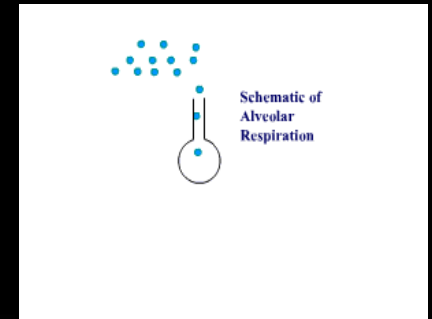


# Alveolar Recruitment Strategies



Marc Coolen & Paul Theunissen  
Ventilation Practitioners  
Roermond 15 januari 2008

# RM's (Recruitment Maneuvers) Recruteren

van Dale taalweb

U hebt gezocht op **recruteren**:

**RESULTAAT** (maximaal 20 woorden)

**re-cru-te-ren** (ov.ww.) **1** verzamelen voor de krijgsmacht => *aanwerven, lichten*

# Doel van recruitment

Het openen van de potentieel recruteerbare alveoli met tijdelijk hogere beademingsdrukken om de verhoogde openingsdruk van de surfactant-deficiënte alveoli te bereiken en ze vervolgens met voldoende PEEP open te houden, zonder dat relatief gezonde alveoli hierbij overrekt worden.

# Alveolar Recruitment Strategies

## Introductie



[Filmpje via www.youtube.com](http://www.youtube.com)

[Filmpje via server openomy](#)

(traag; 15 mb)

*A. S. Slutsky  
Lung Recruitment in  
Patients with ALI/ARDS  
Satellite Symposium,  
October 2, 2000, Rome.*

# Alveolar Recruitment Strategies

## Introductie



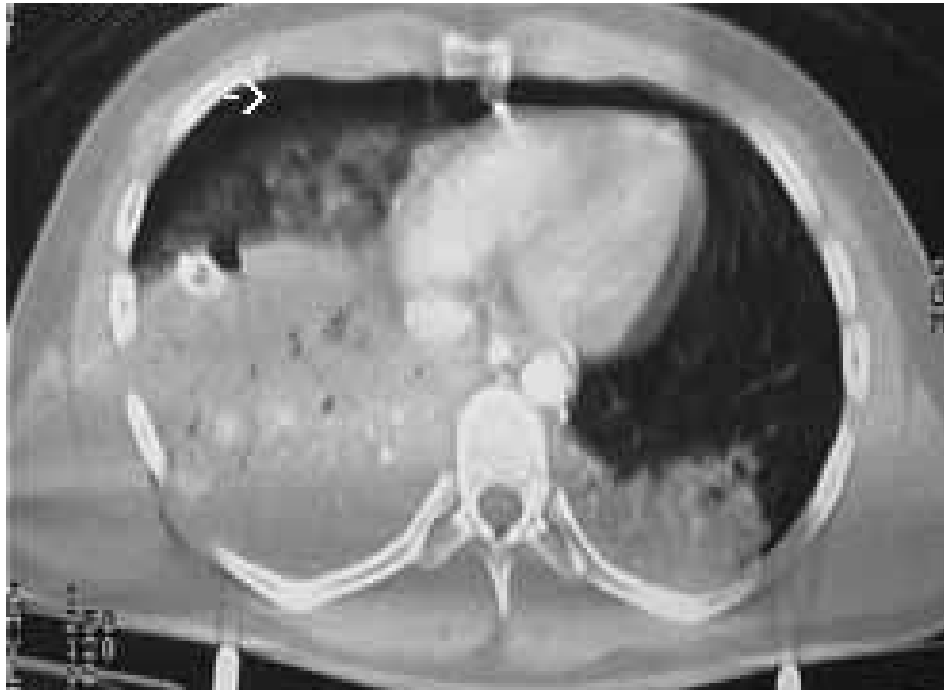
[Link filmpje video google](#)

[Link naar filmpje openomy server](#) (traag:  
8 mb)

*Recruitment after  
Endotracheal-lavage,  
Intra-Pleural-In-Vivo-  
Microscopy,  
Pig-lung*

# Alveolar Recruitment Strategies

## Introductie



**De ARDS long bestaat uit drie componenten**

- De normale long
- Ziek longweefsel dat recruteerbaar is
- Ziek longweefsel dat niet recruteerbaar is

# Alveolar Recruitment Strategies

## Problemen

- Atelectases zijn slecht
- Overrekking is slecht
- Alveolaire collaps in de expiratiefase is slecht
- De ARDS long is niet uniform
- Veel PEEP is eng
- Auto-PEEP is onveilig

# Alveolar Recruitment Strategies

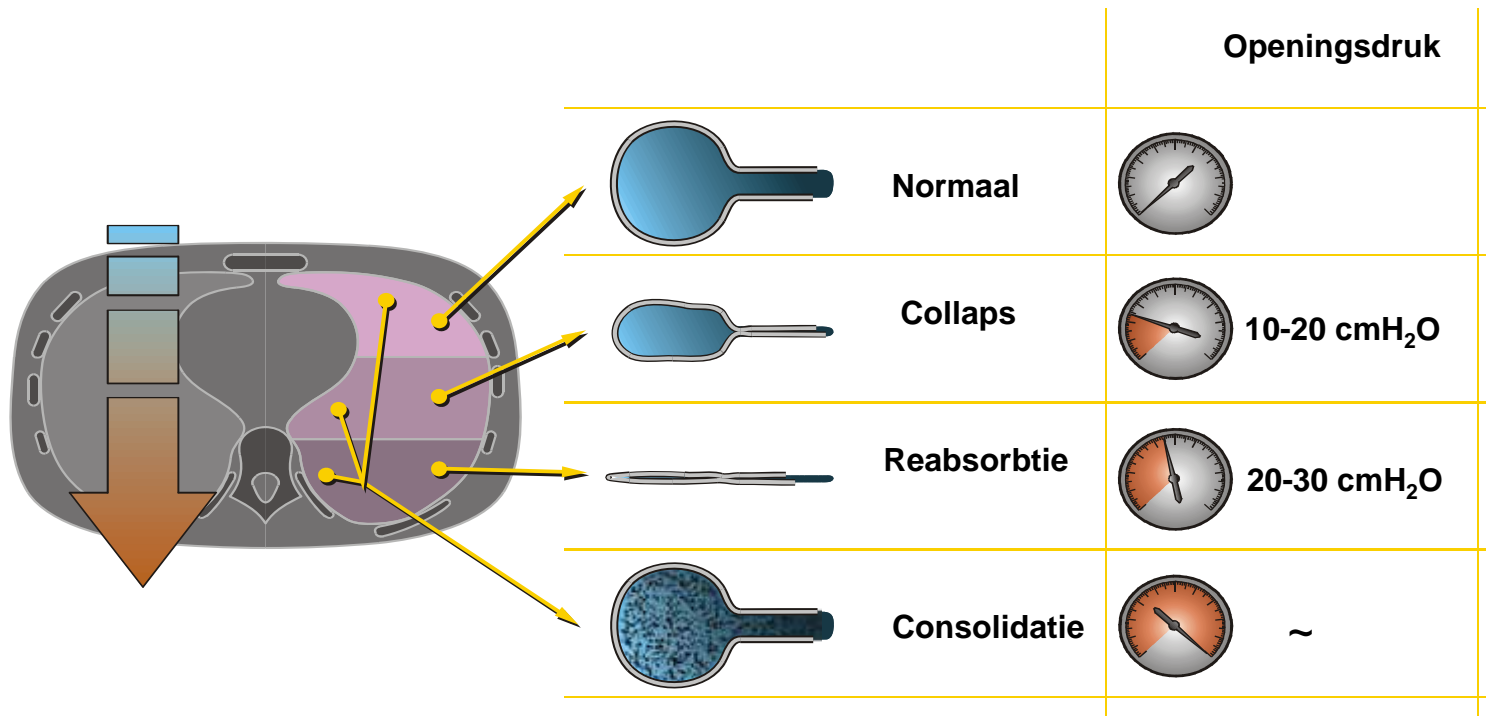
## Problemen

**Hoeveel druk is nodig om de long te recruteren?**

**Hoeveel PEEP is nodig om de long open te houden?**

# Alveolar Recruitment Strategies

## Openings- en sluitingsdrukken



# Alveolar Recruitment Strategies

## Patiënten selectie

***Acute respiratory distress syndrome caused by pulmonary and extrapulmonary disease. Different syndromes?***

*Gattinoni L, Pelosi P, Suter PM, Pedoto A, Vercesi P, Lissoni A.  
Am J Respir Crit Care Med. 1998.158(1):3-11.*

- **Pulmonary ARDS (primary ARDS)**

Largely consolidation and little atelectasis

- pneumonia, aspiration, diffuse pulmonary infection, near-drowning, toxic inhalation, lung contusion, etc

- **Extra-pulmonary ARDS (secondary ARDS)**

Predominately atelectasis

- sepsis, nonthoracic trauma, pancreatitis, transfusion related injury, etc.

