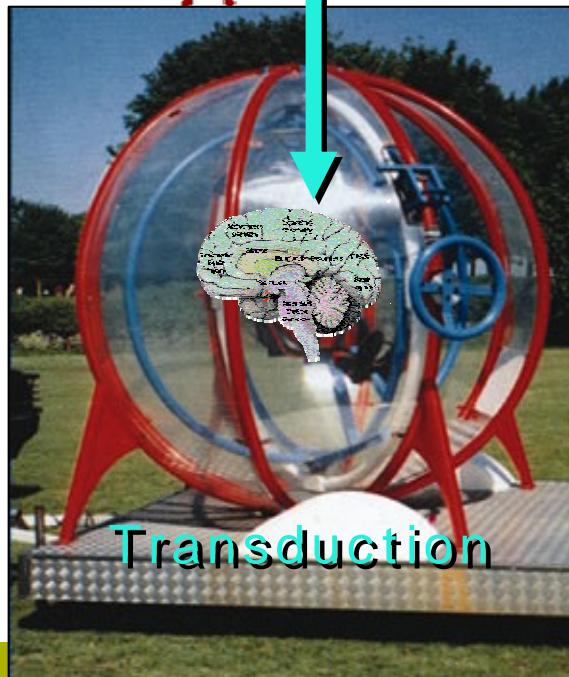


Ranieri VM ea. JAMA 1999; 282: 54-61



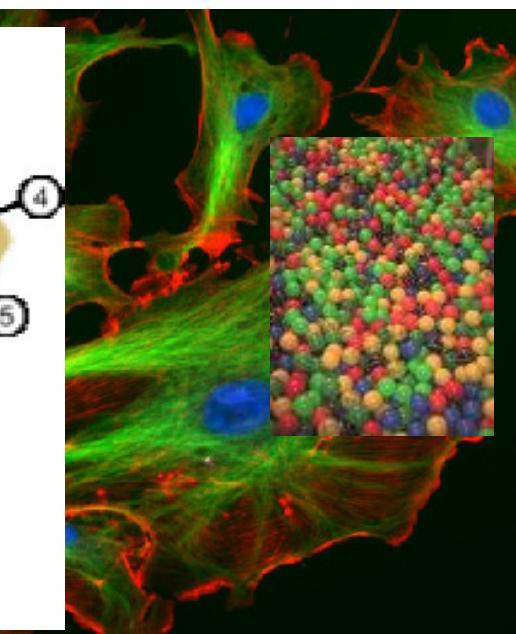
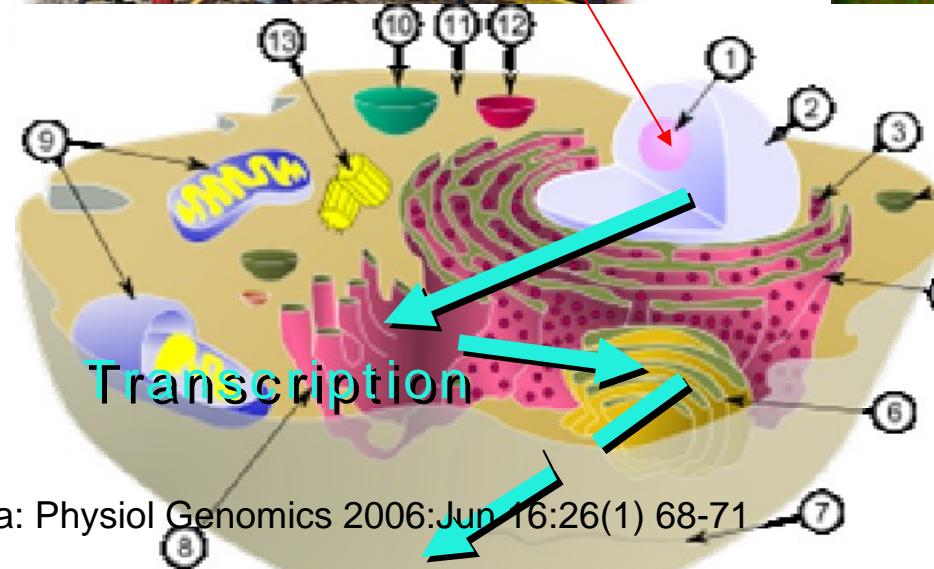
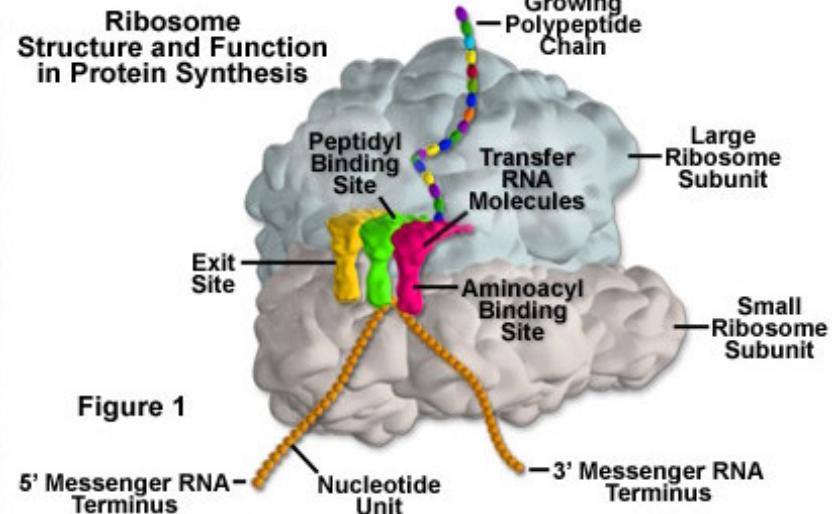


Scanning Electron Micrograph  
Normal Alveoli





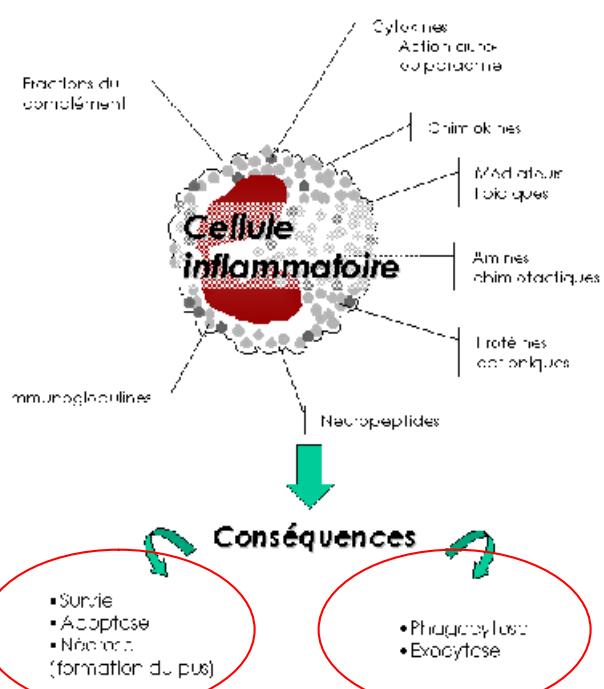
## ☞ Angry cell or dying cell(LLLLLL)



## Réponse inflammatoire - Amplification

### Phase cellulaire

#### Activation des cellules inflammatoires

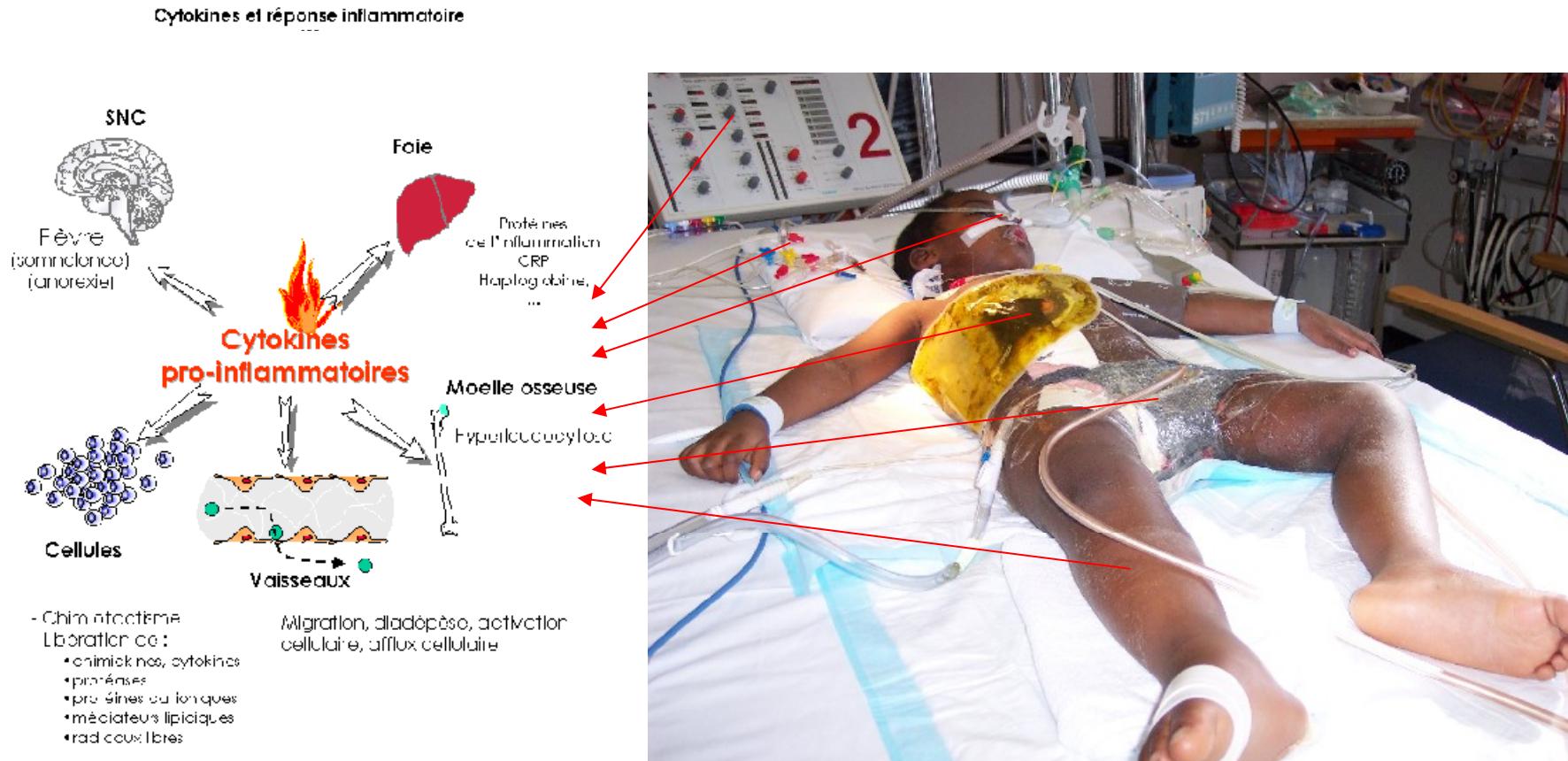


**Wrigge H ea. Int Care Med 2005 Oct  
3;31(10):1379-87**



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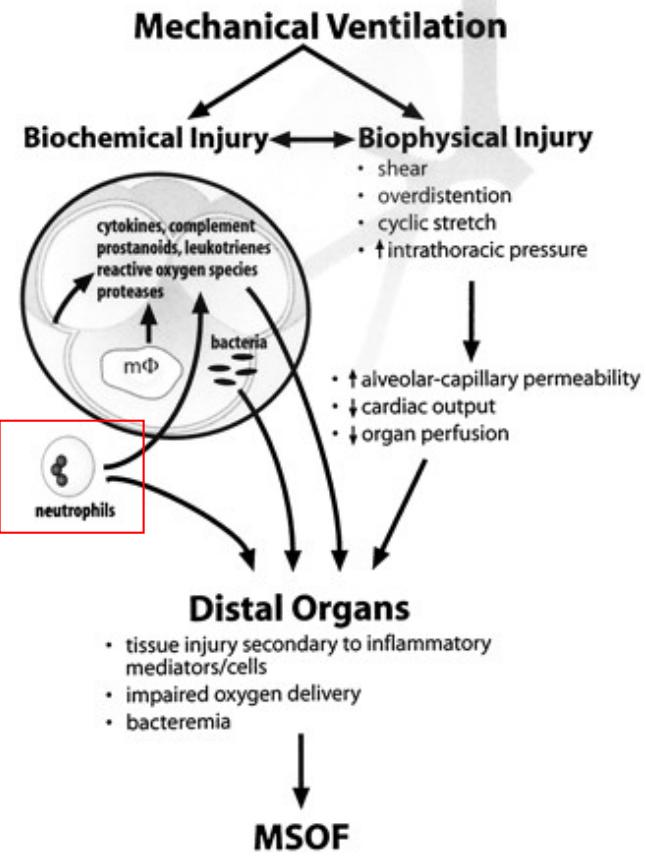
Supine position (FRC = RV), cranial displ't diaphragm (= upper part V), anesthesia, muscle relaxants



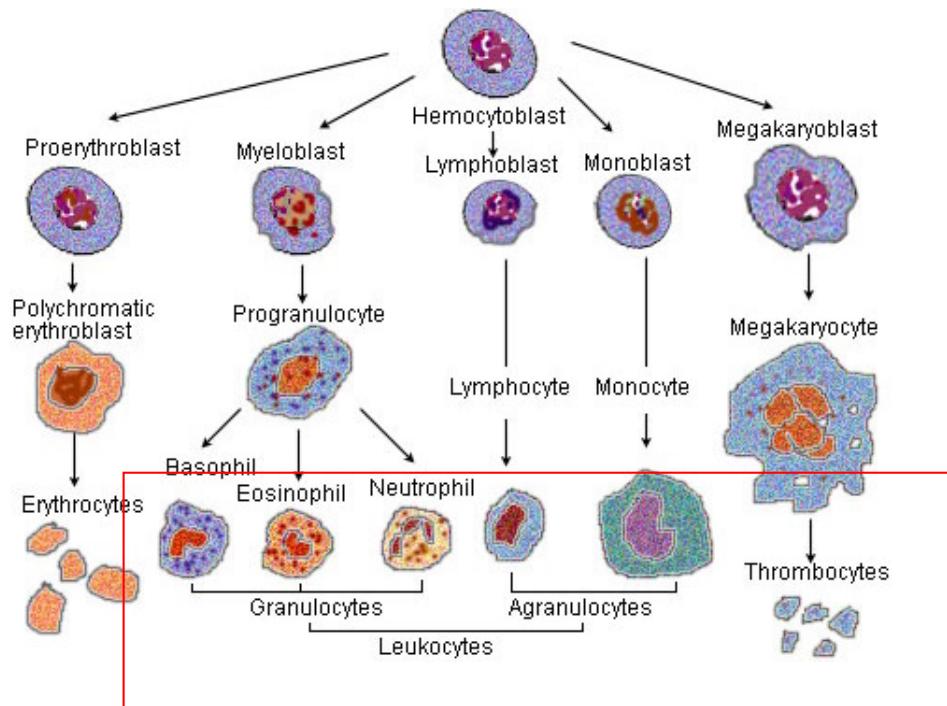
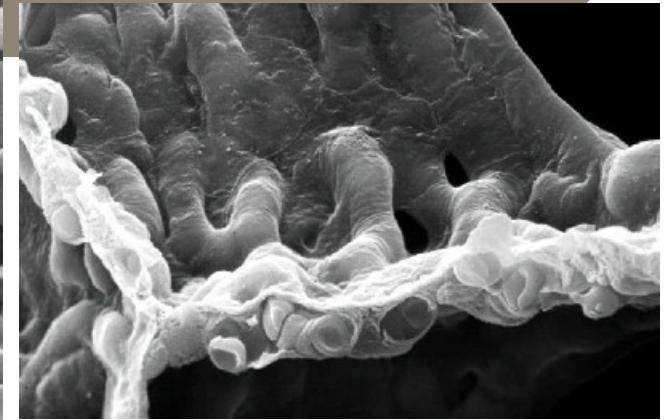
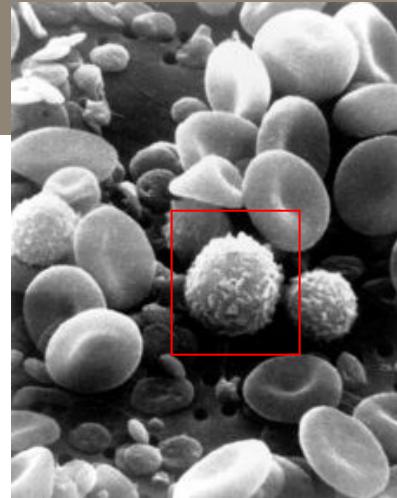
Uhlig U ea. Anesthesiology 2006 Dec; 105(6):1192-200



