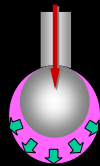
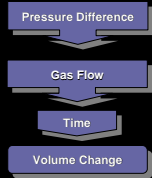
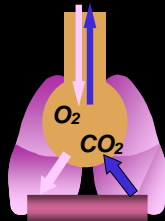


Respiratory Monitoring

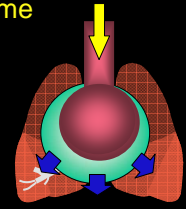
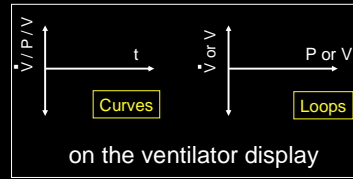
Basic Mechanism of PPV



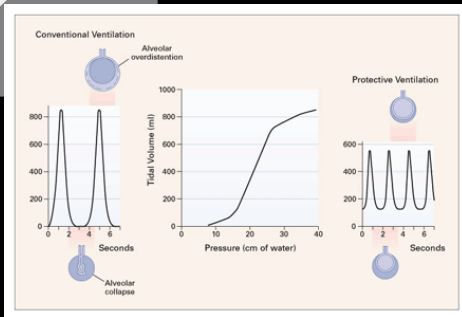
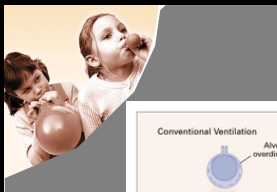
Gas Exchange



Pressure – Flow – Time - Volume

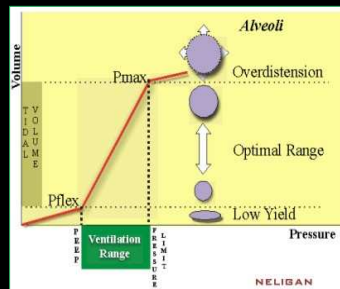


- to assess patient-ventilator synchrony
- to get some information on respiratory mechanics under dynamic conditions (!)
- to detect erroneous ventilator settings
- to guide in the search for optimal ventilator settings



Tobin M NEJM 2002

The Pressure-Volume Curve: Useful at bedside?



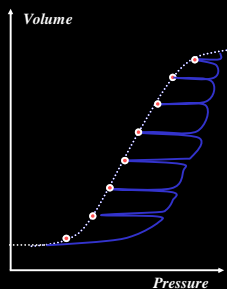
How to monitor at bedside?

- 1) PV-tools +/-

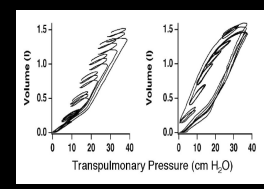
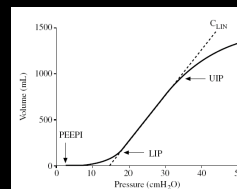
Assessment of Static P-V Curve

Super-syringe method:
Stepwise inflation from a big syringe with multiple occlusions at each volume to record recoil pressure

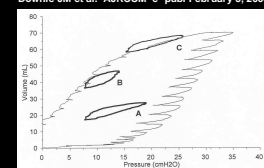
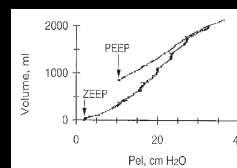
- Time consuming
- Cumbersome to perform
- Difficult to standardize
- Patient must be paralyzed
- Great risk of oxygen desaturation



Is the static PV-curve useful?