## Patiënten selectie

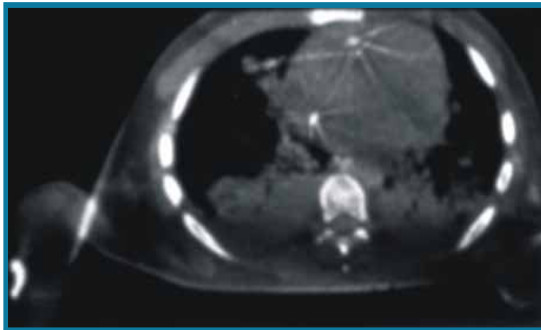
- **Secundair** ARDS is beter recruteerbaar dan **primair** ARDS
- **Vroeg** stadium ARDS is beter recruteerbaar dan **laat** stadium ARDS

# Alveolar Recruitment Strategies

## Primary ARDS

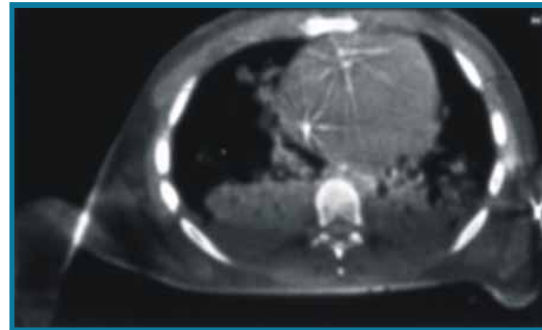
**5 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 97 mm Hg



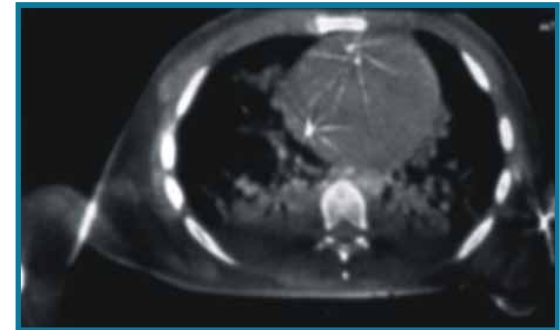
**10 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 103 mm Hg



**15 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 104 mm Hg



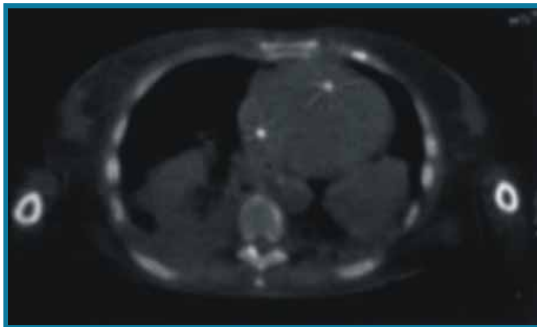
**Consolidation - low potential for recruitment**

# Alveolar Recruitment Strategies

## Secondary ARDS

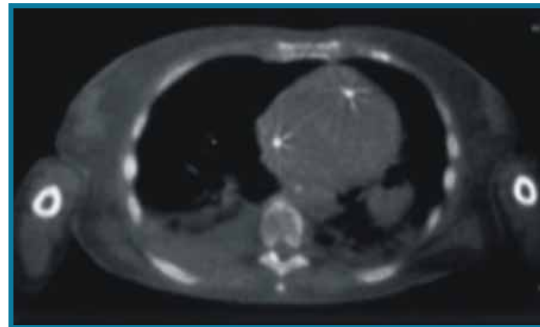
**5 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 34 mm Hg



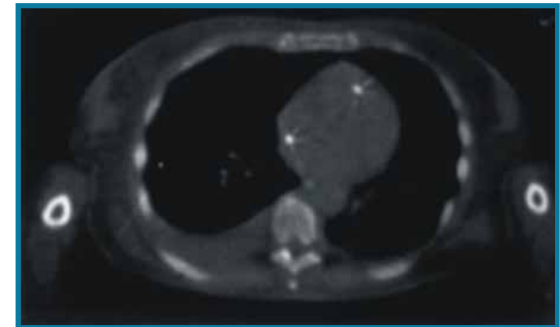
**10 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 49 mm Hg



**15 cm H<sub>2</sub>O**

PaO<sub>2</sub>: 121 mm Hg



**Collapse - high potential for recruitment**

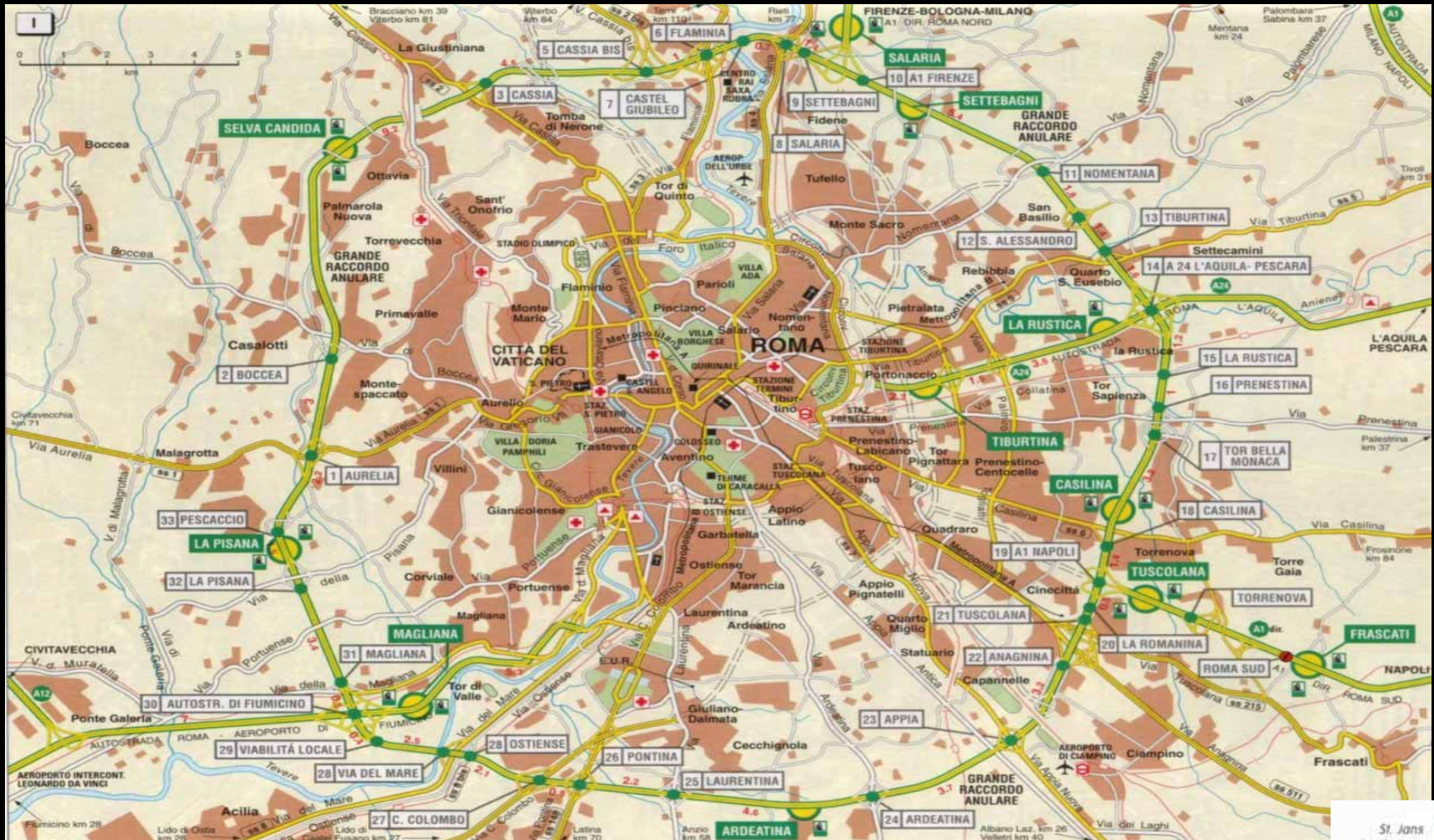
Alveolar Recruitment Strategies

**Open The Lung Techniek** (basis principe)

*.....how to do???*

# Alveolar Recruitment Strategies

## How to do?



# Alveolar Recruitment Strategies

## How to do?

### Types of Recruitment Maneuvers

- Apneic TLC maneuvers

Sedation and pre-oxygenation, CPAP of 30 cm H<sub>2</sub>O for 30-40 sec.  
Monitor Vt and oxygenation for 15-30 min.

If unresponsive, repeat at CPAP of 35 to 40 cm H<sub>2</sub>O.