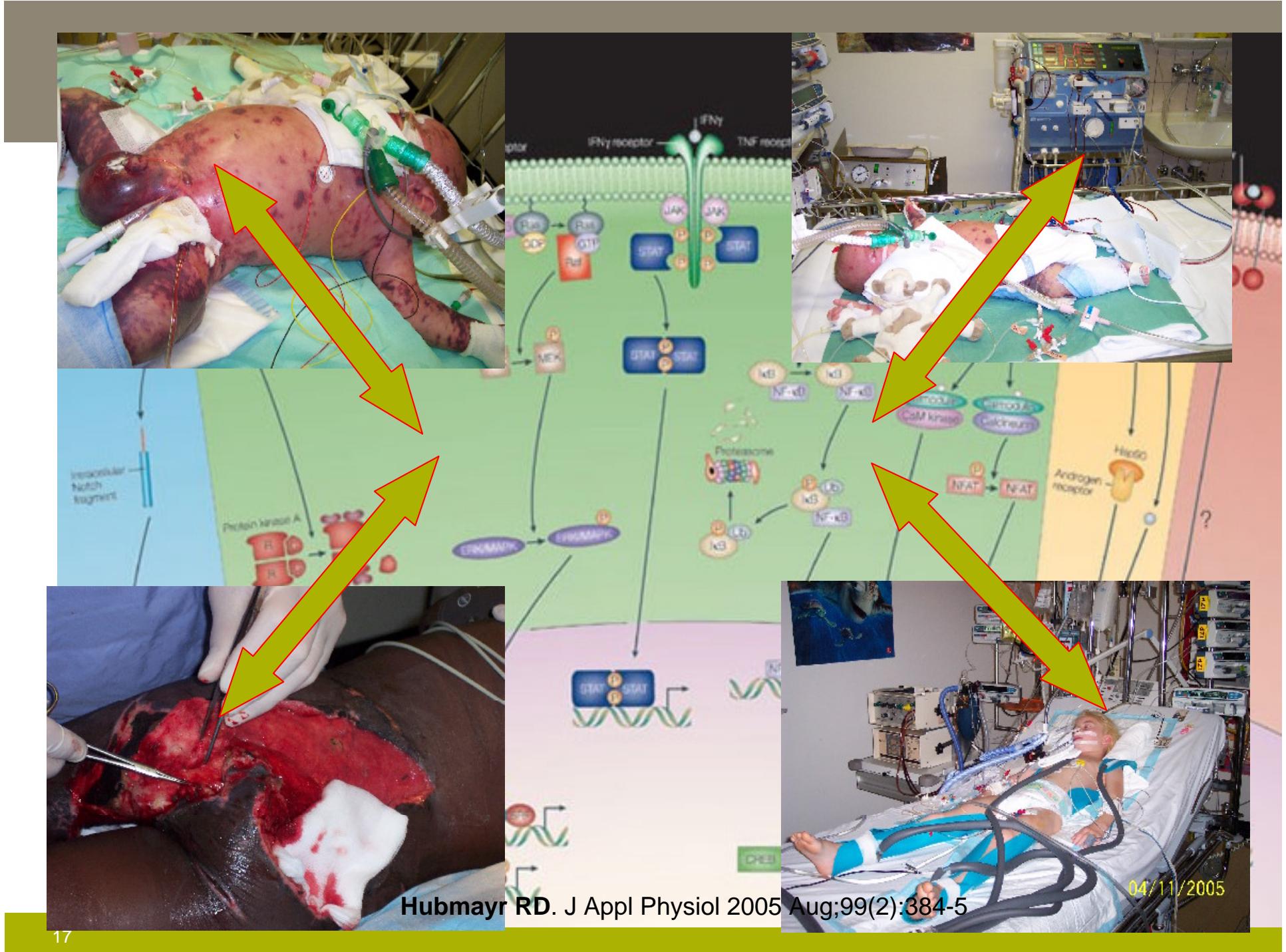
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(by Slutsky A)



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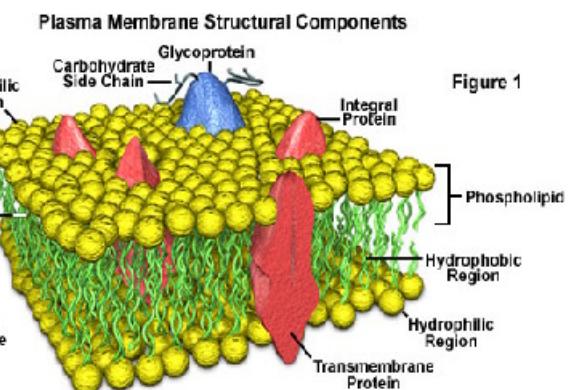
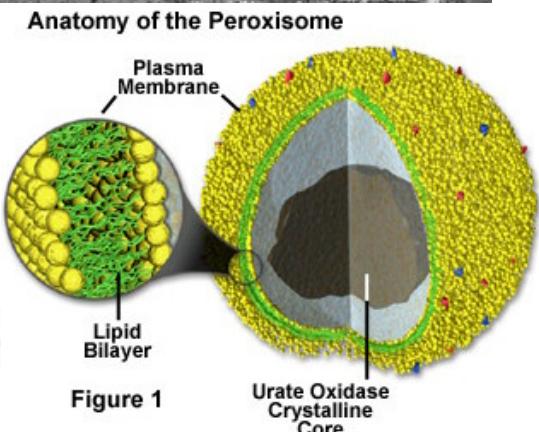
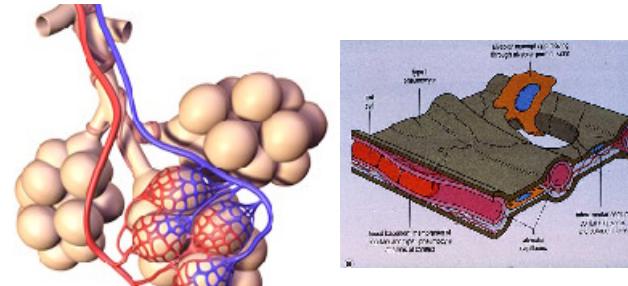
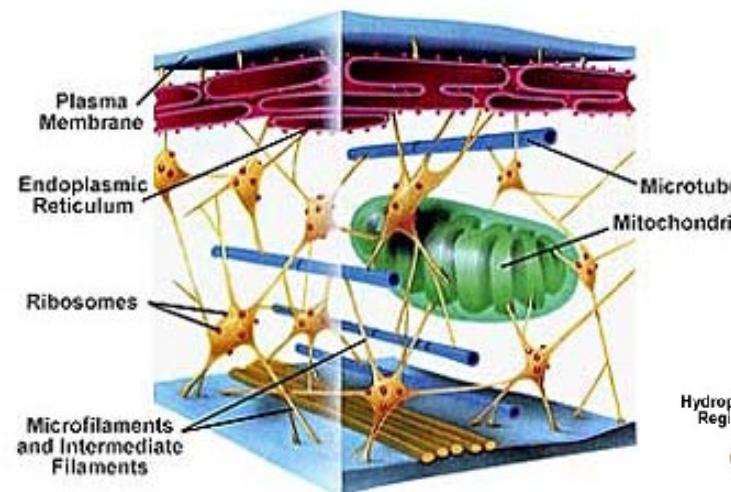
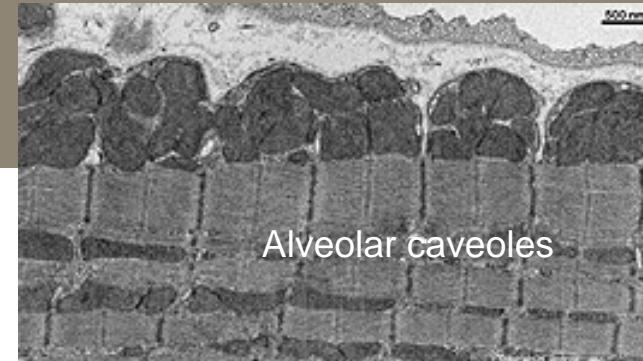
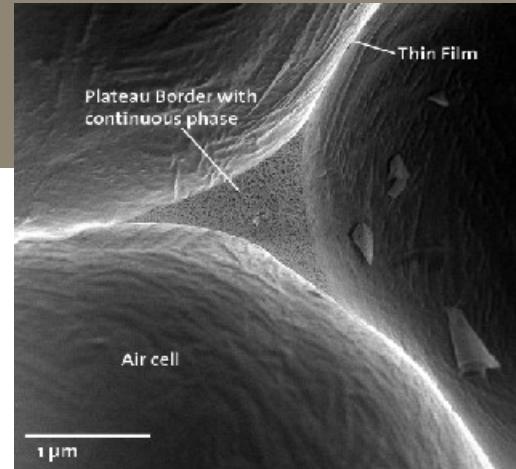
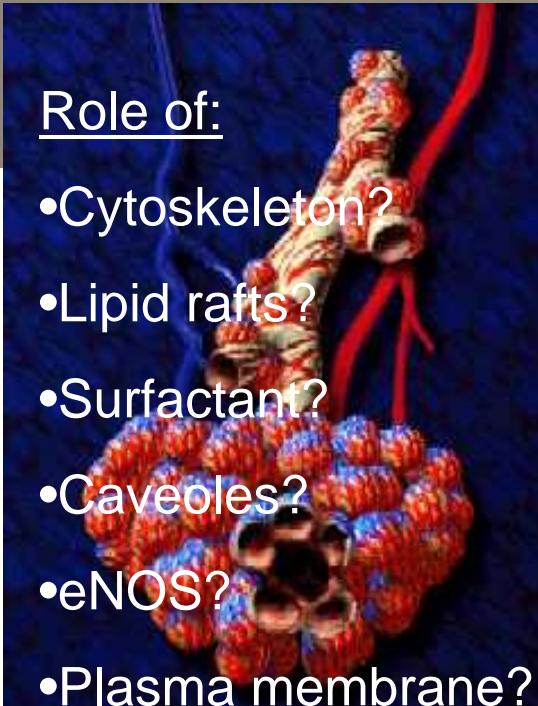


## Role of:

- Cytoskeleton?
- Lipid rafts?
- Surfactant?
- Caveoles?
- eNOS?
- Plasma membrane?
- Metalloproteases?
- Cell nucleus?
- Alveolar geometry?
- Alveolar ducts?
- Alveolar mouth?



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Nieman GF ea. Am J Respir Crit Care Med 2004 Jan 1;169(1):57-63



**2007 = more questions than answers**

**So**

**What do we do?**

1953 Rancho Los Amigos, CA

☞ Avoid invasive mechanical ventilation: masks & prongs

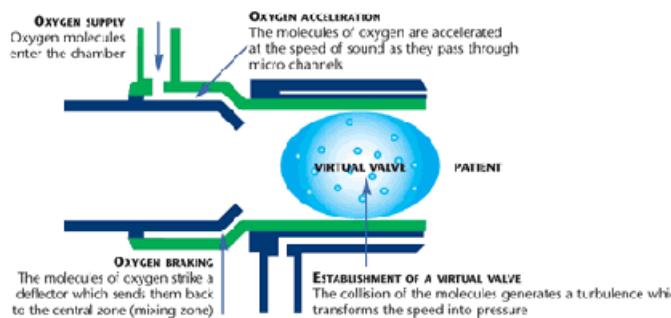


Primum Non Nocere

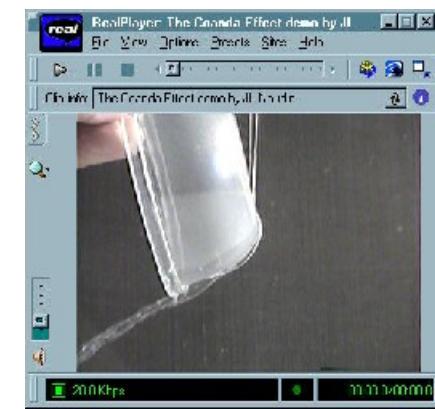
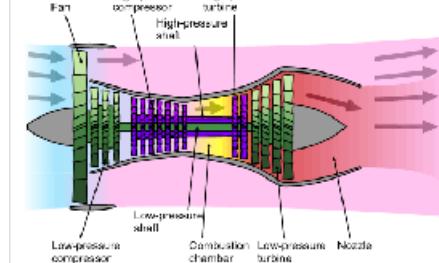


