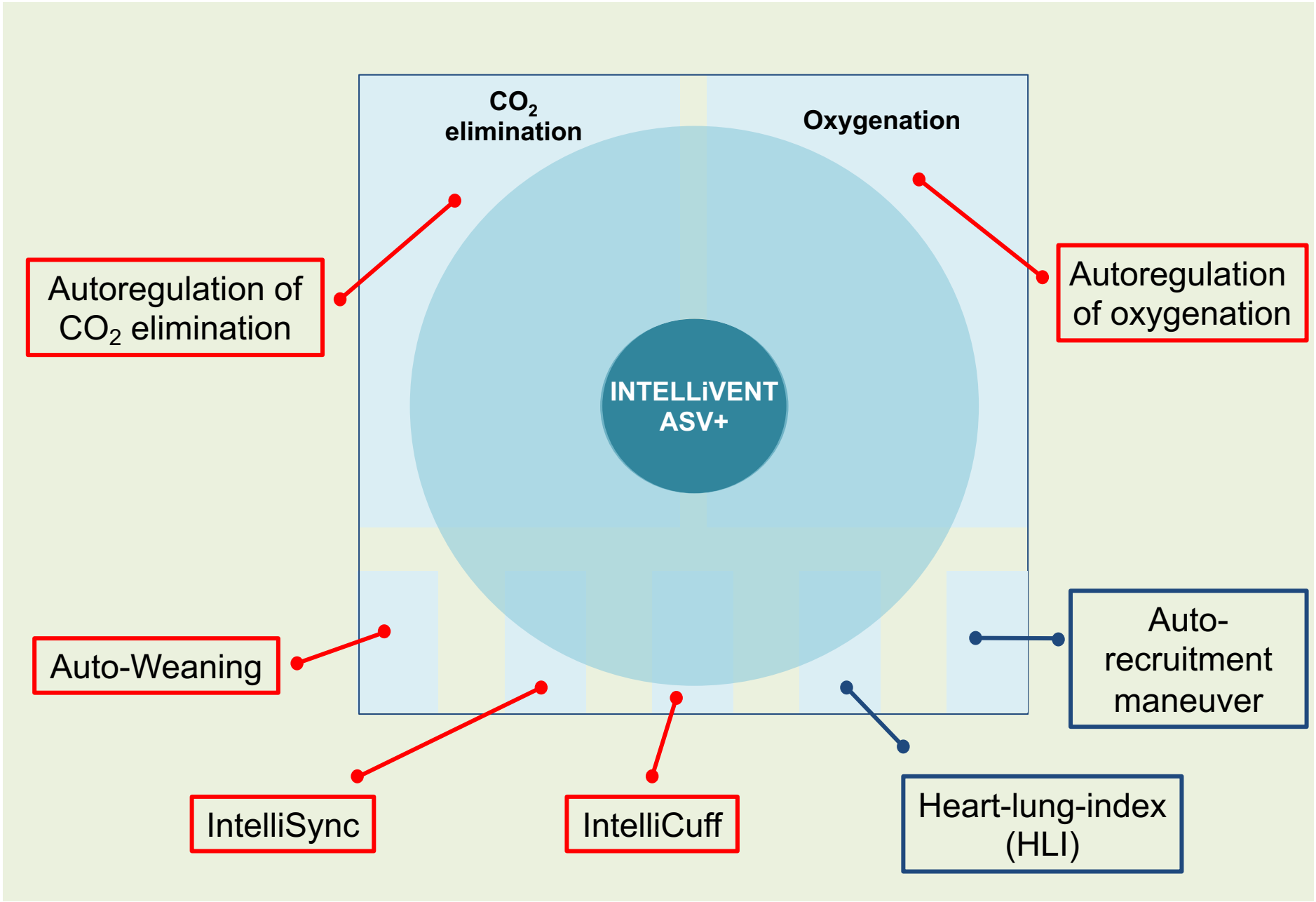
Einführung Beatmung

INTELLiVENT-ASV+



ASV und INTELLiVENT-ASV+

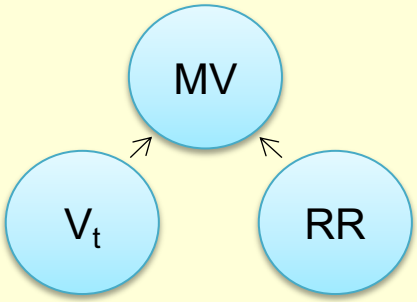
Manual setting

Automatic setting

Ventilation
Control $PaCO_2$

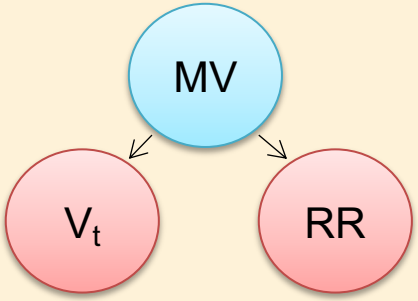
Oxygenation
Control PaO_2

Volume control



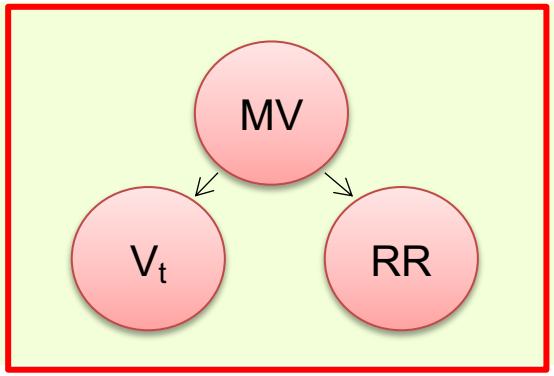
F_iO_2 PEEP

ASV
Adaptive Support Ventilation



F_iO_2 PEEP

INTELLiVENT-ASV+



F_iO_2 PEEP

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

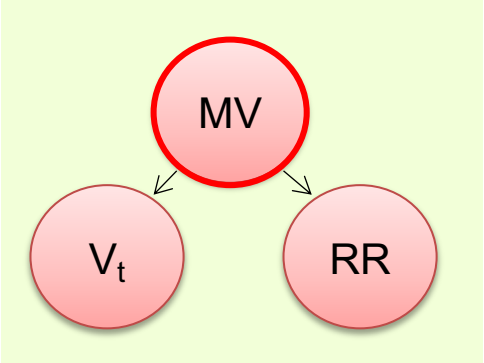
Druckkontrollierte Beatmungsform

⟶ Druckunterstützte Beatmungsform

Ein vordefiniertes MV wird appliziert....

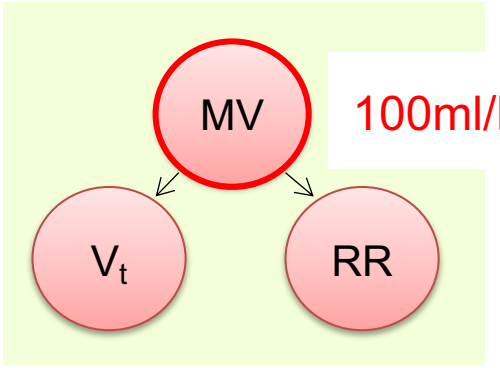
...unter Einhaltung von Lungenschutzparametern....

...eine Spontanatmung ist jederzeit möglich.



Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+



Ideales Körpergewicht		Normoventilation (ml/min)
Frauen: Körpergrösse (cm) - 100 - 10% Männer: Körpergrösse (cm) - 100 - 5%	→	100ml/kg KG
180cm grosse Frau Ideales Körpergewicht: 180cm-100-0.1x(180cm-100cm) =72kg	→	100%Minutenvolumen: 100ml x 72kg = 7200ml/min = 7.2L/min

INTELLiVENT-ASV+

Ventilation
Control $PaCO_2$

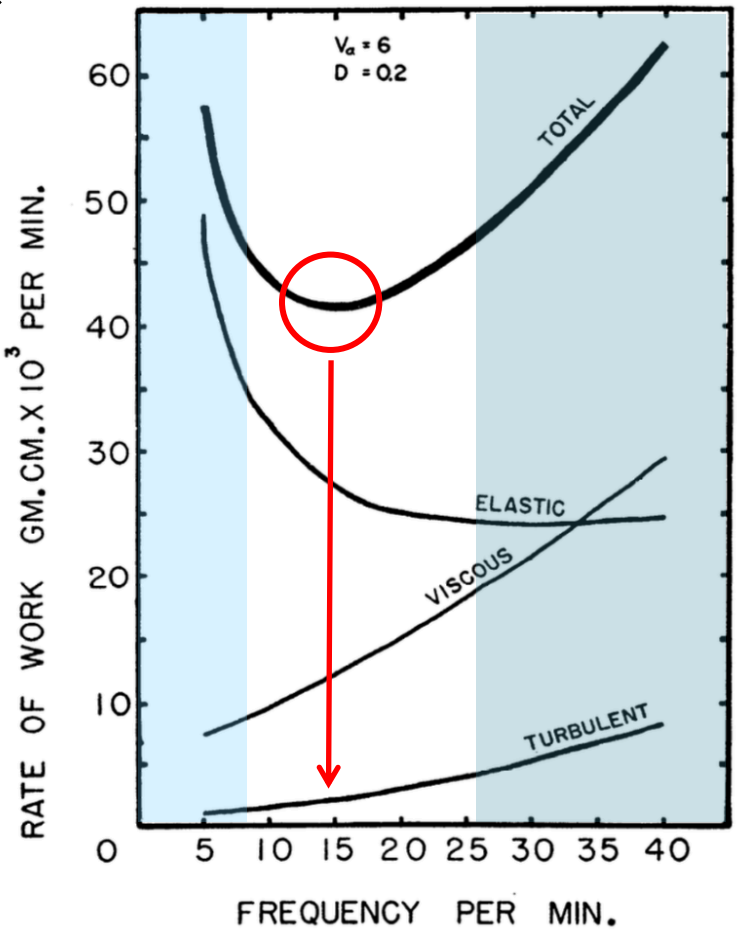
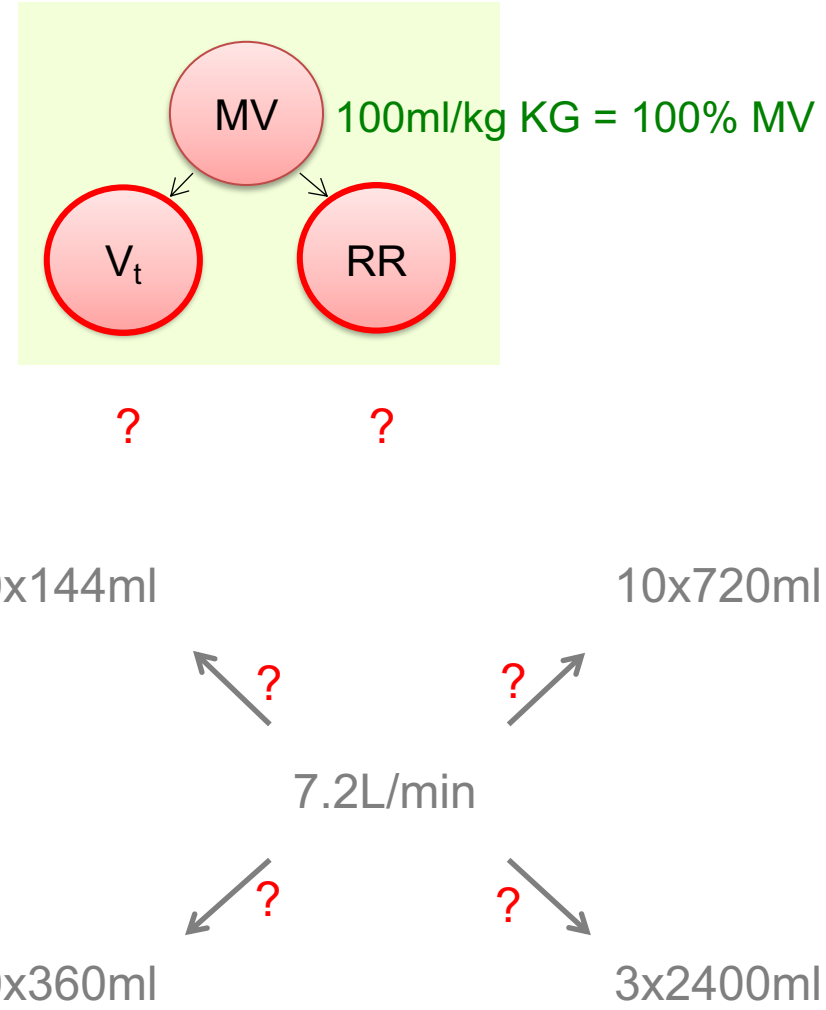


Fig. 7. RELATIONSHIP of elastic, viscous, turbulent, and total work of breathing/min. to frequency of breathing when alveolar ventilation is 6 l/min., and dead space is 200 cc. Curves calculated according to *equation 13*.



