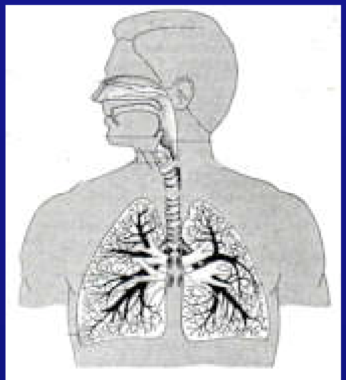

What can I do with my New Anaesthetic Ventilator?

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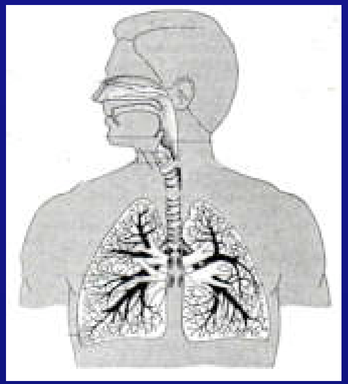
AREA HEALTH SERVICE
NSW HEALTH

Which of the following are true?

- Modern machines are easy to breathe through
- Lung collapse under GA is uncommon
- ICU ventilation modes aren't needed
- Volume Control IPPV is still the best
- 10 ml/kg * 10 with I:E 1:2 is just about right
- Rotameters and a bellows are essential
- Can't breathe on the bag = intubation

Anaesthesia vs ICU ventilators



- Very basic compared to those in ICU
- ICU ventilation concepts (mask CPAP, PS, Open Lung, Recruitment, Low Volume High Rate) uncommon in anaesthetic practice
- Anaesthetists been more interested in better drugs and monitoring than ventilation.

Ventilation problems are common...

- Saturations of 91 in recovery
- See-saw / inadequate respiration with LMA's
- Inadequate ventilation requiring assistance
- High airway pressures on IPPV
- Post-operative pulmonary morbidity
- Hit or miss weaning from IPPV
- Patients who say "I can't breathe on a mask"

A recent review...

Oxygenation is impaired in almost all subjects during anesthesia... hypoxemia for shorter or longer periods is a common finding.

Postoperative lung complications occur in 3-10% after elective abdominal surgery and more in emergency operations.

Rapid collapse of alveoli on induction of anesthesia and more widespread closure of airways seem to explain the oxygenation impairment... this may also contribute to postoperative pulmonary infection.

Hedenstierna, Goran. Edmark, Lennart. The effects of anesthesia and muscle paralysis on the respiratory system. [Review] [52 refs] Intensive Care Medicine. 31(10):1327-35, 2005 Oct.

How could a better ventilator help?

- Patient comfort during pre-oxygenation
- An extra hand to squeeze the bag
- Support for inadequate respiration
- Prevention and Rx of lung collapse
- Reduced alveolar shear stress
- Smart weaning
- Reliability and Accuracy

Spontaneous Breathing Support
=
Minimising Work of Breathing

- Work = Force x Distance

  ie Pressure x Volume

- The more negative the patient's inspiratory effort (intrapleural pressure), the greater the work performed.

Work of breathing factors

Two main components:

1. Elastic work
(overcoming lung stiffness)

2. Air Flow work
(overcoming resistance)

Both contribute equally to total work in normal lungs

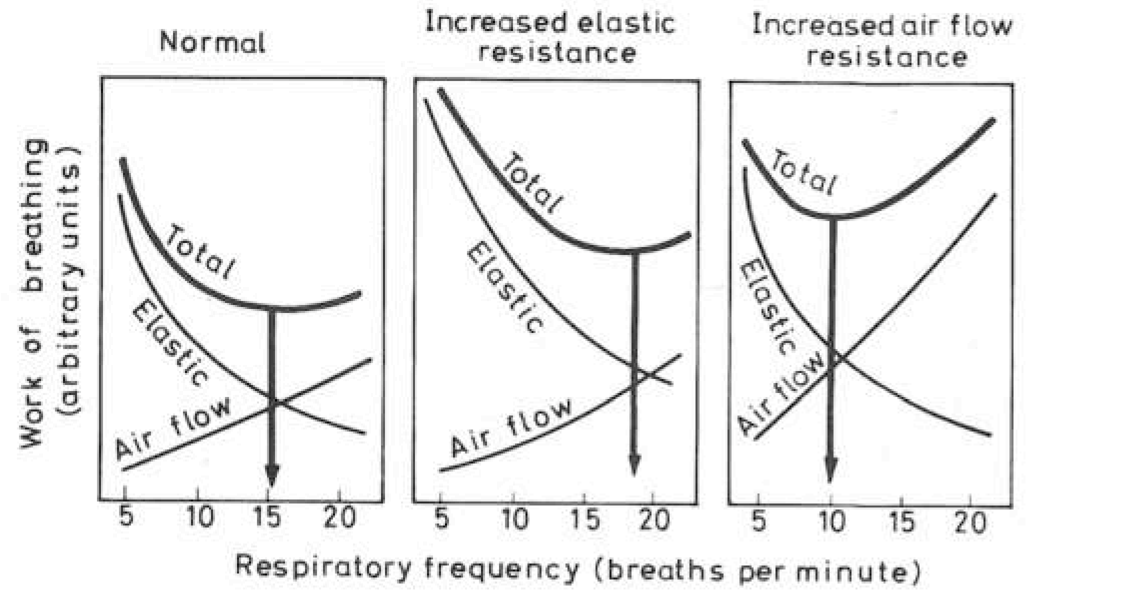


Figure 72. The diagrams show the work done against elastic and air flow resistance separately and summated to indicate the total work of breathing at different respiratory frequencies. The total work of breathing has a minimum value at about 15 breaths per minute under normal circumstances. For the same minute volume, minimum work is performed at higher frequencies with stiff (less compliant) lungs and at lower frequencies when the air flow resistance is increased

NB: normal respiratory rate is 15;
faster with stiff lungs,
slower for airway resistance

Work of breathing during anaesthesia

- Circuit Resistance: work ↑ by 50%

  Due to resistance of ETT, APL, absorber, tubing, valves etc.

- Anaesthesia per se

  ↓ FRC →↓ compliance & ↑ resistance → ↑ work

- Can be 2 – 6 times more difficult than normal !

  Poorly tolerated by some patients

  upper airway obstruction
  tachpnoea, see-saw respiration
  expiratory push

Machine components and resistance

- Resistance increases negative airway pressures at the Y-piece
- With ETT, most circuits exceed Nunn's maximum safe pressure drop
  3.0 cm H20 @ 30 l/min
- Expiratory resistance after the bag fills (APL valve) as well.

Part	Resistance
2 m circle system*	2.5
7 – 8 ETT	2.0 – 3.5
APL (bag full) **	> 2
TOTAL	> 5

Resistance to flow, cm H20 at 30 l/min
* including valves etc
** fully open; depends on type

NB: Normal PiFR ≈ 30 l/min
→ 10 cm H20 intrapl. press. drop

Work due to anaesthesia itself

- FRC ↓ by ≈ 400ml, causing:
- ↑ resistance (≈ doubles)
  → 2x air flow work
- ↓ compliance (≈ half)
  → 2x elastic work
- Net effect is to quadruple the work of breathing
- Minimised if ↓FRC is prevented or treated.

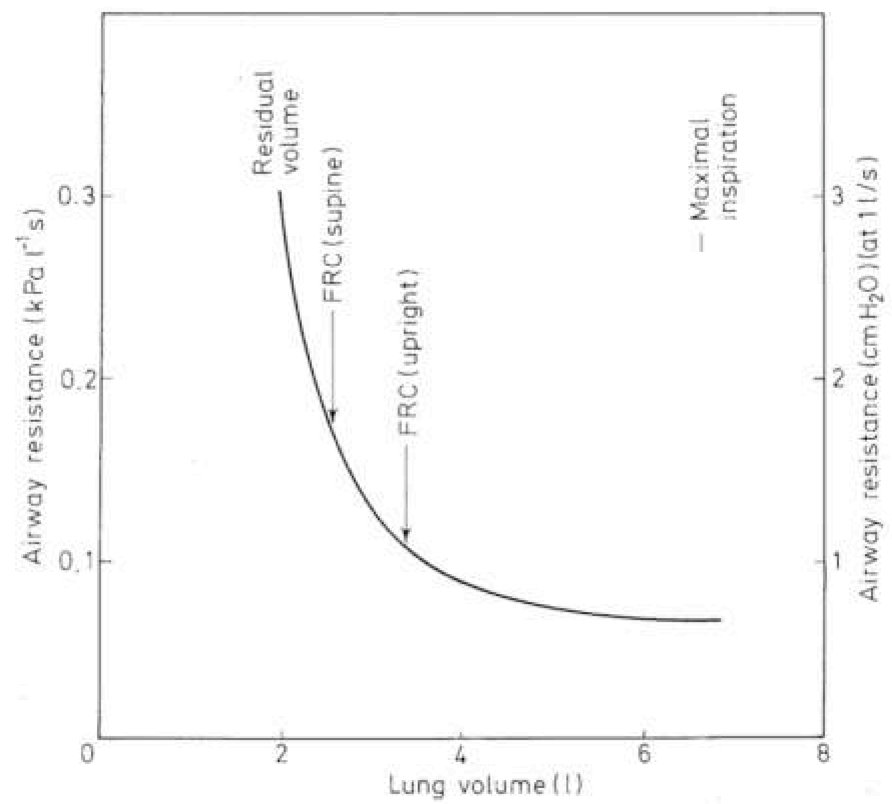


Figure 43. Airway resistance is a function of lung volume. This curve is a hyperbola and conductance (reciprocal of resistance) is linearly related to lung volume. Note that a reduction of FRC of about 0·4 l, which is known to occur during anaesthesia, would itself increase the airway resistance sufficiently to account for most of the actual increase in resistance which has been reported under these circumstances. (This curve is compounded of curves reported by Mead and Agostoni (1964) and Zamel et al. (1974))