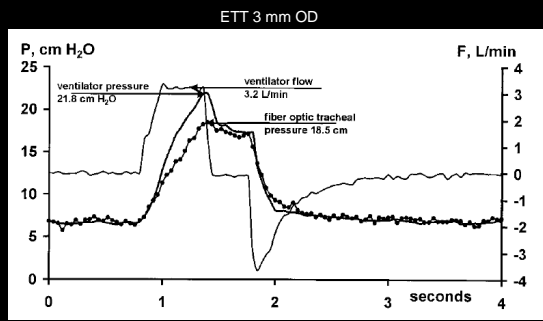
Downie JM et al. AJRCCM e- publ February 5, 2004



Jonson B AJRCCM 1999;159:1172-1178

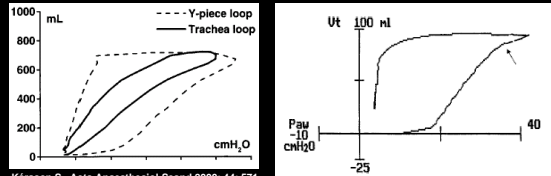
Rimensberger PC Crit Care Med 1999; 27:1946-52

Pressure measurements under dynamic conditions

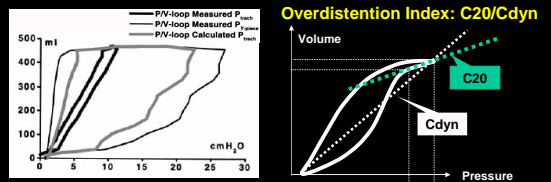


Sondergaard S Ped Research 2002; 51: 339-45

Monitoring of the dynamic cycle: Is it better?

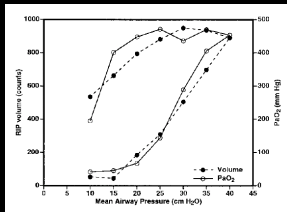


Káráson S Acta Anaesthesiol Scand 2000; 44: 571

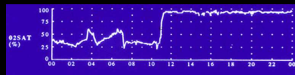


Káráson S Acta Anaesthesiol Scand 2001; 45: 173

Lung protection and the open lung concept



Brazelton TB Crit Care Med 2001; 29:2349

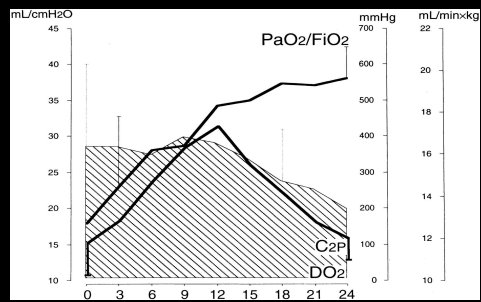


How to monitor at bedside?

- 1) PV-tools +/-
- 2) O₂-response?

The oxygen response (limitations)

P/F-ratio, oxygen delivery and Crs during PEEP steps



Lichtwarck-Aschoff M AJRCCM 2000; 162:2125-32

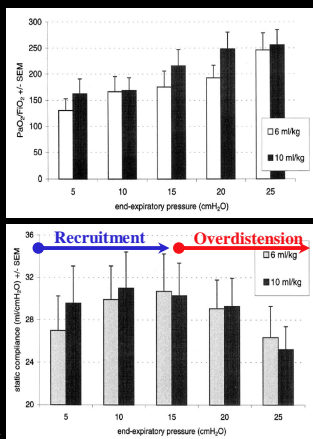
The oxygenation response: Can it be used?

PEEP and Vt effects

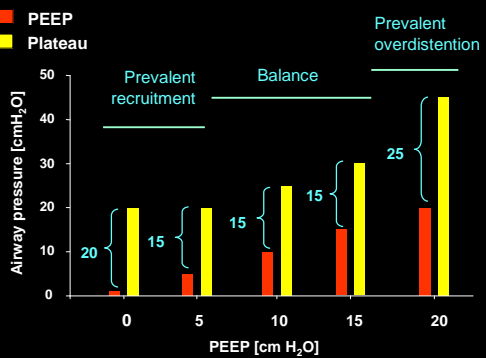
"static" compliance:

$$C_{st} = \frac{\text{tidal volume}}{\text{static PIP (Pplat)} - \text{PEEP}}$$

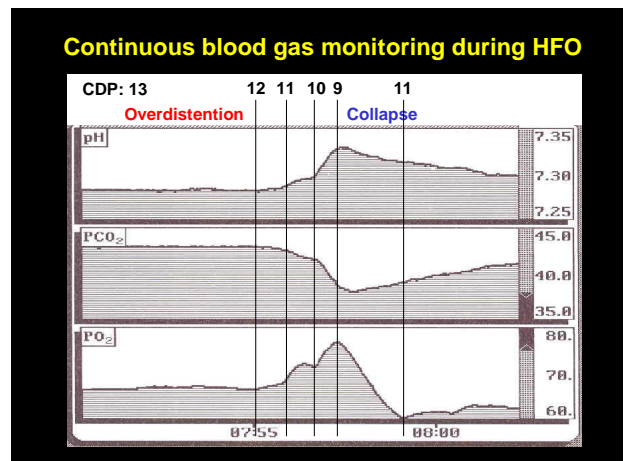
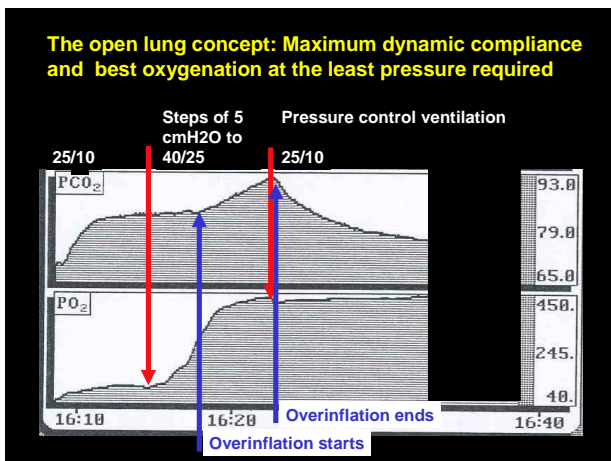
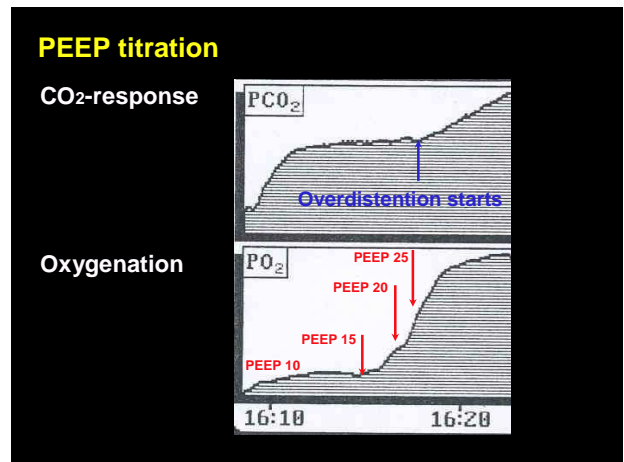
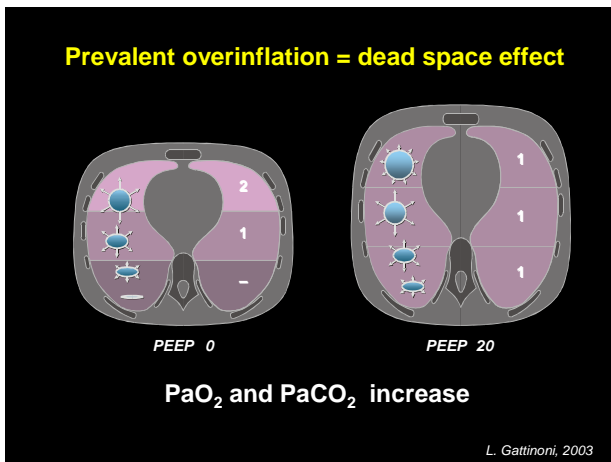
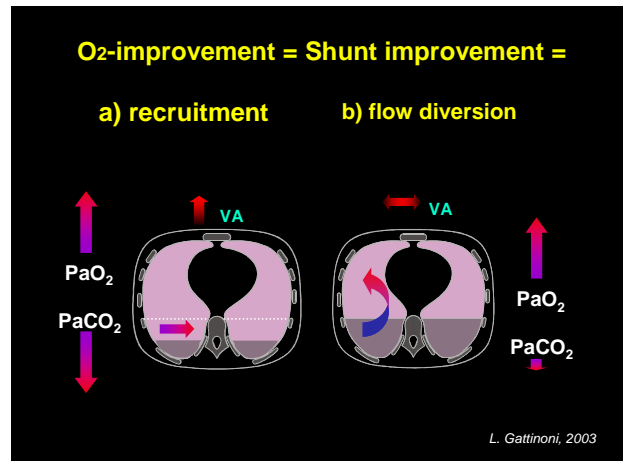
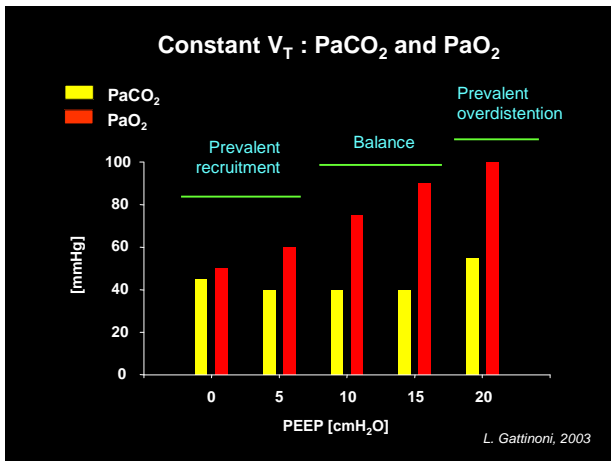
Burns D J Trauma 2001;51:1177-81