## Boussignac

**Boussignac CPAP works the same way as the turbines of a jet engine.**

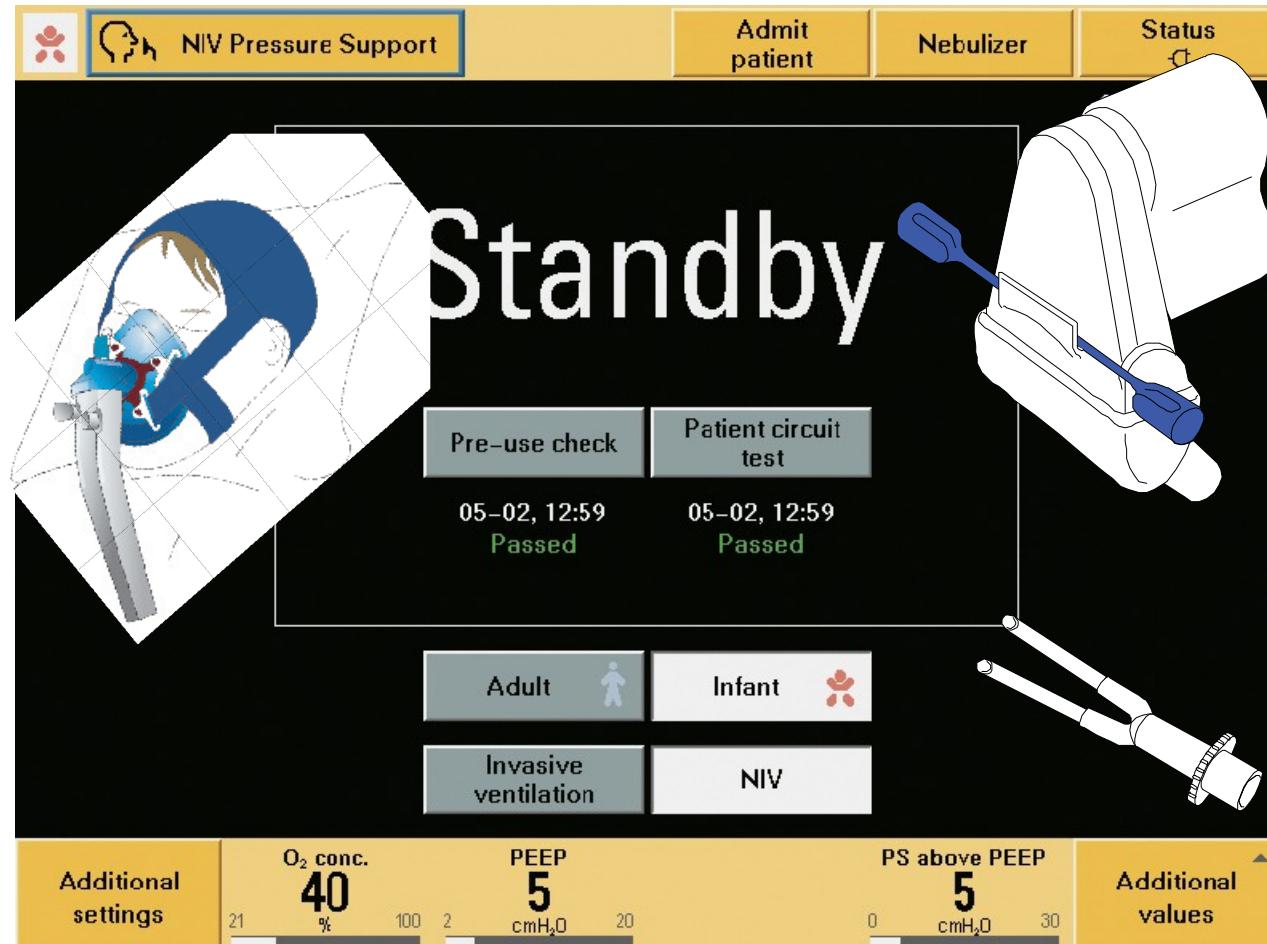
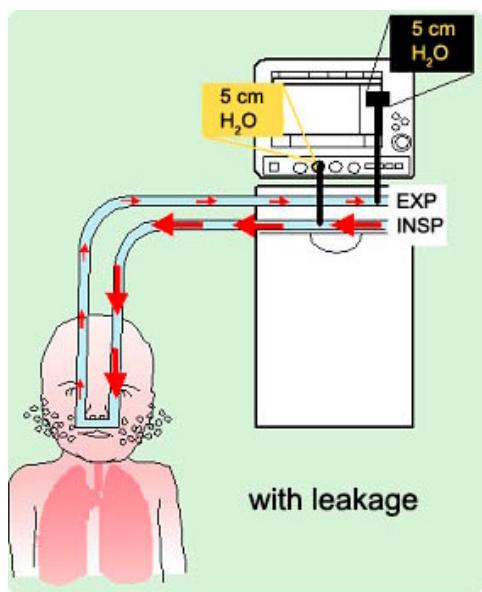
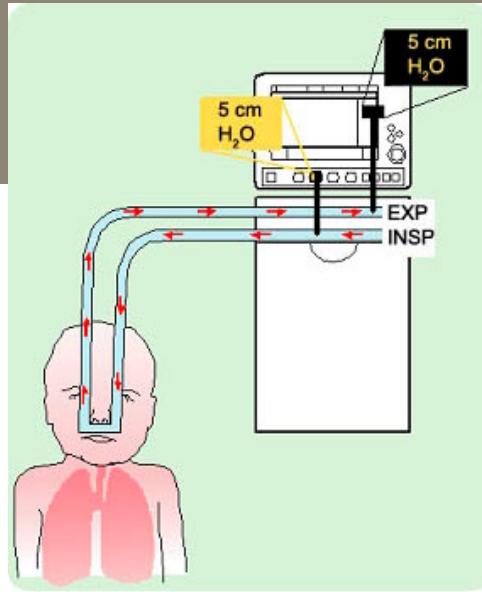


**Coanda-effect (boundary layer attachment) =  
Turbofans Airplane Jet Engine**



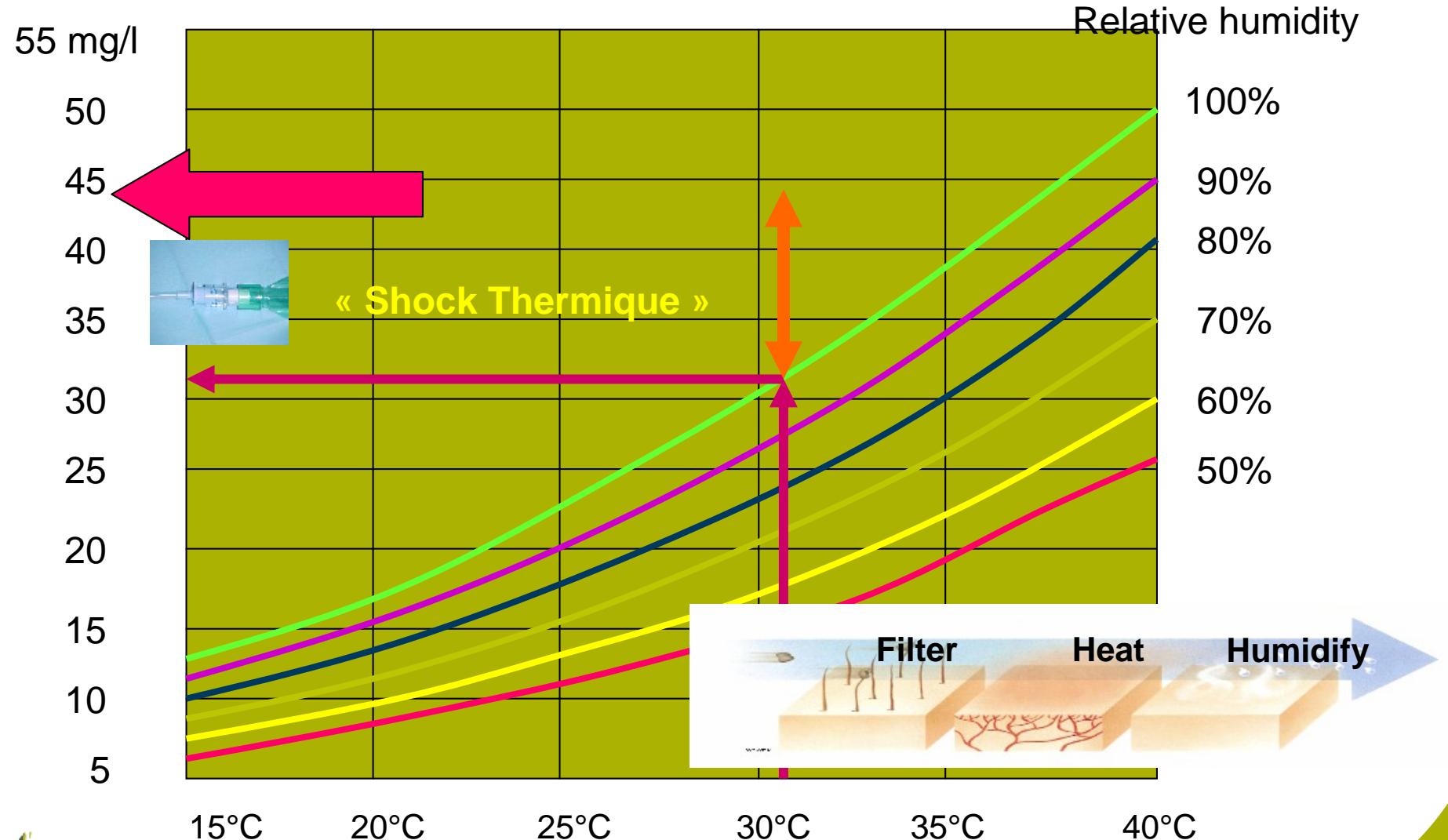
Huth R ea. Int Care Med 2003 Oct;29(10):1770-3

## ☞ NIV: Masks & Prongs

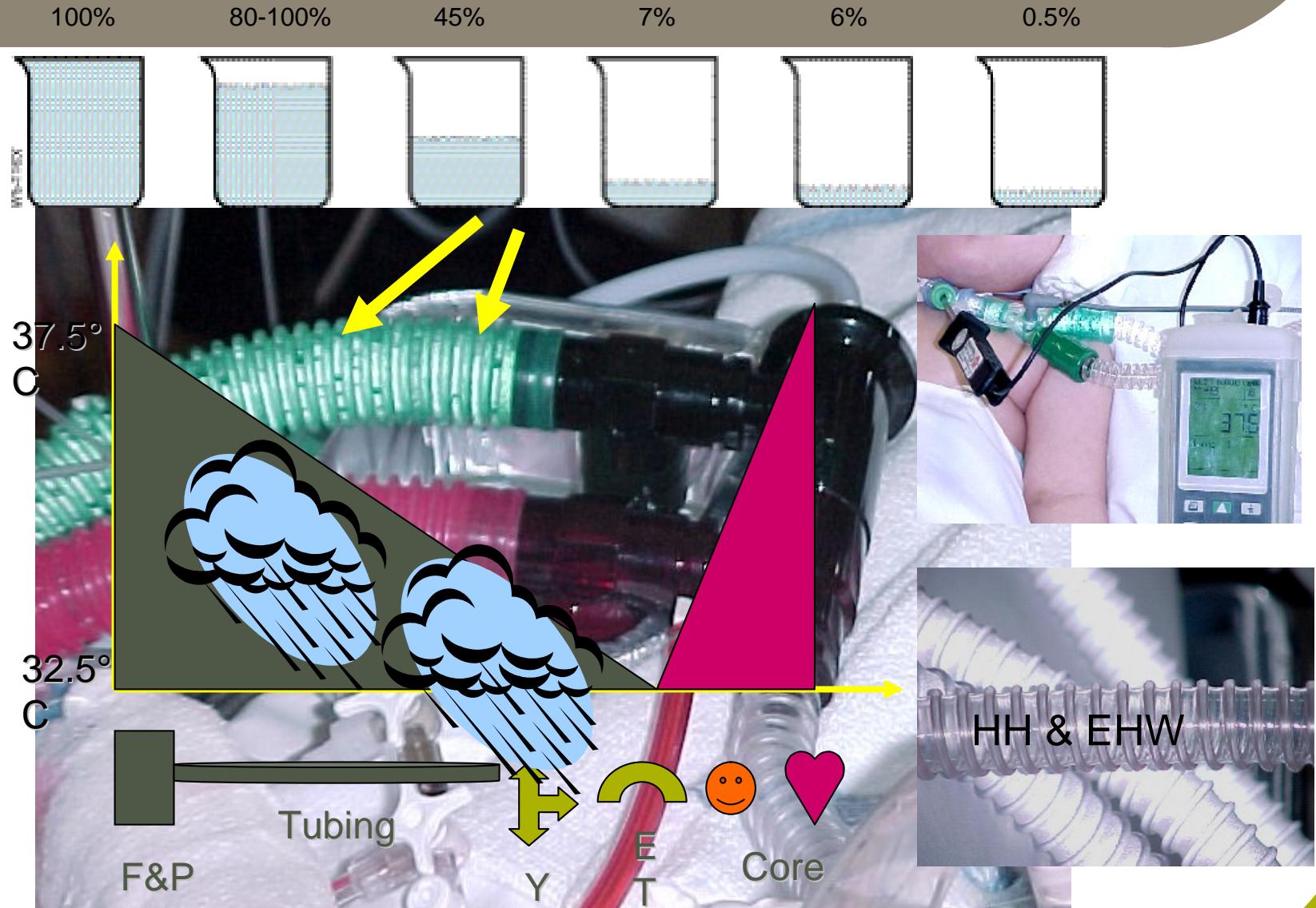


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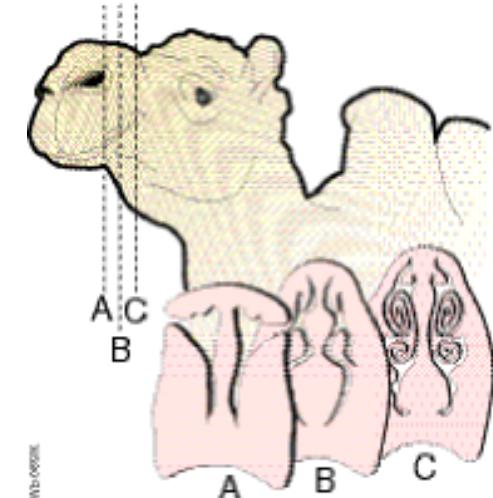
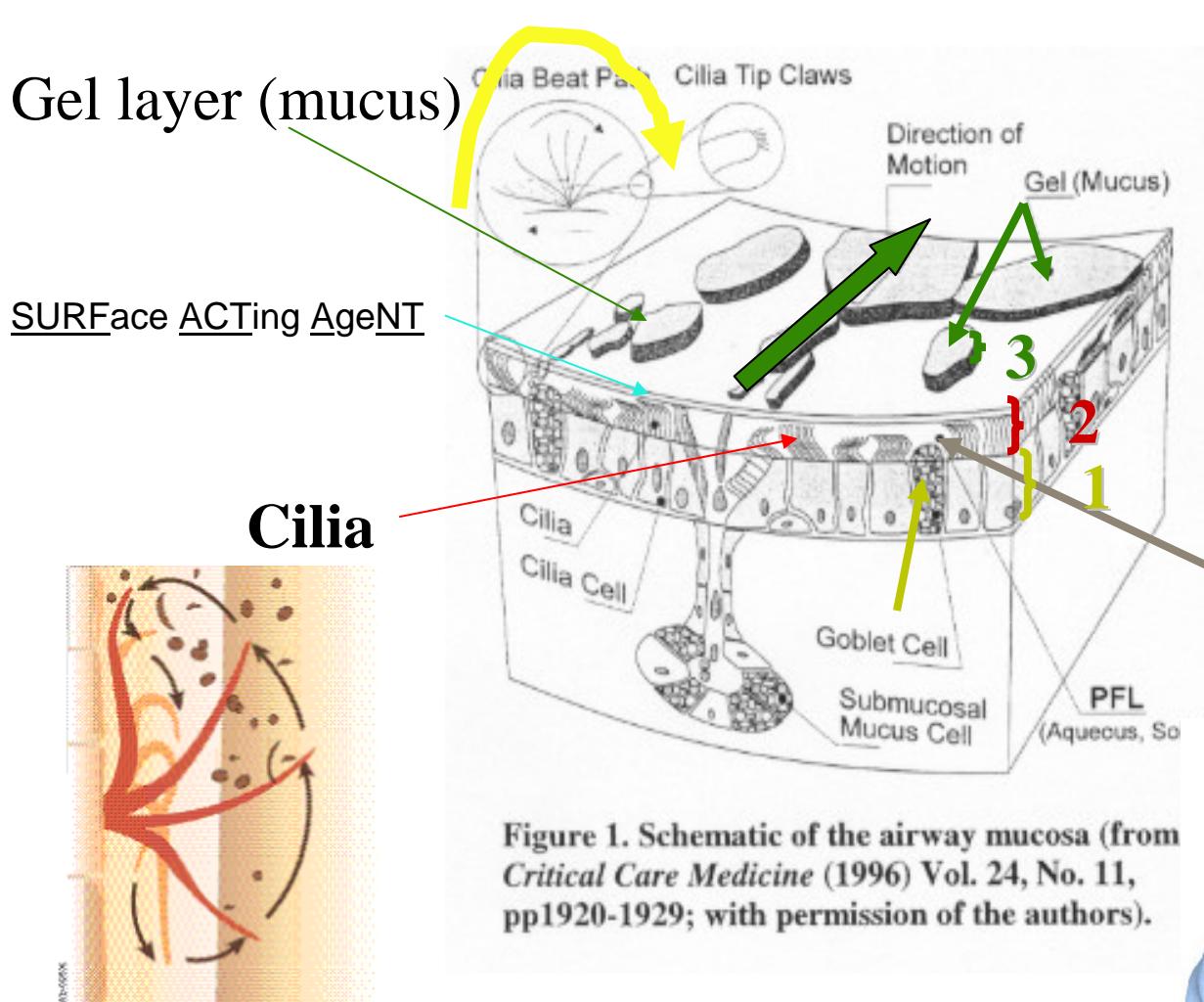
## ☞ Mimicking isothermic saturation point in artificial circuit



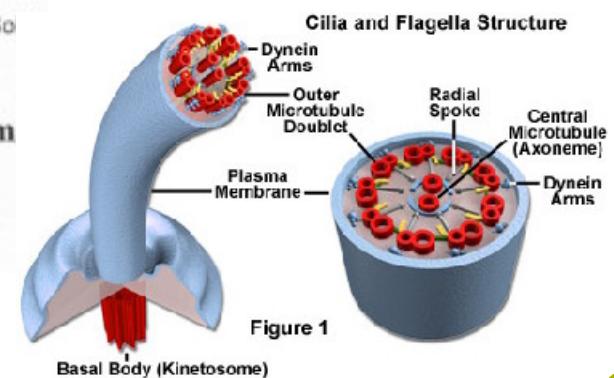
## ☞ Mimicking isothermic saturation point in artificial circuit