Lung volume reduction and resistance from Nunn 2ndEd Fig 43

Minimising work of breathing

- Maintain FRC / Prevent lung collapse

  recruit
  use optimal PEEP

- Minimise circuit resistance

  larger ETT / LMA diameters
  ICU-circuit-type machines

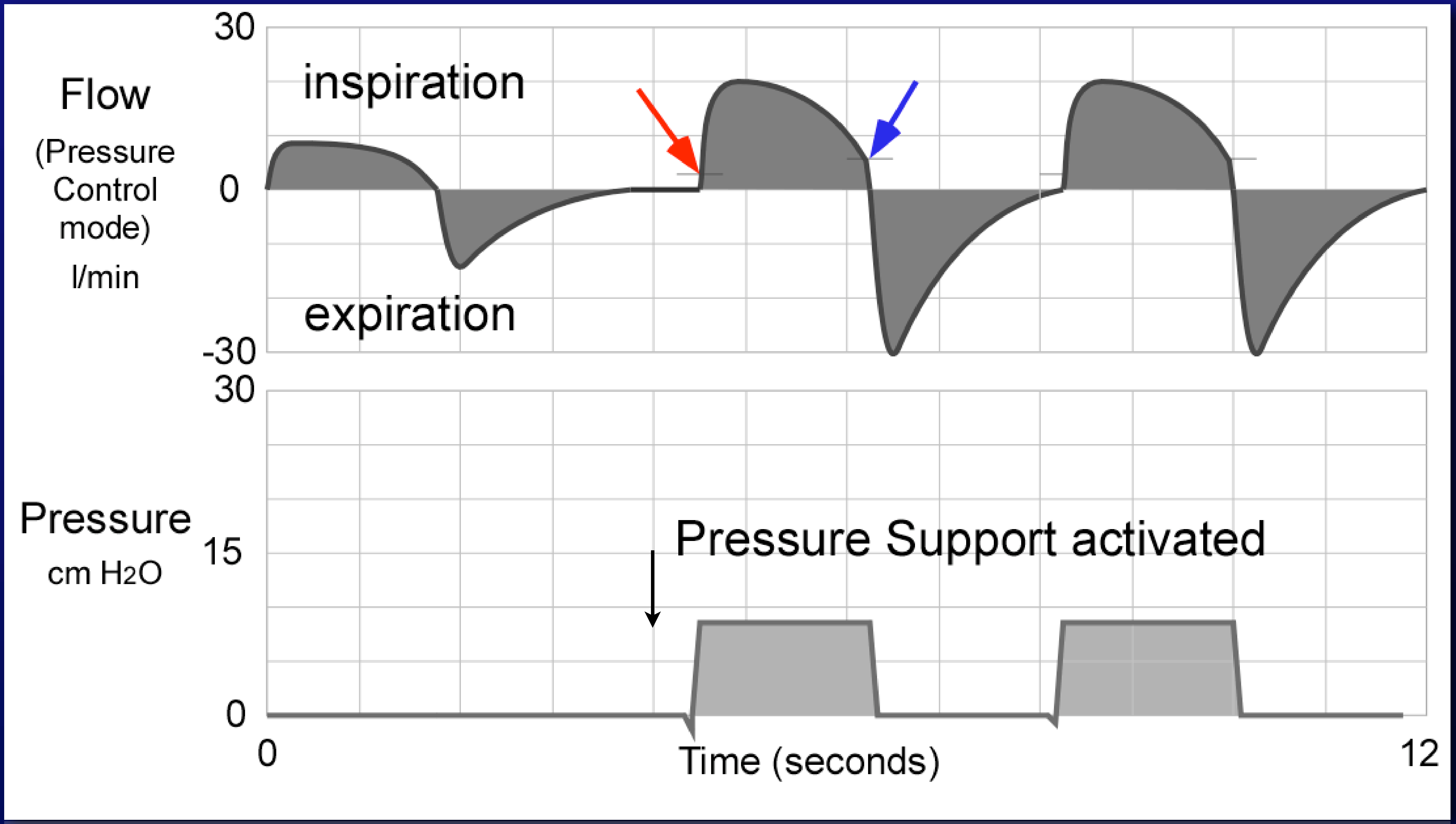
- Assist spontaneous ventilation

  learn how to use "Pressure Support" ...

Pressure Support ventilation

- "Smart" assistance for spontaneous respiration
- Adds airway pressure on inspiration
  - Inspiratory time auto-adjusts to suit the patient
  - PEEP / CPAP can be added
  - Added safety of fallback ventilation on apnoea
- Like the 'educated hand' only better!
- Improves tidal volumes, lowers CO_2

Pressure Support breaths



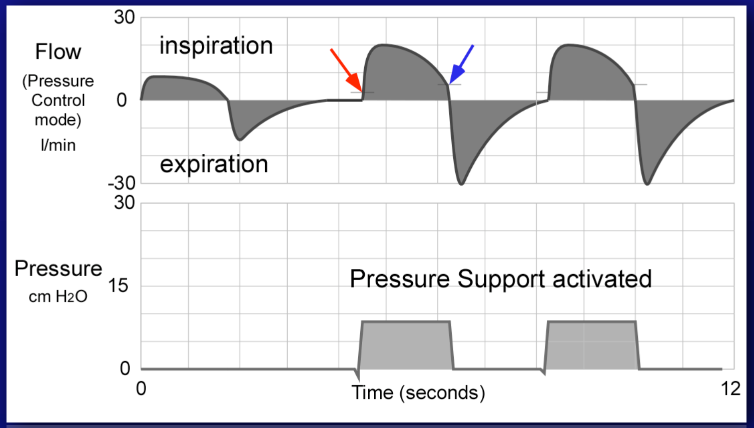
Pressure Support - Synchronisation

- Automatic sync
- Insp. Trigger: flow +/- pressure
- Must be fast and reliable
- Threshold should be adjustable

  too low → false triggering on heartbeat
  too high → patient effort unsupported

- NB: won't trigger if obstructed !

Pressure Support : Inspiration



- Set the Insp Pressure:

  start at 5 – 8 cmH_2O, then adjust

- Inspiration ends when either:

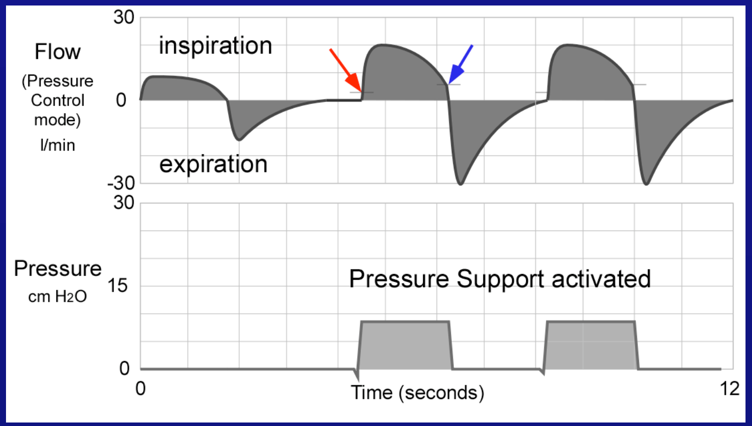
  flow falls to 25% of the peak insp. flow rate, or
  an arbitrary maximum time elapses

- Peak flow capability must be very high

- Rise time should be adjustable

  0.3s works well for most people
  faster for children, gasping respiration

Pressure Support : Expiration



- Pinsp drops when patient breaths out
- Patient sets their own respiratory rate
- add PEEP easily

  functionally works like ICU CPAP
- Expiratory resistance should be small

  can be high; best with ICU-type circuit design

Pressure Support – Apnoea

- Transient apnoea is relatively common
  - e.g. narcotic administration
  - too much pressure support lowering CO_2 (!)
- Automatic "Fall-back" ventilation
  - intended to assist ventilation
  - machine self-triggers at a 'fallback rate'
  - either uses PS breaths (Dräger) or PCV (GE)
  - alarm or message
  - auto-return to PS when apnoea ends (Dräger only)

Clinical applications of Pressure Support

1. Improving ventilation during LMA cases

   typical values:
   5-12 cmH_2O of support,
   with 5-10 cmH_2O of PEEP if needed

2. Weaning from IPPV

   Fallback rate 7–8
   Enough PS for decent tidal volume
   Enough PEEP to prevent collapse
   Patient weans themselves

3. Induction of anaesthesia

- Practicalities:

  Get a good mask seal
  Keep flow rates high enough for leaks
  Go to standby when taking the mask off

- Settings:

  Fallback rate of 15
  5 cm H_2O PS while awake
  On induction, increase to maintain tidal volumes
  Add PEEP to counter obstruction

- Like a second person squeezing the bag!