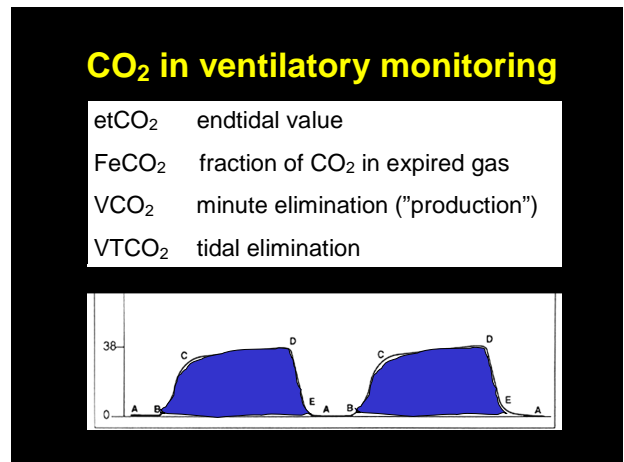
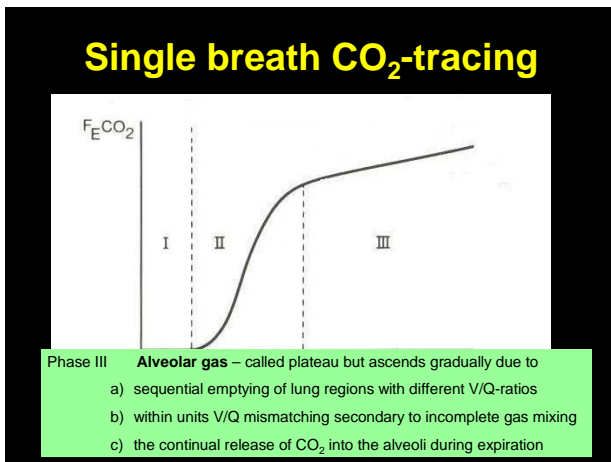
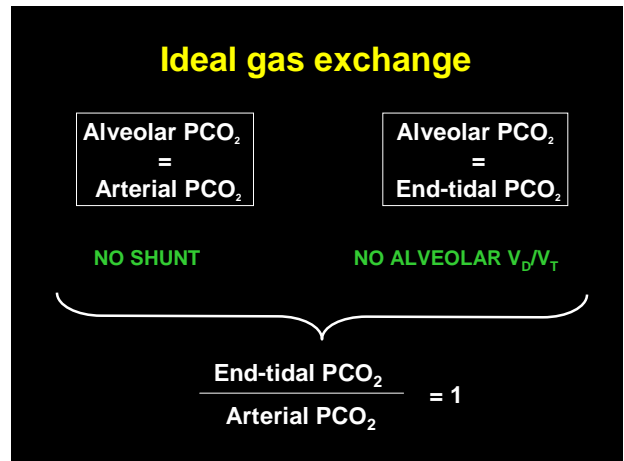
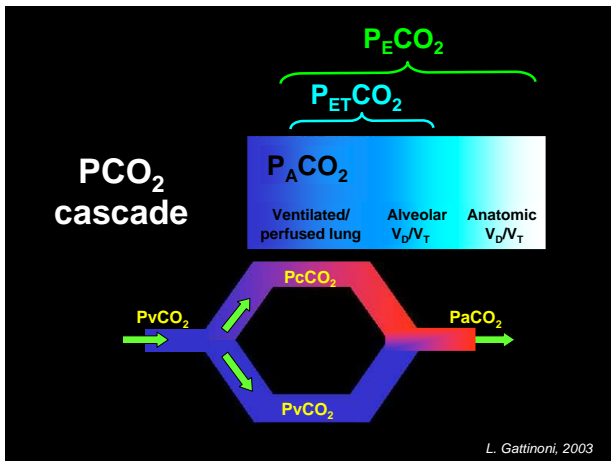