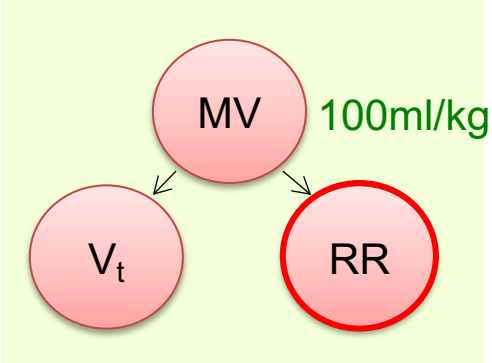
Frequency too low: much elastic work is required to produce the tidal volume

Frequency too high: much work is uselessly done in ventilating the dead space with each breath

Otis A. Mechanics of Breathing in Man. J Appl Physiol 1950

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+



$$f_{target} = \frac{\sqrt{1 + 2a \times RCe \times (MV - VD) / VD} - 1}{a \times RCe}$$

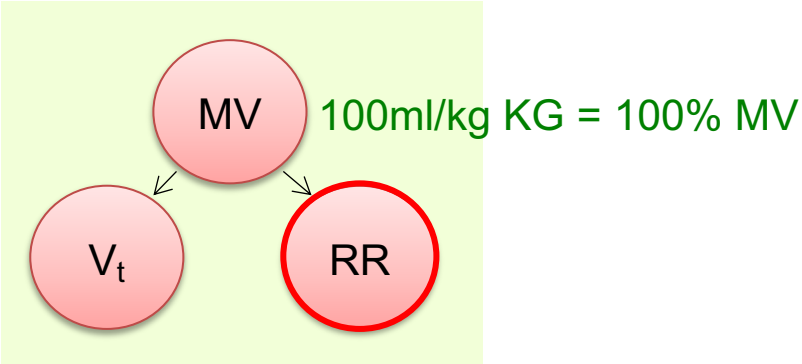
Otis Formel

f_{target}	Ziel-AF für minimal Work of Breathing
a	Faktor, welcher vom Flowmuster abhängt
MV	Minutenvolumen
VD	Totraumvolumen
RCe	expiratorische Zeitkonstante

+ Mead Formel → f_{target} aus beiden Formeln wird gemittelt

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+



What‘s the idea behind?

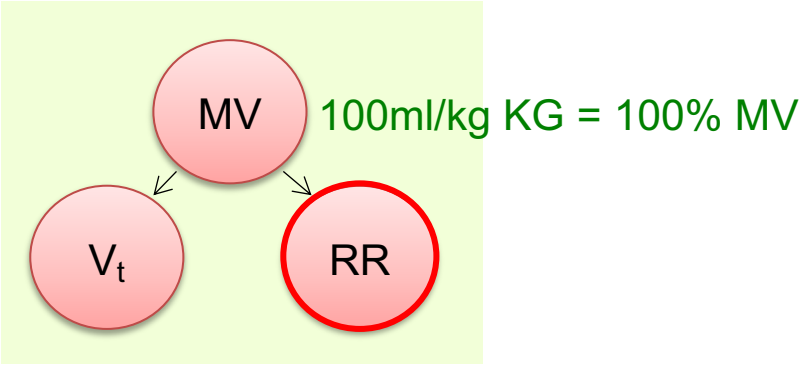
Mead und Otis-Formel

Spontan atmender Patient:
bei welcher Atemfrequenz ist die Atemarbeit am geringsten?

Kontrolliert beatmeter Patient:
bei welcher Atemfrequenz kann das vordefinierte Atemminutenvolumen mit dem geringstmöglichen Inspirationsdruck appliziert werden?

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+



RCe (exspiratorische Zeitkonstante)

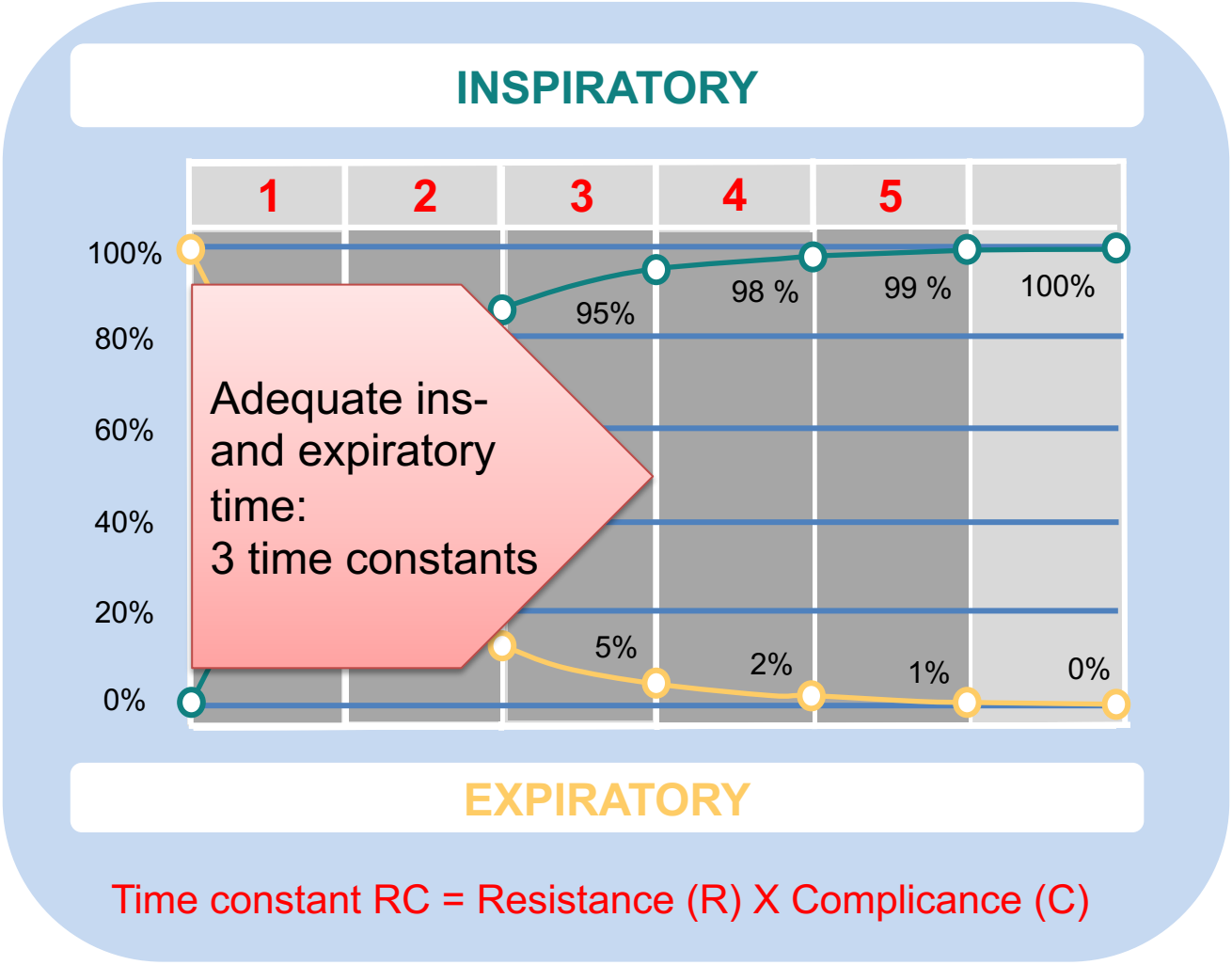
Die exspiratorische Zeitkonstante (RC) ist ein Mass für die Zeit, welche es für die Entleerung der Lunge braucht.

Sie ist ein Mass für die Compliance und die Resistance der Lunge als auch der Atemwege.

RESPIRATORY PHYSIOLOGY

TIME CONSTANT

Expressed in second. It does NOT directly indicate the length of time required to complete a flow course.

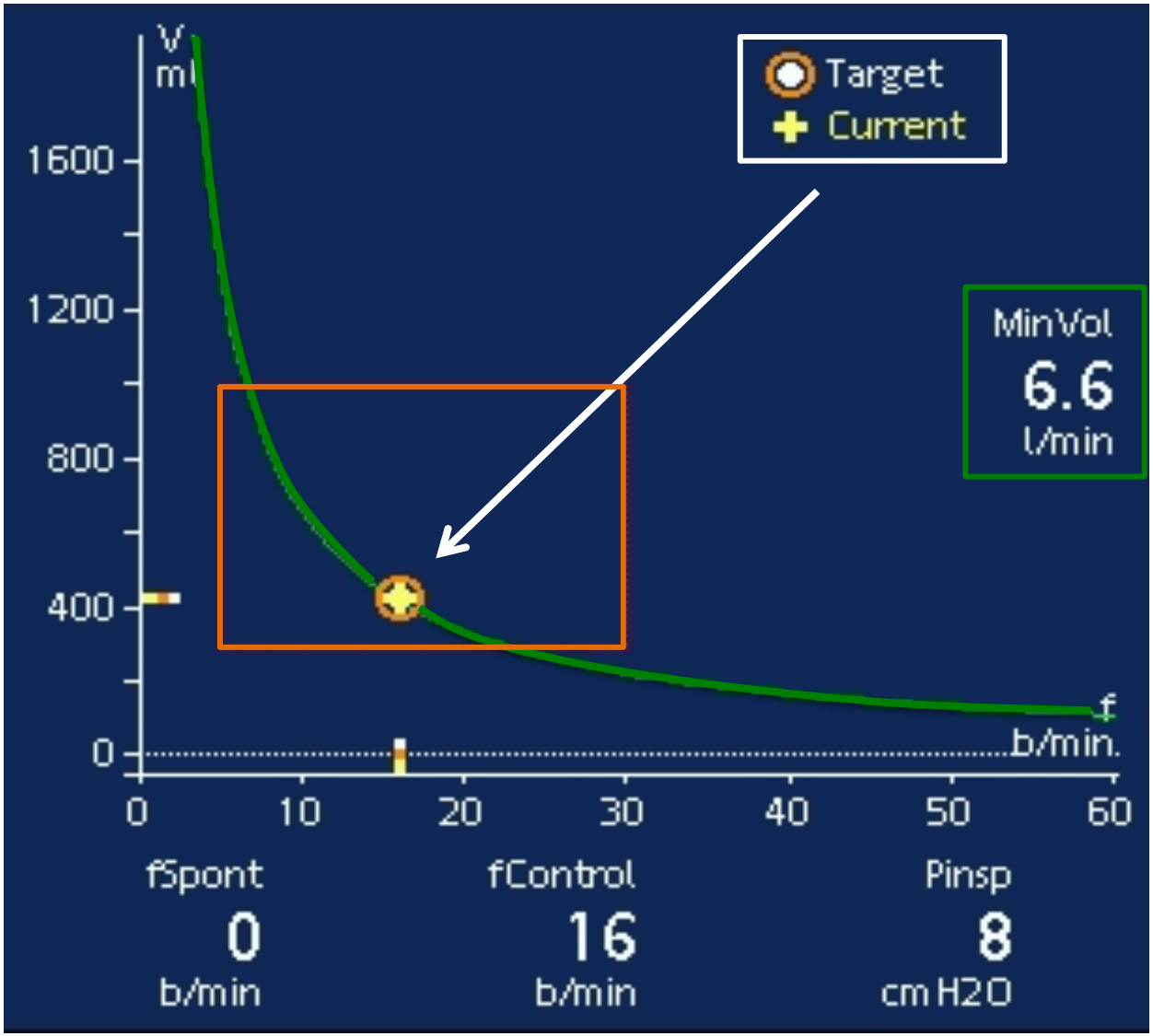


Time constant RC = Resistance (R) X Complicance (C)