Lung Collapse / Loss of FRC

- Occurs on induction, continues during case
- Contributing factors:

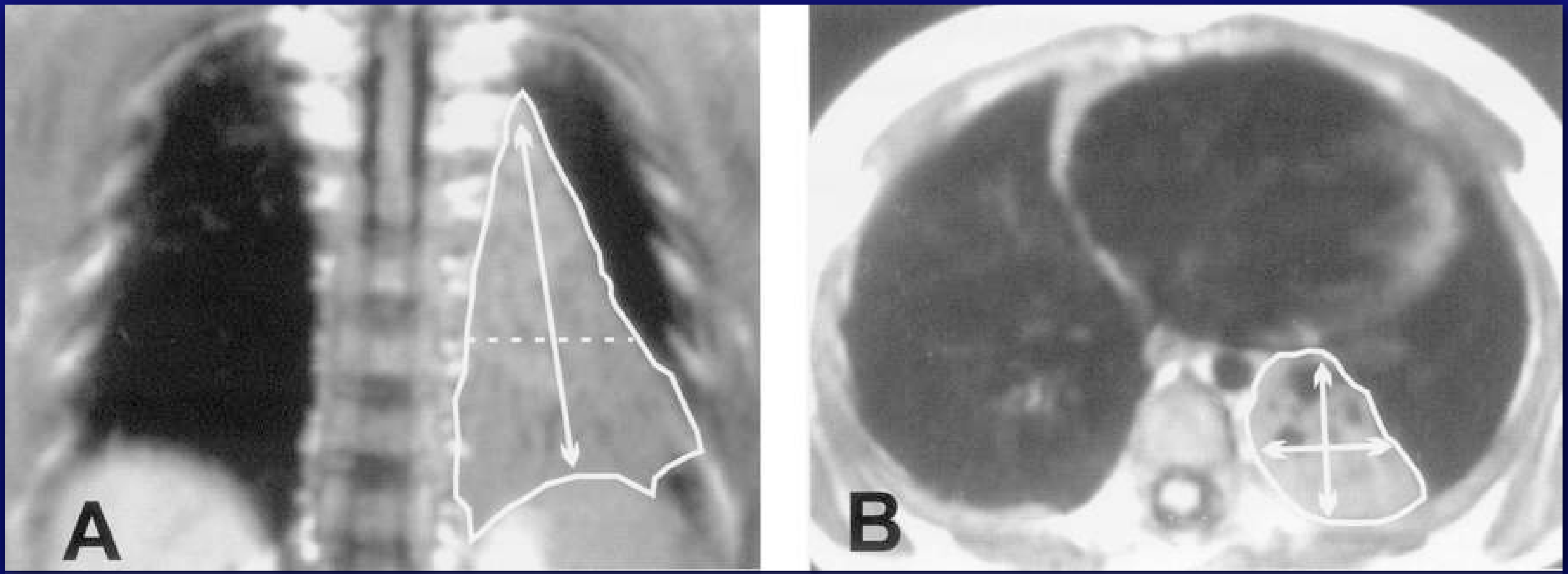
  apnoeic episodes in O_2 or O_2 / N_2O
  obesity, increasing age, – trendelenburg etc (↓ FRC)
  not enough PEEP / CPAP

- Can worsen lung compliance by 30 – 60%

  combination of ↓ elasticity & ↑ resistance
  → higher airway pressures, hypoxaemia, increased work of breathing, etc

➡ Post-operative lung dysfunction

Tusman et al, MRI images in children

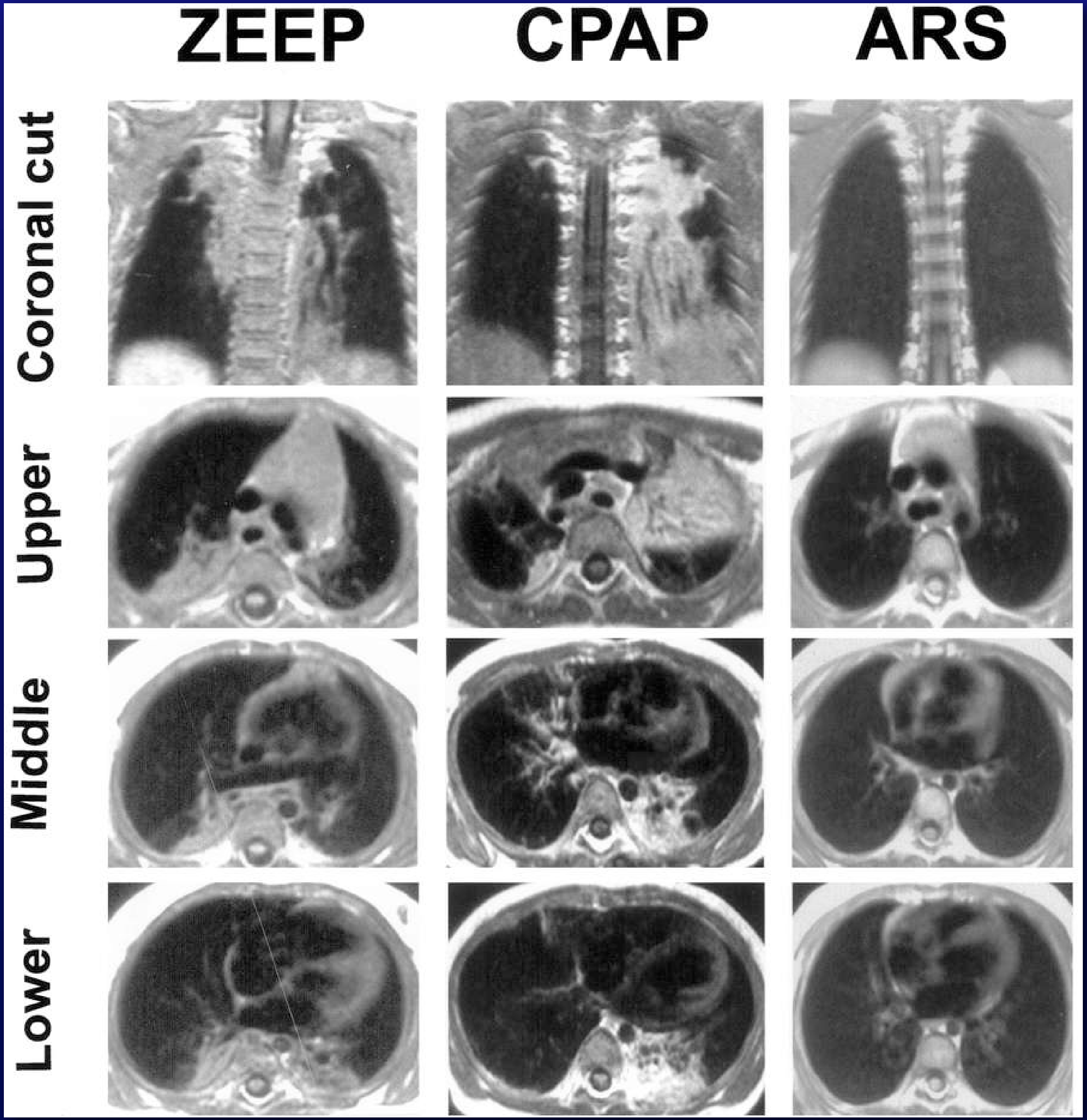


24 children, 6 months - 6 years having MRI, intubated deep without relaxant then spontaneous respiration on ETT.

3 groups: no PEEP, 5 of PEEP and Recruitment + PEEP.

Effects of recruitment maneuver on atelectasis in anesthetized children. Tusman G. Bohm SH. Tempra A. Melkun F. Garcia E. Turchetto E. Mulder PG. Lachmann B. Anesthesiology. 98(1):14-22, 2003 Jan.

Tusman et al 2



PEEP alone was useless...

Table 2. Atelectatic Volumes

	ZEEP	CPAP	ARS
Atelectasis volume (cm^3)			
Right	1.25 (0.75–4.56)*	9.5 (3.1–23.7)	0†‡
Left	4.25 (3.2–13.9)	8.8 (5.3–28.5)	0†‡

Data are presented as median, first (25%) quartile, and third (75%) quartile.

Significant difference (Mann–Whitney U test) between *ZEEP and CPAP, between †CPAP and ARS, between ‡ZEEP and ARS. All $P < 0.05$.

ARS = alveolar recruitment strategy group; CPAP = continuous positive end-expiratory group; ZEEP = zero end-expiratory pressure group.

NB: ARS = Recruitment to 40/15 for 10 breaths then PEEP

"CPAP" was applied with PEEP valve, ie not true CPAP.

Prevention of Lung Collapse

- Avoid apnoeic episodes
- Perform recruitment manouevre/s

  35-40 cm H_2O over 15-20 cm H_2O of PEEP
  hold for 10 breaths or 30s
- Monitor compliance & re-recruit if needed
- Optimise PEEP / CPAP

  to best lung compliance or best PaO_2 or both
- Use Pressure Mode; optimise Ti and Te

Maintaining ‘open lungs’ post-op

- Maintain PEEP at all times

  wean using Pressure Support with PEEP
  don’t intermittently bag without PEEP
  don’t leave apnoeic to induce respiration

- Recruit the lung just before extubtion

- Extubate sitting up

  ... in as little oxygen as possible
  ... as awake as possible
  ... with good analgesia

PEEP ALONE IS NOT ENOUGH

RECRUITMENT IS ESSENTIAL

PEEP SHOULD BE OPTIMISED

What is optimal PEEP ?

