Looks like a lot of air to me...

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
“... 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)*

« ...The force applied should be limited to as much as a man can bear... (1745) »
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
- Secundary (remote) organ failure
- Role of central nervous system
Baro- & volutrauma & Atelectrauma

Volume (ml)

Pressure (hPa)

Hedenstierna G ea. Int Care Med; Dec 2006; 32(12):1933-4
Racet Repetitive Alveolar Collapse & Expansion (RACE)

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

High lung volumes (Vt > 6.3 ml/kg)
Bagging (manual ventilation episodes, resuscitation...)
Ventilation modus
Invasive diagnostics/therapeutics (fiberoptic)
Mucus recruiting manoeuvres
Impairment of venous return & LEF (CO)

Lungs = huge surface, connected to the environment & receiving all the blood volume of the body

Ranieri VM ea. JAMA 1999; 282: 54-61
Angry cell or dying cell (sississssss)
Réponse inflammatoire - Amélioration

Phase cellulaire

Activation des cellules inflammatoires

Cellule inflammatoire

Consequences

- Suture
- Asepsis
- Hémostase
- Inflammation du pus

Wrigge H ea. Int Care Med 2005 Oct
3;31(10):1379-87
Supine position (FRC = RV), cranial displ’t diaphragm (= upper part V), anesthesia, muscle relaxants

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

Biochemical Injury → Biophysical Injury
- shear
- overdistention
- cyclic stretch
- intrathoracic pressure

Cytokines, amplifiers, proinflammatory mediators, reactive oxygen species

- neutrophils

Distal Organs
- tissue injury secondary to inflammatory mediators/cells
- impaired oxygen delivery
- bacteremia

↓

MSOF
(by Slutsky A)
Role of:
- Cytoskeleton?
- Lipid rafts?
- Surfactant?
- Caveoles?
- eNOS?
- Plasma membrane?
- Metalloproteases?
- Cell nucleus?
- Alveolar geometry?
- Alveolar ducts?
- Alveolar mouth?

2007 = more questions than answers

So

What do we do?
Avoid invasive mechanical ventilation: masks & prongs

**Primum Non Nocere**

Boussignac

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

NIV: Masks & Prongs
Mimicking isothermic saturation point in artificial circuit

- « Shock Thermique »

Graph showing the relationship between temperature (15°C to 40°C) and relative humidity (5% to 100%). The diagram also includes stages for filtering, heating, and humidifying.
Mimicking isothermic saturation point in artificial circuit

100% 80-100% 45% 7% 6% 0.5%

F&P
Tubing
Y
E
T
Core

HH & EHW

100% 80-100% 45% 7% 6% 0.5%
Preserving biorheology

Gel layer (mucus)

SURFace ACTing AgeNT

Cilia

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 derecruting) 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. Heulitt. 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.

**Sampling Rate** 2000 Hz vs 50 Hz

**Respons Time** 0,5 msec vs 20 msec

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

Dynamic compliance

\[ \frac{V}{P} \]

TV

\[ \frac{i}{EIP - PEEP} \]

\[ \Delta C_{\text{dyn}} \]

Additional settings

- \( O_2 \text{ conc.} \): 60%
- PEEP: 10 cmH₂O
- Resp. Rate: 15 breaths/min
- PC above PEEP: 10 cmH₂O

Additional values

- \( O_2 \text{ (l/min)} \): 274
- \( VT \text{ (l)} \): 274
- \( V_{TCO_2} \text{ (l/min)} \): 275
- \( V_{TCO_2} \text{ (ml/min)} \): 111.0
- \( VT \text{ (ml)} \): 271
- \( V_{TCO_2} \text{ (ml/min)} \): 7.5

Other parameters:

- \( P_{\text{peak}} \): 20 cmH₂O
- \( P_{\text{mean}} \): 15 cmH₂O
- \( RR \): 15 breaths/min
- \( I:E \): 1.0:1
Lung Protective Ventilation: keeping the lung open

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

OLC is not just about PEEP (= opening unstable alveoli)
OLC is also PiP (= vital capacity maneuver)
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 PaO$_2$ are due to sudden alveolar de-recruitments (arrows). (Figure provided by courtesy of Dr M. Amato, São Paulo, Brazil)
Venous Return

### Spontaneous breathing

**Pressure (kPa)**

- **Intrapulmonary pressure**
- **Intrapleural pressure**

- **Insp**
- **Exp**

**Time (s)**

### Controlled Ventilation

**Pressure (kPa)**

- **Intrapulmonary pressure**

- **Insp**
- **Exp**

**Time (s)**
Venous Return
Venous Return: High Frequency Ventilation
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
Neurally Adjusted Ventilation

**Pressure Support Ventilation**

$E_{adi} = \text{Electrical Activity of diaphragm} = \text{Diaphragm EMG}$

(Sinderby C ea. Nature Medecine, 1999)

Ventilator reaction too late after diaphragm activation

No reaction from ventilator although diaphragm activation
Ventilator reaction too late after diaphragm activation

Ventilator produces flow after diaphragm relaxation

Neurally Adjusted Ventilation

Eadi of Edi = Electrical Activity of Diaphragm

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

The “synchronised” cycle is actually 53% asynchronous and 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.

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.

Neurally Adjusted Ventilation

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

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

L. Brander ea. Presented at ESICM in Barcelona 2006
Proportional Ventilation

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