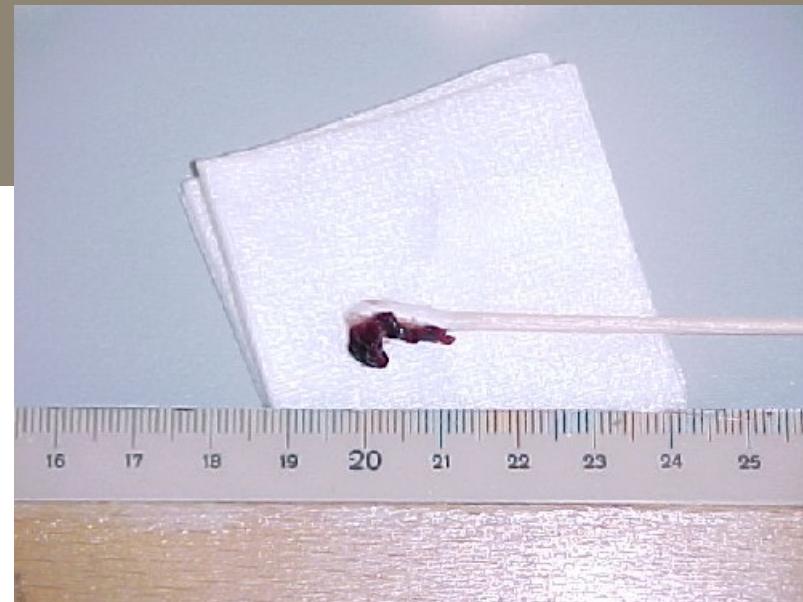
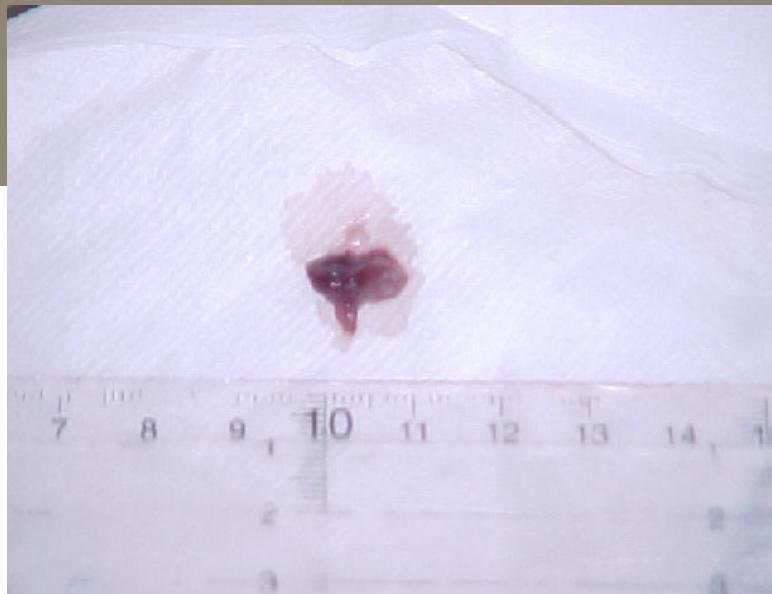


## ☞ Preserving biorheology



**Periciliary Fluid Layer (*Sol layer*)**





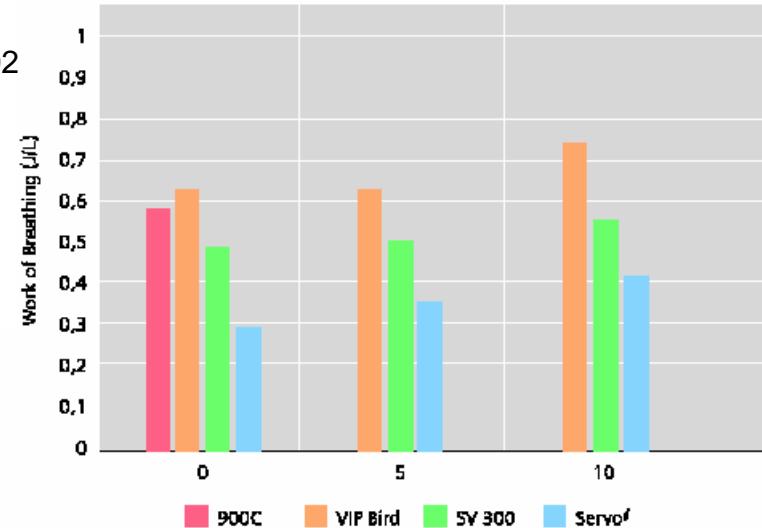
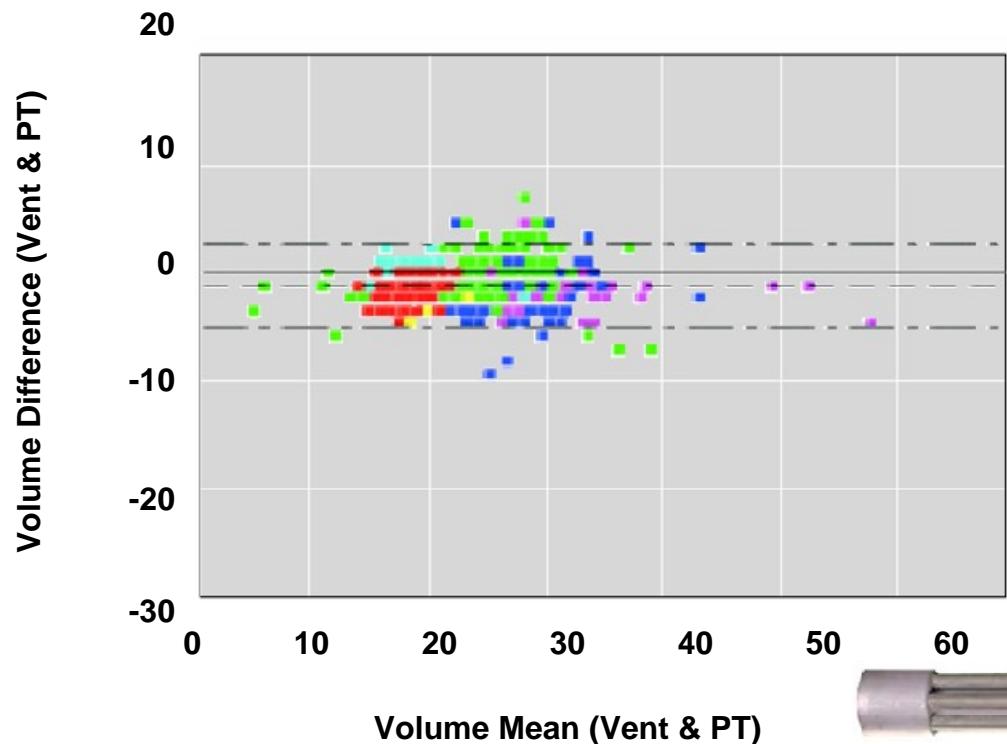
- Need for aerosol
- Need for instilled water or saline
- = airway mucosa dysfunction
- = pulmonary injury
- = denaturation surfactant

- Dehydratation SOL ([Williams ea, Crit Care Med 96](#))
- Thickening of mucus ([Branson ea, Resp Care 99](#))
- Imotile cilia-like S ([Boucher ea, J Phys 99](#))
- Plugging & ET narrowing ([Cohen ea, Crit Care Med 98](#))
- Infection (VAP) ([Piedalue, Resp Care 00, Boots ea, Crit Care Med 06, Lecouna ea, Crit Care 06](#))
- Need for open (lung derecruiting) suctioning techniques ([Schwenker ea, Am J Crit Care 98](#))
- Lesions ([King ea, Am J Resp & Crit Care Med 95](#))

## ☞ Accurate measurement & rapid response of equipment

Comparison of four ventilators. Chart kindly provided by M.Heulett.  
Mechanical Ventilation in Anesthesia & Intensive Care Symposium, Jan 2002

Recruitment = continuous phenomenon



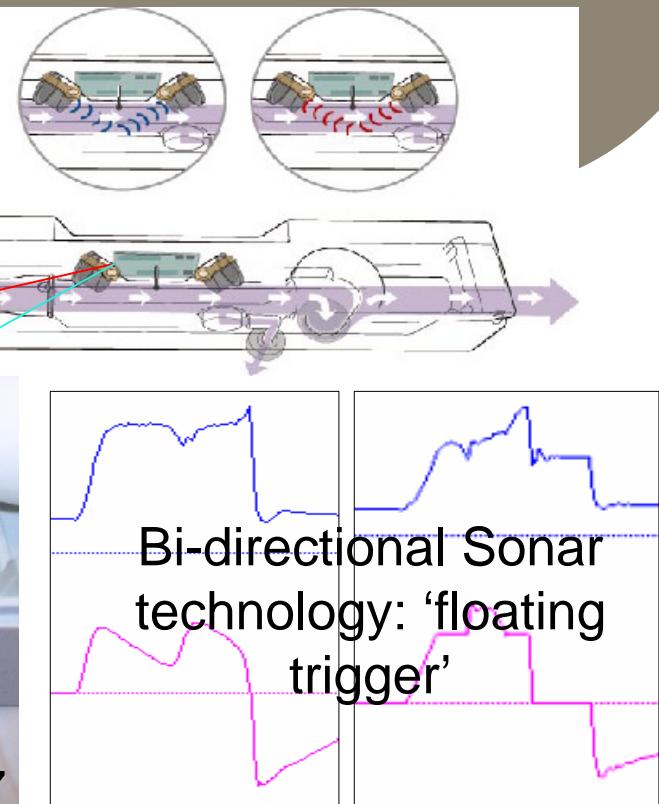
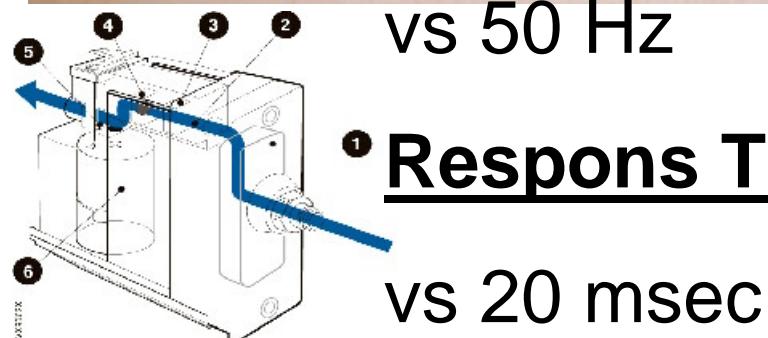
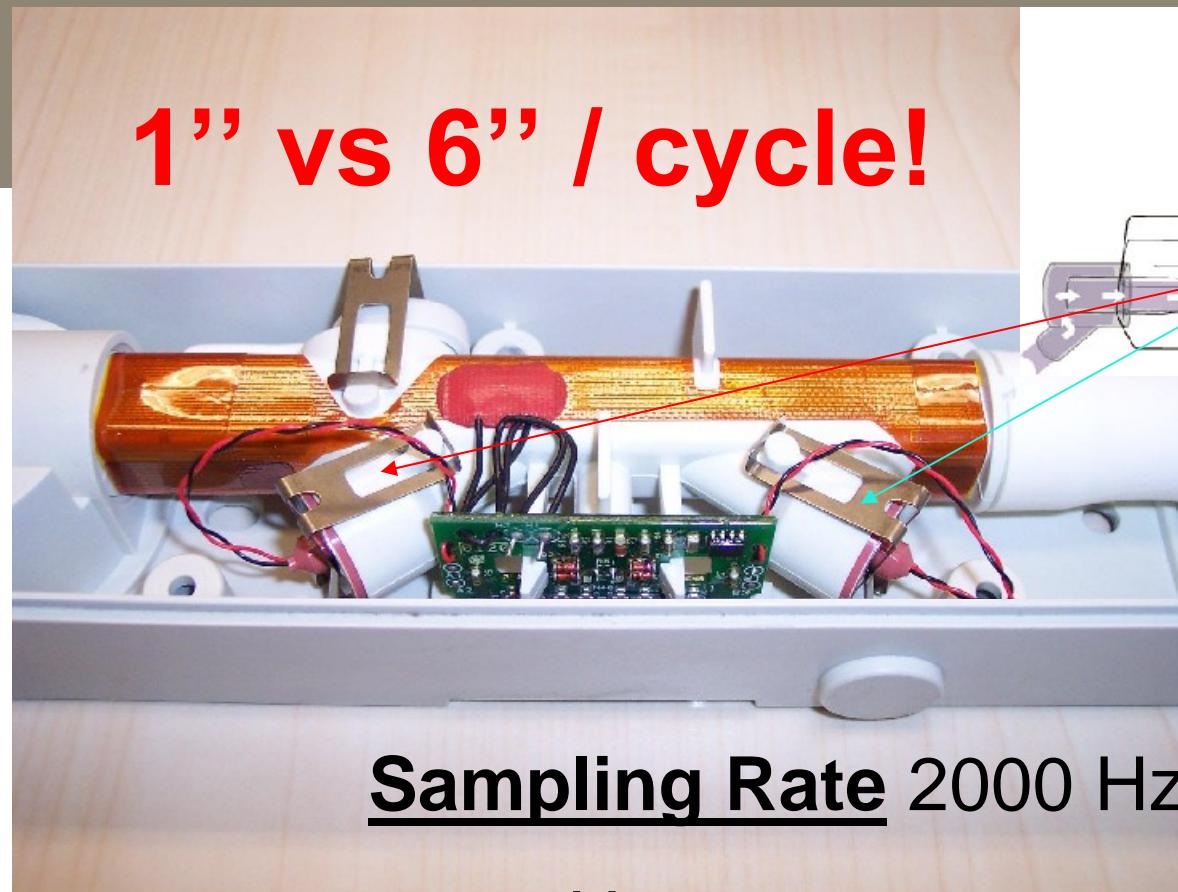
Bland-Altman plot showing matching of tidal volumes measured by Servo-i and pneumotachograf in seven spontaneously breathing piglets.

Heulitt MJ et al: Reliability of Measured Tidal Volume in Mechanically Ventilated Young Pigs, *Respiratory Care* 2002;47(9):1063.



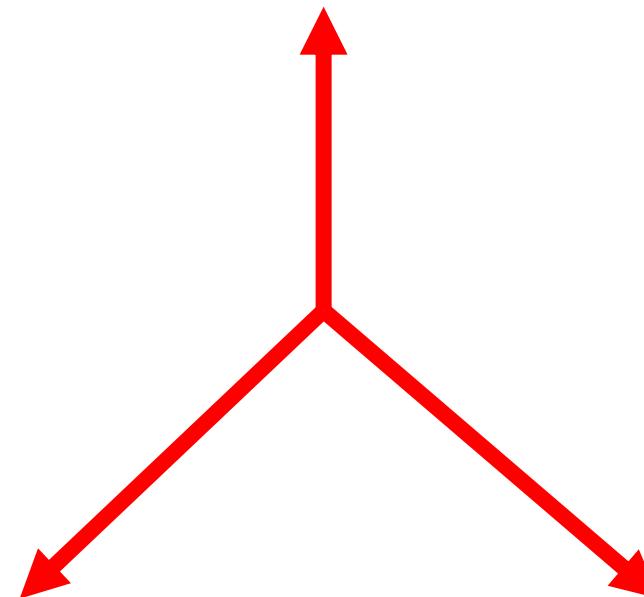
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# 1" vs 6" / cycle!