Optimal PEEP provides best -

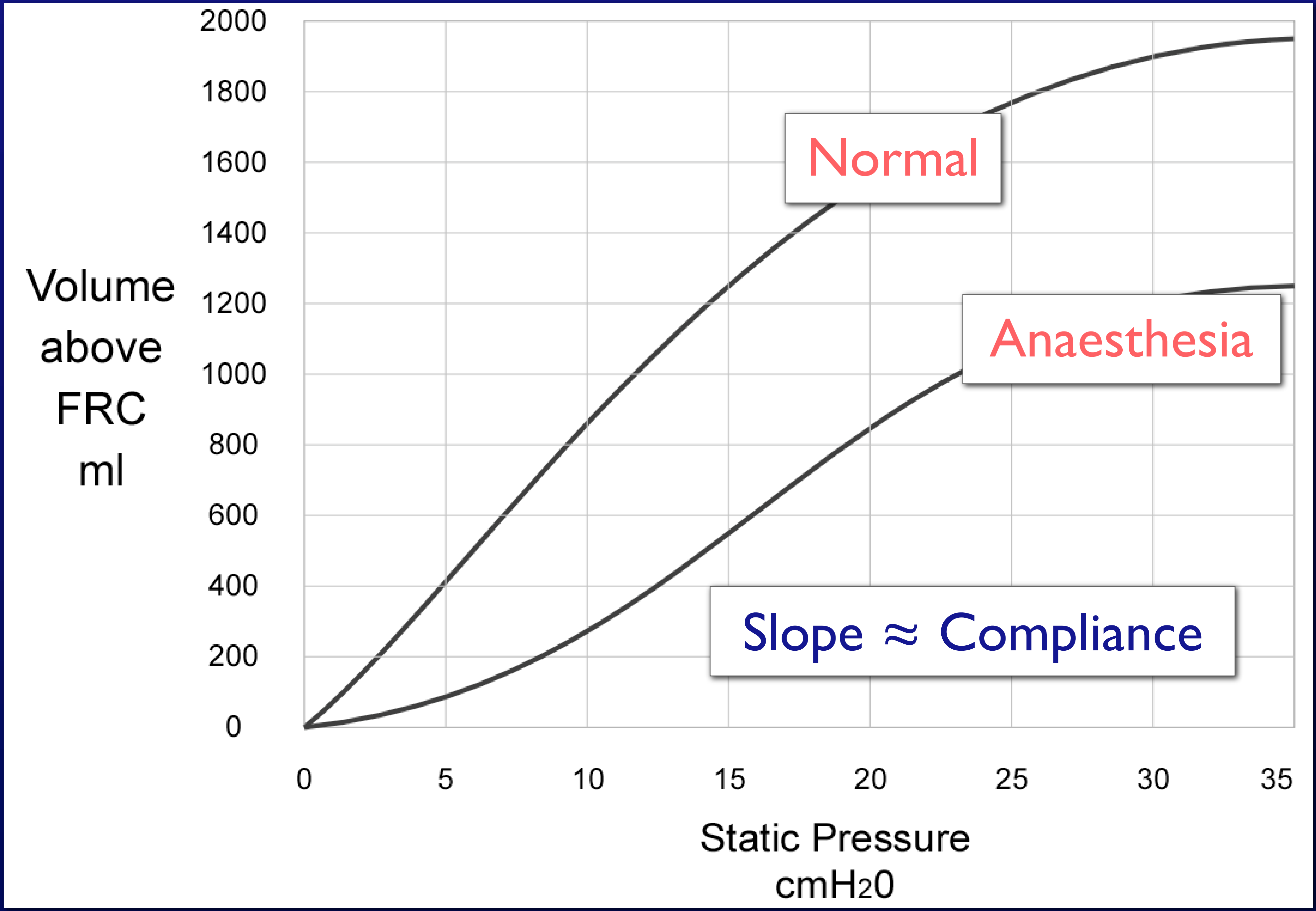
- Mechanical compliance

  and/or

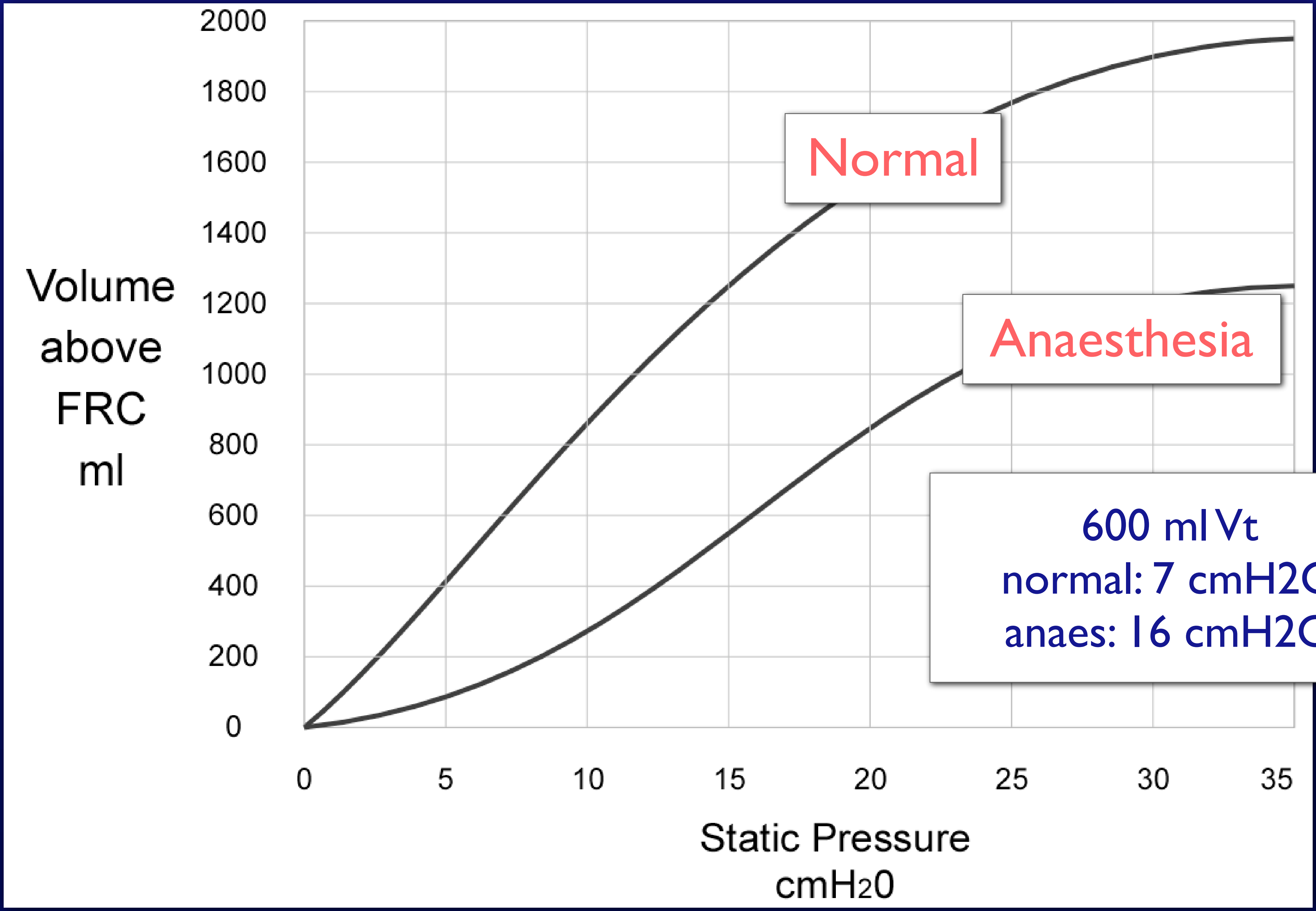
- PaO_2

without undue cardiovascular depression

Typical compliance curves



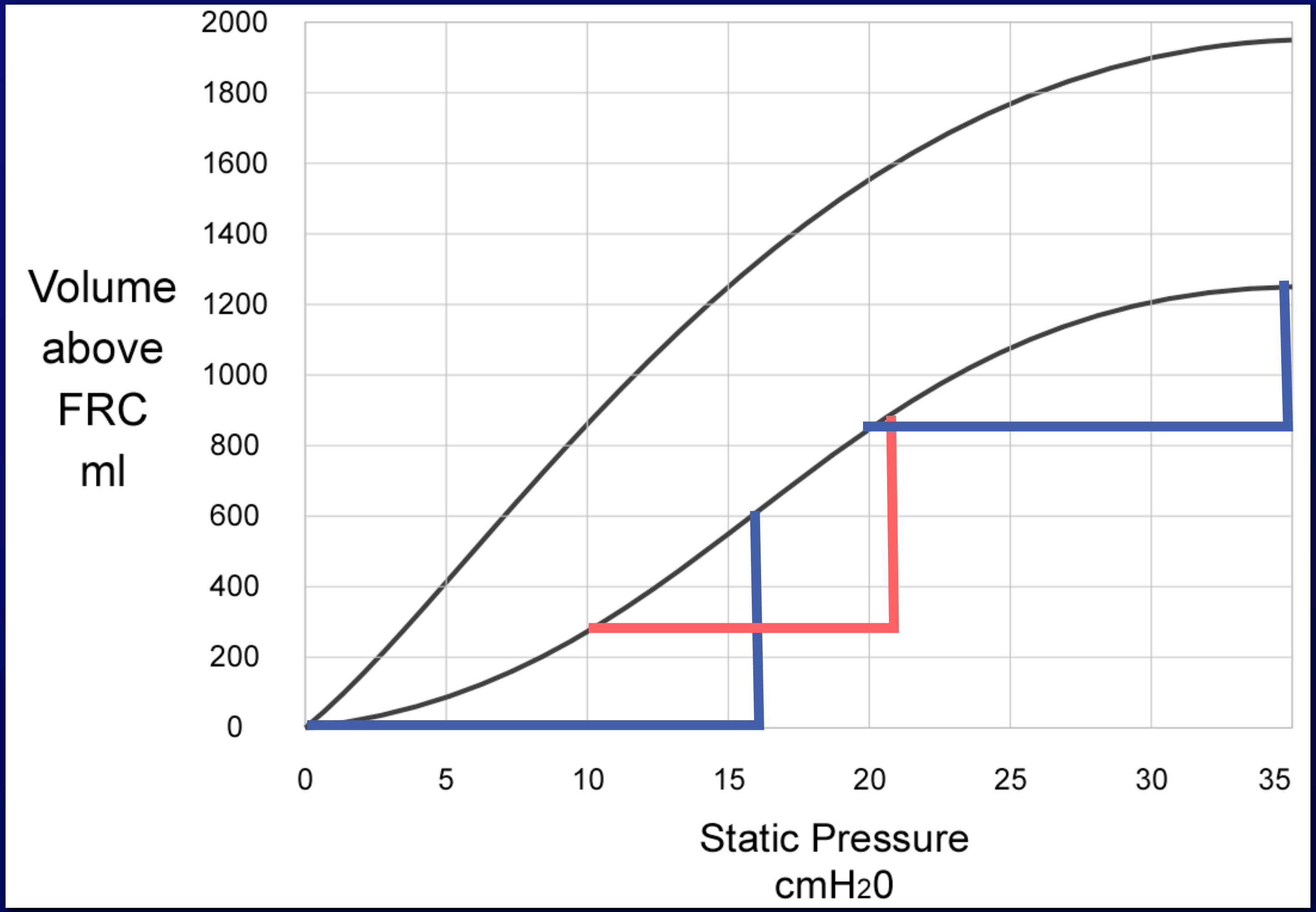
Typical compliance curves



600 ml Vt
normal: 7 cmH2O
anaes: 16 cmH2O

Optimal mechanical PEEP is where compliance is best

Typical pressures for a 600ml breath while anaesthetised



PEEP	Pressures	ΔP
0	16/0	16
5	18/5	13
10	21/10	11
15	27/15	12
20	42/20	22

... optimal PEEP = 10 cmH20 for this patient

How I determine optimal PEEP...

- Use Pressure Control
- With PEEP at 0, set:
  - ΔP to give adequate Vt,
  - I:E ratio 1:1,
  - rate 10 (3s insp)
- Increase PEEP in steps with same Δ pressure
- Find the PEEP that gives the best tidal volume.

PEEP	Vt
0	300
5	470
10	550
15	510
20	350

optimal PEEP = 10 cmH20 for this patient

Then include a recruitment manouevre

- Recruit at PEEP of 20 with peak pressures of 35 – 40 for 30s

PEEP	Vt up	Vt down
0	300	
5	470	
10	550	
15	510	
20	350	400

Then include a recruitment manouevre and drop down to the starting PEEP

- Recruit at PEEP of 20 with peak pressures of 35 – 40 for 30s