- Non-apneic TLC maneuvers

PCV of 10-20 cm H<sub>2</sub>O, RR=10/min., I:E ratio=1:1,  
PEEP 20-40 cm H<sub>2</sub>O, Apply for 45 sec. to 2 min. Monitor Vt and  
oxygenation for 15 - 30 min. If unresponsive, repeat at higher PEEP.

- Prone positioning ([Gattinoni NEJM 2001; 345: 568-573](#))

- Open lung concept ([Lachmann 1992](#))

# Alveolar Recruitment Strategies

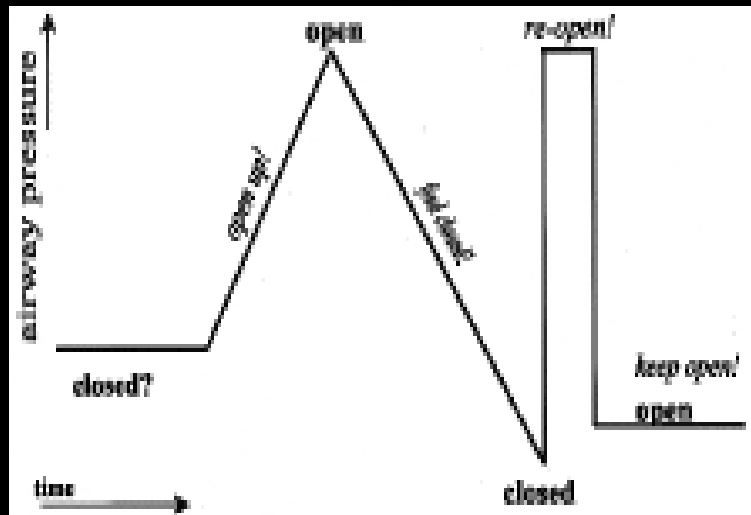
## How to do?

**Consensus.....?**

**Need!!**

# The Open Lung Concept

1. Bepalen van de openingsdruk ( $P_o$ )
2. Bepalen van de sluitingsdruk ( $P_c$ )
3. De longen (her-) openen
4. De longen open houden



# OLT

## The Open Lung Tool op de Servo I

- OLT is een grafisch hulpmiddel waarmee eenvoudig gemeten kan worden wanneer de alveoli maximaal geopend zijn en bij welke druk ze collabereren
- De optimale PEEP wordt vervolgens met behulp van meting van de dynamische compliantie bepaald. Met de OLT kan grafisch de hoogste compliantie bij de laagste toegediende PEEP vastgesteld worden. Het gebruik van de OLT levert zo dus de twee belangrijkste parameters op voor longsparende beademing: openingsdruk en sluitingsdruk / PEEP

OLT

## The Open Lung Tool op de Servo I

- Real-time Monitoring, die veranderingen in de longmechanica, tijdens de Recruitment Maneuver registreert
- Grafische visualisatie van gemeten en berekende waarden
- Breath-by-Breath Trend Monitor
- Cursor functie voor het analyseren van openings- en sluitingsdrukken

[Link naar film \(20 min\) via google video](#)

[Link naar film \(20 min\) op Openomy Server.](#) **500 MB !!!**

# OLT

## OLT Parameters



- Graphical Breath-to-Breath Observation of
  - End Inspiratory Pressure
  - PEEP
  - Inspired Tidal Volumes
  - Expired Tidal Volumes
  - Dynamic Compliance
- Breath-by-Breath Trend Monitor

OLT

## Basisinstellingen

- PCV
- I:E 1:1
- Capnografie
- $FiO_2$  1,0
- RR 20-30/min.
- Stabiel haemodynamiek
  
- ABG



# Compliance

Statische compliance

TV exp.

P plateau-PEEP tot.

Normaal 1ml/cmH<sub>2</sub>O kg (60-100))

Dynamische compliance

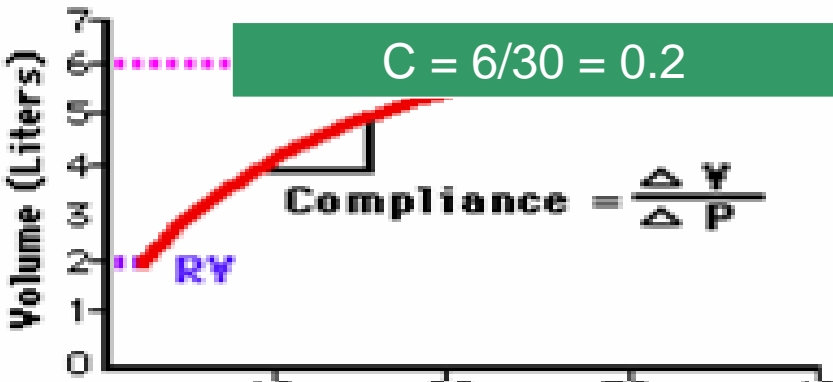
TV exp

Peak druk-PEEP

Normaal 50-80 ml/cm H<sub>2</sub>O

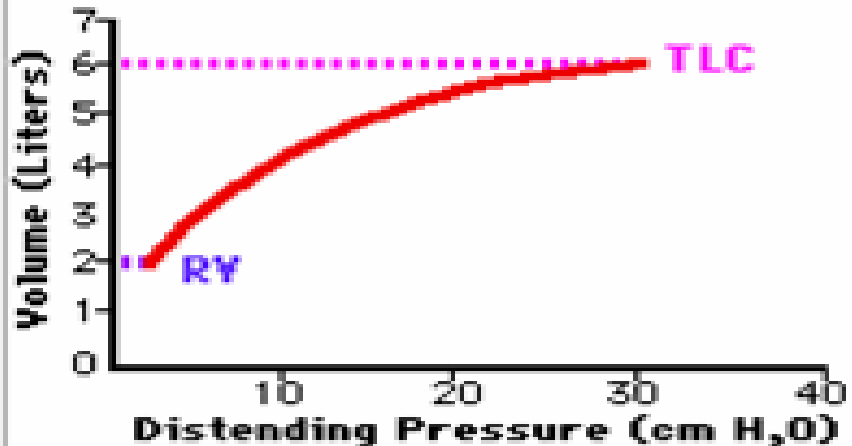
Continu meting Servo

### Normal Compliance Curve



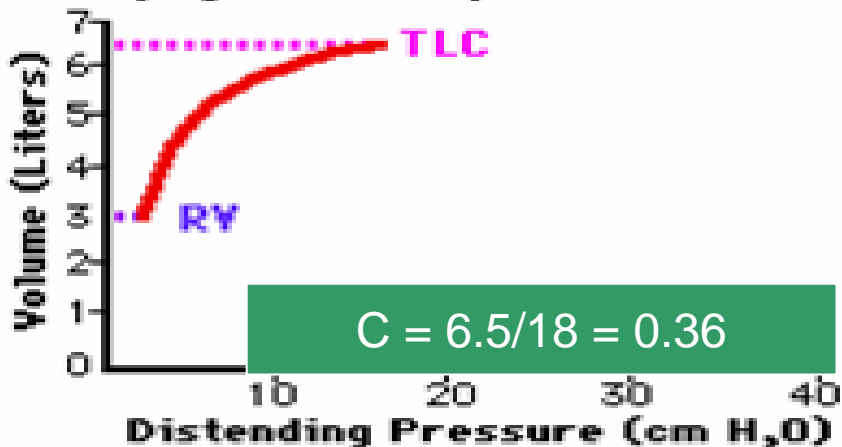
Dus bij een onderdruk van 1cm H<sub>2</sub>O wordt 0.2 liter lucht aangezogen

### Asthma Compliance Curve



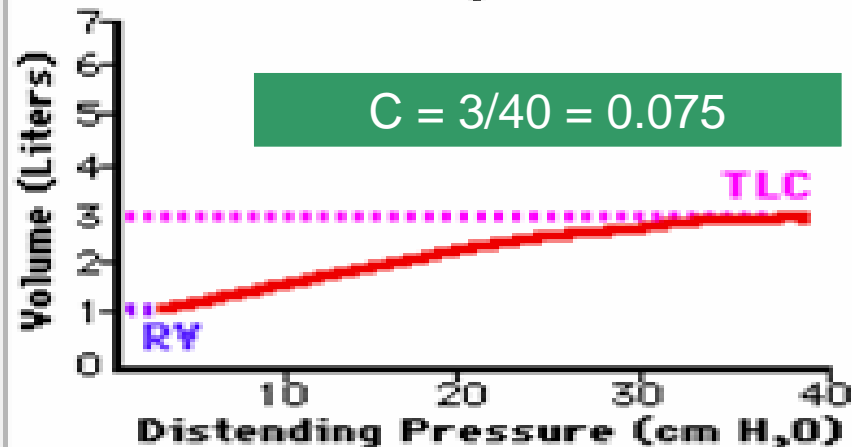
Same as normal in most circumstances, if there are no complications.