Constant V_T : Plateau - PEEP [Δ]



L. Gattinoni, 2003





Volumetric Capnography (NICO₂) Single Breath CO₂ Analysis

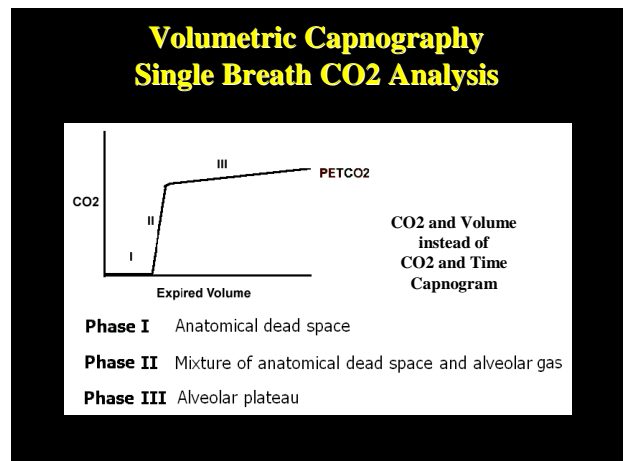
The NICO₂ device displays the following data:

ETCO ₂	30 mmHg	SpO ₂	---	VCO ₂	260 mL/min	Vt	540 mL
RR	29	PR	29	NRV15.0	---	VLI	585

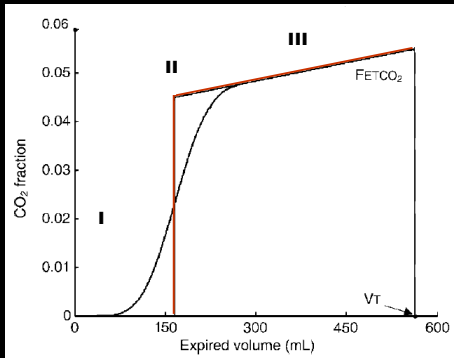
Additional data shown on the screen:

Vt alv	240 mL	Vd/Vt	0.65
Vd alv	158 mL	PcCO ₂	12 mmHg
Vd alv	195 mL		

Validated against a metabolic analyzer by **Kallet et al, Resp Care 2005** and used in many studies for dead space fraction measurements