- Return to initial ΔP, dropping back through same PEEP steps

PEEP	Vt up	Vt down
0	300	500
5	470	700
10	550	750
15	510	670
20	350	400

Best Vt at 10 of PEEP

Then include a recruitment manouevre and drop down to the starting PEEP

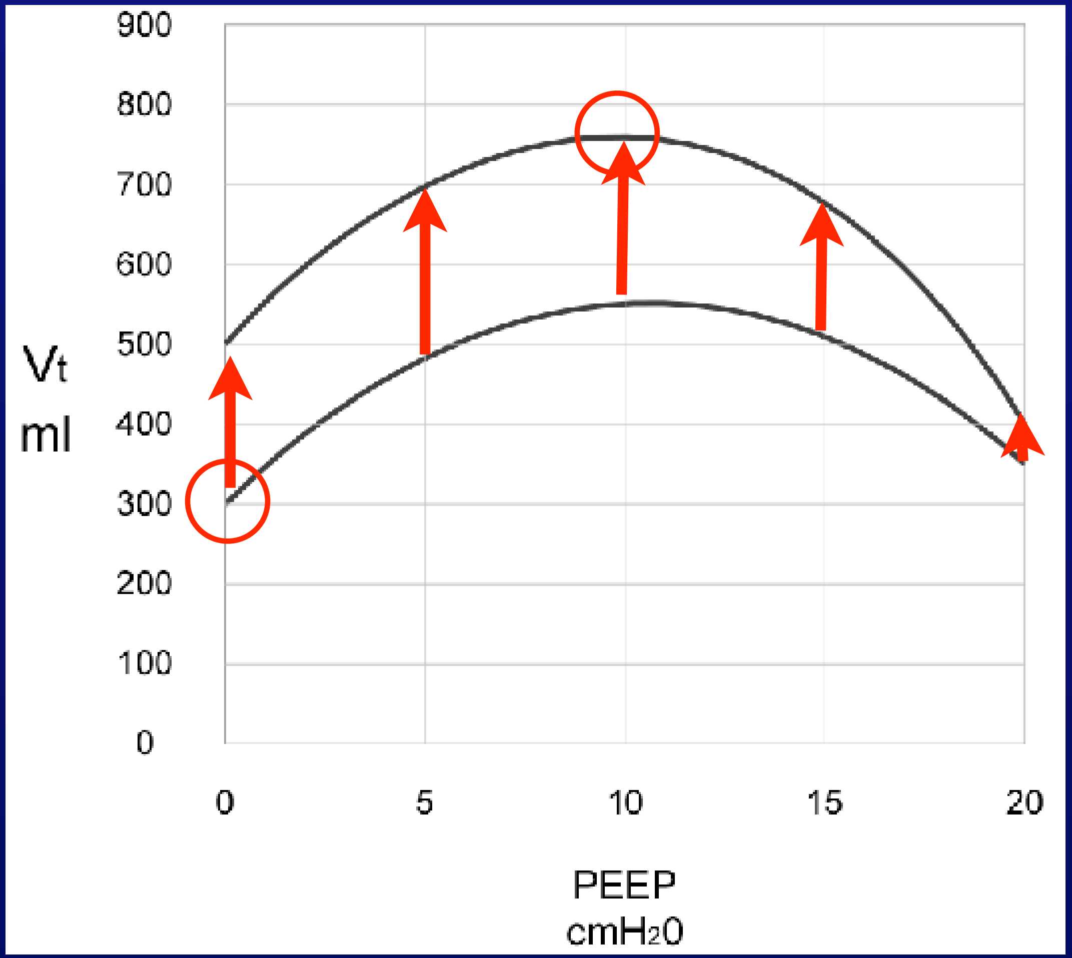
- Recruit at PEEP of 20 with peak pressures of 35 – 40 for 30s
- Return to initial ΔP, dropping back through same PEEP steps
- Benefit of PEEP + recruitment can be quantified

PEEP	Vt up	Vt down
0	300	500
5	470	700
10	550	750
15	510	670
20	350	400

Overall compliance doubled
≈ 1/3 of the lung had collapsed.

Optimal mechanical PEEP : typical result of recruitment

- Markedly improves compliance ie Vt at same ΔPaw
- Reduces shear stress for given tidal volume
- Keeps recruited alveoli open



Recruitment ↑Vt from 300ml to 750ml at same ΔPaw

What is 'open lung' ventilation?

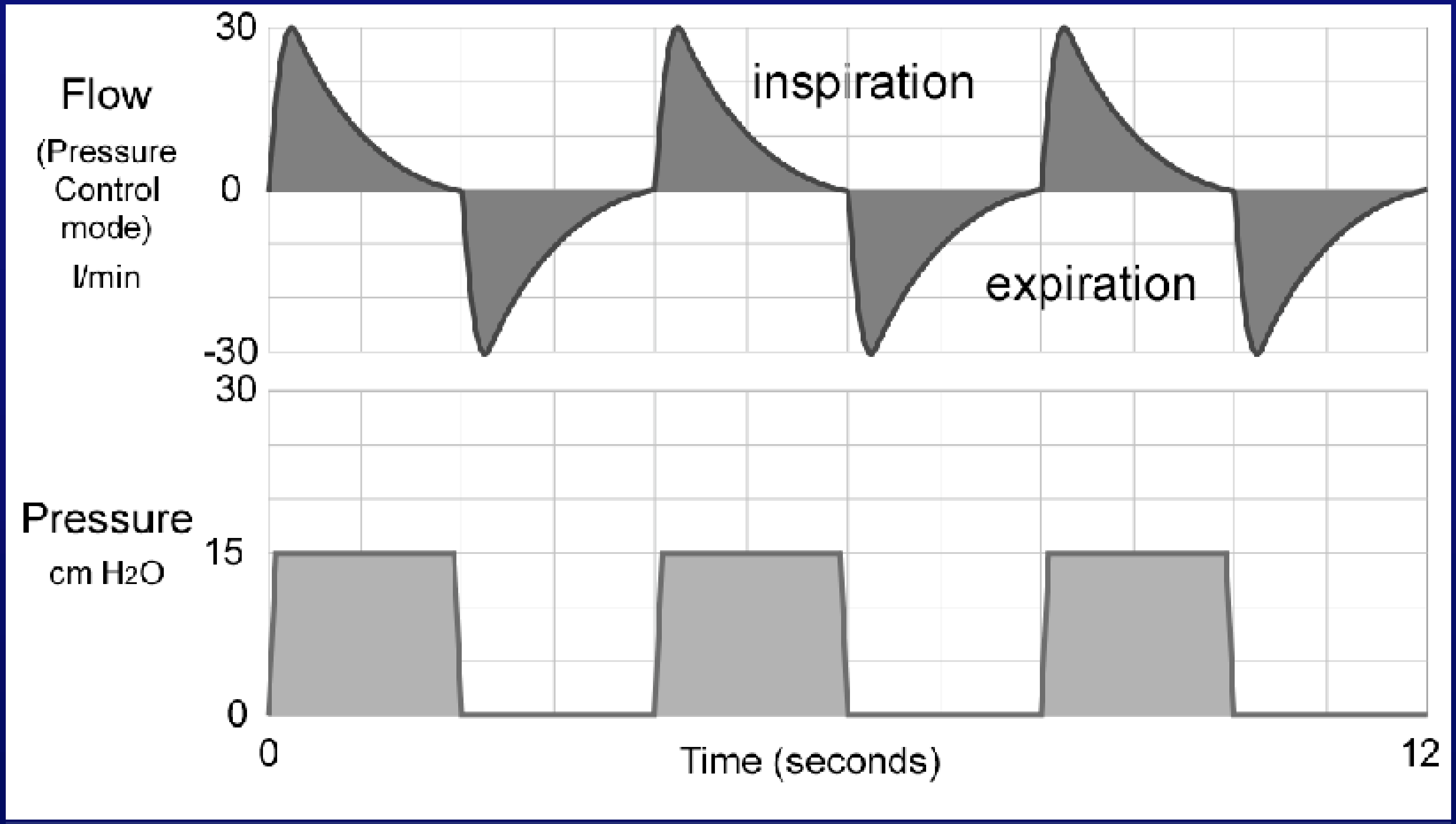
- Minimal differential airway pressures
  → reduce shear stress, barotrauma, ARDS
- Techniques:
  Optimal PEEP / CPAP
  Recruitment manouevres
  Optimal inspiratory and expiratory times
  Lower volumes / higher rates
  Permissive hypercapnoea