### Emphysema Compliance Curve



Total Lung Capacity = 6.5 L  
Residual Volume = 3 L

### Fibrosis Compliance Curve



Total Lung Capacity = 3 L  
Residual Volume = 1 L

# Fase 1. Recruitment

**Start:** FiO<sub>2</sub> 1.0, Freq 20, I:E=1:1  
PC 20cm, PEEP 15 cm, PIP=35cm

**Stap1.** Peep verhogen tot 20 cm (PIP 40)  
Het PEEP-level van 20 cm wordt gedurende de gehele  
openingsfase gehandhaafd

**Stap 2.** PC verhogen in 2 stappen van elk 5 cm  
tot PIP 50cm is

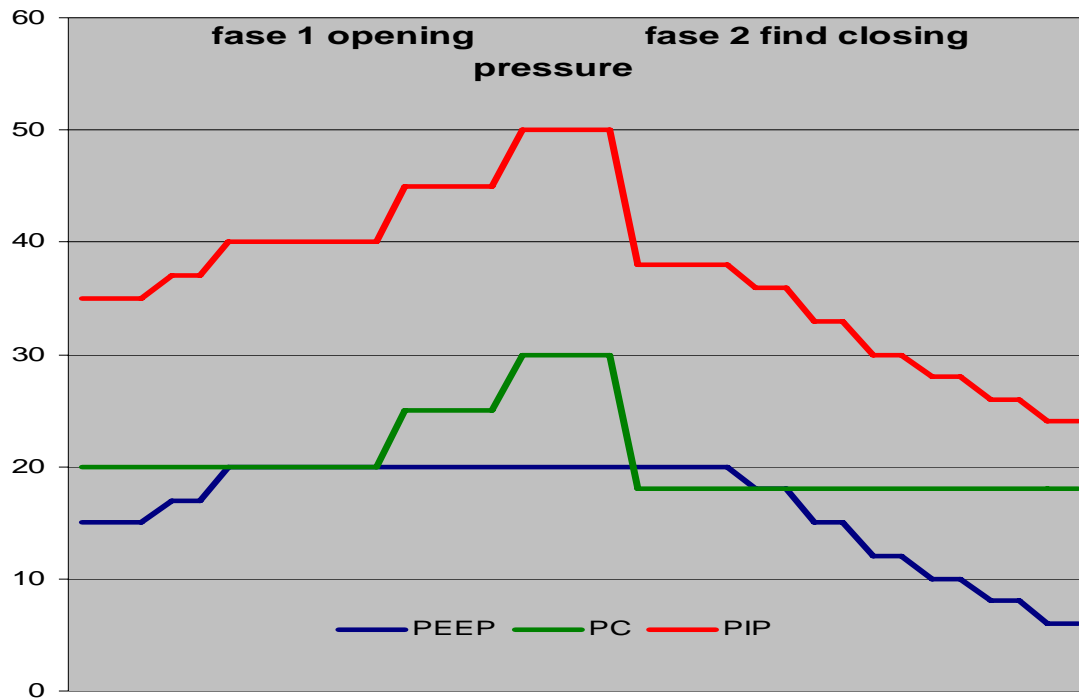
Elke stap van PEEP of PC verhogen duurt 2 minuten  
(zo worden alle lange tijdsconstanten van de long bereikt)



OLT trend-overzicht: Basis instellingen

PC 20cm + PEEP 15cm = PIP 35cm

Freq. 20 I:E 1:1 (Ti = 1.5 s) FiO2 1.0



- PIP is het resultaat van PC en PEEP level
- PEEP blijft constant in de openingsfase na 2 stappen (20 cm)

# Fase 1

## Recruitment

### First action

Stepwise  
increase

**PEEP** till 20 cm

By 2 cm each  
2 minutes



PEEP is stepwise increased from 15-20cm  
(so PIP increases from 35-40cm) !  
(2 minutes rest after each step)

## Fase 1

### Recruitment

#### Second action

increasing  
**PC-level**

5 cm each 2  
minutes



Now PC level is increased from 20-25 cm  
(so PIP will increase further to 45cm, see  
next)