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

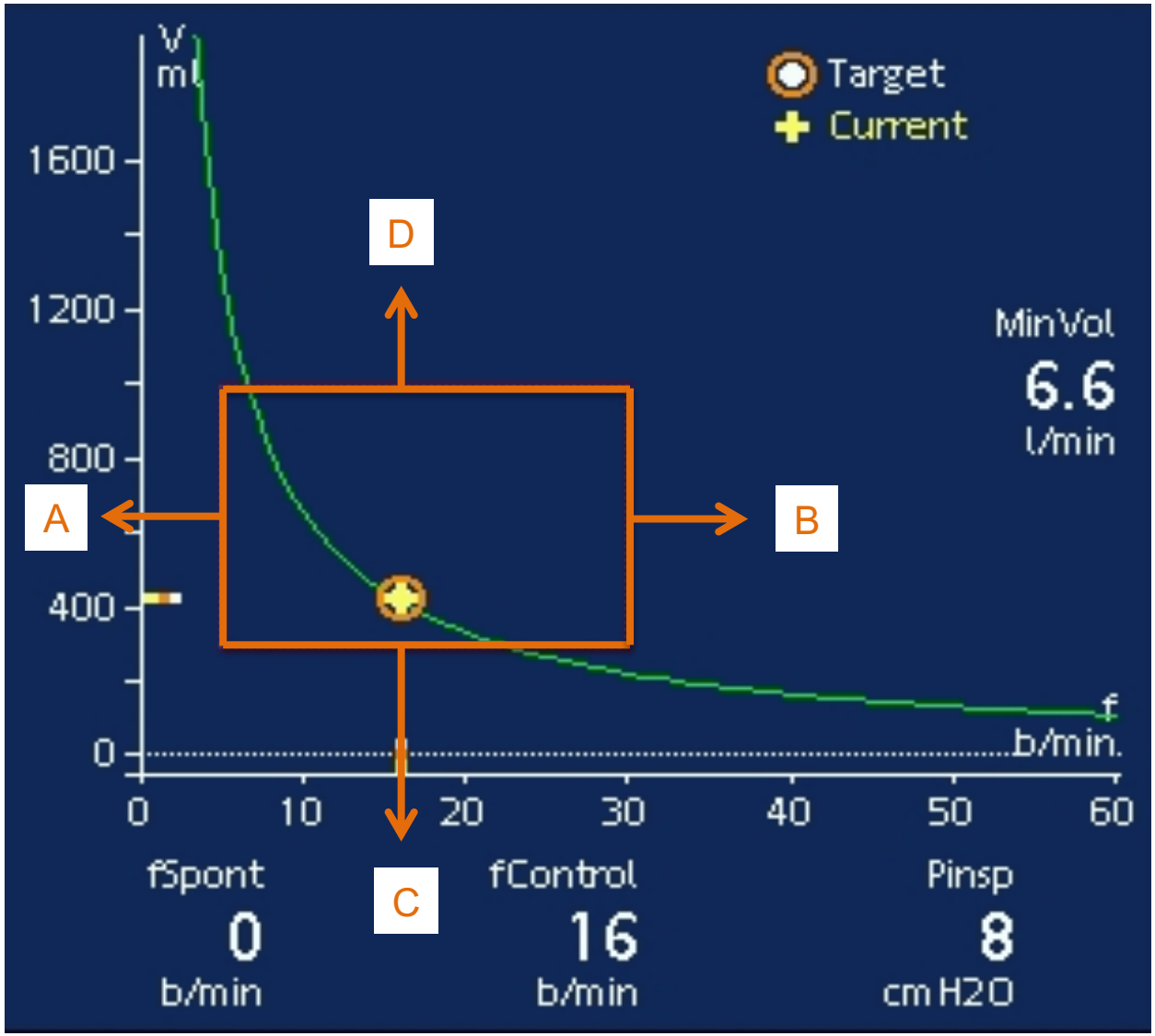
ASV Screen



Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

ASV Screen



Lungenschutzregeln

A Schutz vor Apnoe

B Vermeiden von dynamischer Hyper-inflation und Breath Stacking

C Vermeiden von niederiger alveolarer Beatmung

D Vermeiden von zu hohen Tidalvolumina und Drücken

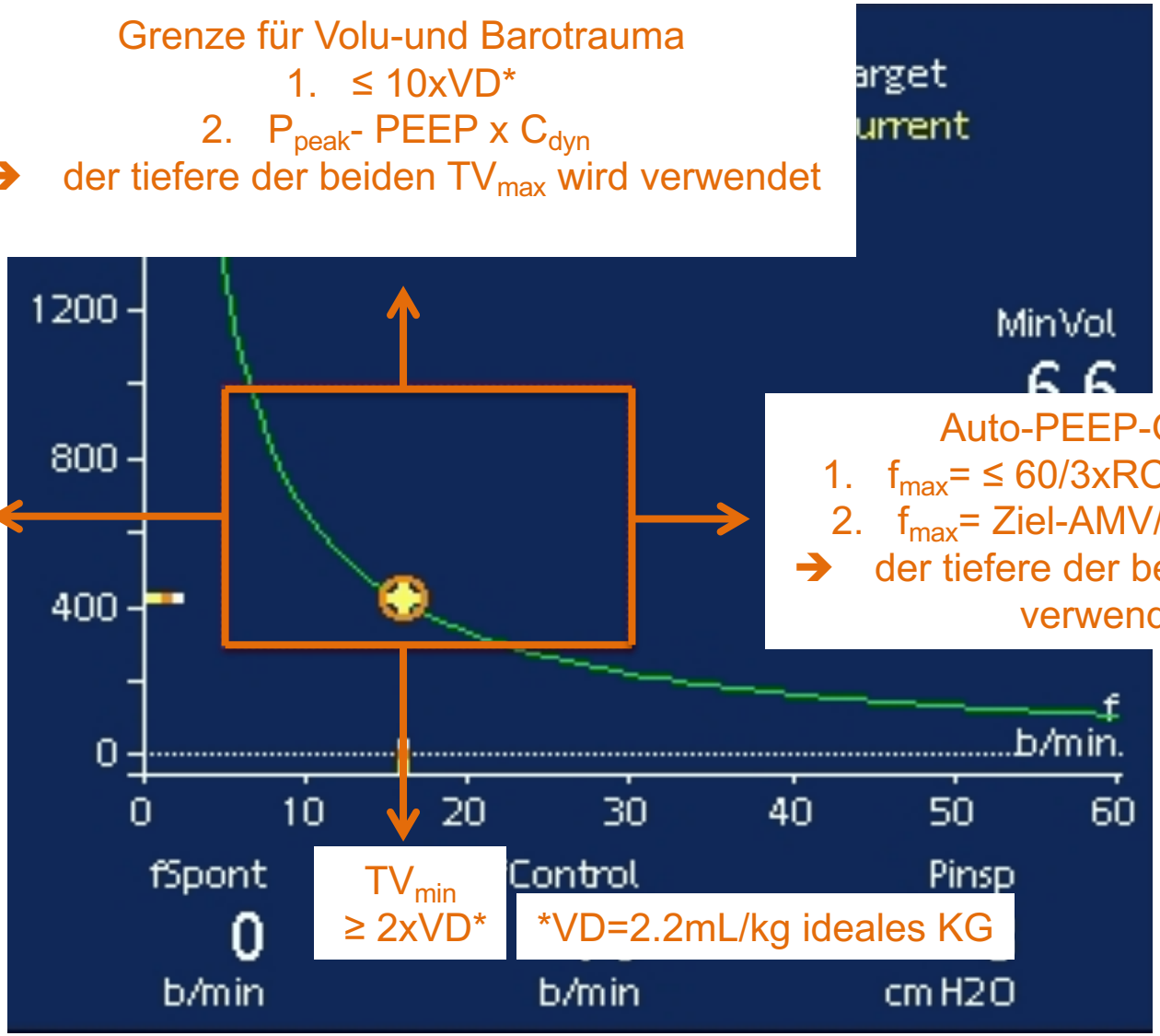
Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

ASV Screen Lungenschutzregeln

Grenze für Volu-und Barotrauma
1. ≤ 10xVD*
2. P_{peak}- PEEP x C_{dyn}

➔ der tiefere der beiden TV_{max} wird verwendet



Apnoe-Grenze
AF ≥ 5

Auto-PEEP-Grenze
1. f_{max}= ≤ 60/3xRC_{exp} = 20/Rc_{exp}
2. f_{max}= Ziel-AMV/minimales Vt

➔ der tiefere der beiden fmax wird verwendet

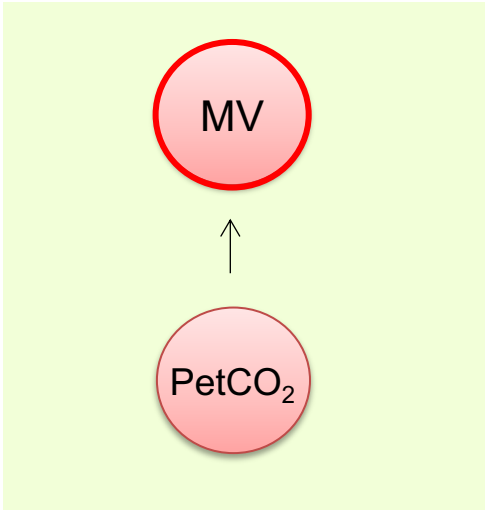
TV_{min}
≥ 2xVD*

*VD=2.2mL/kg ideales KG

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in passive patients



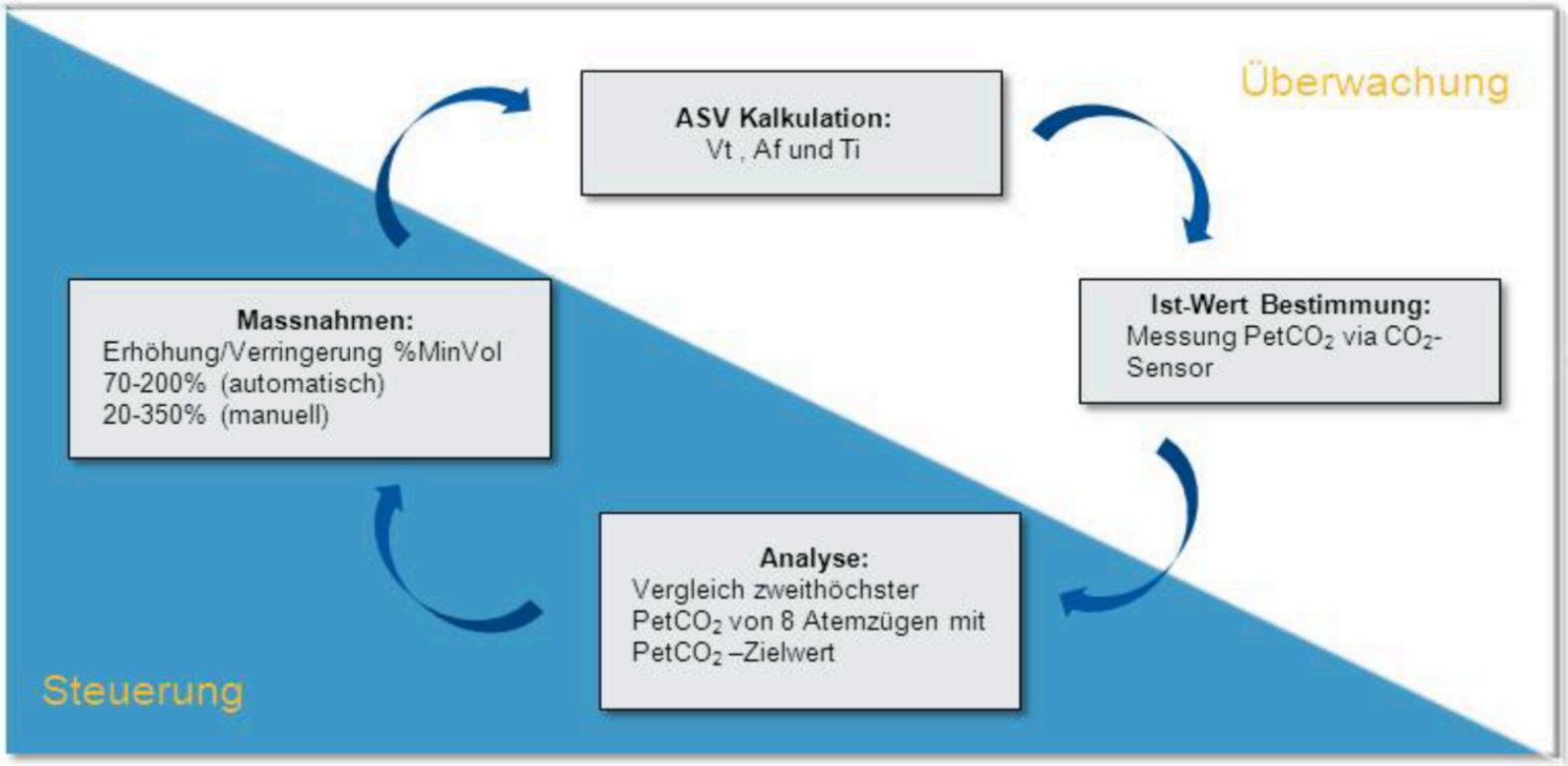
Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in passive patients