Lower tidal volumes and higher rates

- Physiologically normal values:
  Tidal volume : 5 – 7 ml/kg
  Respiratory rate : 12 – 15 breaths per minute
- 10 ml/kg * 10 is NOT normal.
- With 50% collapse, Paw increases only 1/3, but the remaining lung tissue gets DOUBLE the effective shear stress
- High shear stress over time induces ARDS

Optimal inspiratory and expiratory times

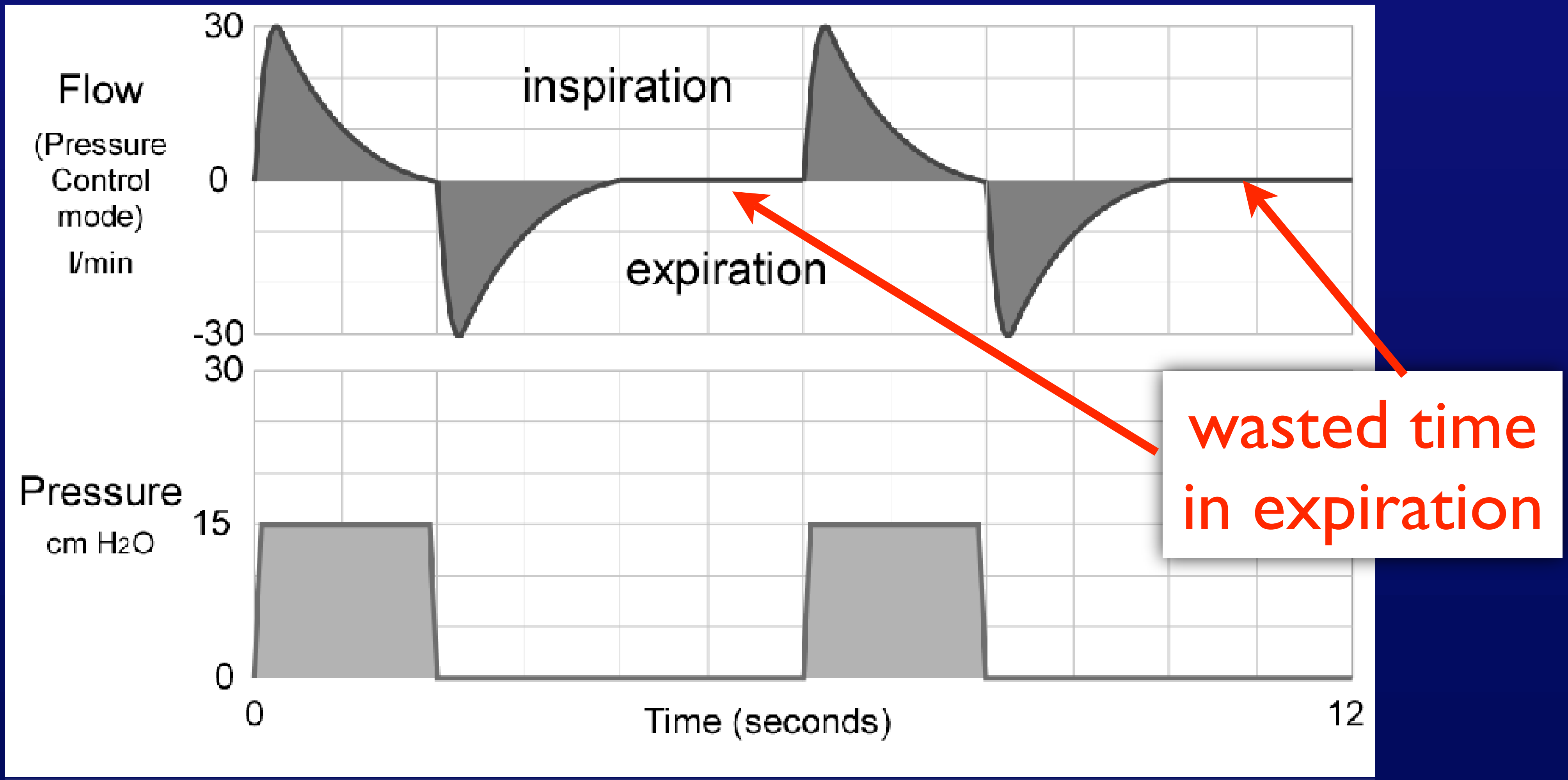
Flow curves in Pressure Control should never be flat!



No gas flow = No ventilation

Optimal expiratory times

No gas flow = No ventilation



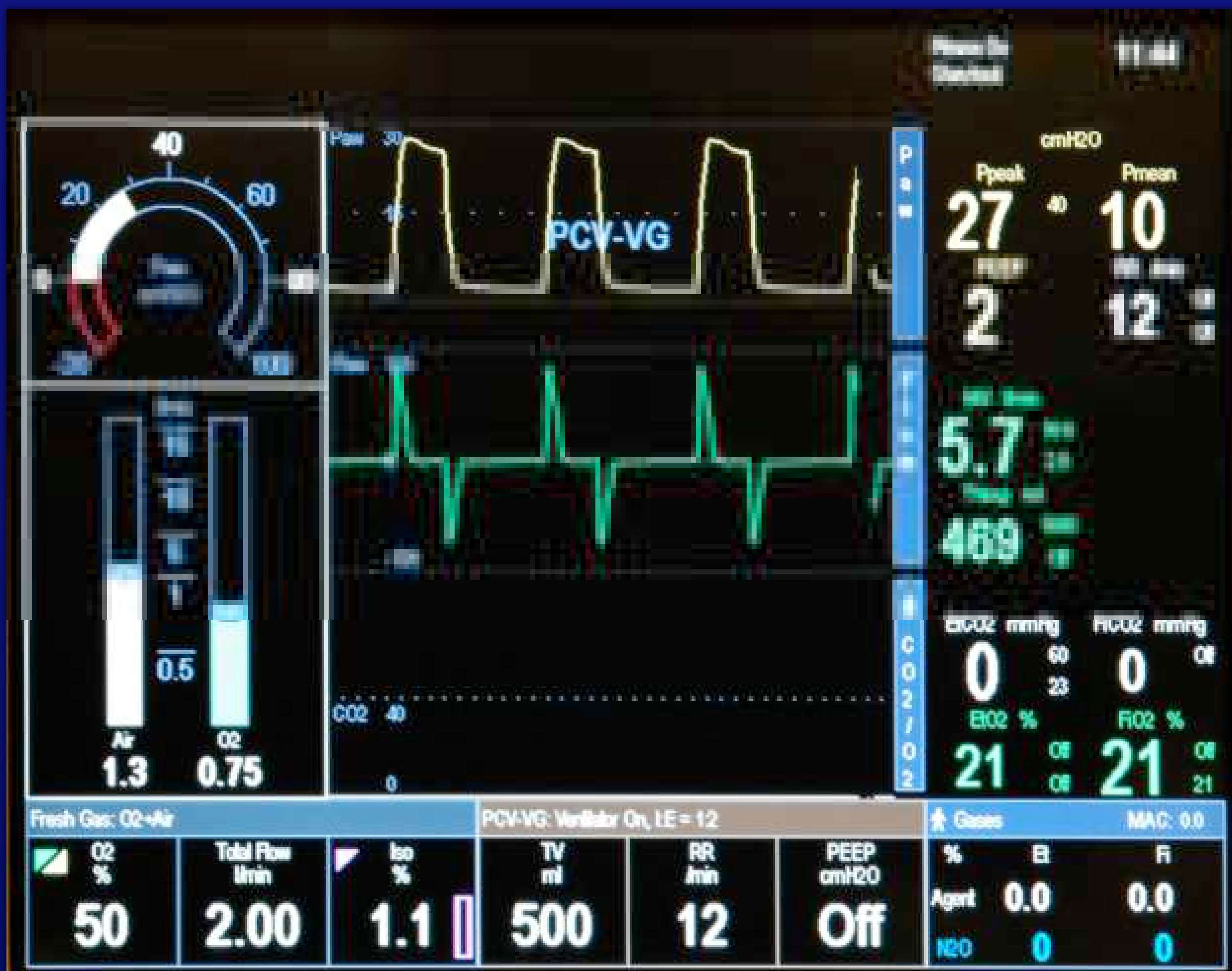
Optimal inspiratory and expiratory times

time	Inspiration	Expiration
Too short	hypoventilation and collapse of long time constant alveoli → hypoxia, loss of FRC etc	hypoventilation and hyperinflation of long time constant alveoli → hypoxia, reduced compliance, etc
Too long	tidal volumes need to be larger than usual; increases Paw. doesn't improve ventilation once gas flow stops, can impair C.O.	tidal volumes need to be larger than usual; enhances collapse. doesn't improve ventilation once gas flow stops