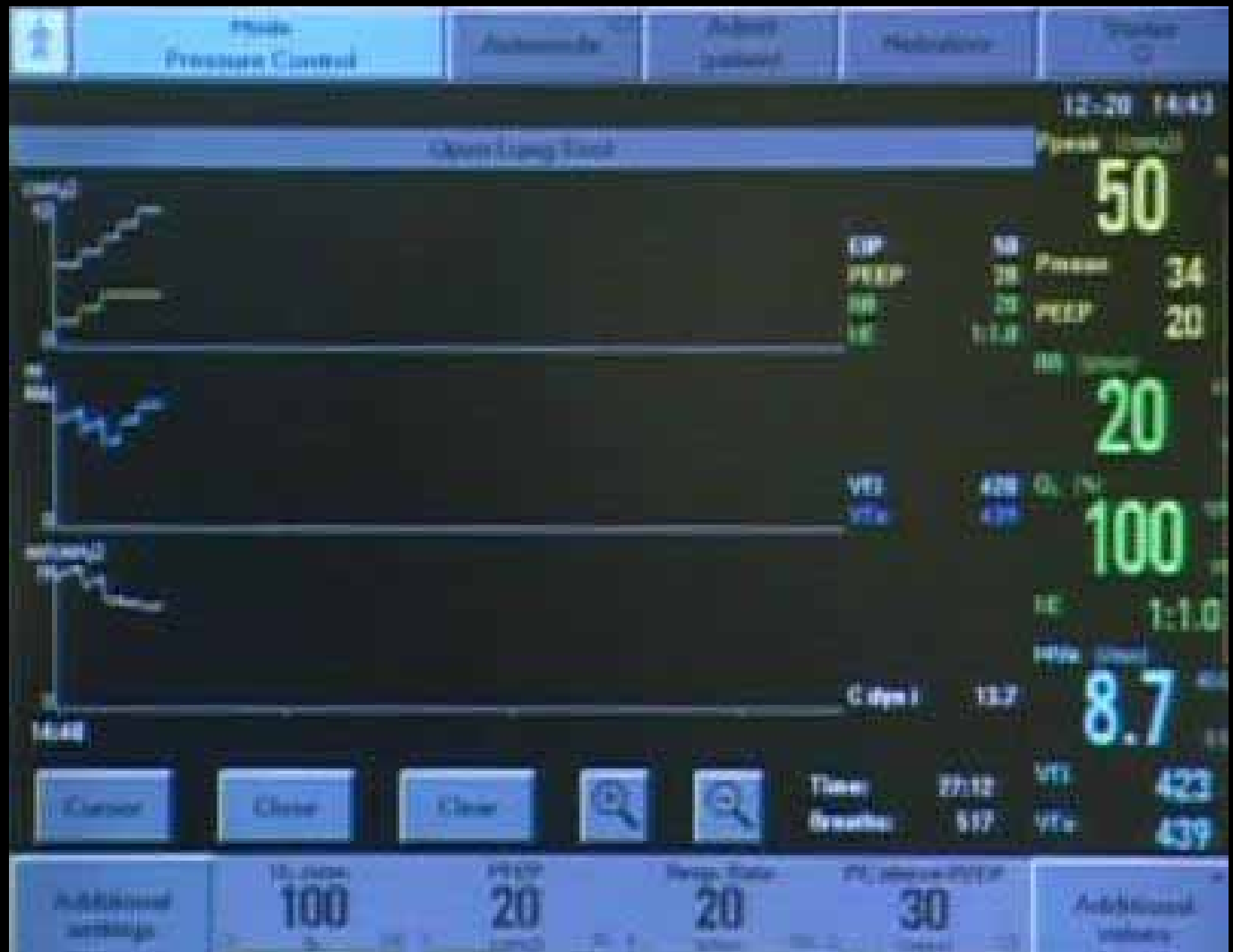
# Fase 1

## Recruitment

### Second action

increasing  
**PC-level**

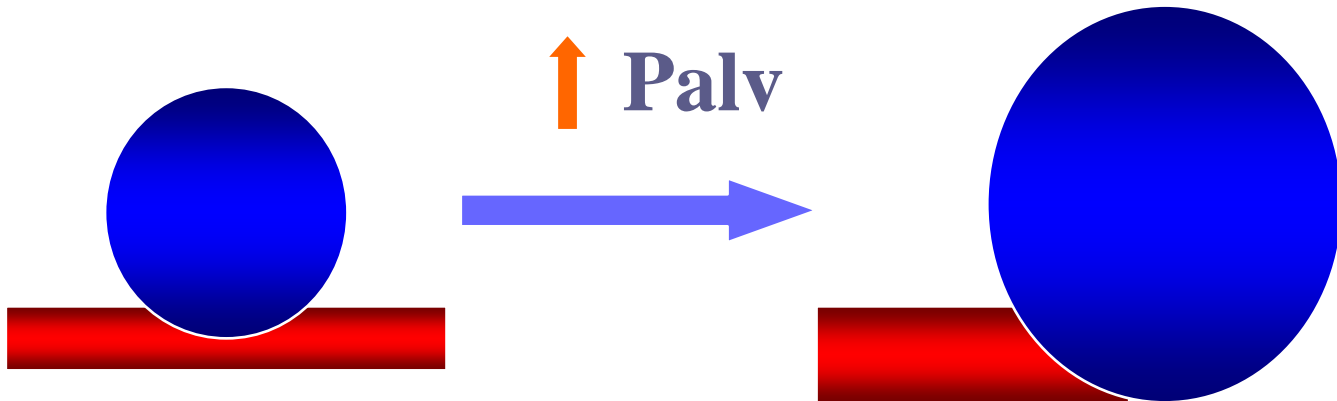
5 cm each 2  
minutes



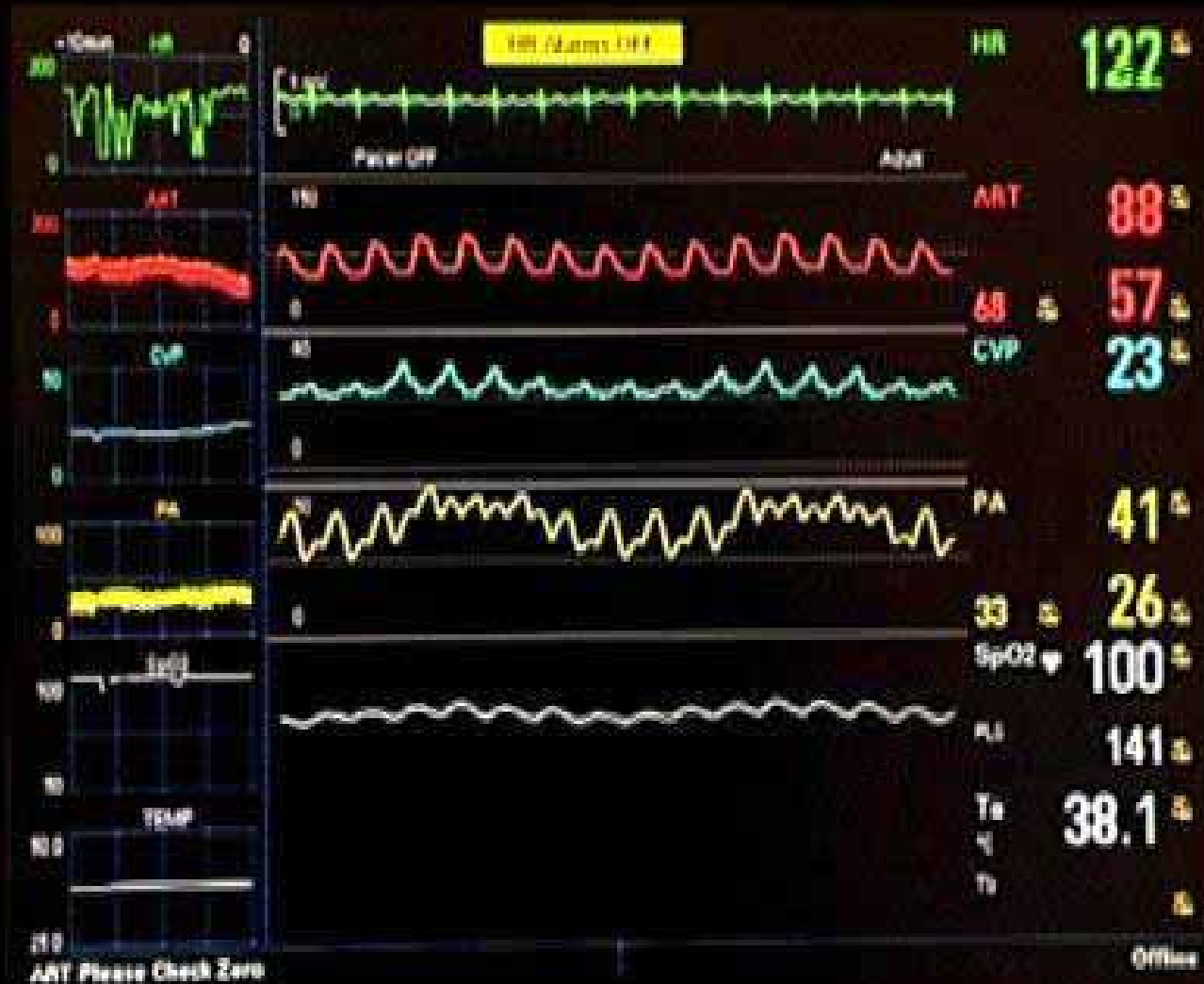
PC level is increased from 25 – 30 cm  
(so PIP is 50cm, the final level in this case)

Note the decreased Compliance

# Starling Resistor Phenomenon



# Haemodynamische effecten ten gevolge van de hoge druk in de openingsfase worden gemonitord



## Fase 2. **Find closing pressure**

In de belangrijke tweede fase wordt het PEEP level, dat de gerecruteerde long beschermt tegen collaps, beëindigd.

Deze fase start met een snelle afname van de PIP, tot gewenst  $T_v$  bereikt is.

In dit geval van 50 naar 38 cm door de PC level te verminderen van 30 naar 18 cm (PEEP blijft 20 cm )

## Fase 2

### Find closing Pressure

#### First action

PC level is decreased to a more normal Vt

Note: it's a 35 kg pig in this model



PC level from 30 to 18 cm (so PIP from 50 to 38 cm)

Note: Compliance increases. (PEEP stays at 20 cm)

## Fase 2

Find closing Pressure

Stepwise decreasing of PEEP level

By 2 cm each 2 minutes !



The PEEP is at this picture moment 16 cm. Note: the increasing Vt and Compliance. Even by equal PC level the Vt and Compliance increases.

## Fase 2

Find  
closing  
Pressure

Stepwise  
decreasing  
of PEEP  
level



At this moment the PEEP is decreased from 20cm to 6 cm (resulting in PIP from 38 to 24cm)  
Note: the decreasing Vt and Compliance.

## Fase 2

**Closing Pressure**  
gevonden door de cursor te gebruiken

Bij een PEEP van 12cm



Met de trendcursor wordt gezocht naar het PEEP-niveau waarbij Cdyn de hoogste waarde heeft bereikt.

Uiteindelijk wordt het PEEP-niveau 2 cm boven closing pressure ingesteld!!

## Fase 3. **Re-open the lung**

Een hernieuwde openingsessie is noodzakelijk.