Bedienereingabe:
Grösse, Geschlecht, automatisches oder manuelles Management, Weaning-strategie, %MinVol

Wenn kein CO2 Signal verfügbar, wird %MinVol Steuerung automatisch eingefroren

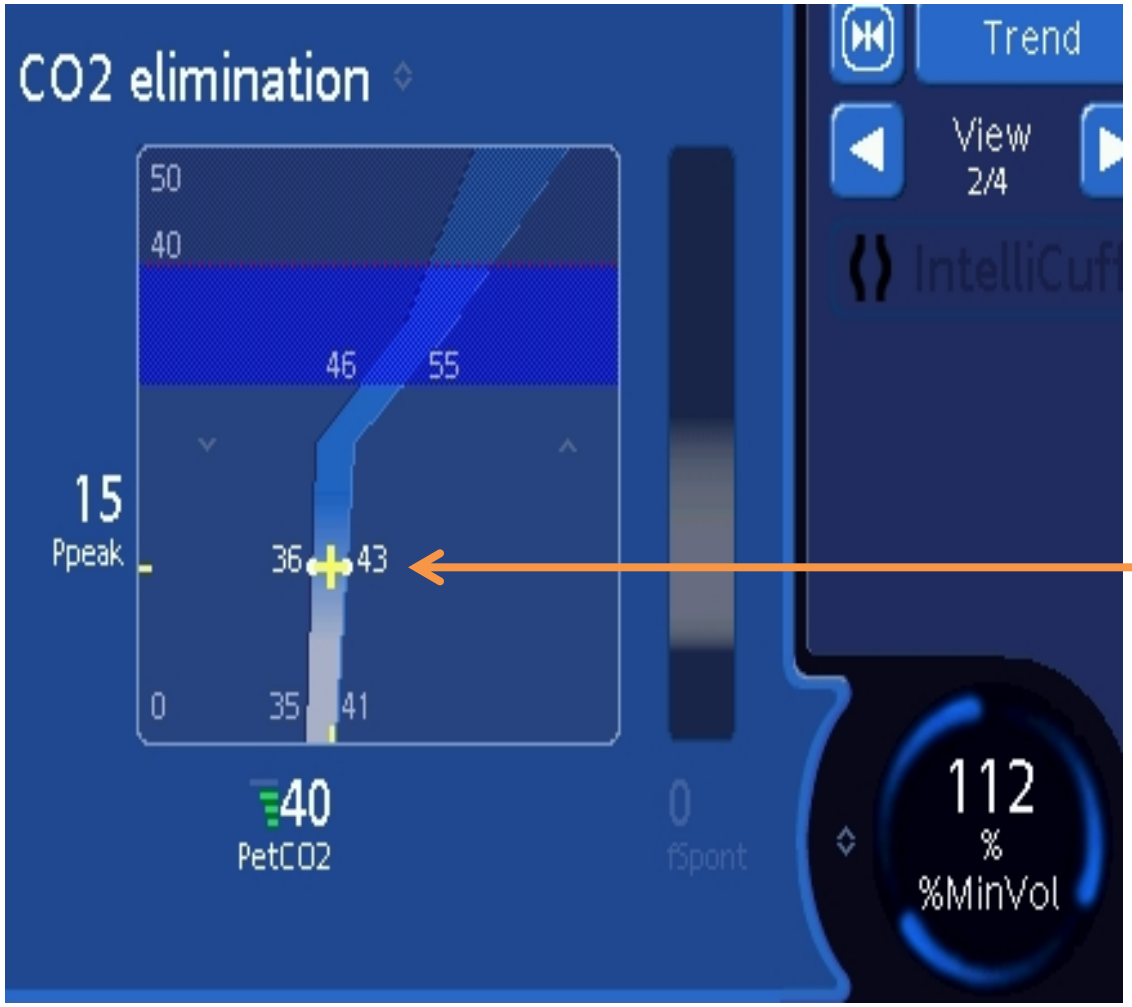


Zielwerteingabe:
Zielbereich $PetCO_2$ über Target Shift, Behandlungsprofil Patient (ARDS, SHT…, (Grenze P ASV Limit integriert)

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in passive patients



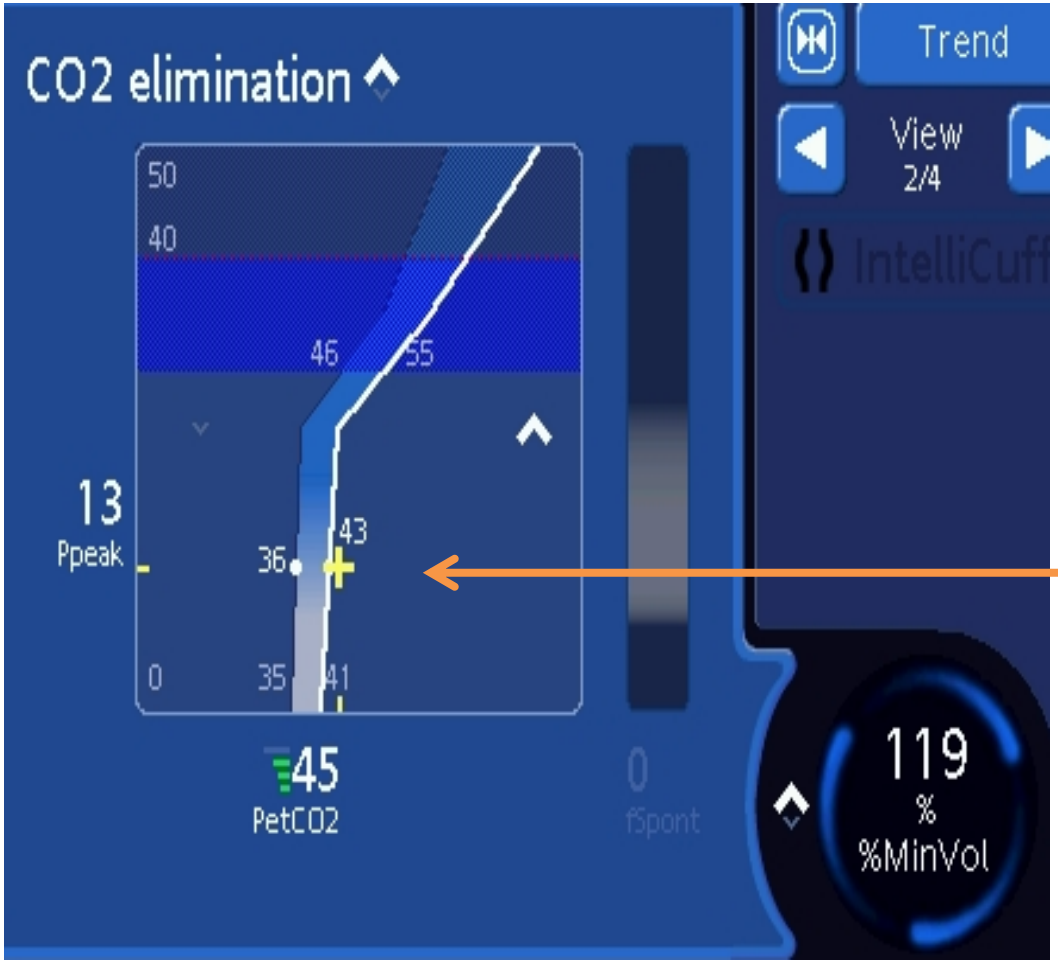
$P_{ET}CO_2$ in target range:
Treatment kept constant

➡ Fine %MV adjustment to target the middle of range

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in passive patients



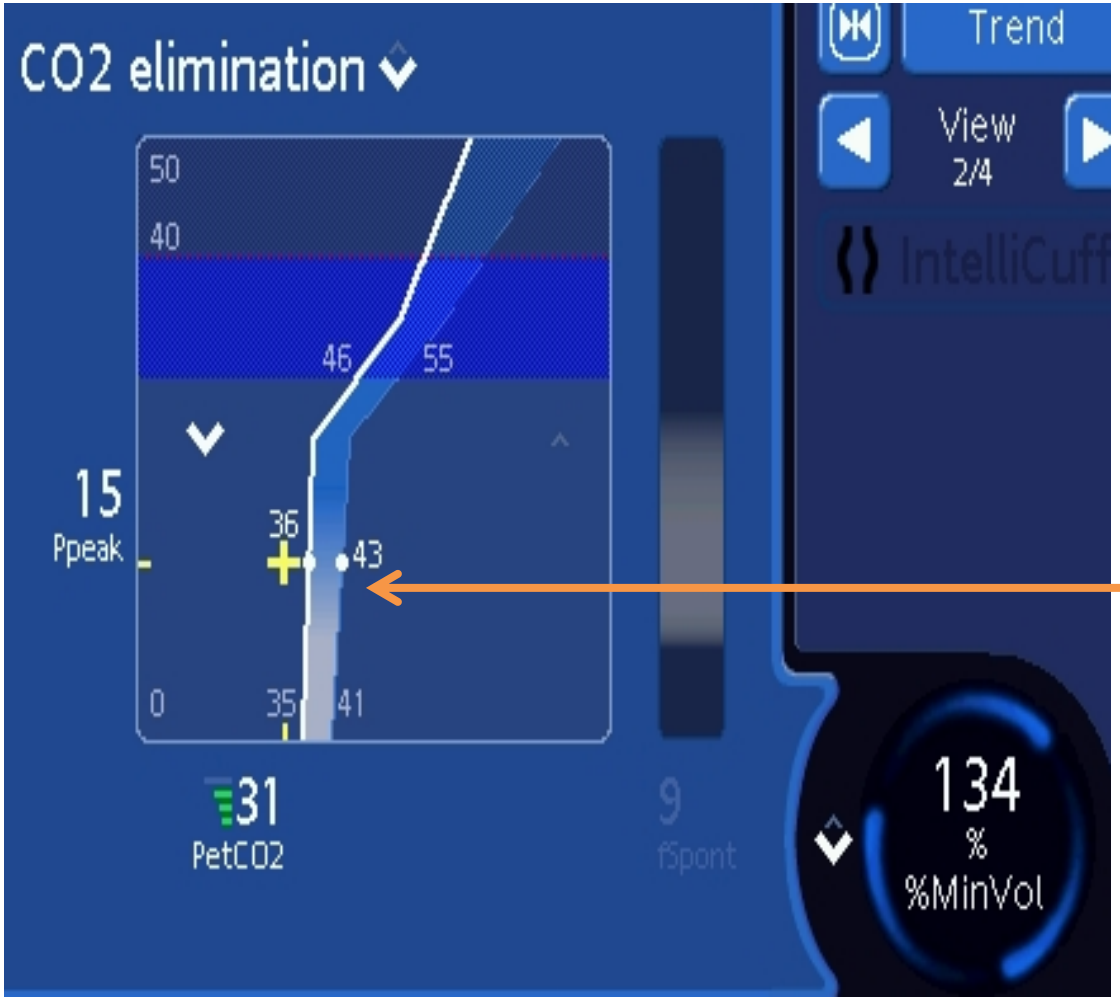
$P_{ET}CO_2$ above target range:
Increasing target MV

