Hot to choose optimal settings

Decision taking

Mechanical Ventilation

Patient Equipment

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Defined Clinical Targets and Goals

1) Achieve good oxygenation and acceptable CO2
2) reduce WOB in spontaneous breathing patients
3) Try to protect the lung
   - limit peak pressure
   - use lower Vt
   - use higher PEEP

Have changes in ventilation practice improved outcomes?

ARDS network trial (6 vs. 12 ml/kg)

Mortality: 31 vs. 38 (p < 0.007)

Small Vt ventilation

ARDS network trial (6 vs. 12 ml/kg)

Physiologic Vt (normal lungs with spont. breathing) : 6 to 7 ml/kg
The concept of small Vt ventilation is a concept of “physiologic Vt ventilation”

ARDS network trial (VT 6 vs. 12 ml/kg)

Mortality: 31 vs. 38 (p < 0.007)

Physiologic Vt (normal lungs with spont. breathing) : 6 to 7 ml/kg

The ARDS lung is small, with a normal aerated portion having the dimension of the lung of a 5- to 6-year-old child (200 – 300 g of lung tissue as compared to 700 g)

Gattinoni L, Intensive Care Crit Dig 1987; 6:1-4

The ARDS lung is rather small than stiff

Airway pressure (cmH2O)

Volume (l)

The normal lung

Overdistention

The baby lung

Allowable VT depends on pathology and disease severity

The baby lung

The ARDS lung is small, with a normal aerated portion having the dimension of the lung of a 5- to 6-year-old child (200 – 300 g of lung tissue as compared to 700 g)


The baby lung

1) Adult and child: Acute respiratory distress syndrome (ARDS)

ARDS is a heterogeneous lung disease

2) Neonate: (Infant) Respiratory distress syndrome (iRDS)

iRDS is a heterogeneous lung disease

MRI signal intensity from non-dependent to dependent regions

The water burden of the lung makes the lung of the preterm infant, despite surfactant treatment, vulnerable to VILI

Adams EW, AJRCCM 2002; 166:397–402

The baby lung

The ARDS lung is small, with a normal portion having the dimension of the lung of a 5- to 6-year-old child (200 – 300 g of lung tissue as compared to 700 g)


Allowable VT depends on pathology and disease severity

The baby lung

VT of 6 ml/kg bw in a patient with a by 50% reduced TLC corresponds to an VT of 12 ml/kg, he should therefore receive only 3 ml/kg bw!

➢ "permissive hypercapnia", HFOV, ECMO or ECCO2-R
**Higher PEEP during small Vt ventilation or peak pressure limitation**

ARDS network trial (6 vs. 12 ml/kg) n = 861

Mortality: 31 vs. 38 (p < 0.007)

- PIP:
  - M vs. HI: 32 vs. 39 cmH₂O
- Pplat: 25 vs. 33 cmH₂O

**CT-aeration**

At ZEEP and 2 PEEP levels

- **Diffuse CT-attenuations**
- **Focal CT-attenuations**

Rouby JJ. AJRCCM 2002;165:1182-6

**The PEEP step approach: “Functional” Recruitment**

Focus is on “opening”, but certainly on avoiding overdistending lung units

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

**“Anatomical” Recruitment**

Recruit to TLC (?)

Focus is on “opening” (re-aerating) previously collapsed lung units

**O₂-improvement = Shunt improvement =**

a) recruitment

b) flow diversion

**PEEP and FiO₂ allowances in PEEP studies**

<table>
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**ARDS Network 6 versus 12 ml/kg**

NEJM 2000;342:1301-1308
Prevalent overinflation = dead space effect

\[ \text{PaO}_2 \text{ and PaCO}_2 \text{ increase} \]

Qattinoni L (2003)

PEEP titration: \( \text{O}_2 \) and \( \text{CO}_2 \) response

Steps of 5 cmH\(_2\)O to 40/25

Pressure control ventilation

Overinflation ends

Overinflation starts

Understanding lung opening and closing

Behavior of the whole lung: Hysteresis

Law of Laplace: \( P = 2 \times T/r \)

Behavior of a single alveolus

Lung opening and closing

Frequency distribution of opening and closing pressure in patients with ARDS

Lung recruitment allows to place the respiratory cycle on the deflation limb

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

Crotti S AJRCCM 2001; 164: 131–140

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

Small tidal volume ventilation (5 ml/kg)
Oxygenation response in two groups: with and without recruitment (identical PEEP)

Oxygenation

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

The open lung concept searches for maintaining lung volume

Halter JM AJRCCM 2003, 167:1620-6

Optimal = “Maximum dynamic compliance and best oxygenation at the least pressure required”
Use of dynamic compliance for open lung positive end-expiratory pressure titration in an experimental study

F. Suarez-Sipman
Crit Care Med 2007; 35:214–221

Get the lung as much homogeneous as possible


Volume distribution


Regional «homogeneity» on the deflation limb

Dargaville P, Frerichs I, Rimensberger PC (submitted).

Volume distribution


ARDS / RDS lung
(Heterogeneous)

Normal lung / recruited lung at optimal lung volumes

→ various time constants
→ heterogeneous
VT distribution

→ similar time constants
→ homogeneous
VT distribution
Heterogeneous: Injured Lung
Alveolar Overdistension into the Area of the Collapsed Alveoli

Homogeneous: Normal Lung
Minimal Change in Alveolar Size with Ventilation

Correlation of Inflection Points with Individual Alveolar R/D

Best approach to recruitment:
«Open the lung and keep it open»
Use the smallest VT you can afford (you deal with a baby lung !)
then you have to work you through to find the optimal least PEEP approach = “Functional Approach to Recruitment”

Your tools at bedside: P/F ratio, PaCO2 and Cdyn

There is no sound rational for fixed PEEP and FiO2 schemes as used in PEEP studies!

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Lo-PEEP/Hi-FiO2, Treatment Group FiO2

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Hi-PEEP/Lo-FiO2, Study Group FiO2

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There is a significant risk of overdistending many patients

But there is a significant risk of overdistending many patients