Wederom stapsgewijs: eerst PEEP, daarna PC level

# Fase 3

## Re-Opening

First PEEP

In 2 steps

2 minutes



Starting with PEEP increasing

## Fase 3

### Re-Opening

#### First PEEP

In 2 steps

2 minutes

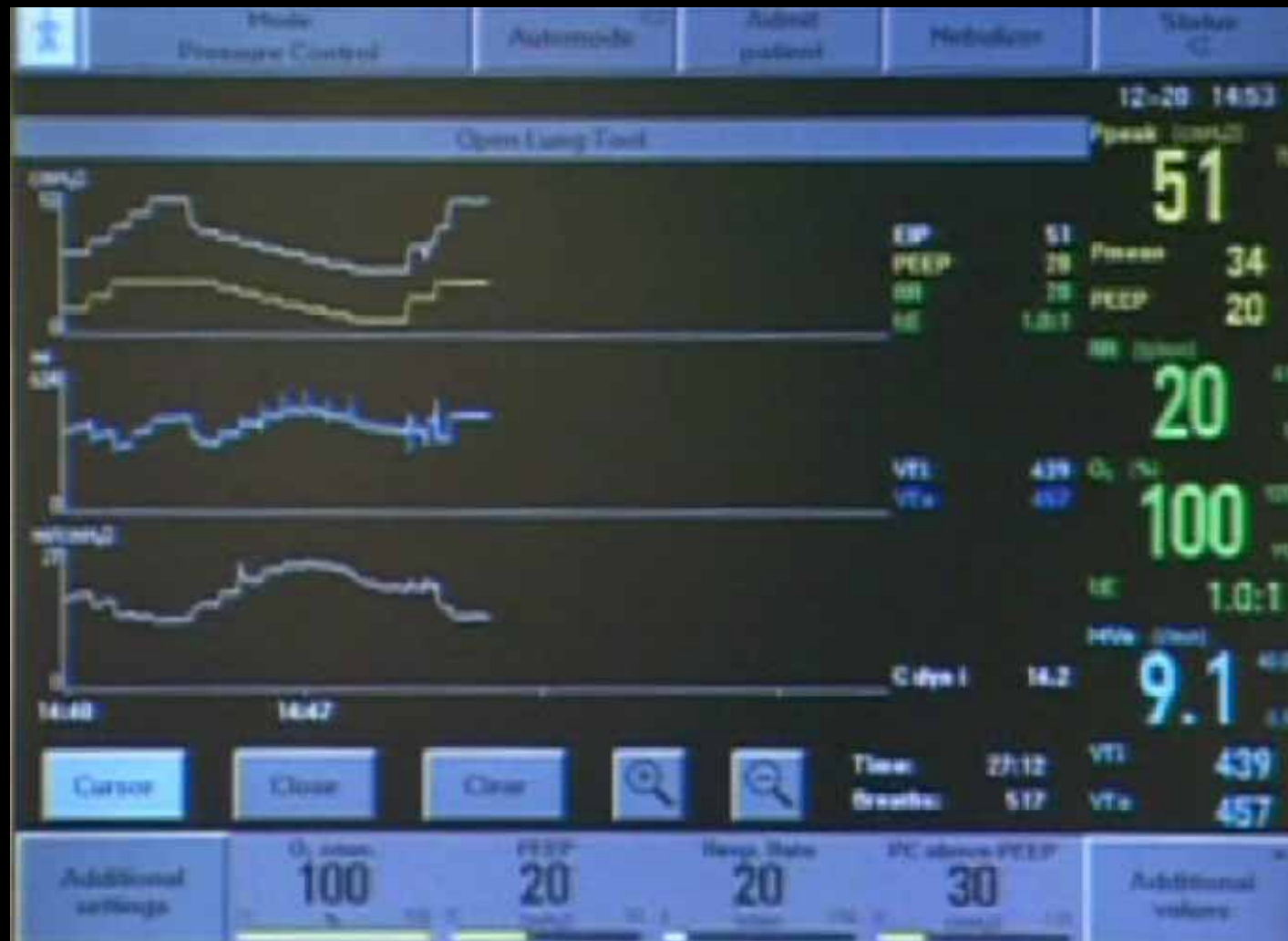
#### Second PC

In 2 steps

Staying at

50cm PIP

For 2 minutes



First: PEEP > 6-15-20cm (resulting PIP 24-33-38cm) Second: PC >18-20-30cm (resulting PIP 38-40-50cm)

## Fase 4. **Keep the lung open**

Stap 1. PC level afbouwen tot gewenst tidal volume is bereikt

Stap 2. PEEP 2 cm boven closing pressure instellen

## Fase 4.

Keep the lung open

First

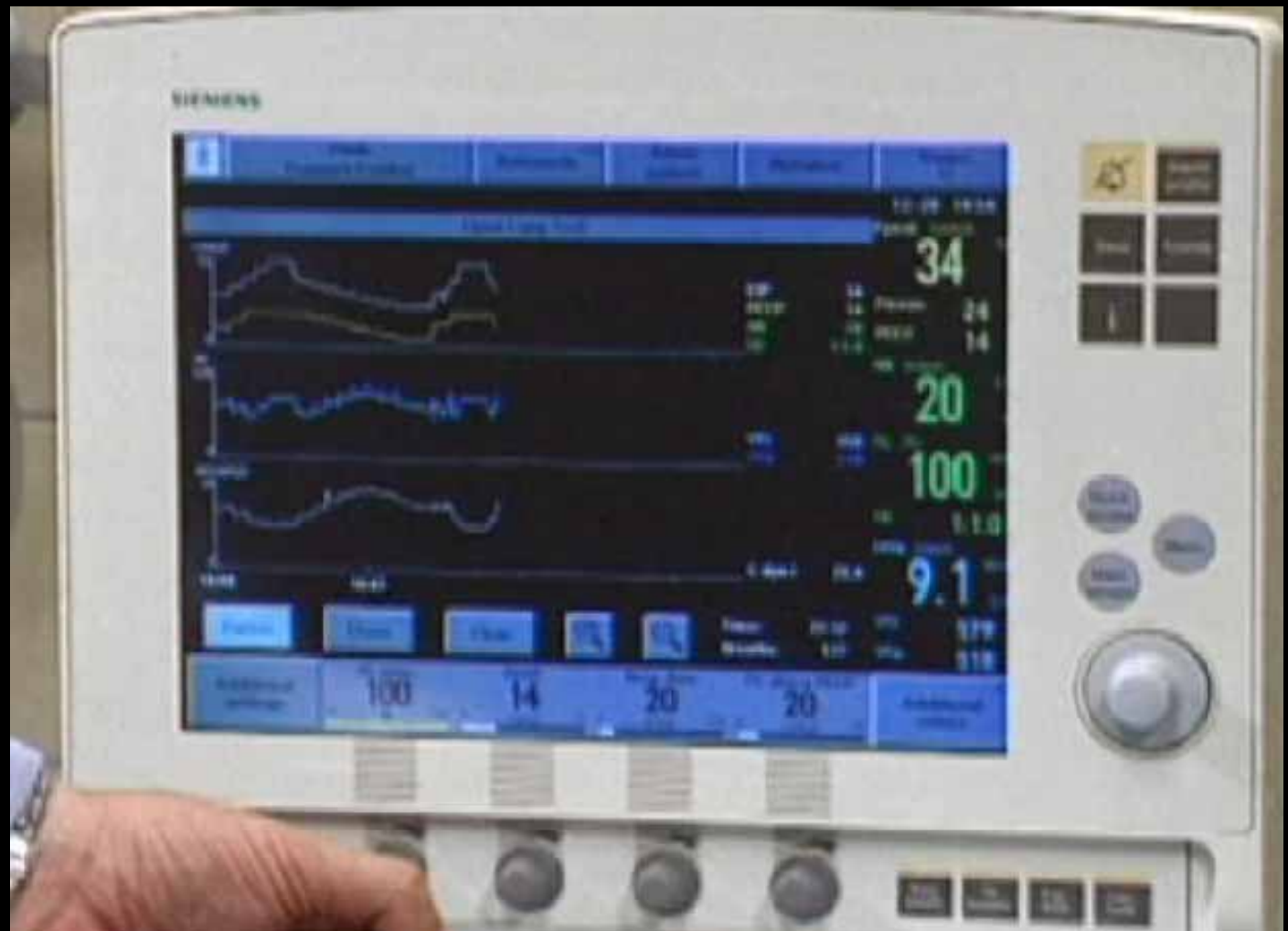
PC level

In 2 steps

Second

PEEP

Is set at 2 cm above closing-pressure



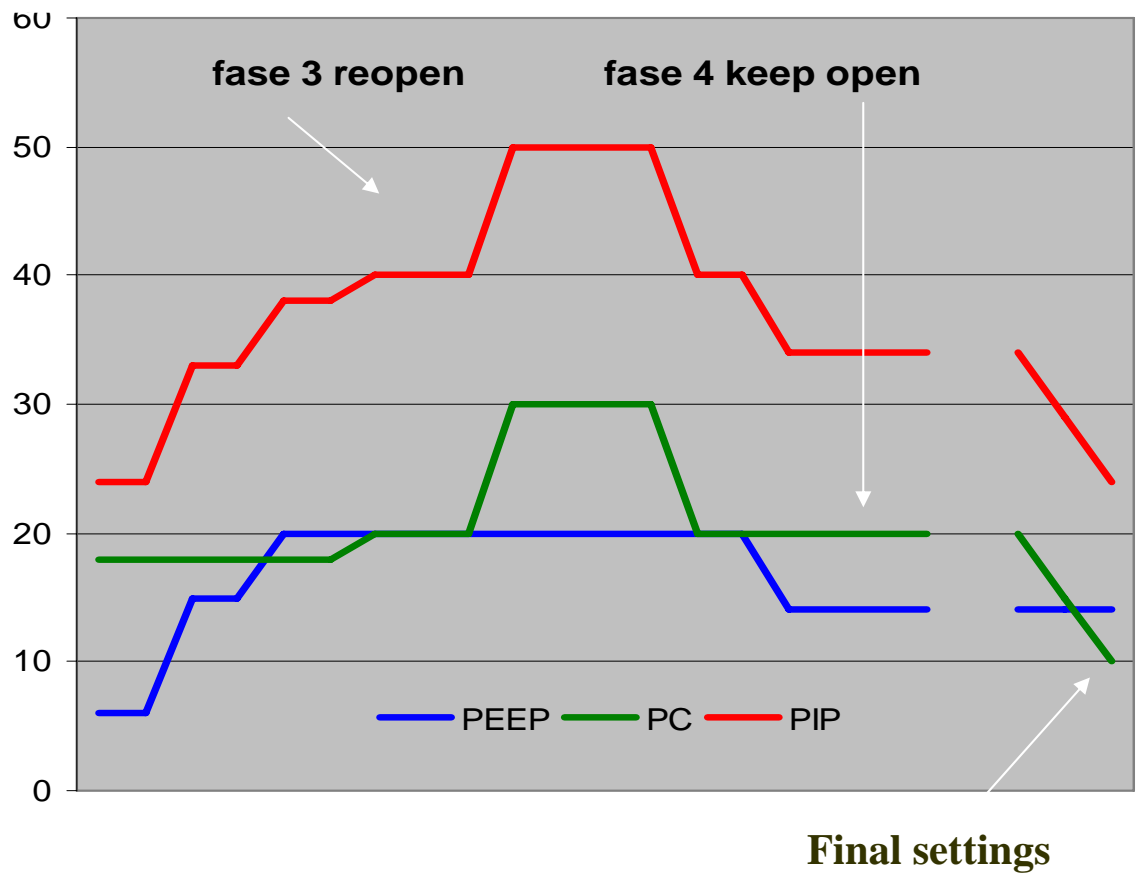
After 2 minutes of reopening pressure at first the PC- level is decreased from 30 to 25 to 20cm.