Breath by breath %MV increase of 1% per breath

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in passive patients

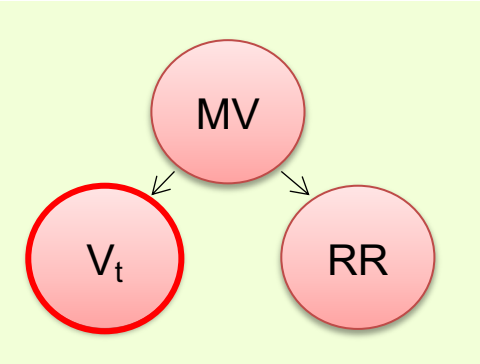


$P_{ET}CO_2$ below target range:
Decreasing target MV

Breath by breath %MV decrease of 1% per breath

Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

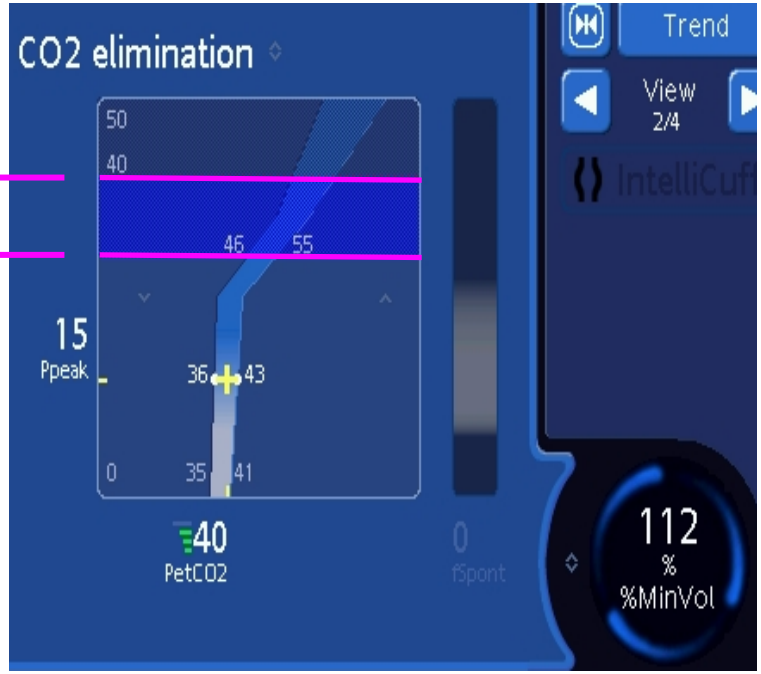


Is there a pressure limit to generate a predefined tidal volume ?

P_{ASV} limit

Hochdruck-Alarm

P_{ASV} limit

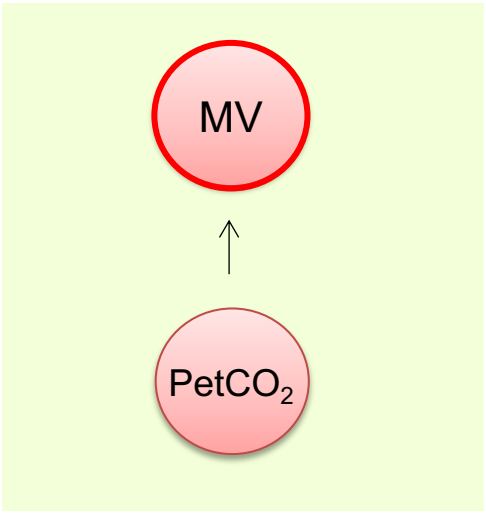


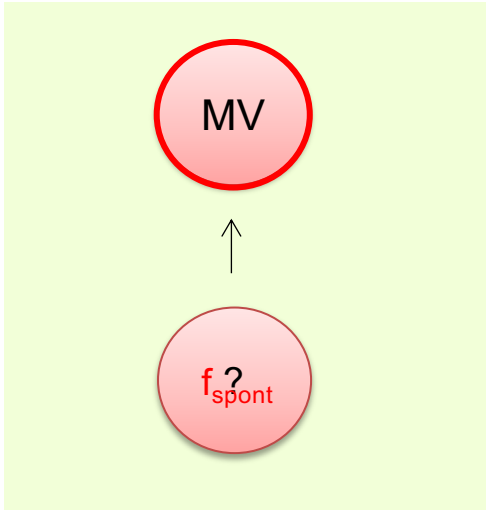
Ventilation
Control $PaCO_2$

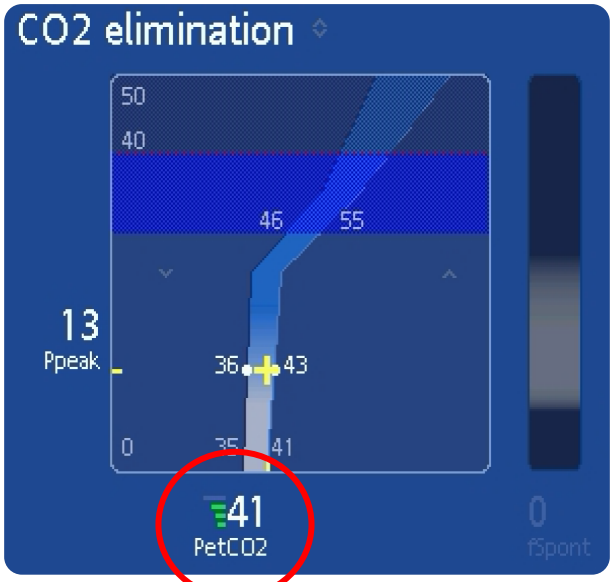
INTELLiVENT-ASV+

Minute Volume Adjustment in active patients

Passive patient ⟶ Active patient





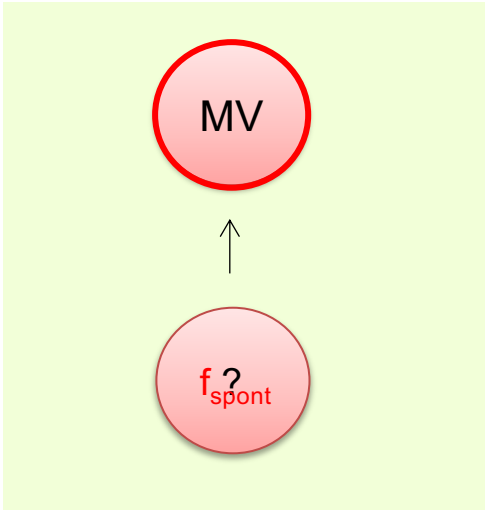


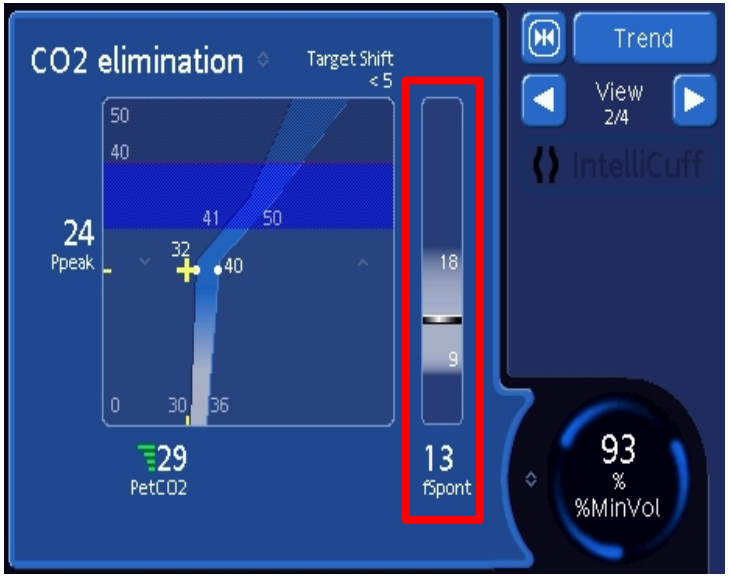
Ventilation
Control $PaCO_2$

INTELLiVENT-ASV+

Minute Volume Adjustment in active patients

Active patient





Too high

Acceptable range

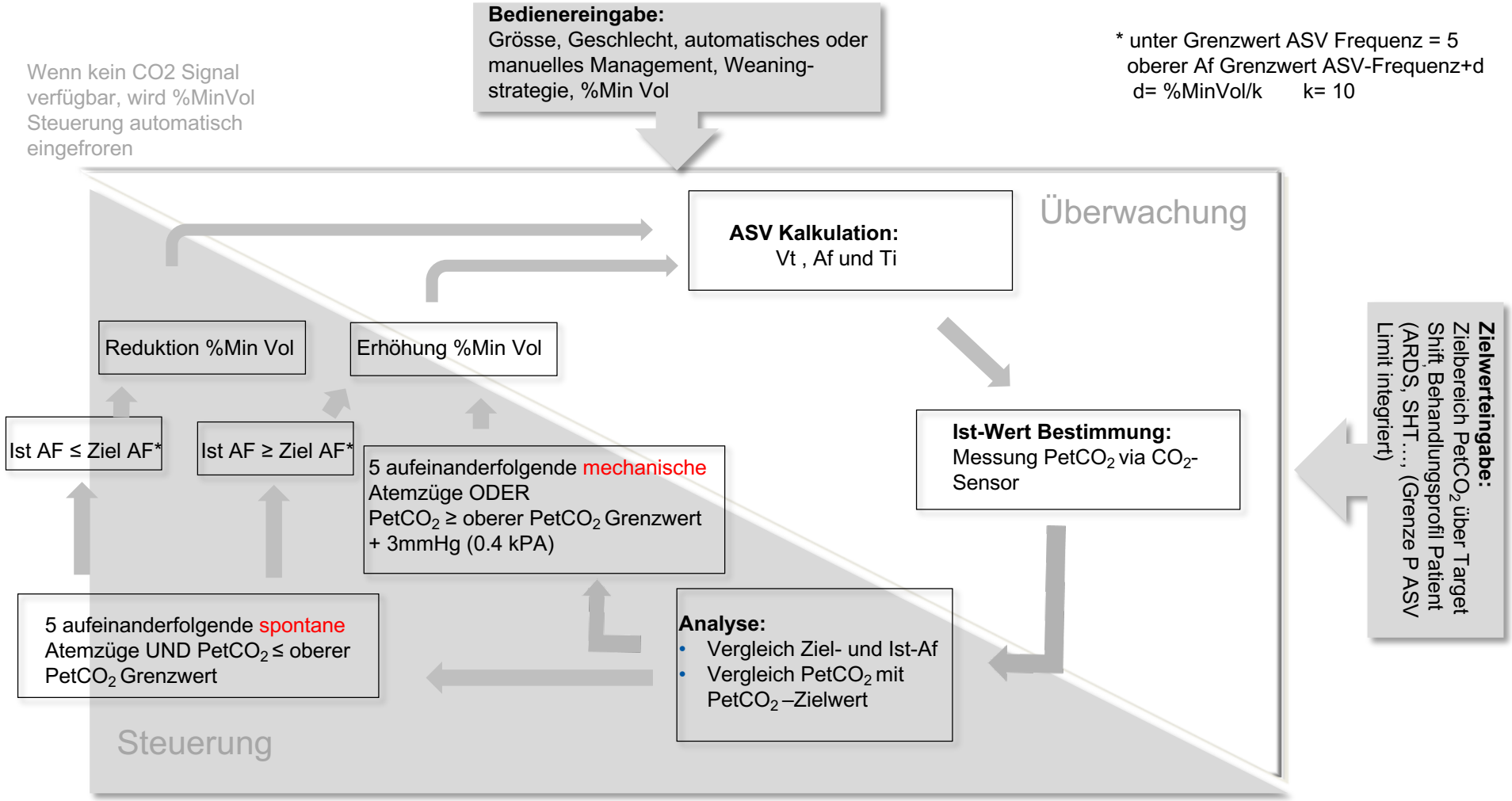
Too low

↗ MV

Fine adaptation to target the middle of the range

↘ MV

INTELLiVENT-ASV: Ventilationsmanagement aktiver Patient



ASV und INTELLiVENT-ASV+

Manual setting

Automatic setting

	Ventilation Control $PaCO_2$	**Oxygenation** Control PaO_2
Volume control	MV, V_t, RR	F_iO_2, PEEP
ASV	MV, V_t, RR	F_iO_2, PEEP
INTELLiVENT-ASV+	MV, V_t, RR	F_iO_2, PEEP