Heulitt MJ ea. Int Care Med 2005 Sep;31(9):1255-61

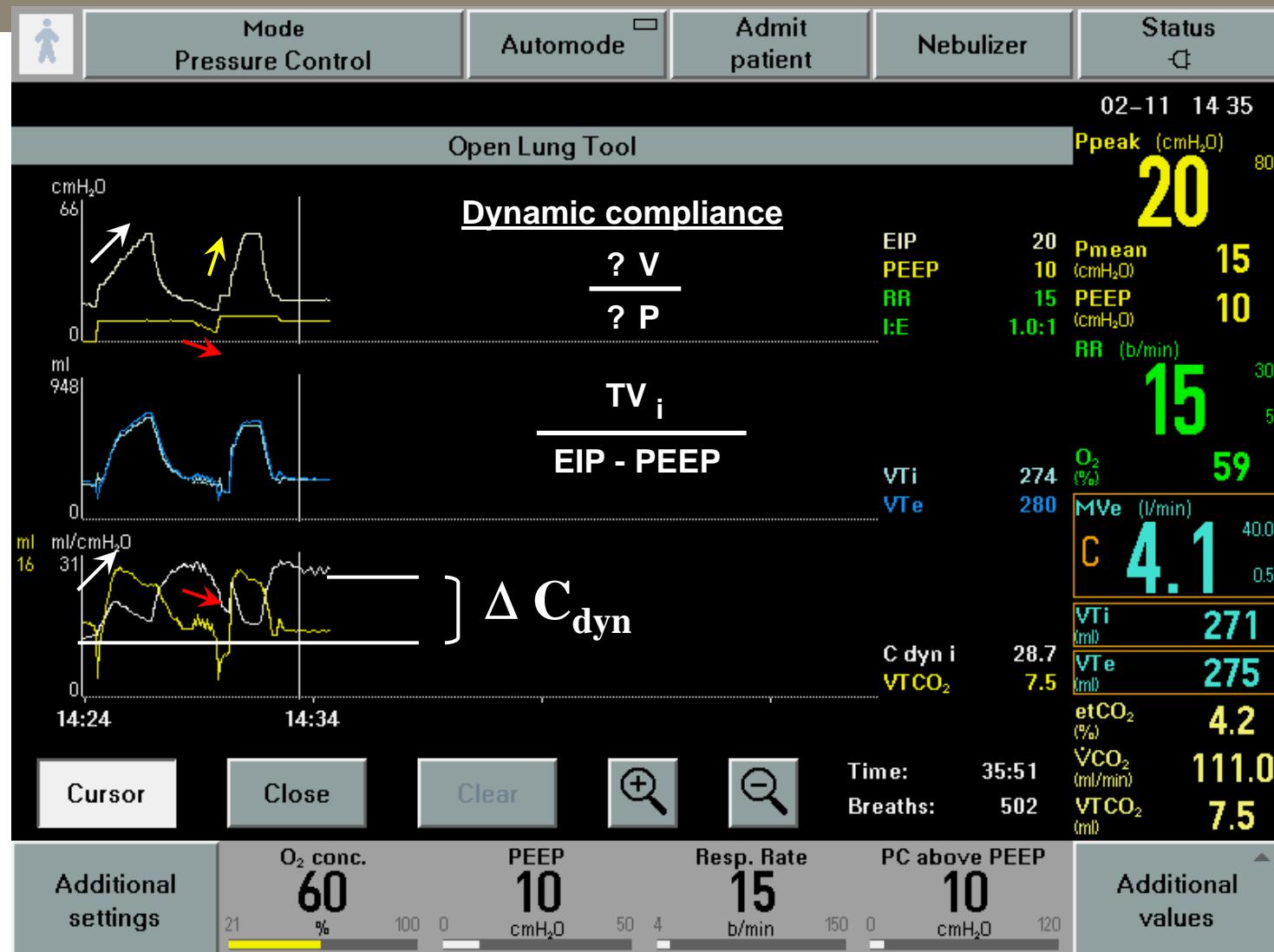
☞ (Spontaneous) Lung  
Protective Ventilation



☞ Proportional Ventilation

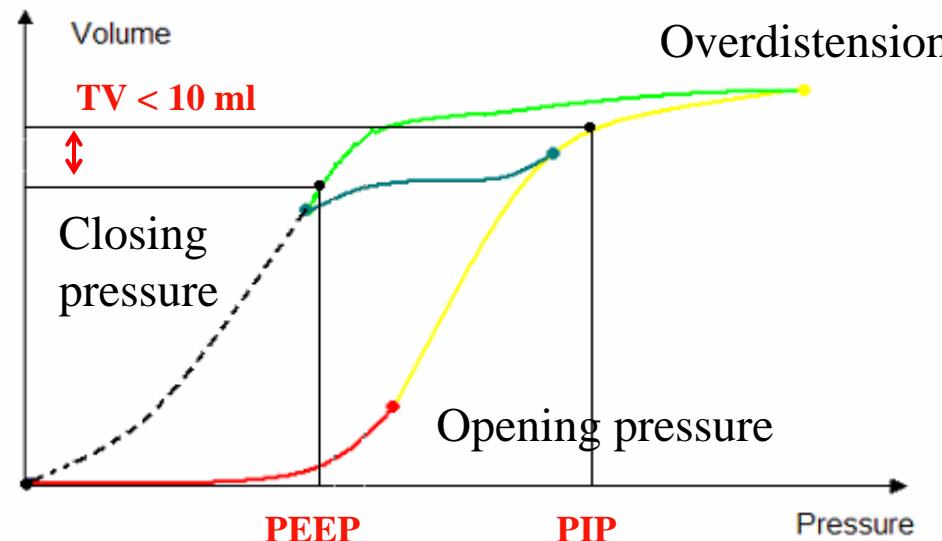
☞ Venous Return

## ☞ Lung Protective Ventilation: Open Lung Tool



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## ☞ Lung Protective Ventilation: keeping the lung open



OLC is not just about  
PEEP (= opening  
unstable alveoli)

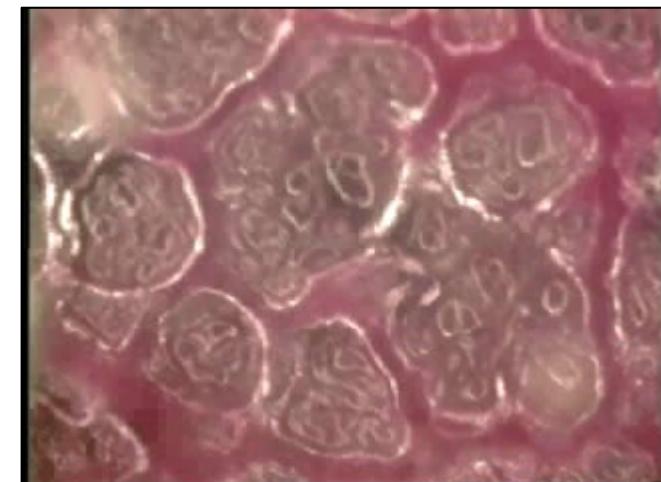
OLC is also PiP (= vital  
capacity maneuver)

### Keep the lung open :

To keep the alveoli opened, reduce the airway pressure to a point that is safely above the closing pressure.

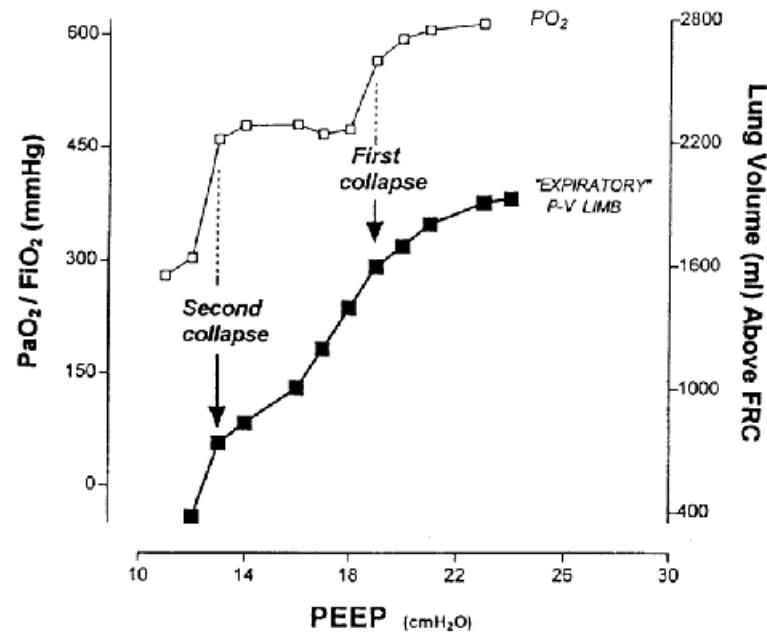
- > PEEP safely above the closing pressure.
- > PiP safely under the point of overdistension.

Desmond B ea. Respir Care 1998;43(11):952-960

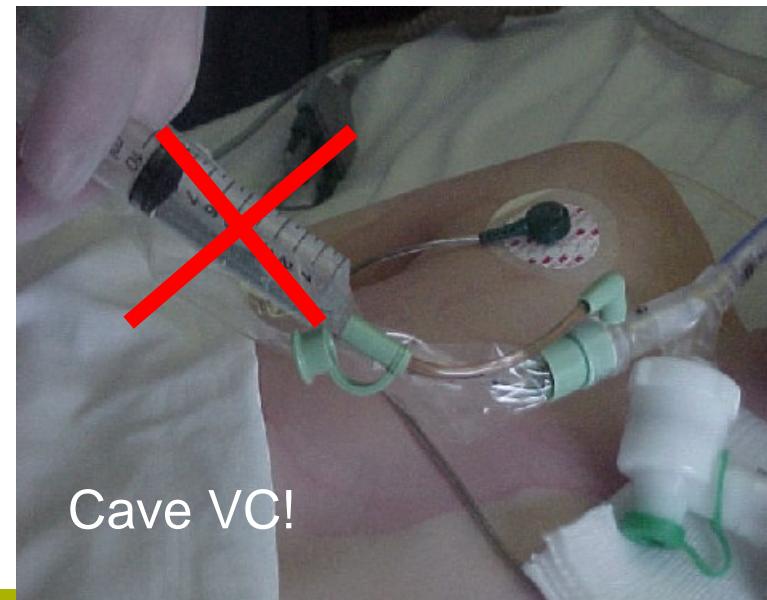
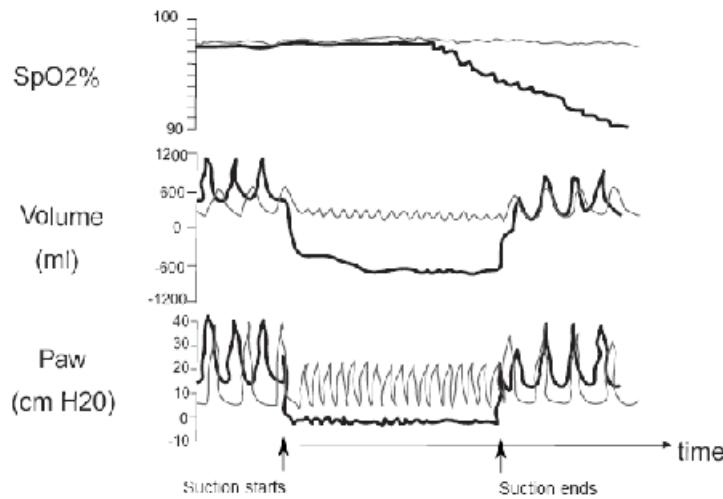


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## ☞ Lung Protective Ventilation: avoid derecruitments



**Fig 5.** The deflation limb of a pressure-volume curve (open squares) together with online arterial oxygen tensions (solid squares) from a ventilated patient are displayed as a function of PEEP. The drops in  $\text{PaO}_2$  are due to sudden alveolar de-recruitments (arrows). (Figure provided by courtesy of Dr M. Amato, São Paulo, Brazil)

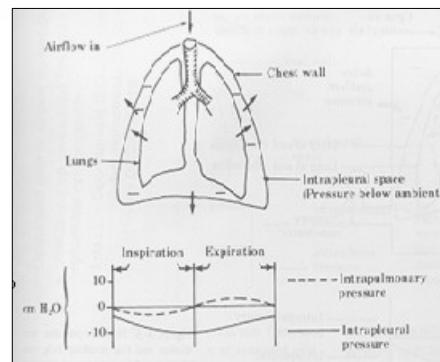
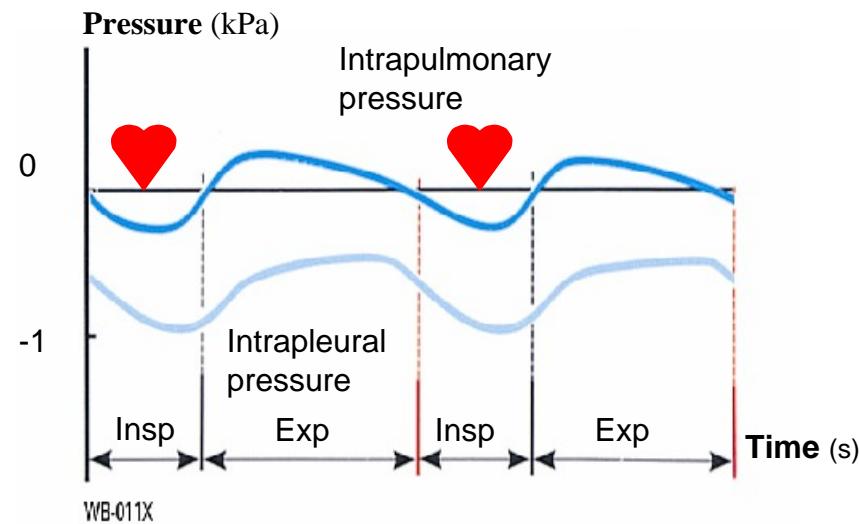


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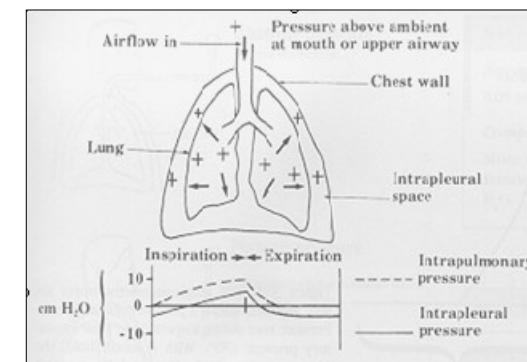
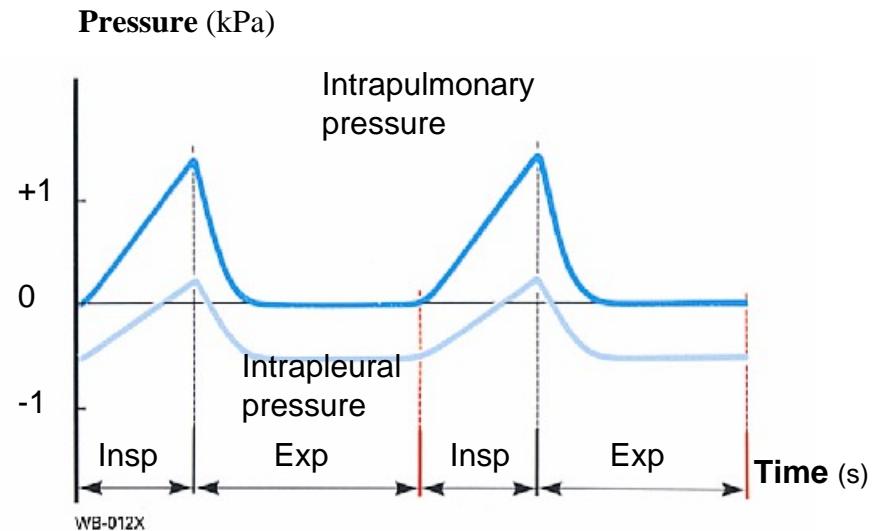