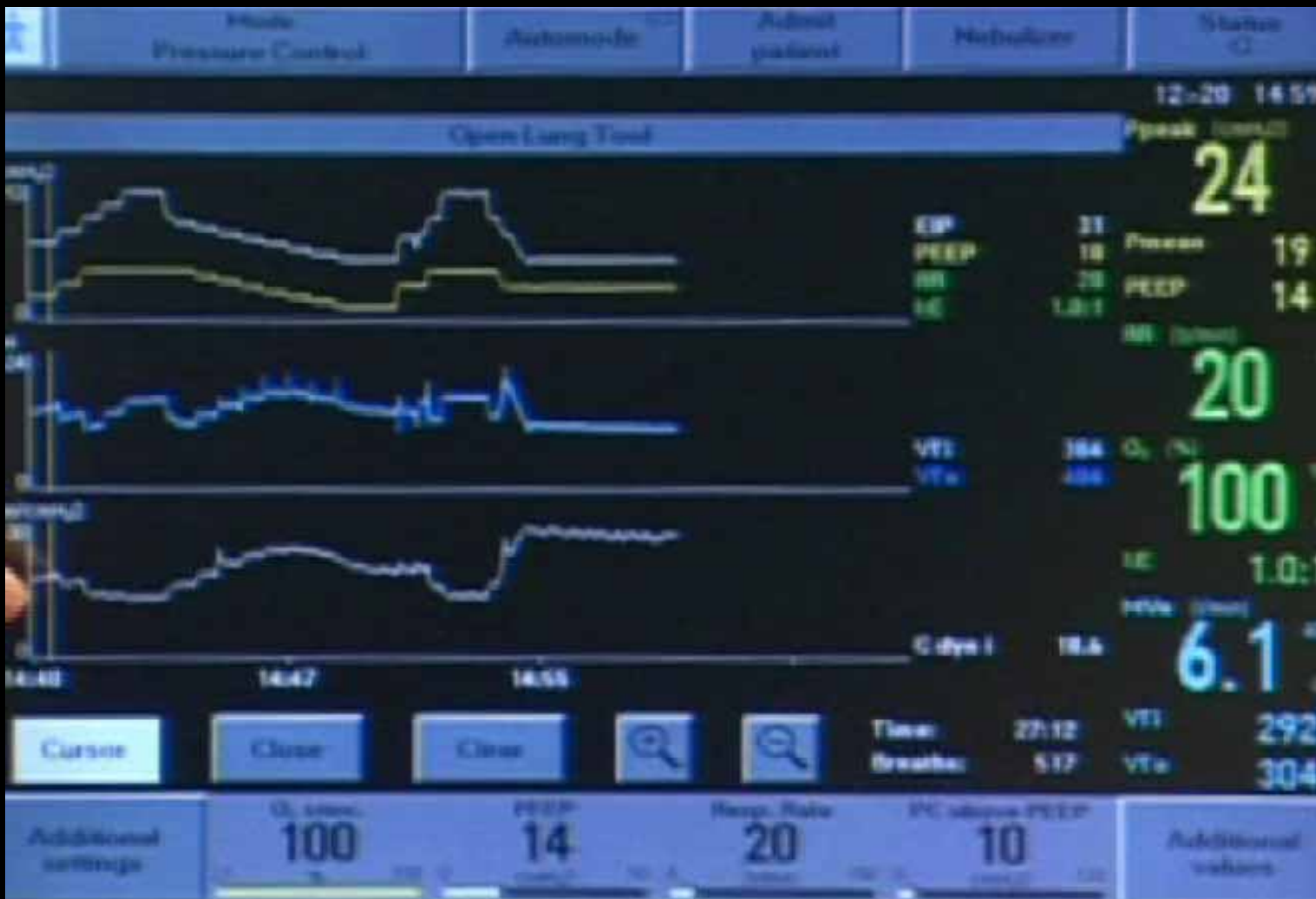
Secondly the PEEP is decreased from 20 to 14cm (so 2cm above closing pressure) The resulting PIP is 34cm

# Titrating the final Ventilation after fase 4

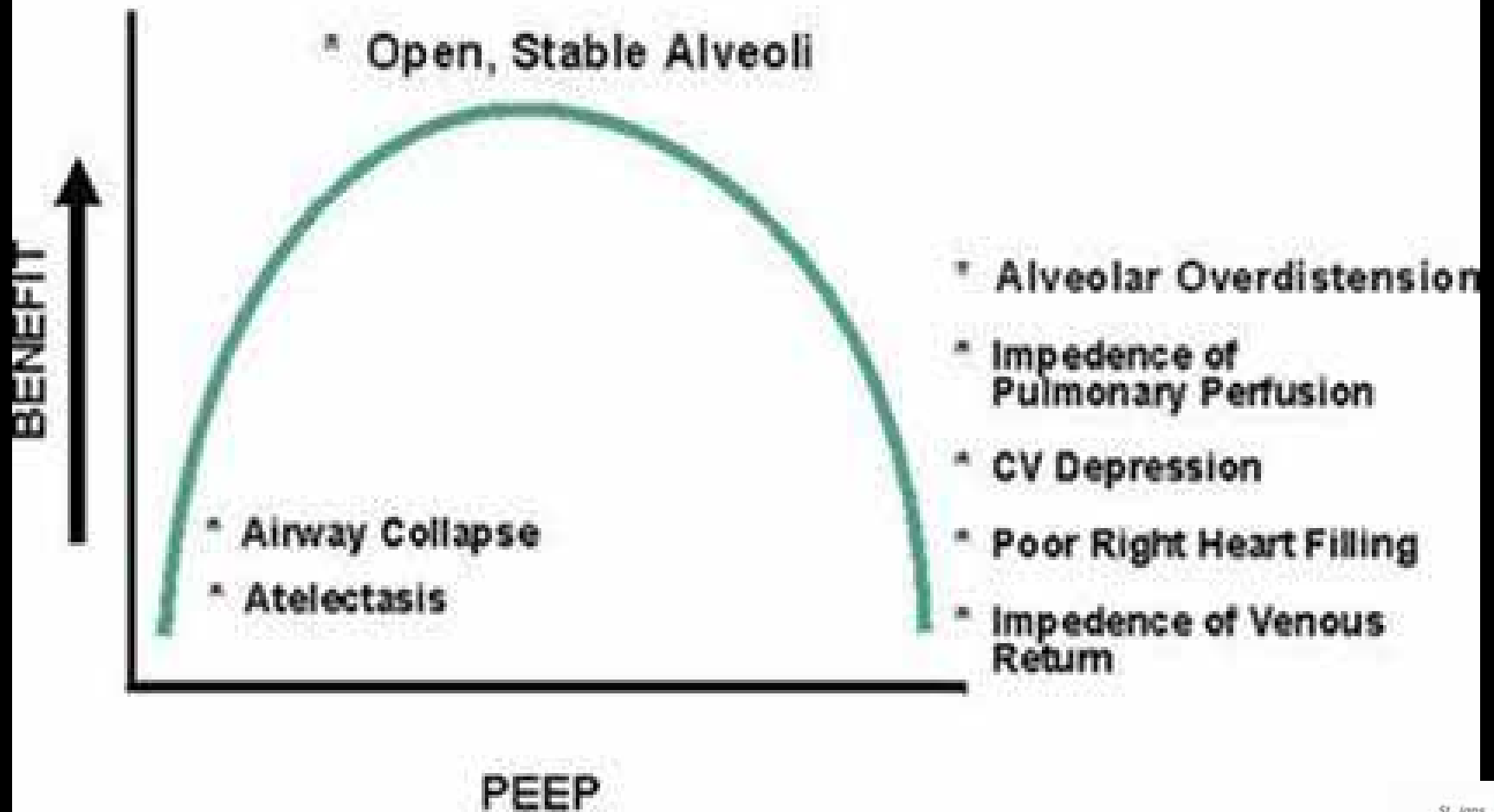
PEEP 12 +2 = 14cm

PC level according to VT (ml/kg) and/or PIP (Pplat) less than 30cm or at least 35cm





The finally chosen settings in this case: Vt of 10ml/kg (in this model a pig of 35kg): PEEP 14cm PC-level 10cm (resulting PIP 24cm) Freq. of 20/min and I:E 1:1