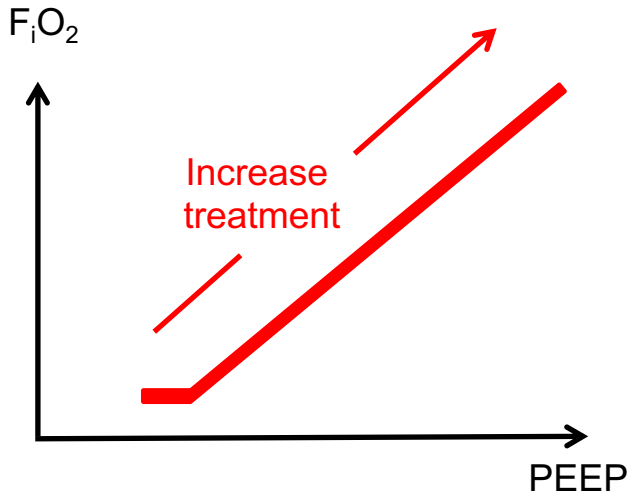
INTELLiVENT-ASV+

Oxygenation
Control PaO_2

INTELLiVENT-ASV+

Oxygenation
Control PaO_2

Increase treatment



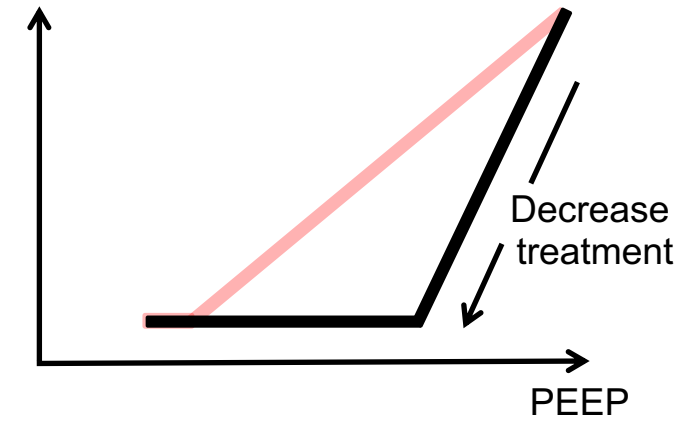
- F_iO_2: 10% alle 30sec
- PEEP: 1mbar alle 6min

Higher PEEP/lower FiO2

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

FiO_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

Decrease treatment



- F_iO_2: 5% alle 60sec
- PEEP: 1mbar alle 6min

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

INTELLiVENT-ASV+

Oxygenation
Control PaO_2

Bedienereingabe:
Grösse, Geschlecht, automatisches oder manuelles Management, Weaning-strategie, %MinVol

Überwachung

Recruitment-management möglich

ASV Kalkulation:
Vt , Af und Ti

Ist-Wert Bestimmung:
Messung SpO_2

Zielwerteingabe:
Zielwerteingabe für SpO_2, Grenzwertbereich Peep, Behandlungsprofil Patient (Grenze P ASV Limit integriert)

Massnahmen:
automatisch:

- Erhöhung O_2 Zufuhr: 10%/30s
- Verringerung O_2 Zufuhr 5%/60s
- Peep Erhöhung 1mbar/6min
- Peep Verringerung 1mbar/6min.
- HLI ≥ 15%: Erhöhung O_2 Zufuhr

oder manuell

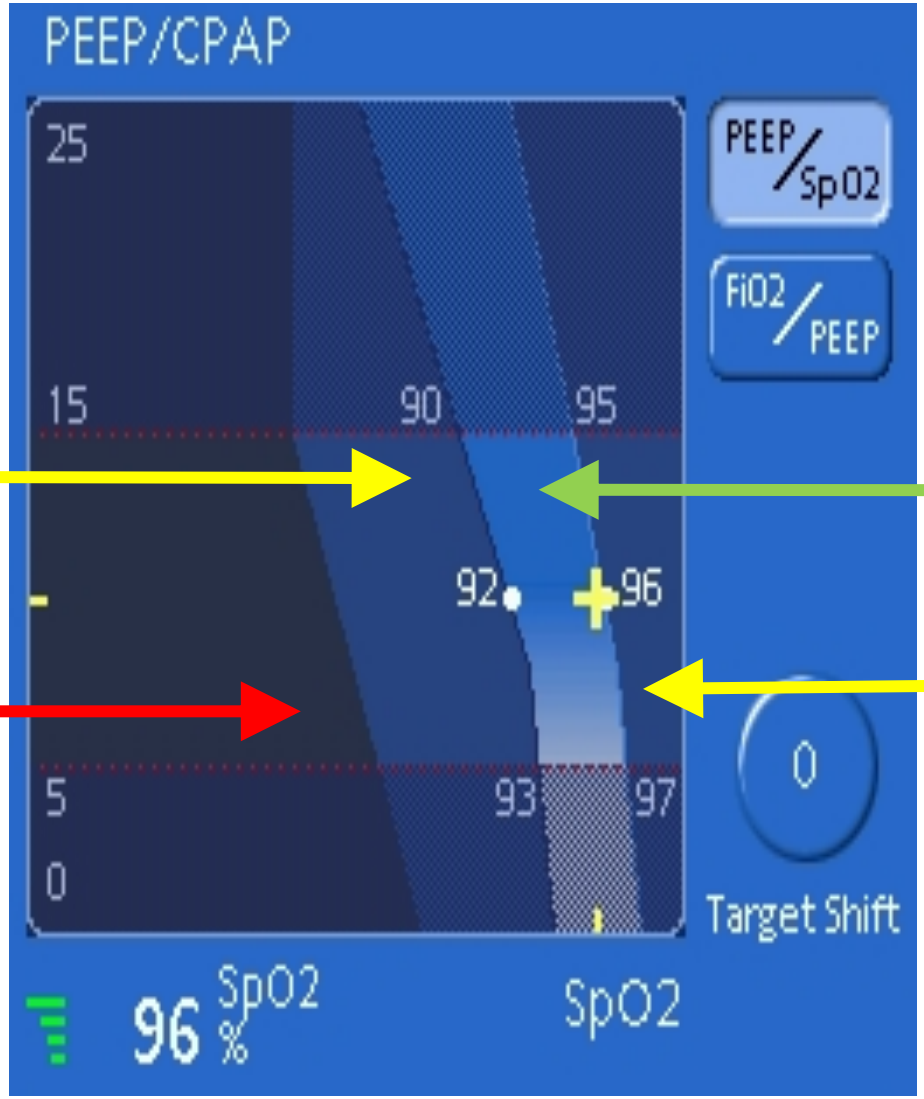
Analyse:
Befindet sich SpO_2 bei aktuellem Peep im Zielwertbereich?
Berechnung HLI (sofern aktiviert)

Steuerung

Oxygenation
Control PaO_2

INTELLiVENT-ASV+

Oxygenation Controller



Increase Oxygen/PEEP

Emergency 100% Oxygen

FiO_2/PEEP maintained (fine tuning)

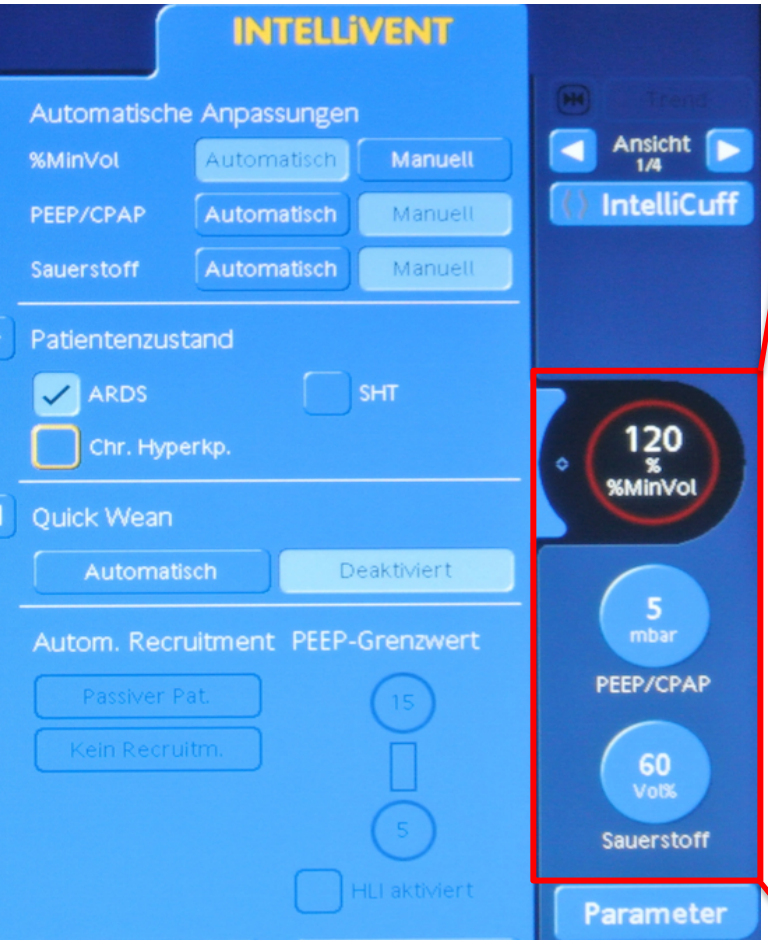
Decrease Oxygen/PEEP

Controller Status

INTELLiVENT-ASV+

INTELLiVENT-ASV+

Controller Status



INTELLiVENT-ASV+

Patienten zustand

Patienten zustand

INTELLiVENT-ASV+

Patienten-zustand	Beatmung			Oxygenierung		Quick Wean	Autom. Recruitment	PEEP-Grenzwert Anpassung anhand HLI
	%MinVol Startwert	*Akzeptabler Bereich Spontan-atmung D=%MinVol/K*	*P ASV Limit (mbar)*	*O_2-Start-wert (%)*	*PEEP-Start-wert (mbar)*			
Normal	100	K = 10	30	60	5	deaktiviert	deaktiviert	deaktiviert
ARDS	120	K = 10	35	100	5	deaktiviert	deaktiviert	deaktiviert
Hyperkapnie	90	K = 10	25	40	manuell	deaktiviert	deaktiviert	deaktiviert
ARDS+ Hyperkapnie	110	K = 10	30	80	manuell	deaktiviert	deaktiviert	deaktiviert
Schädel-Hirn-Trauma	a)		b)	60	manuell	deaktiviert	deaktiviert	deaktiviert

a) Der Startwert wird anhand des Patientenzustands festgelegt

b) Schädel-Hirn-Trauma (SHT): 28 mbar
SHT + Hyperkapnie: 28 mbar
SHT + ARDS: 30 mbar
Übrige Kombinationen: 28 mbar