# ☞ Venous Return

## Spontaneous breathing

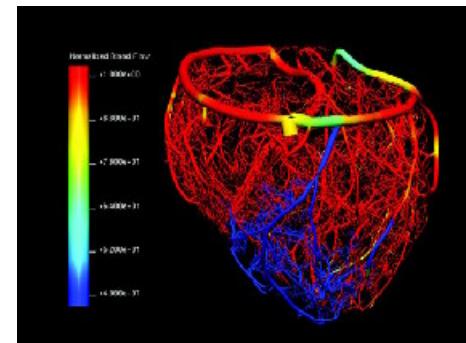
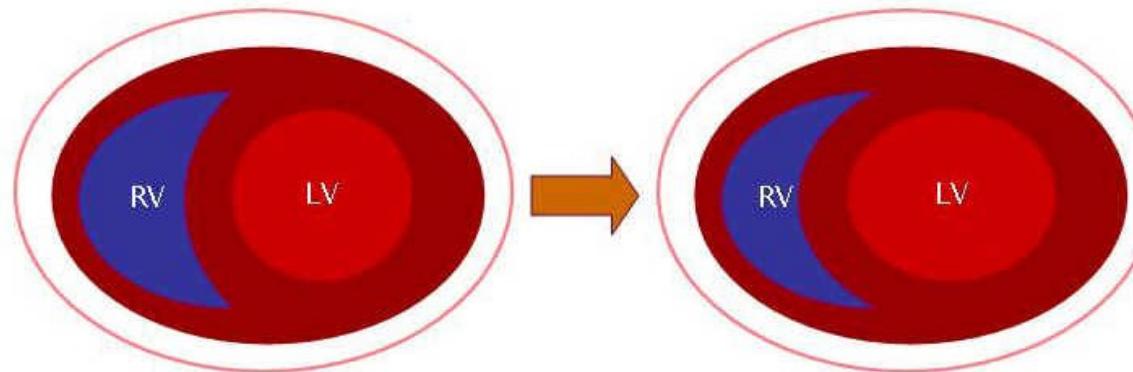
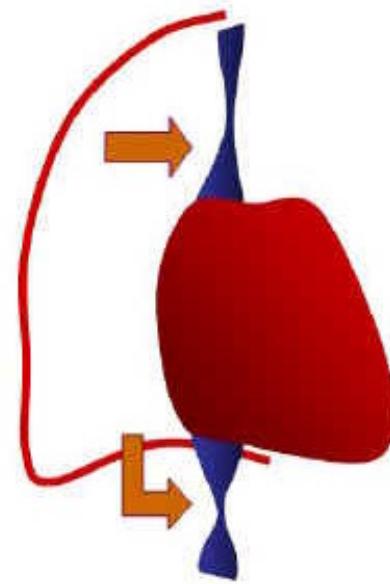
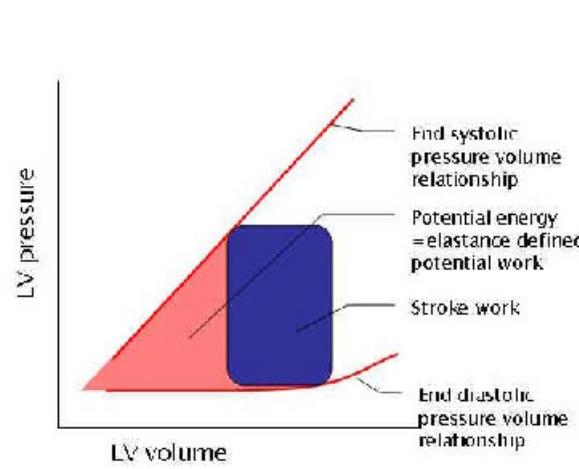
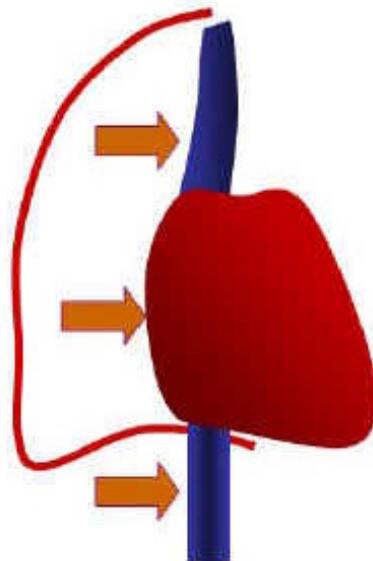


## Controlled Ventilation

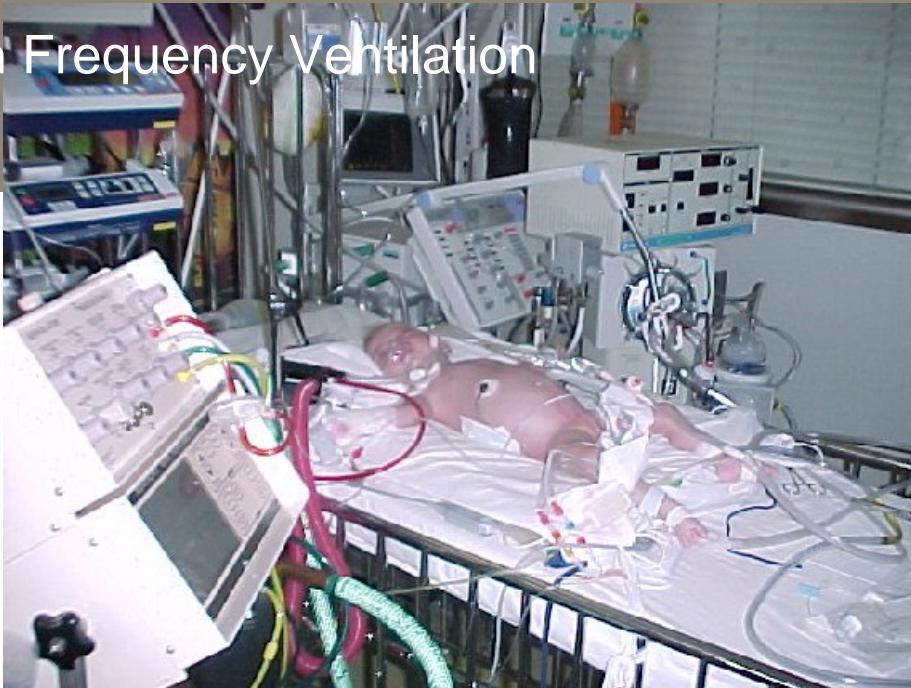
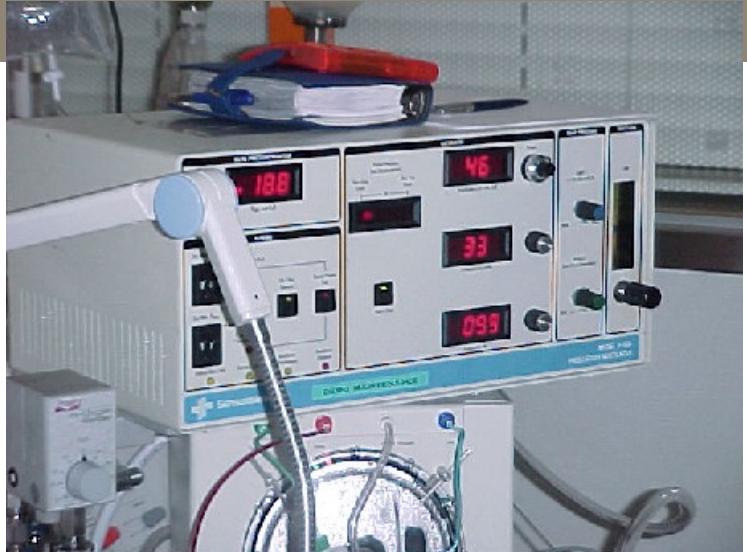


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## ☞ Venous Return



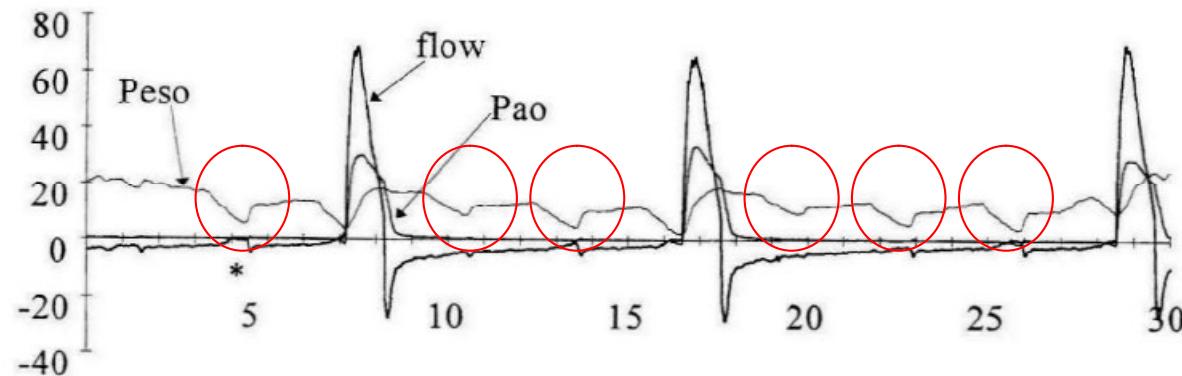
## ☞ Venous Return: High Frequency Ventilation



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## ☞ Neurally Adjusted Ventilation

- . Trigger asynchrony = associated with poor outcome
- . Controlled V = preferential displ't diaphragm (upper part) = upper region V
- . Sp V = dorsal part strongest = lower part V

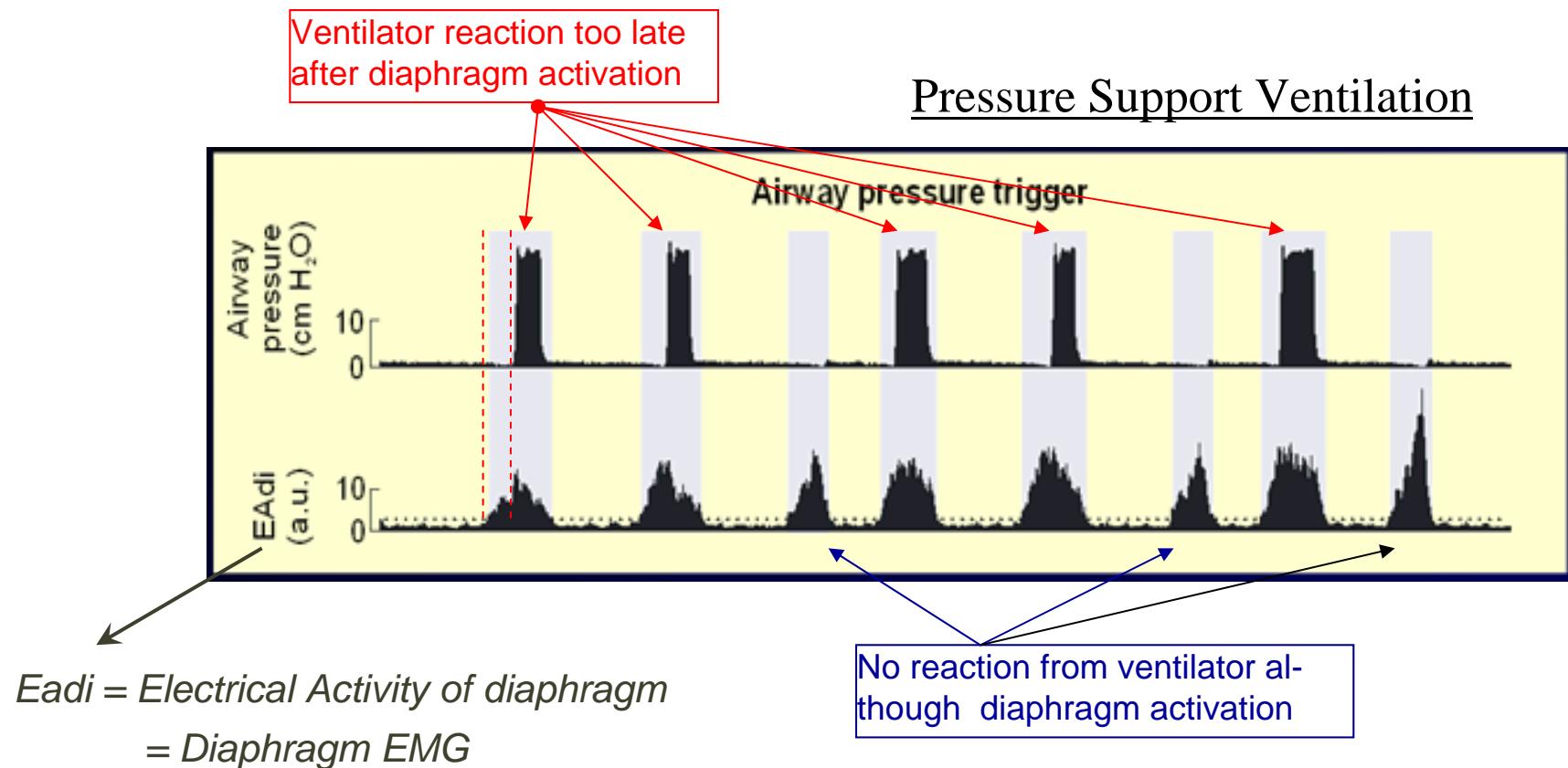


C. Chao et al (Los Angeles); **Patient-Ventilator Asynchrony in Prolonged Mechanical Ventilation**; Chest; 112/6; Dec 1997; 1592 - 1599



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## ☞ Neurally Adjusted Ventilation

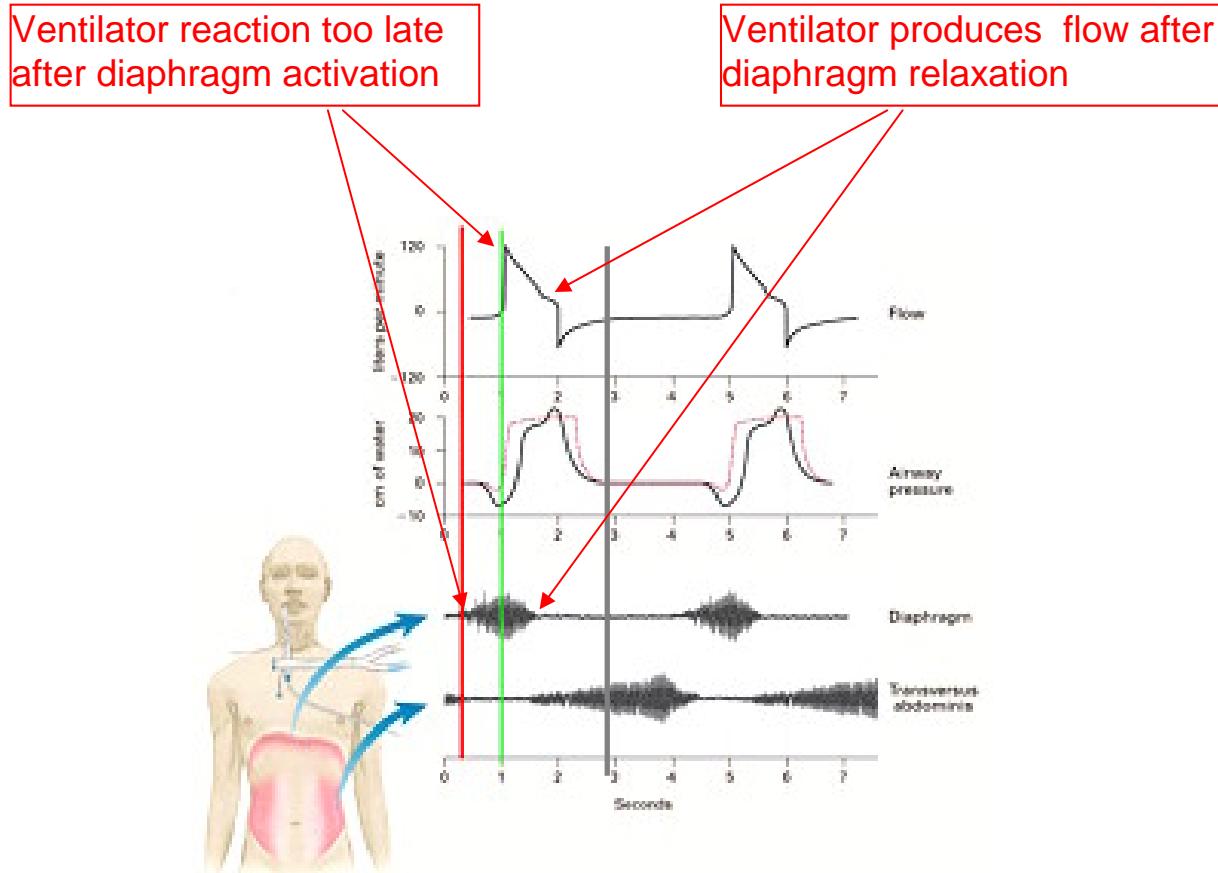


Sinderby C ea. Nature Medecine, 1999



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## ☞ Neurally Adjusted Ventilation