# Alveolar Recruitment Strategies

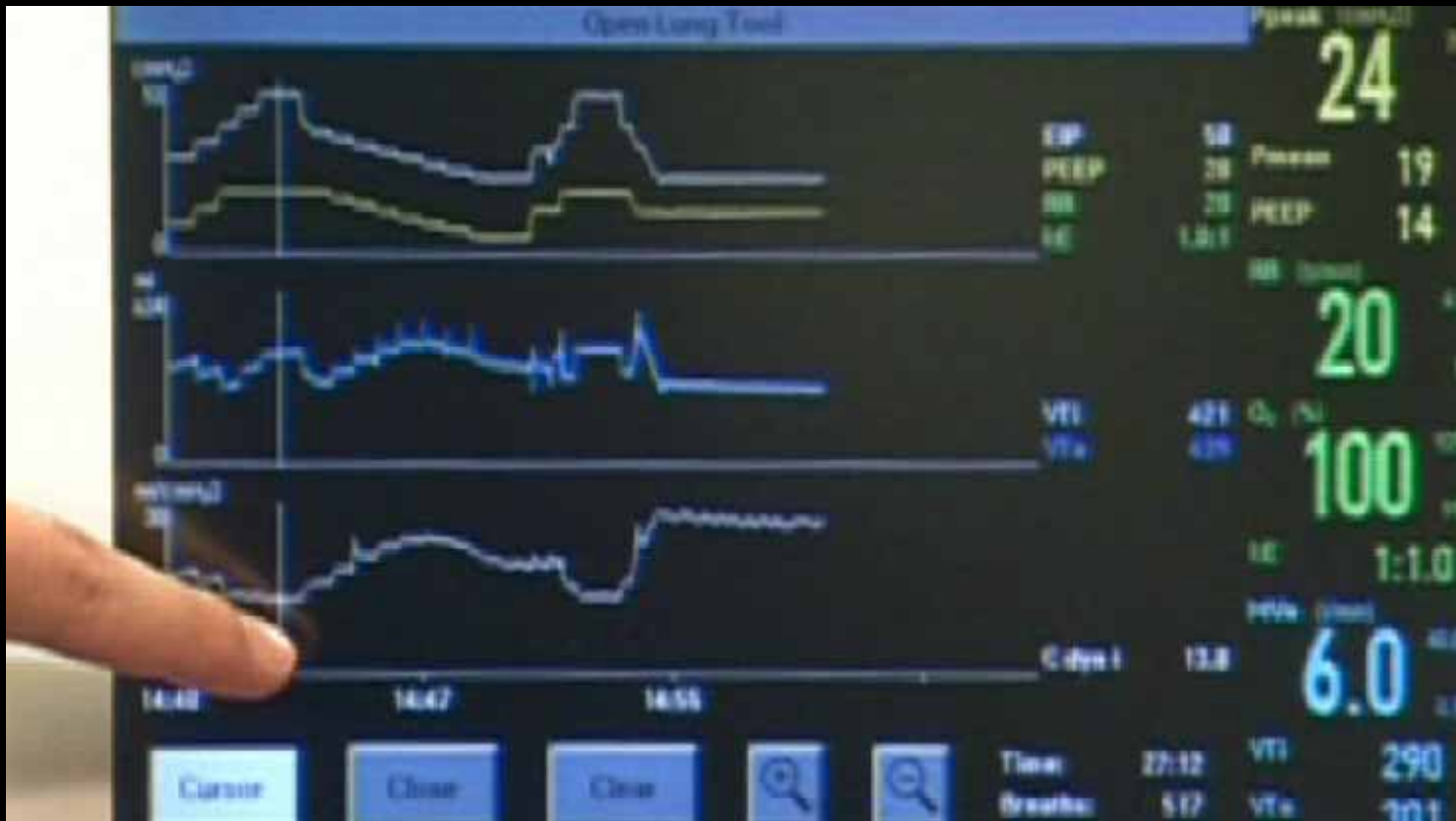
## Effect of recruitment



**Before recruitment**



**After recruitment**



The total process can be followed by the cursor in the OLT trend menu of the Servo-i during and after the procedure. Screenshot in bitmap can be made by the Maquet -datacard.

# Open long concept

Deconnecties en wijzigingen vermijden

Bij deconnecties stap 3 en 4 volledig herhalen

De hele procedure mag niet langer dan 15 à 20 minuten duren

# Lung protective strategy

- Piekdrukken < 30-35
  - FiO<sub>2</sub> < 60%
- PEEP om alveoli open te houden

Complicatie: respiratoire acidose door hypoventilatie

Permissive hypercapnia

# Waar het nu echt om gaat!!

NB: Het is goed te realiseren dat de daadwerkelijke recruitment door de PIP gebeurt en niet door de PEEP!!

Recruitment door kortdurende hoge initiële PIP (Piek Inspiratoire Pressure).

PEEP houdt vervolgens de alveoli open.

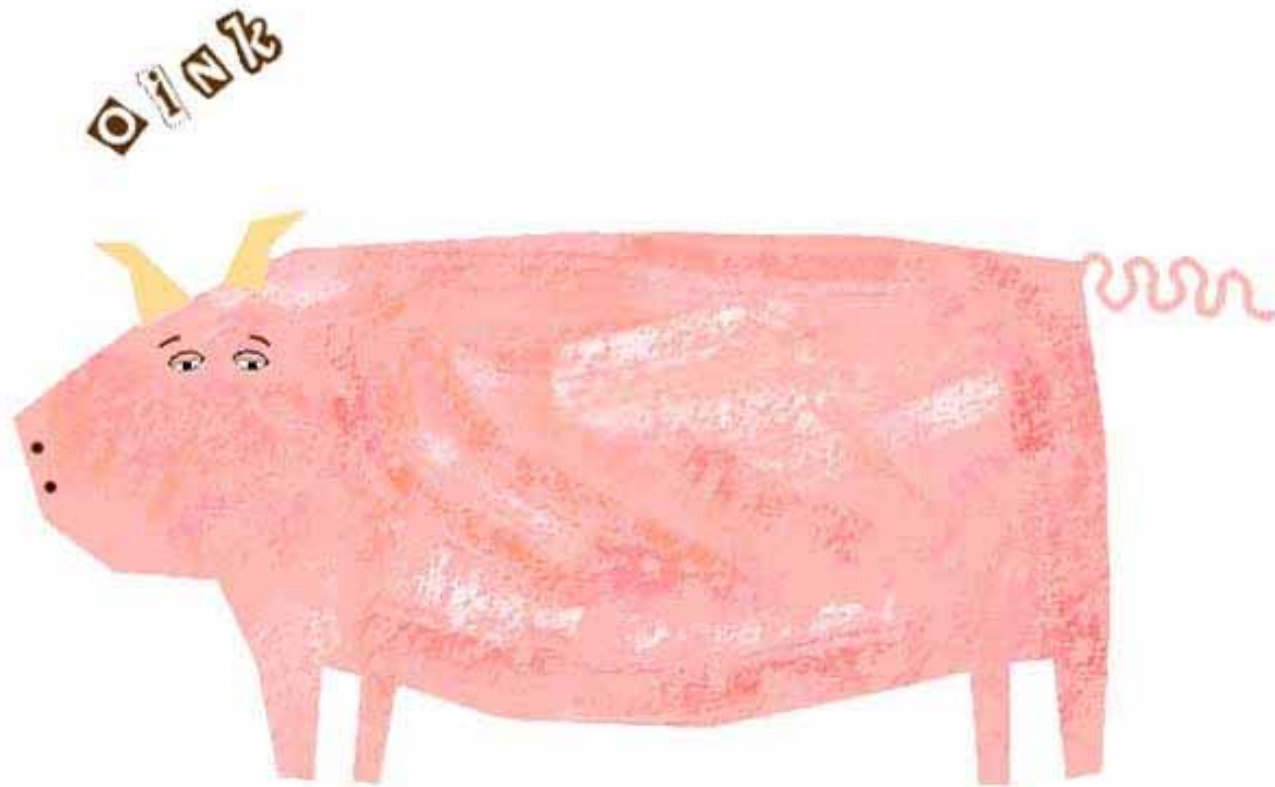
*Open up the lung and keep the lung open, B Lachmann 1992,  
concl:voldoende PEEP en inspiratoire druk zijn essentieel*

*The pressure –volume curve is greatly modified by recruitment, Hickling Keith 1998,  
concl:drukken 20-60 gebruikelijk voor recruitment*

*'Alveolar Recruitment Strategy' improves arterial oxygenation  
during general anaesthesia G Tusman 1999,  
Concl: PEEP tijdens narcose geeft positief effect van PaO<sub>2</sub>*

*Open Lung Management, B Lachmann 2001  
Concl: Onvoldoende recruitment geeft surfactant verlies*

*Open Lung in ARDS, Haitsma, Lachmann 2003,  
Concl: recruitment hoge drukken*





Dank voor jullie aandacht  
**Q&A**

**Marc Coolen Paul Theunissen**  
**Ventilation Practitioners**

Dank aan Maquet voor film en support:  
[www.openomy.com](http://www.openomy.com) voor webruimte.

**MAQUET**