INTELLiVENT-ASV+

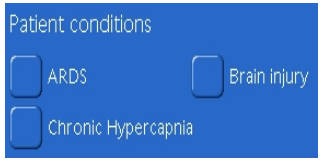
Patienten zustand

Normal

Patienten-zustand	Beatmung		Oxygenierung		
	%MinVol Startwert	*Akzeptabler Bereich Spontan-atmung D=%MinVol/K*	*P ASV Limit (mbar)*	*O_2-Start-wert (%)*	*PEEP-Start-wert (mbar)*
Normal	100	K = 10	30	60	5
ARDS	120	K = 10	35	100	5
Hyperkapnie	90	K = 10	25	40	manuell
ARDS+ Hyperkapnie	110	K = 10	30	80	manuell
Schädel-Hirn-Trauma	a)		b)	60	manuell

a) Der Startwert wird anhand des Patientenzustands festgelegt

b) Schädel-Hirn-Trauma (SHT): 28 mbar
SHT + Hyperkapnie: 28 mbar
SHT + ARDS: 30 mbar
Übrige Kombinationen: 28 mbar



INTELLiVENT-ASV+

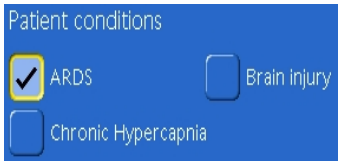
Patienten zustand

ARDS

Patienten-zustand	Beatmung		Oxygenierung		
	%MinVol Startwert	*Akzeptabler Bereich Spontan-atmung D=%MinVol/K*	*P ASV Limit (mbar)*	*O_2-Start-wert (%)*	*PEEP-Start-wert (mbar)*
Normal	100	K = 10	30	60	5
ARDS	120	K = 10	35	100	5
Hyperkapnie	90	K = 10	25	40	manuell
ARDS+ Hyperkapnie	110	K = 10	30	80	manuell
Schädel-Hirn-Trauma	a)		b)	60	manuell

a) Der Startwert wird anhand des Patientenzustands festgelegt

b) Schädel-Hirn-Trauma (SHT): 28 mbar
SHT + Hyperkapnie: 28 mbar
SHT + ARDS: 30 mbar
Übrige Kombinationen: 28 mbar



INTELLiVENT-ASV+

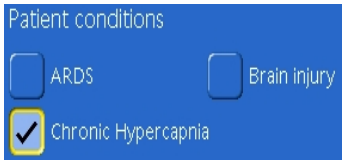
Patienten zustand

Hyperkapnie

Patienten-zustand	Beatmung		Oxygenierung		
	%MinVol Startwert	*Akzeptabler Bereich Spontan-atmung D=%MinVol/K*	*P ASV Limit (mbar)*	*O_2-Start-wert (%)*	*PEEP-Start-wert (mbar)*
Normal	100	K = 10	30	60	5
ARDS	120	K = 10	35	100	5
Hyperkapnie	90	K = 10	25	40	manuell
ARDS+ Hyperkapnie	110	K = 10	30	80	manuell
Schädel-Hirn-Trauma	a)		b)	60	manuell

a) Der Startwert wird anhand des Patientenzustands festgelegt

b) Schädel-Hirn-Trauma (SHT): 28 mbar
SHT + Hyperkapnie: 28 mbar
SHT + ARDS: 30 mbar
Übrige Kombinationen: 28 mbar



Patienten zustand

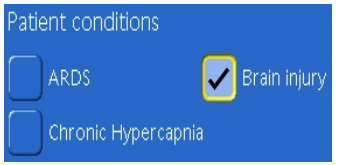
INTELLiVENT-ASV+

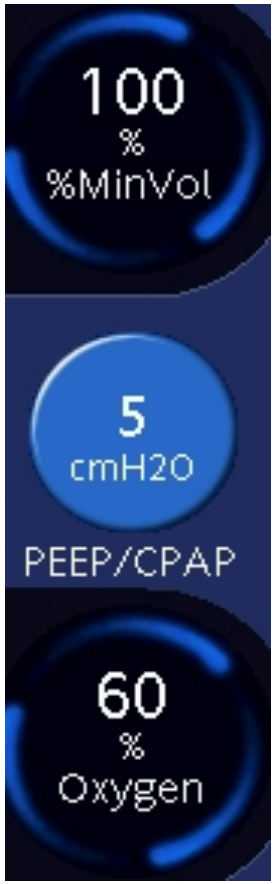
Schädelhirntrauma

Patienten-zustand	Beatmung		Oxygenierung		
	%MinVol Startwert	*Akzeptabler Bereich Spontan-atmung D=%MinVol/K*	*P ASV Limit (mbar)*	*O_2-Start-wert (%)*	*PEEP-Start-wert (mbar)*
Normal	100	K = 10	30	60	5
ARDS	120	K = 10	35	100	5
Hyperkapnie	90	K = 10	25	40	manuell
ARDS+ Hyperkapnie	110	K = 10	30	80	manuell
Schädel-Hirn-Trauma	a)		b)	60	manuell

a) Der Startwert wird anhand des Patientenzustands festgelegt

b) Schädel-Hirn-Trauma (SHT): 28 mbar
SHT + Hyperkapnie: 28 mbar
SHT + ARDS: 30 mbar
Übrige Kombinationen: 28 mbar

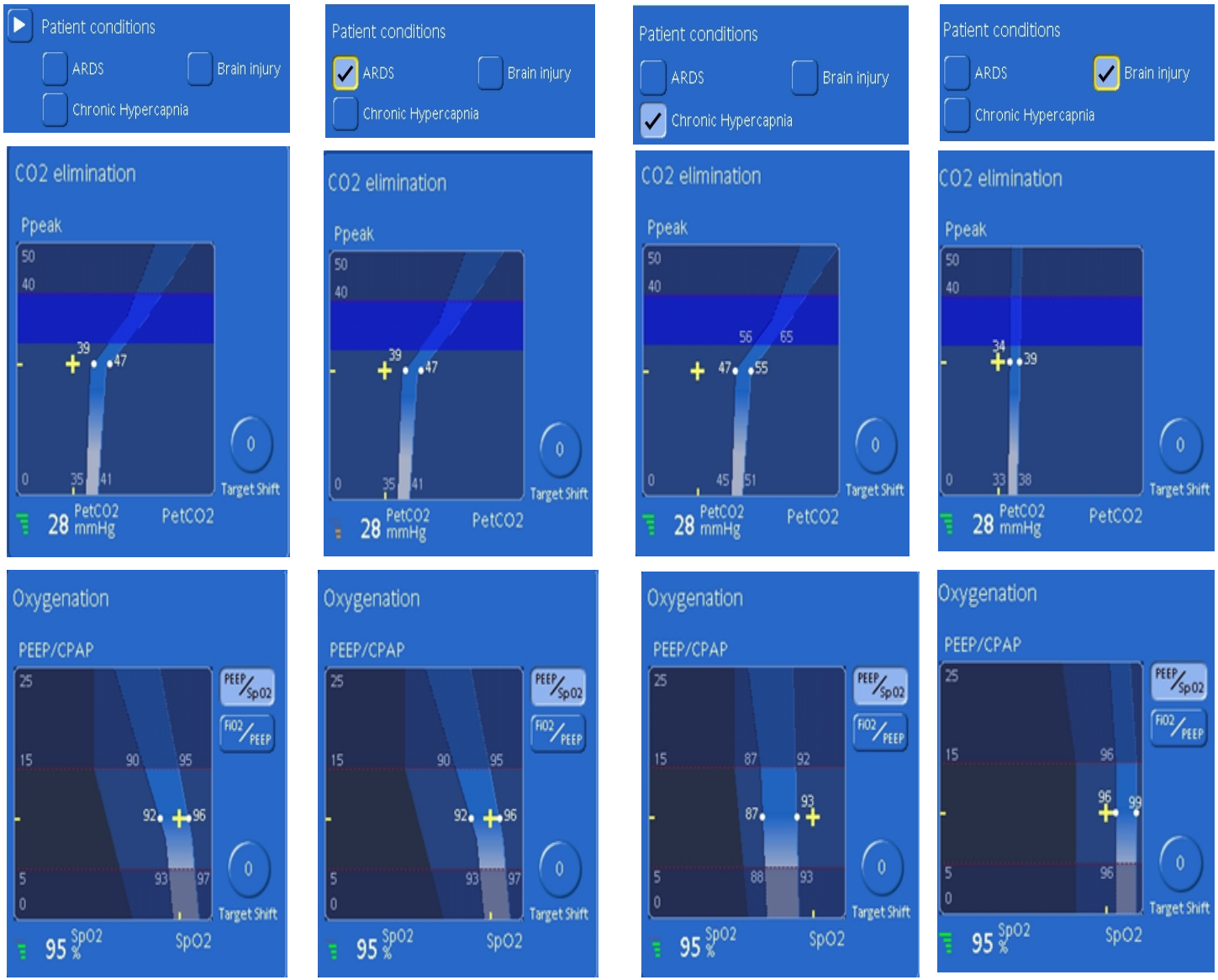




Patienten zustand

INTELLiVENT-ASV+

CO_2 und SpO_2 Targets



INTELLiVENT-ASV+

PEEP Grenzen und Target Shift

Patienten zustand

Patienten-zustand	%MinVol [%]	PASVlimit [mbar]	FiO_2 [%]	PEEP [mbar]	PEEP-Grenzen [mbar] low	PEEP-Grenzen [mbar] high	Target Shift [mbar] CO_2	Target Shift [mbar] O_2
Normal RC_{exp} 0.5 – 0.9 s	100	30	100	5	5	12	-0.7	0
ARDS RC_{exp} < 0.5 s	140	35	100	10	10	15	-0.7	0
Chronische Hyperkapnie RC_{exp} > 0.9 s	100	35	100	8	manuell		Patientenzustand Chr. Hyperkap. 0.7	Patientenzustand Chr. Hyperkap. 0