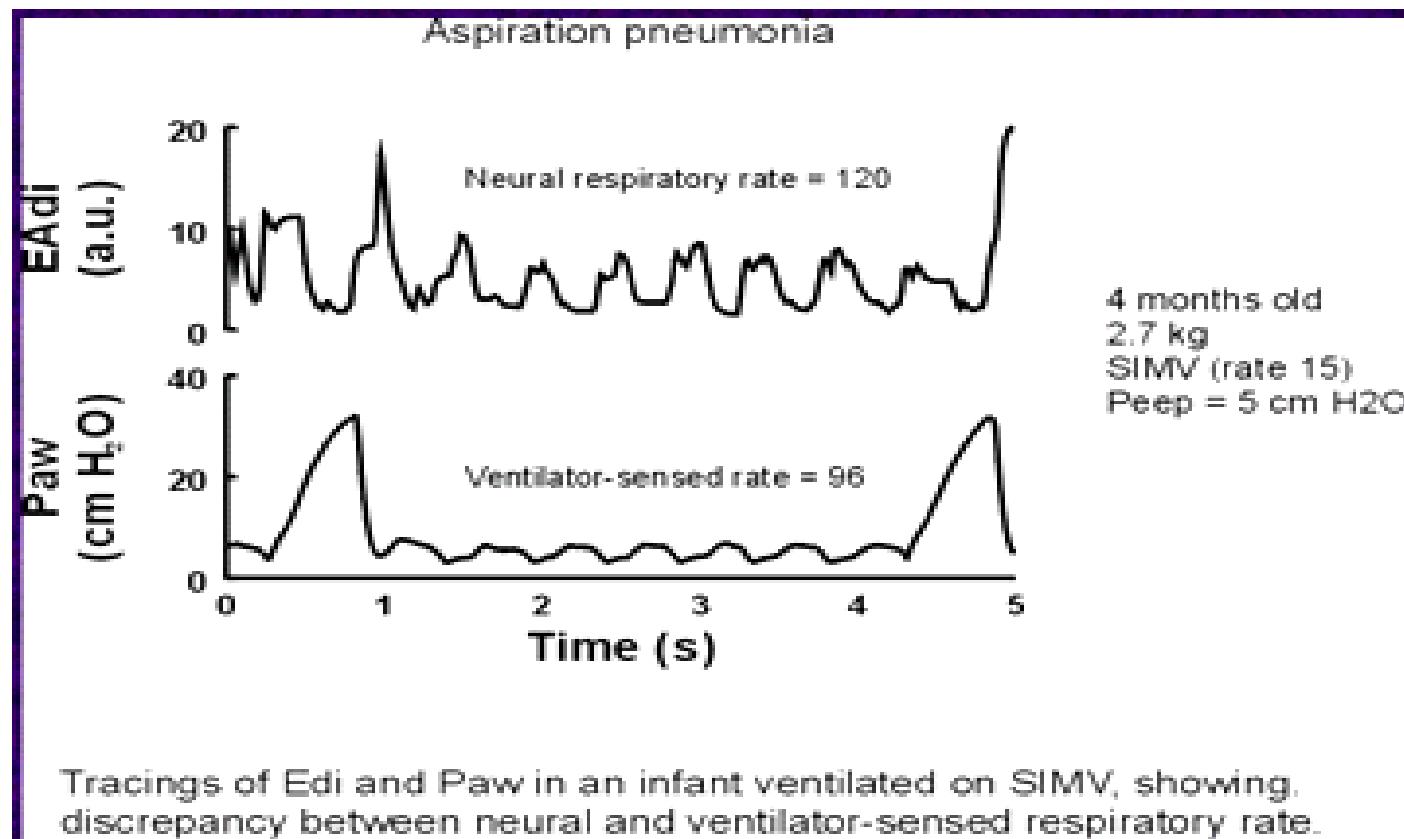


Tobin M ea. N Engl J Med, 2001, 344:1986 -1996



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## ☞ Neurally Adjusted Ventilation

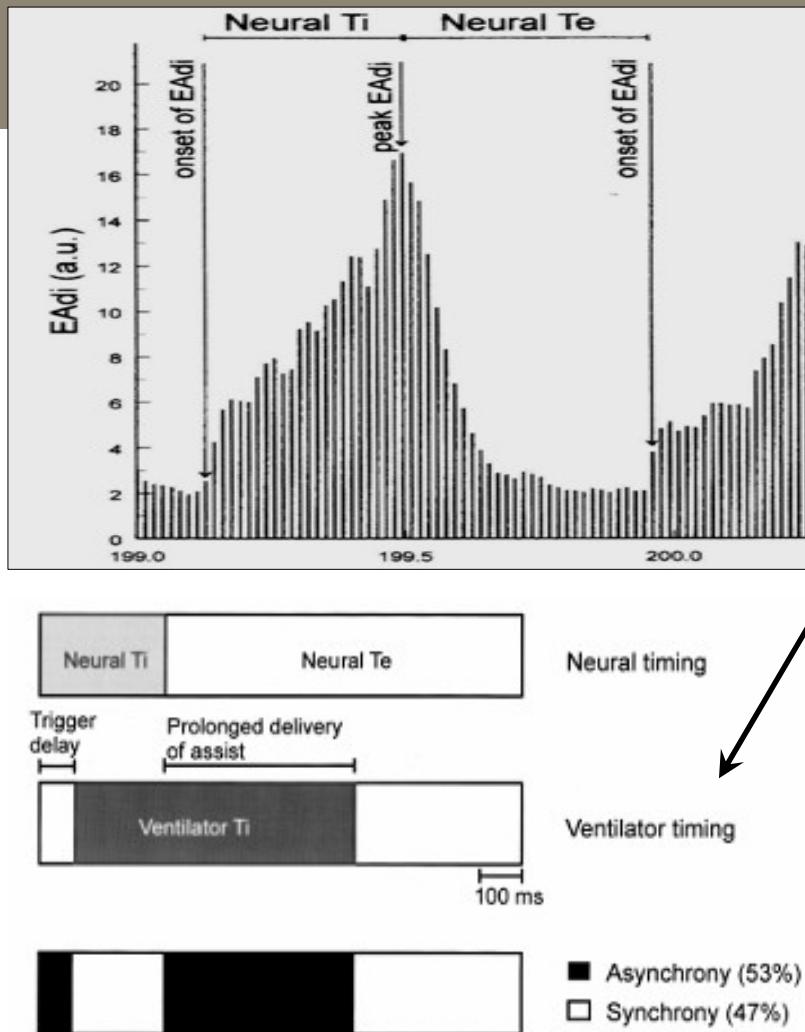


**Eadi of Edi = Electrical Activity of Diaphragm**

J. Beck, Symposium PIC, Boston 2003



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The mandatory SIMV breath is compared with the neural timing of the patient (measured with Eadi)

The “synchronised” cycle is actually 53 % asynchronous en only 47 % synchronous with this neural timing.

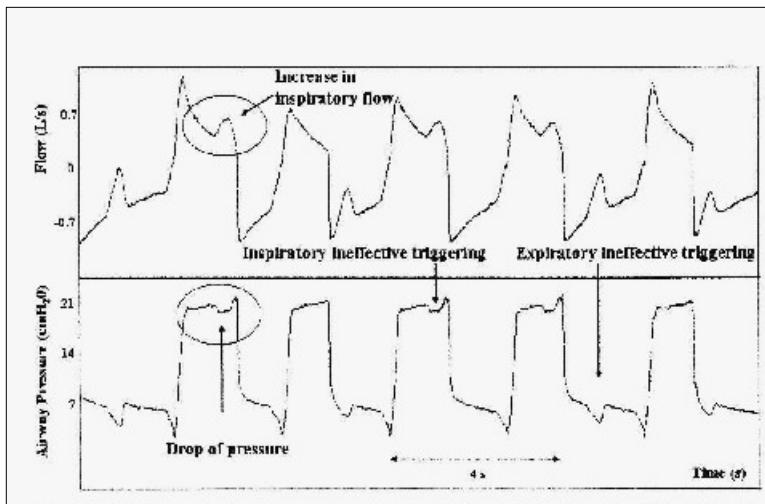
This shows us that conventional ventilation is not as synchronous with the actual respiratory drive from the patient as we always thought it should be.

Beck J ea. Prolonged expiratory neural time induced by mechanical ventilation in infants; Pediat. Res; 2004, 55(5); 747-754

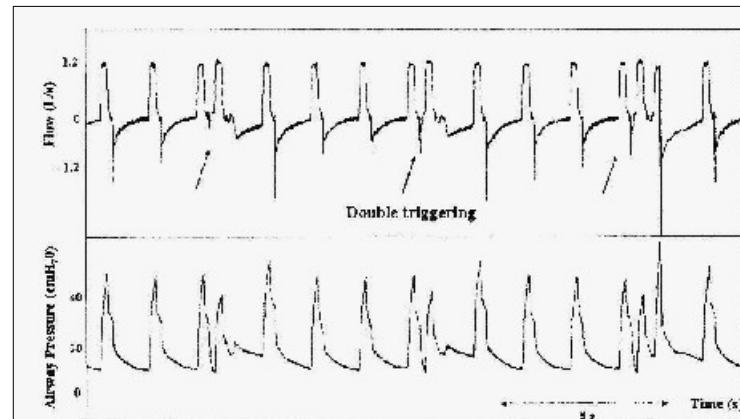


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## ☞ Neurally Adjusted Ventilation



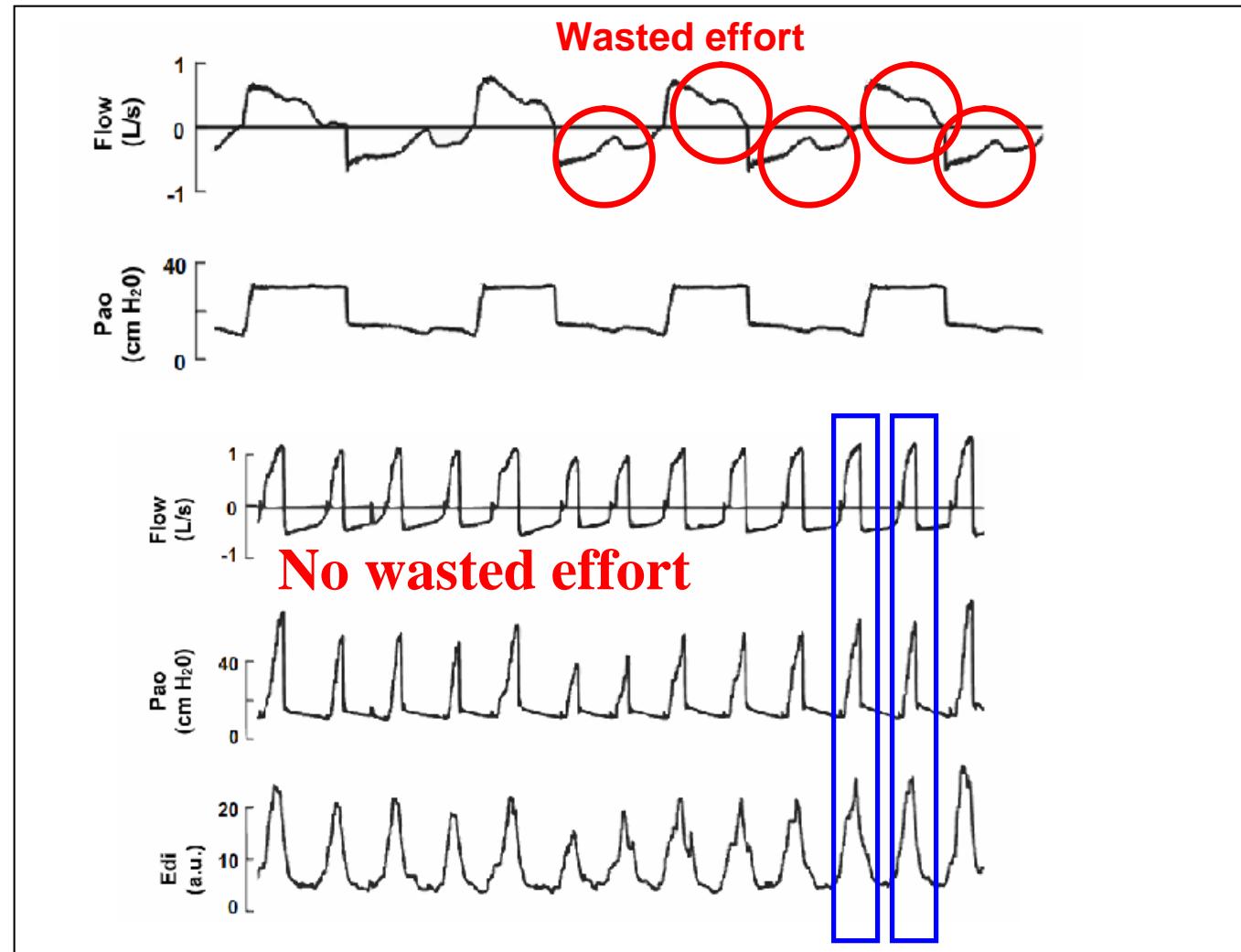
**Fig. 2** Flow and airway pressure recordings showing ineffective efforts occurring both during the expiratory phase and during the inspiratory phase



**Fig. 3** Flow and airway pressure recordings showing double-triggering, defined as two consecutive ventilator cycles separated by an expiratory time less than one-half the mean inspiratory time. Double-triggering occurs when the ventilator inspiratory time is shorter than the patient's inspiratory time. The patient's effort is not completed at the end of the first ventilator cycle and triggers a second ventilator cycle

Thille A.W., Brochard L. et al.; **Patient-Ventilator Asynchrony during assisted Mechanical Ventilation; Intensive Care Med**; 2006; 32 : 1515 - 1522

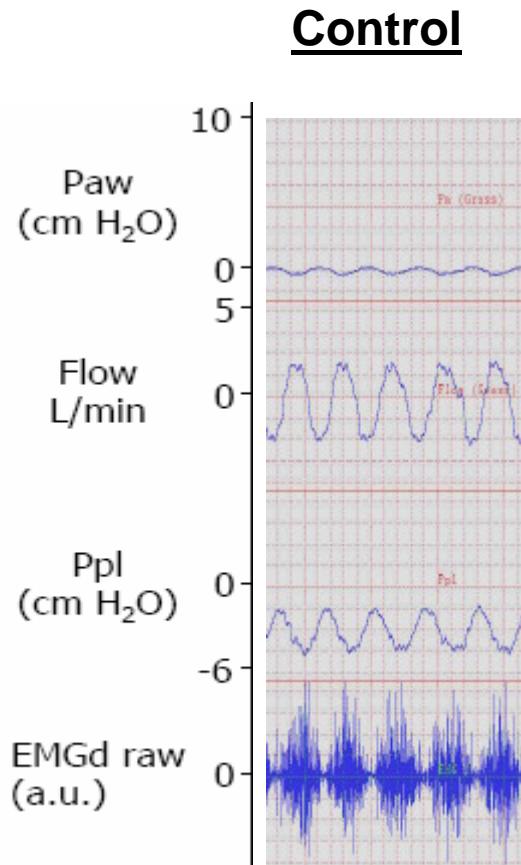
## ☞ Neurally Adjusted Ventilation



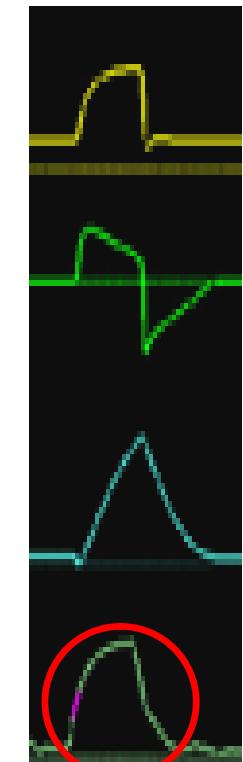
Data from Sacré Coeur Hospital Toronto Spahija et al (by J. Beck)