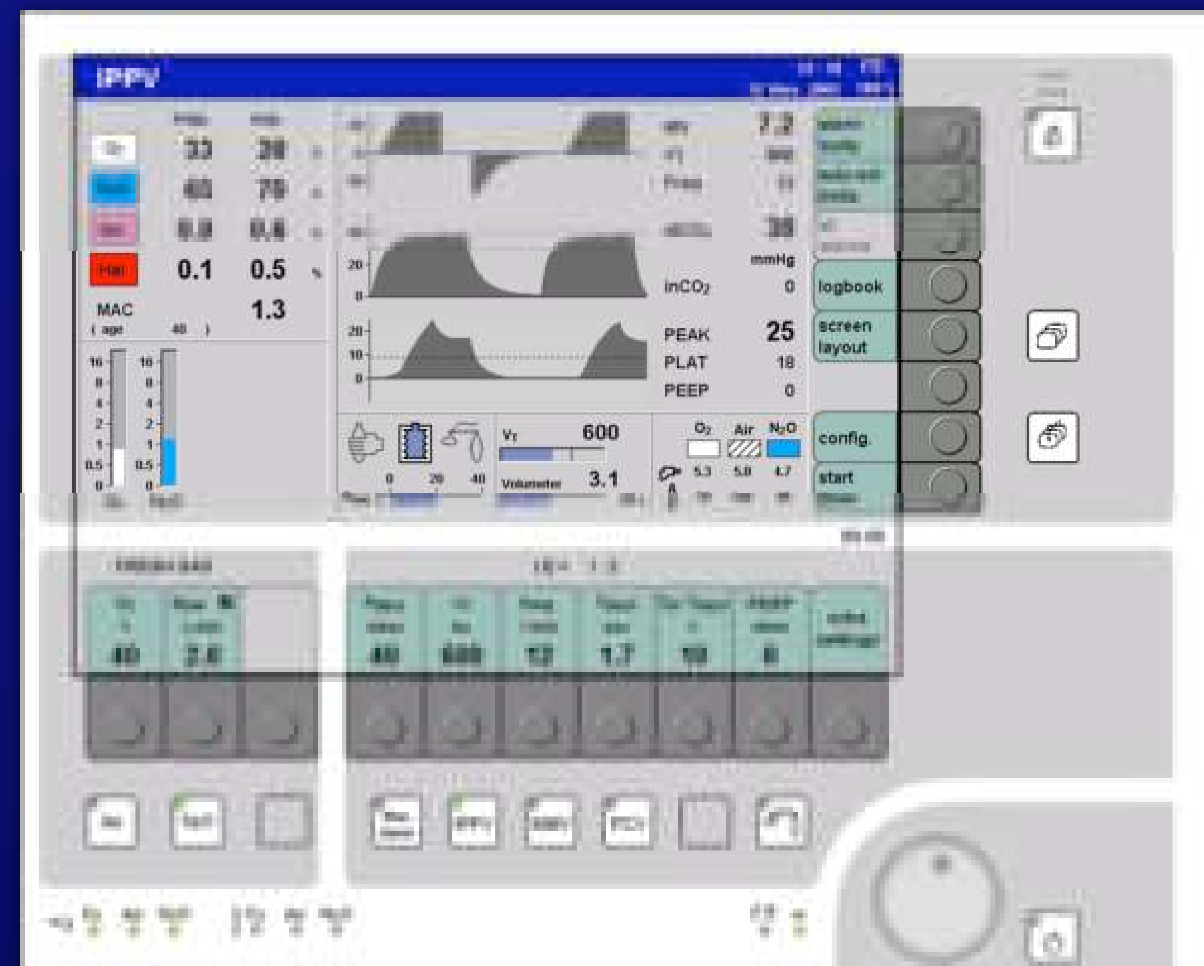
How can an ‘advanced’ ventilator help me?

- Accurate control, adjustment and display of pressure, flow and volume; Pressure Control modes
  - → Ti, Te & PEEP optimisation; recruitment
- Spontaneous breathing support (PS, CPAP)
  - → easier LMA anaesthesia, better airway, easier weaning
  - → two hands free to hold the mask
- Leak detection +/- compensation; useful alarms
- Automated self-checking & calibration
- Knowing exactly what’s going on