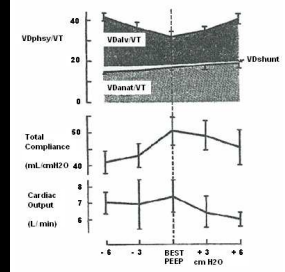
Volumetric Capnography Single Breath CO₂ Analysis



Indicator of Lung Overdistension During PEEP Titration

Optimum End Expiratory Airway Pressure in Patients with Acute Pulmonary Failure

Suter PM, Fairley HB, Isenberg MD. NEJM 1975

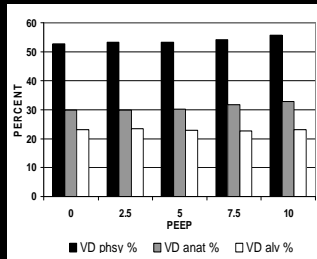


- Best PEEP corresponds to the lowest dead space fraction and the highest compliance

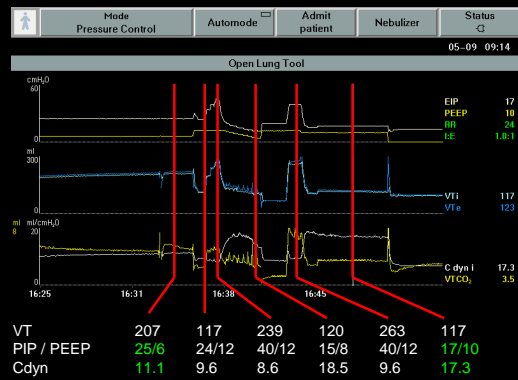
Indicator of Lung Overdistension During PEEP Titration

Effects of PEEP on Dead Space and its Partitions in ALI

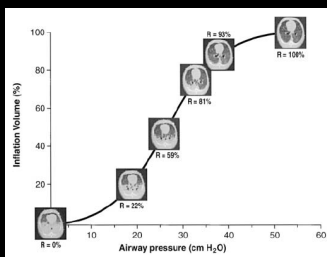
Beydon L, et al. Inten Care Med 2002



- Anatomic dead space increased slightly with PEEP
- Alveolar dead space did not vary systematically with PEEP
- In individual patients a decrease or increase of alveolar dead space paralleled a positive or negative response to PEEP in regards to oxygenation



Lung protection and the open lung concept



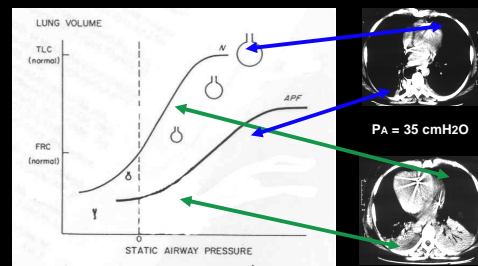
Gattinoni L. AJRCCM 2001; 164:1701-1711

How to monitor at bedside?

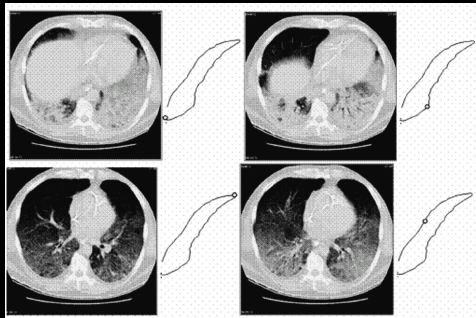
- 1) PV-tools +/-
- 2) O₂- + CO₂-response
- 3) Chest CT and imaging methods?