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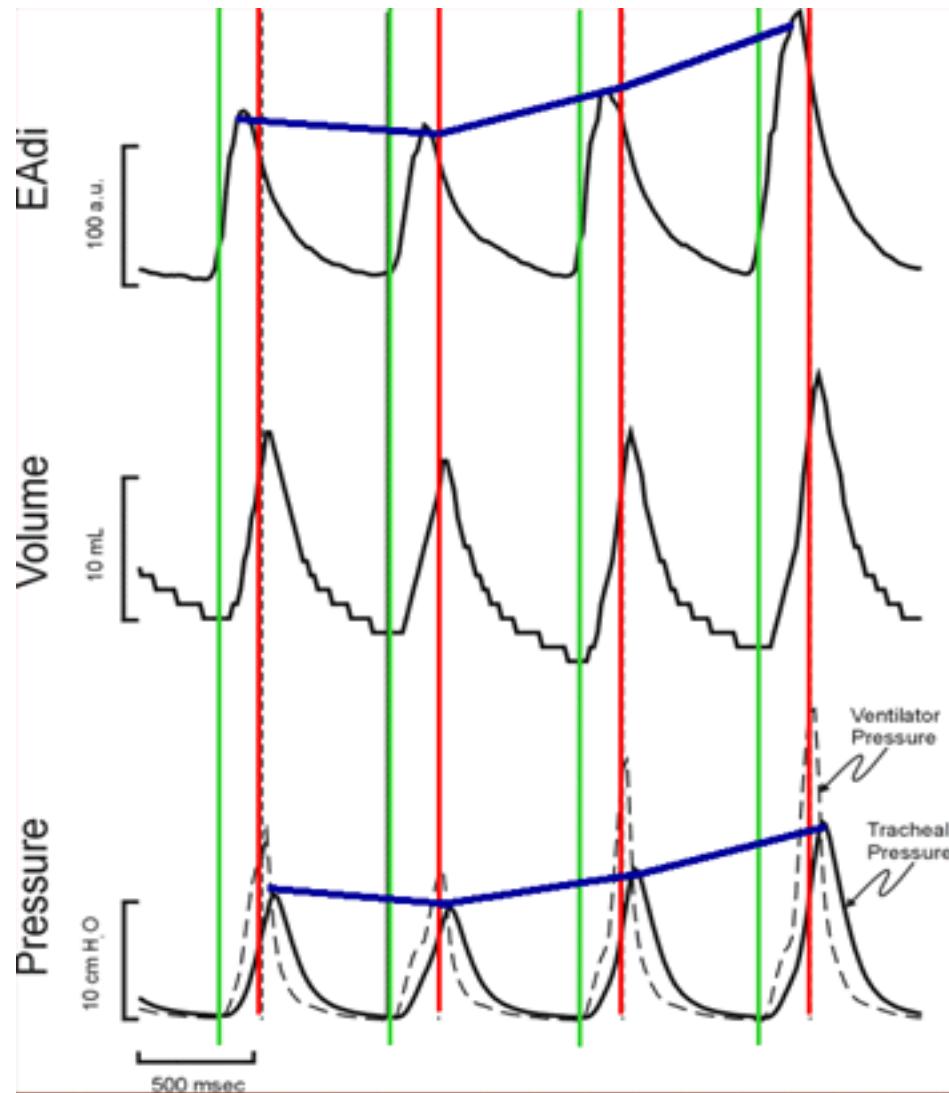
**NAVA**  
*(Data Maquet)*



*With NAVA diaphragm activity remains intact*

Sassoon CS et al. (University of California); **Assist-Control Mechanical Ventilation Attenuates Ventilator - induced Diaphragmatic Dysfunction in rabbits**; Am J Resp Crit Care Med; 2004;  
170 : 626 - 632 (ONLINE DATA SUPPLEMENT)

## ☞ Proportional Ventilation



Stimulated diaphragm =  
reduced atelectasis (G.  
Hedenstierna)

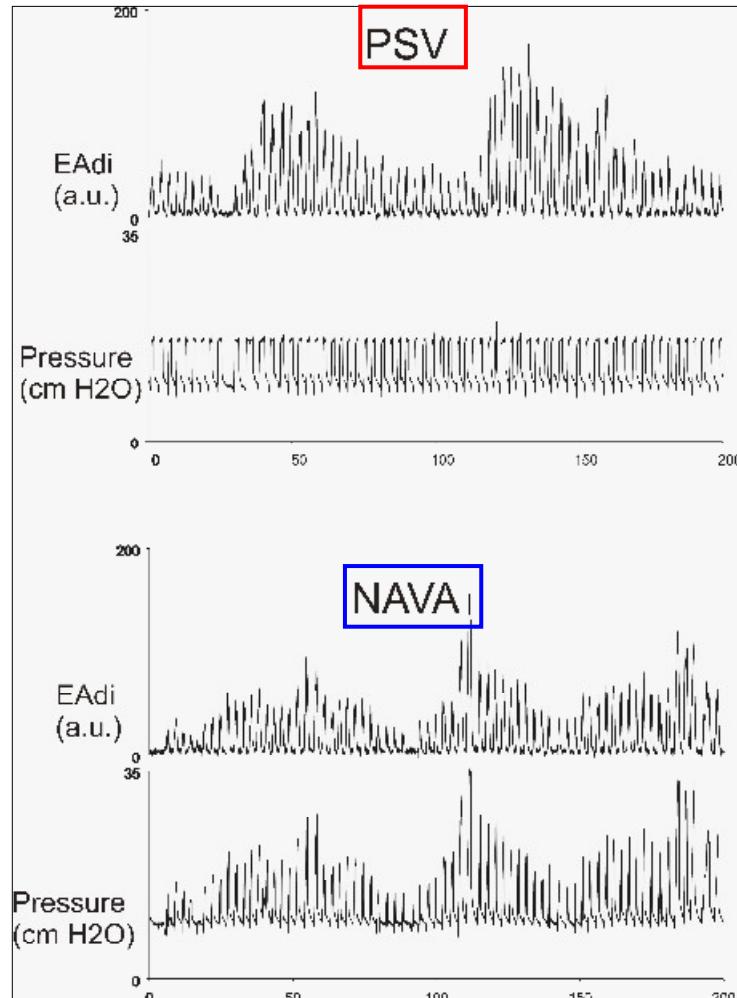
**Proportional,  
Neurally Adjusted,  
Ventilatory Assist**

Data from St. Michael's hospital  
Toronto, Canada  
Sinderby C.



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## ☞ Proportional Ventilation



**The Edi gives us a clear view on the neural demand of the patient.  
This demand is changing over time.  
PSV does not adapt to that and delivers always the same support.**

**Measurement of the Edi makes it possible to monitor the changing neural demand of the patient, regardless the ventilation mode used.**

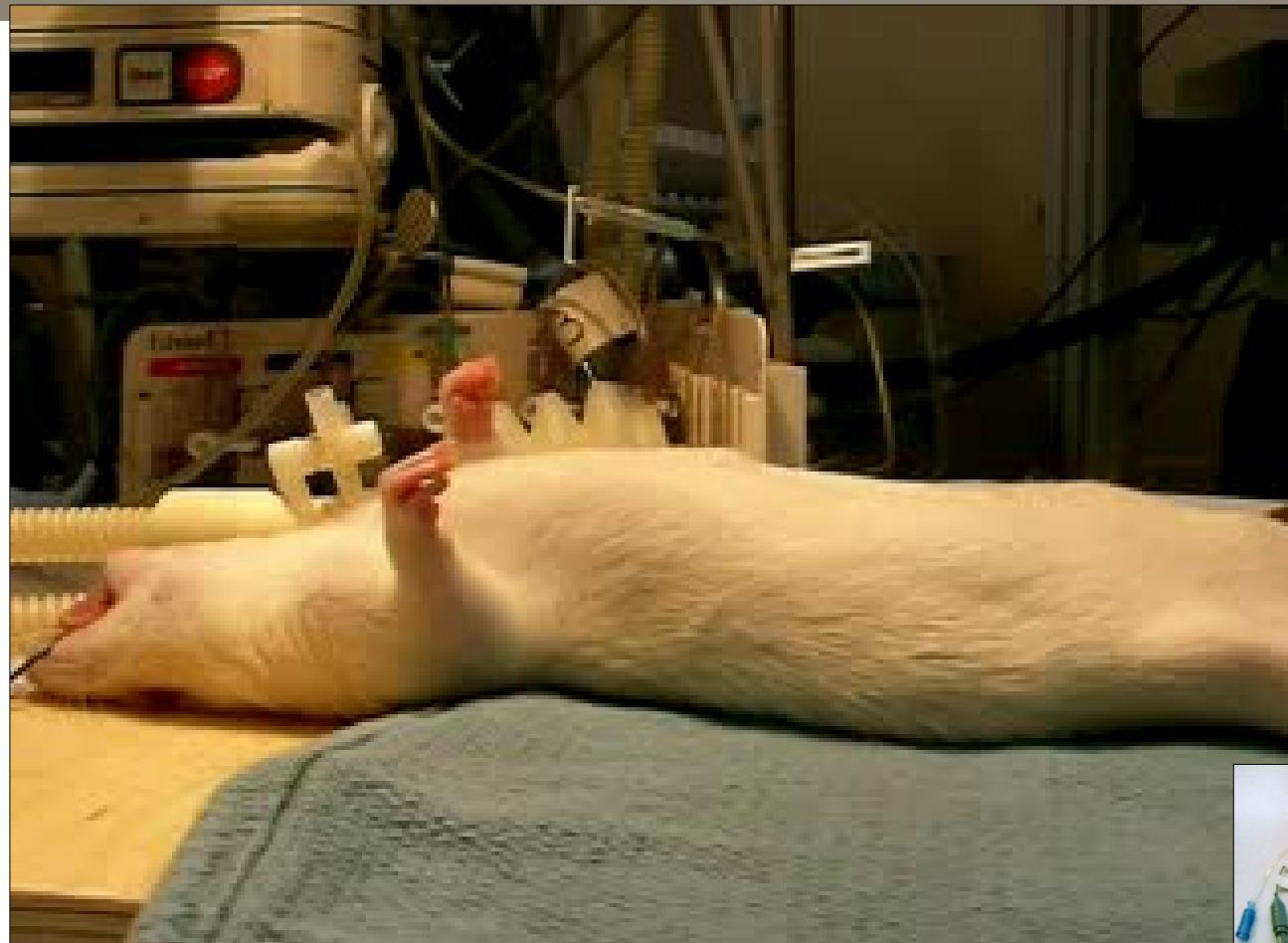
**During NAVA ventilation, the support is real time proportional to the changing demand of the patient.**



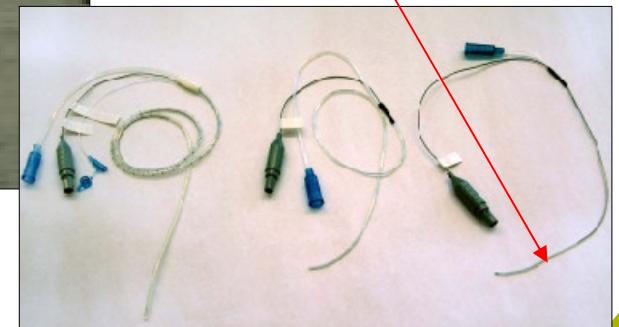
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L. Brander ea. Presented at ESICM in Barcelona  
2006

## ☞ Proportional Ventilation

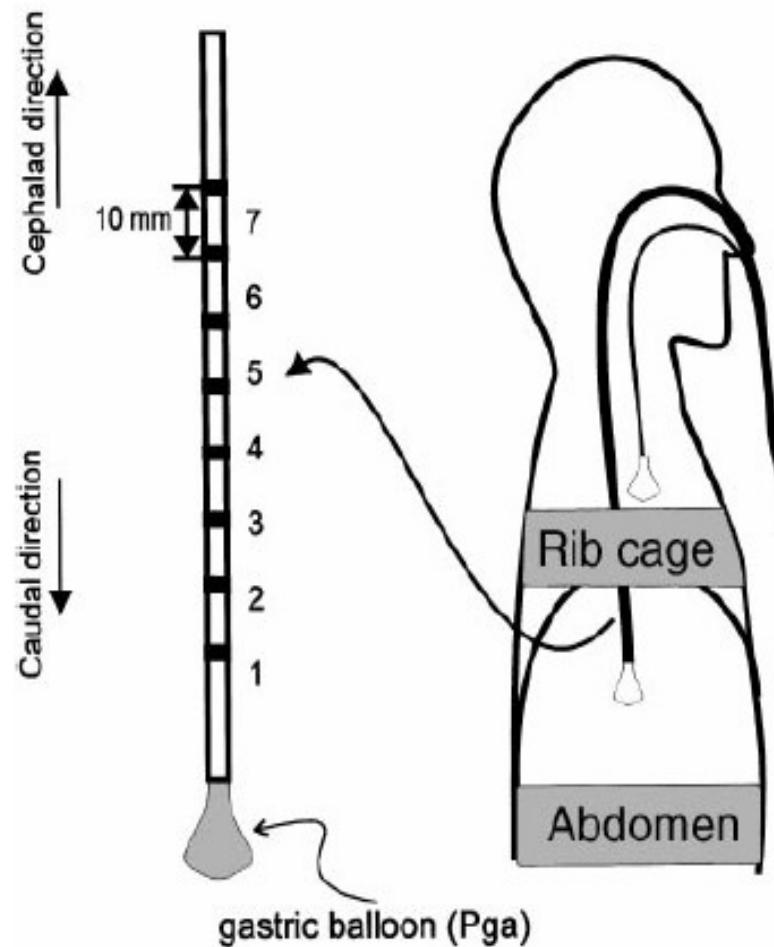


Neonates  
Infants



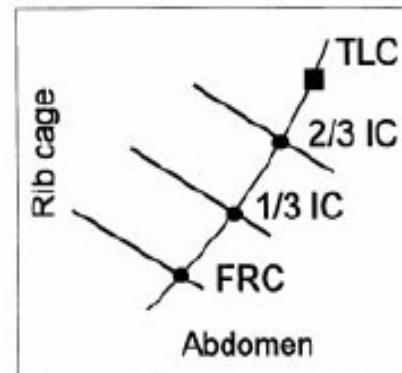
**Data from St. Michael's hospital Toronto, Canada**  
Presented by C. Sinderby at the ESICM congress Berlin 2004

## Diaphragm EMG electrode

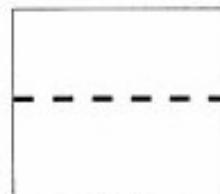


## Feedback about lung volume and transdiaphragmatic pressure

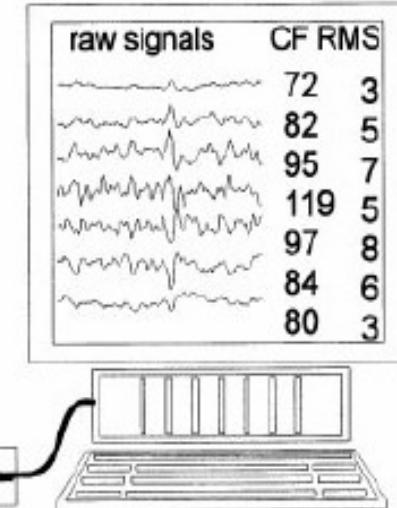
### Konno-Mead diagram



### Target Pdi



## On-Line EMG Display





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