Informative displays - esp flow curves

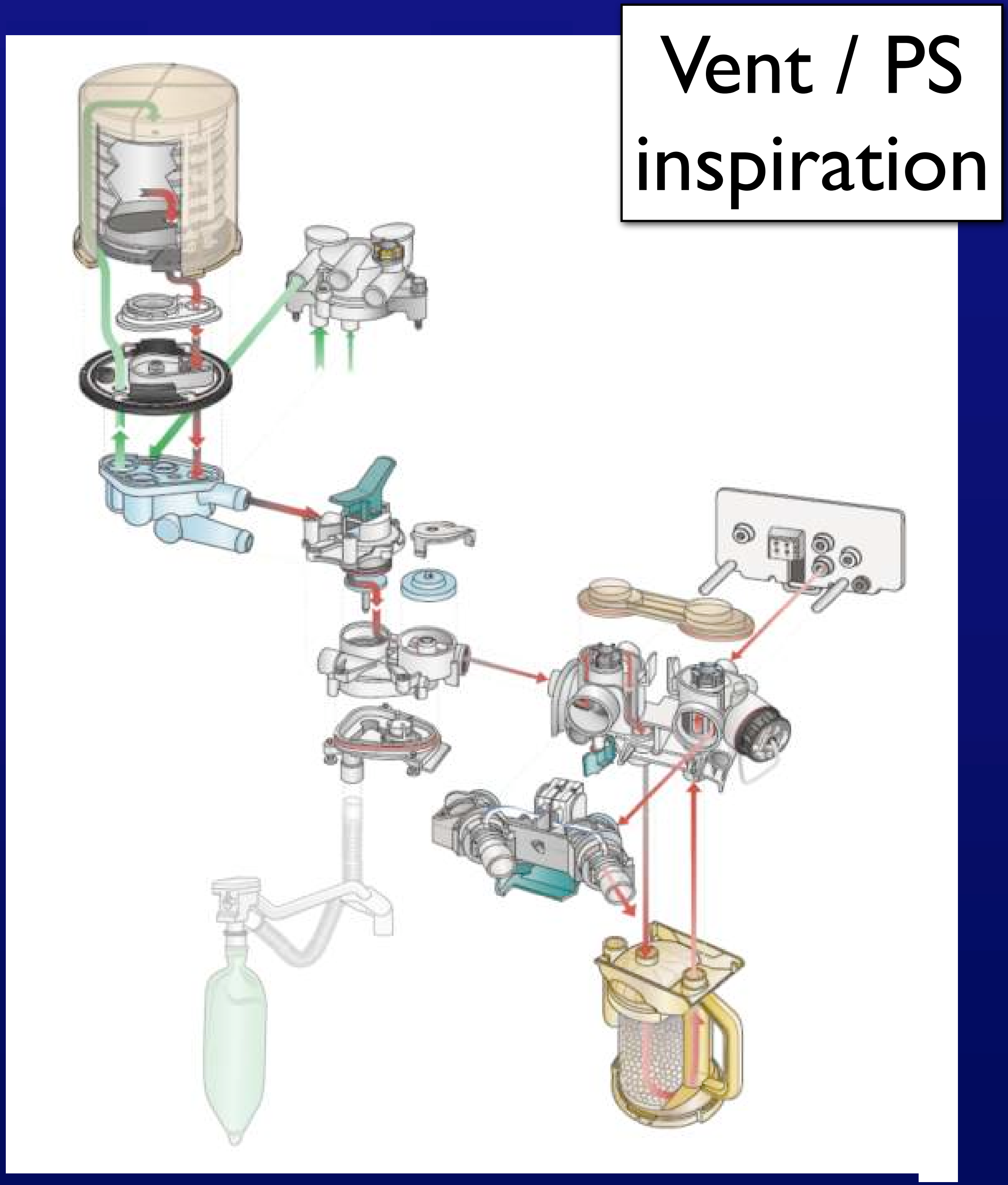


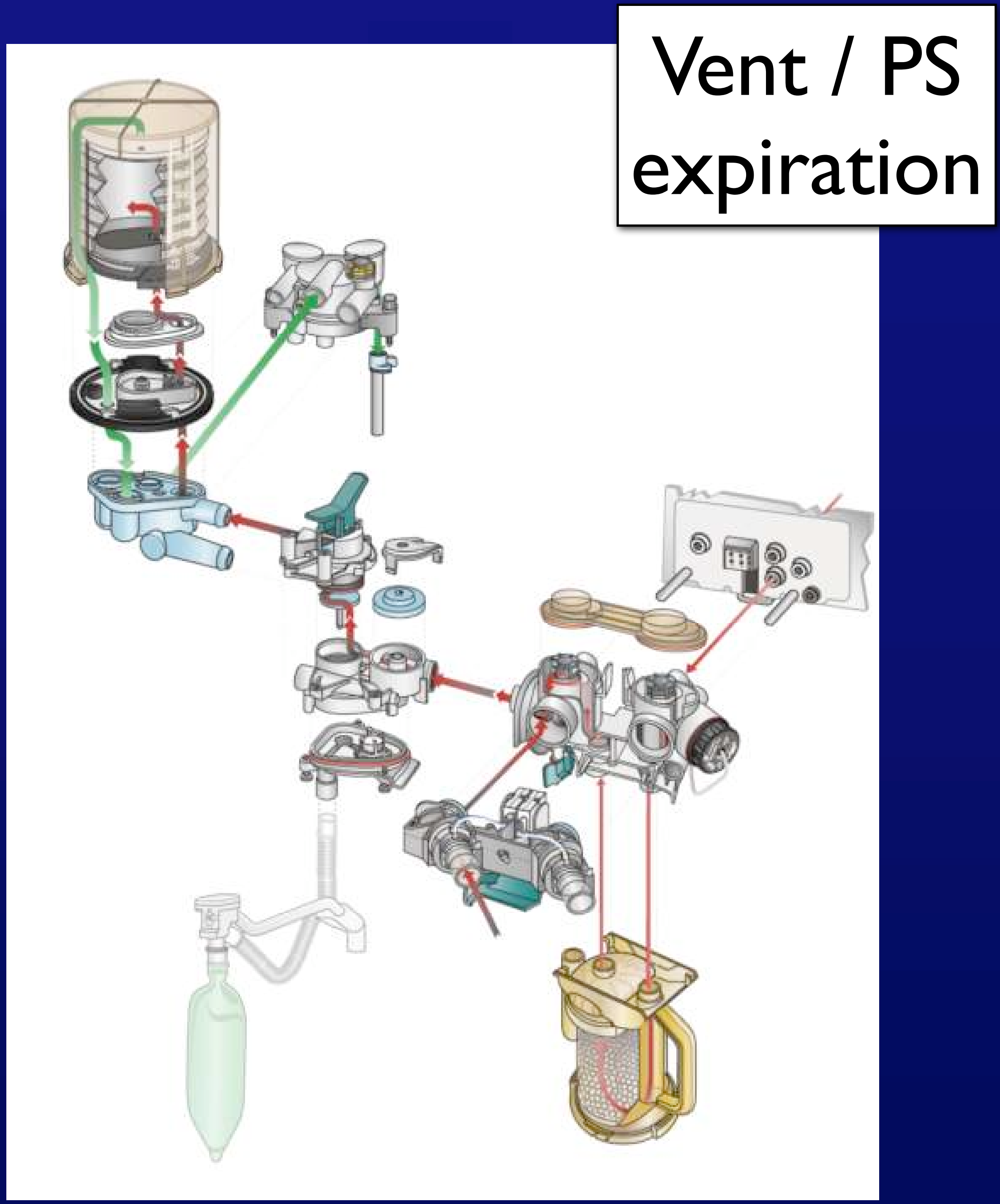
GE Aisys



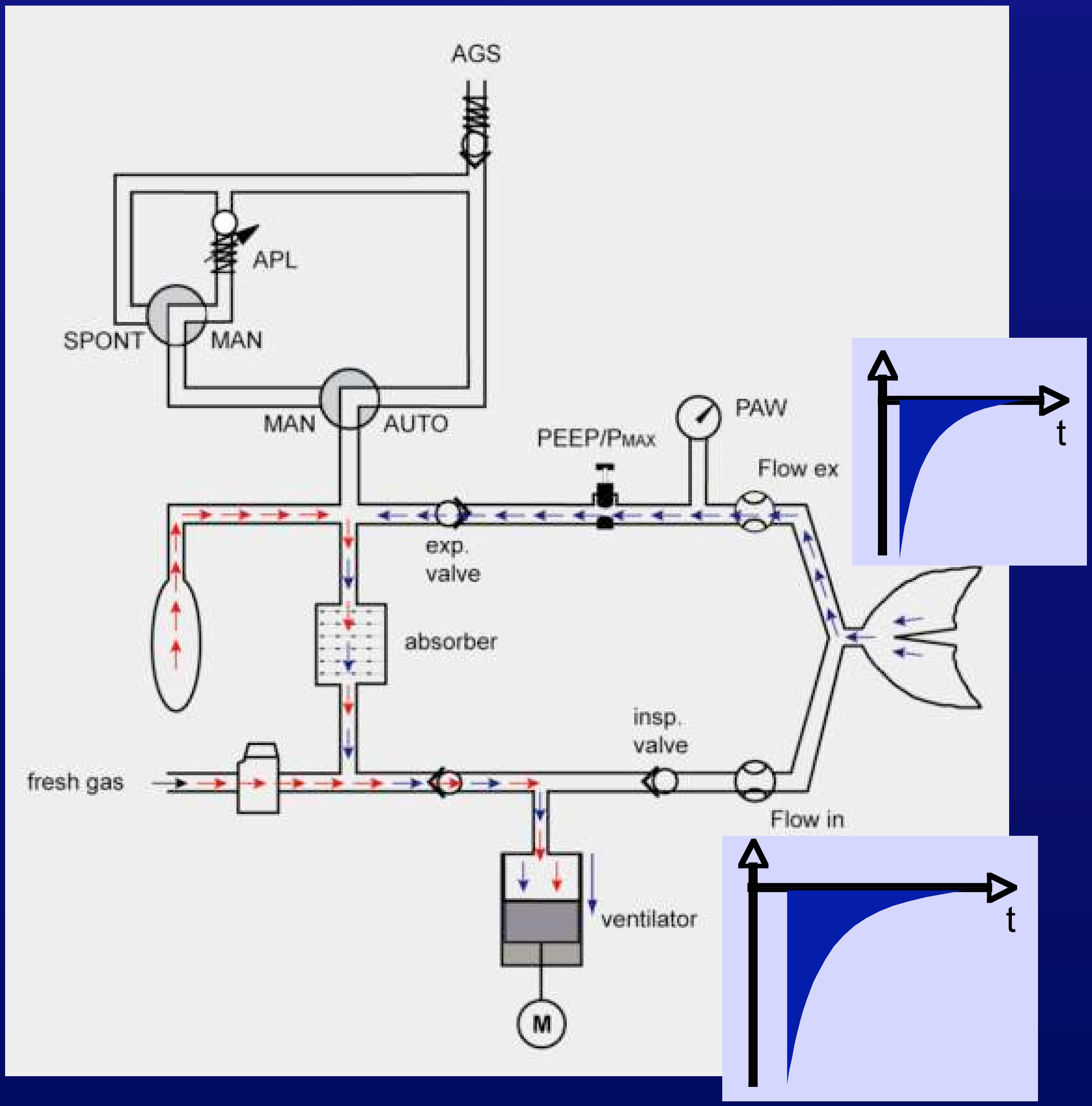
Dräger Primus

Aisys circuit



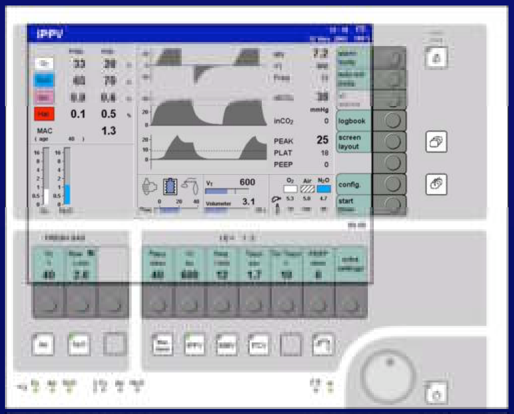


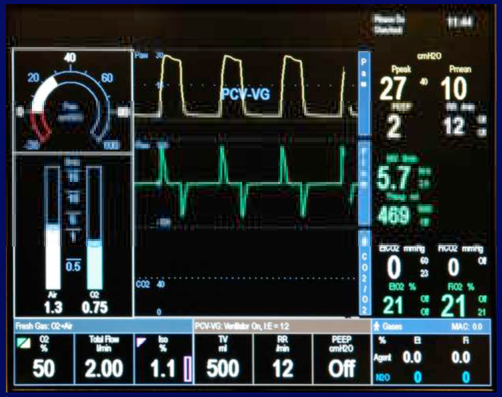
Primus circuit



What should I look for ?

- Low resistance circuit, esp in expiratory phase breathe through it yourself !
- High flow capability (test by breathing fast in PS)
- Crisp waveforms for flow, pressure & CO_2
- Clear indication of spont. vs control breaths
- Vt unaffected by FGF
- 'Mode' should be obvious
- Trends eg compliance
- Simple Circuit





Conclusions:

1. Lung collapse and ↑ work of breathing are very common during anaesthesia.
2. Optimal PEEP & lung recruitment help a lot.
3. PEEP alone is of little or no benefit.
4. Pressure Support is GREAT!
5. Modern ventilators make a real difference... when we've learned how to use them !