Information from CT studies: Lung heterogeneity and intratidal collapse and decollapse

In heterogeneous lung injury inflation behaviour is heterogeneous



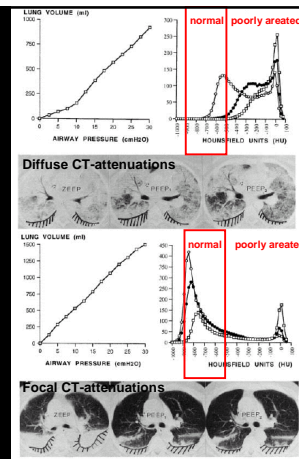
CT to assure more homogenous lung volume distribution



Barbas C Curr Opin Crit Care 2005;11:18-28

CT-aeration

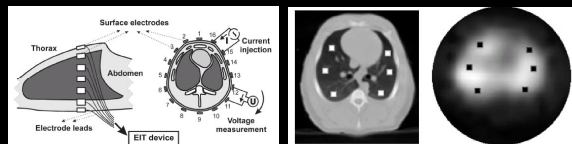
- and how to detect overdistention?



At ZEEP and 2 PEEP levels

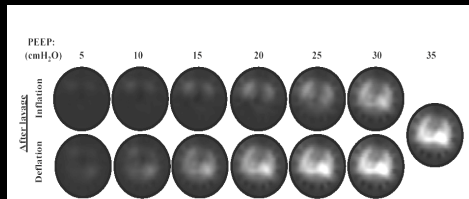
Rouby JJ AJRCCM 2002;165:1182-6

Electrical Impedance Tomography (EIT)



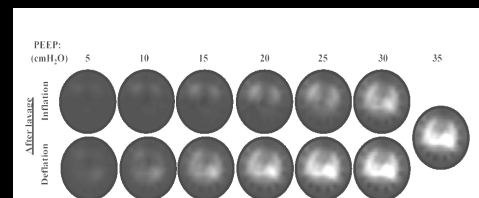
Frerichs I et al. J Appl Physiol 2002; 93: 660-666

Volume distribution

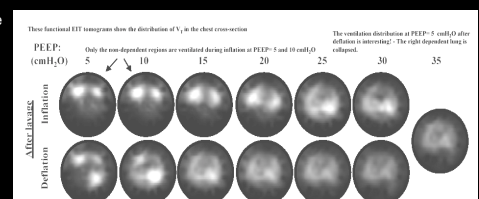


Frerichs I, Dargaville P, Rimensberger PC Intensive Care Med 2003; 29:2312-6

Volume distribution

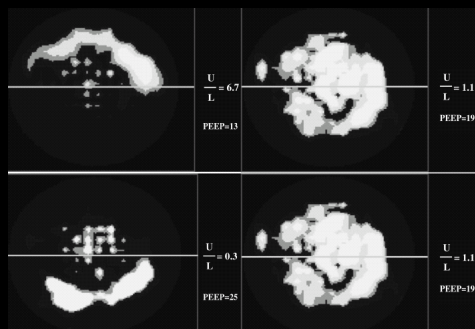


Tidal volume distribution



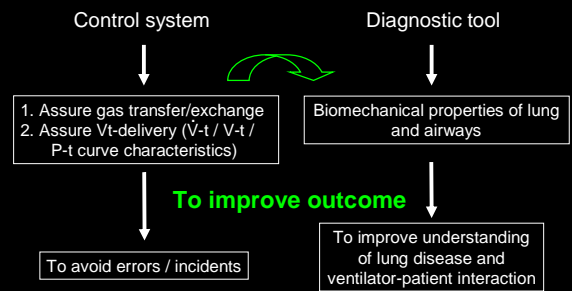
Frerichs I, Dargaville P, Rimensberger PC Intensive Care Med 2003; 29:2312-6

EIT to assure more homogenous lung volume distribution



Barbas C Curr Opin Crit Care 2005;11:18-28

Concepts of respiratory monitoring in the ICU



From classical respiratory monitoring to tracking thoracic volume changes during ventilation maneuvers

1. Flow-, Volume- and Pressure-measurements
2. Pressure-volume methods: static vs. dynamic
observe dynamic compliance changes
3. Gas exchange response: pO_2 and pCO_2
4. Lung-Volume measurement methods:
RIP, dilution methods, CT / MRI / EIT
5. Tidal-volume distribution: EIT