Sensoren

INTELLiVENT-ASV+

Die notwendigen Sensoren

Ventilation

Proximal
flow sensor

Airway CO2
sensor

Oxygenation

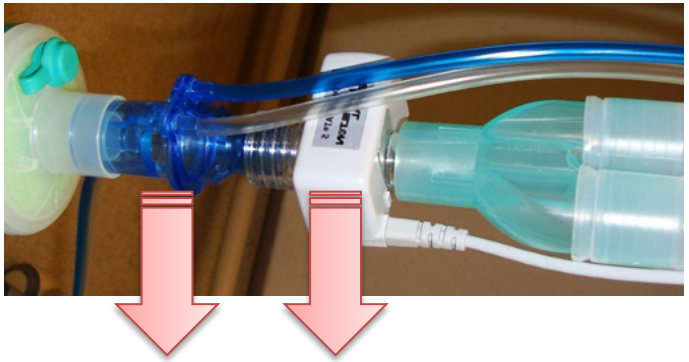
SpO2
sensors

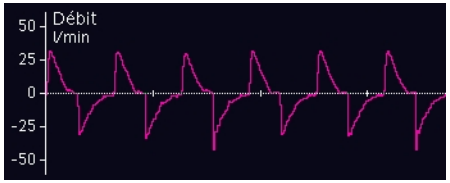
Sensoren

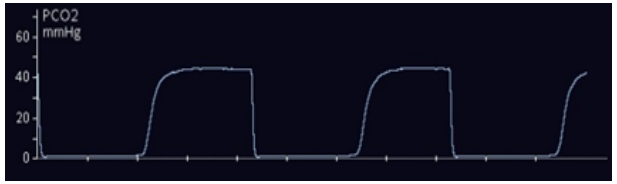
INTELLiVENT-ASV+

Die notwendigen Sensoren

Ventilation

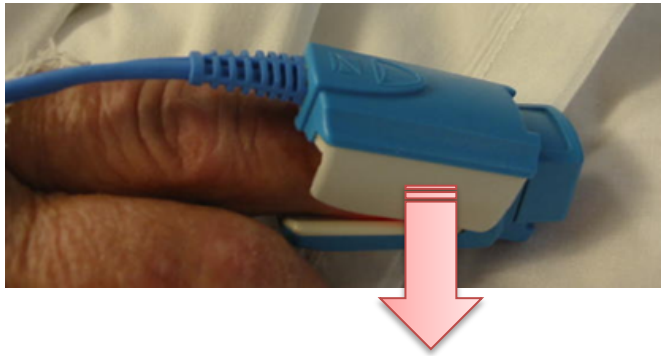


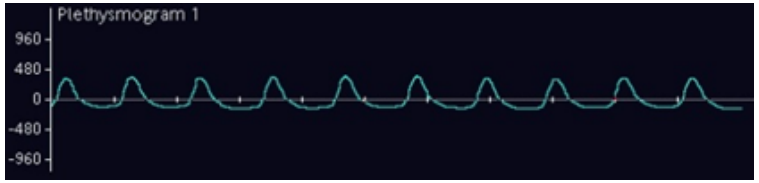




- 2nd highest value of the last 8 breaths
- Quality index

Oxygenation



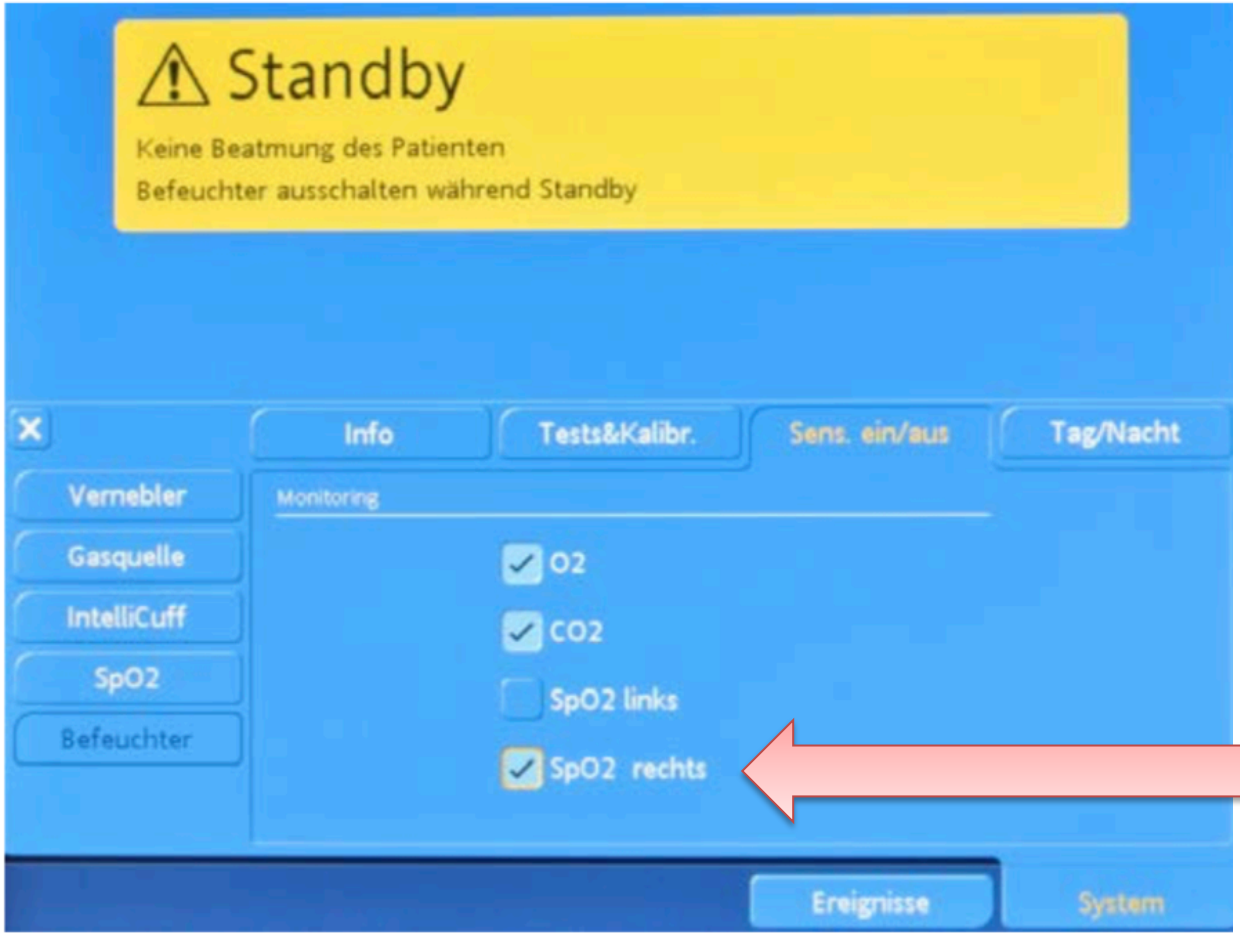


- Mean on the 15 last values
- Quality index

Sensoren

INTELLiVENT-ASV+

Aktivierung der Sensoren



Basic mechanical ventilation

Continuing development of BASIC is supported by an unrestricted educational grant from

MAQUET

Dräger medical
A Dräger and Siemens Company

Mechanical ventilation

- Physics
- Basic concepts
- Complications

Physics

P:	Pressure	Pressure
$\triangle P$:	Pressure Gradient	Force applied over a unit area
V:	Volume	
$\dot{V}$:	Gas Flow	
R:	Resistance	
C:	Compliance	
RC:	Time constant	

Physics

P: Pressure

ΔP: Pressure Gradient

V: Volume

$\dot{V}$: Gas Flow

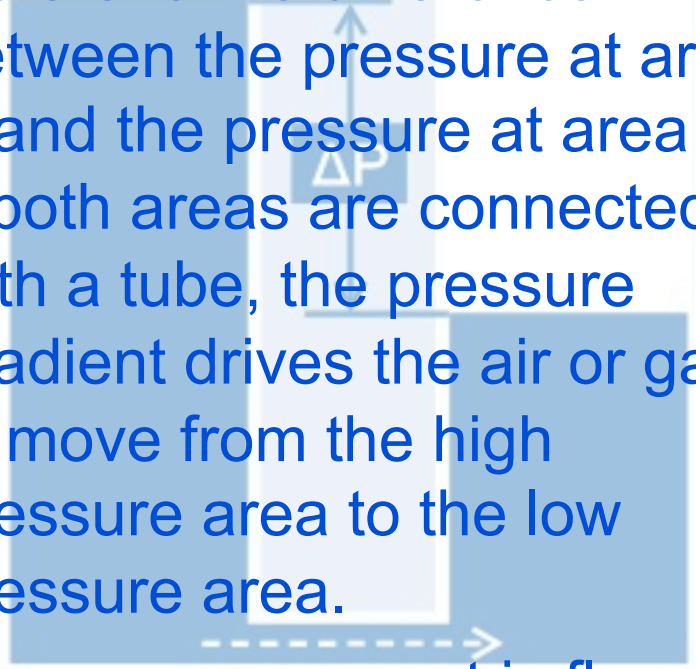
R: Resistance

C: Compliance

RC: Time constant

Pressure Gradient

Refers to the difference between the pressure at area A and the pressure at area B. If both areas are connected with a tube, the pressure gradient drives the air or gas to move from the high pressure area to the low pressure area.



The gas movement is flow.

Physics

P: Pressure

ΔP: Pressure Gradient

V: Volume

$\dot{V}$: Gas Flow

R: Resistance

C: Compliance

RC: Time constant

Volume

Gas volume is a measure of the space occupied by a quantity of gas at a given pressure.

Tidal volume and minute volume are two typical examples of gas volumes.

Gas is compressible.

Physics

P: Pressure

ΔP: Pressure Gradient

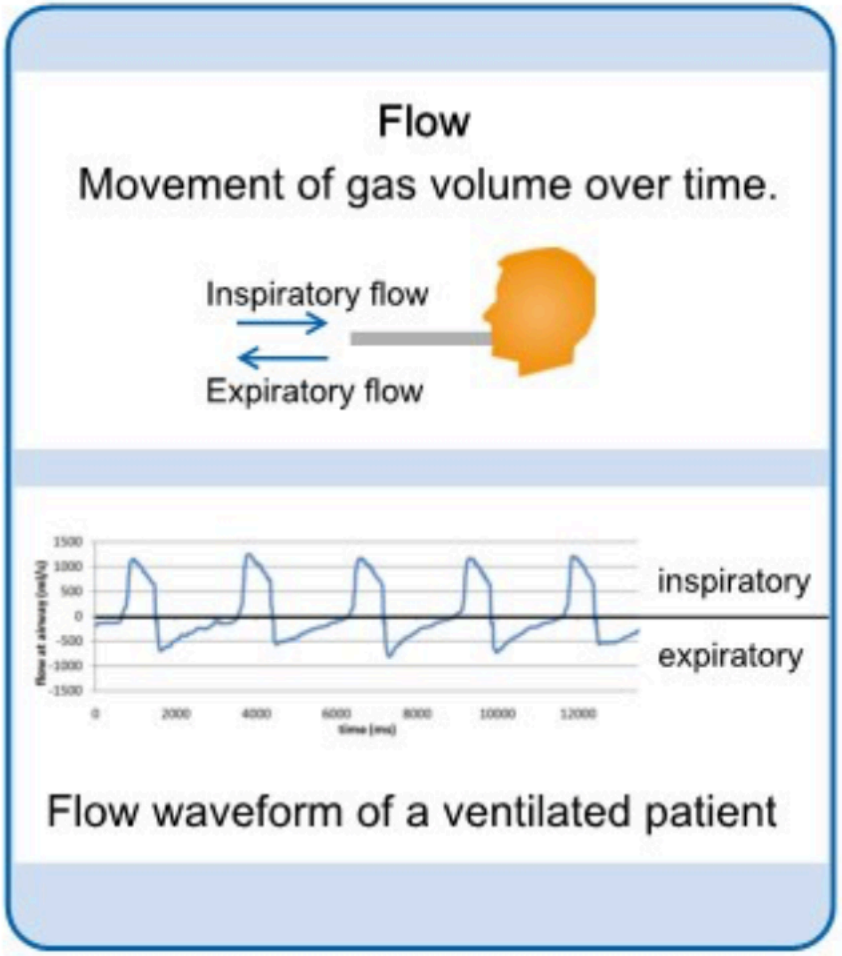
V: Volume

$\dot{V}$: Gas Flow

R: Resistance

C: Compliance

RC: Time constant



Hamilton Medical e Learning

Physics

P: Pressure

$\triangle P$: Pressure Gradient

V: Volume

$\dot{V}$: Gas Flow

R: Resistance

C: Compliance

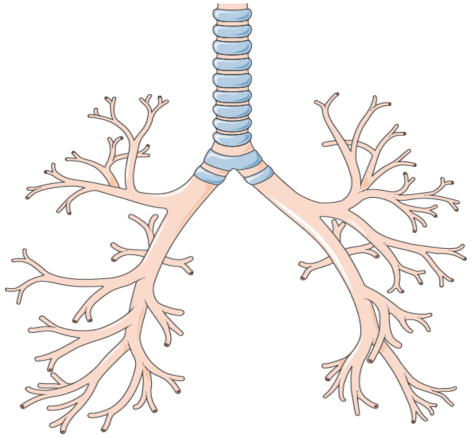
RC: Time constant

RESPIRATORY PHYSIOLOGY

one compartment model

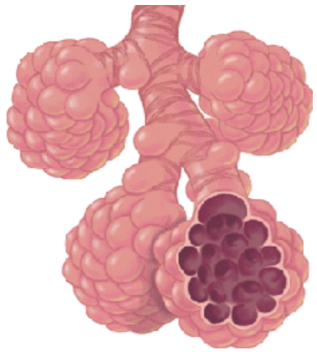
Airway Lung Structure

2 parts



Airways

Tube



Alveoli

Balloon

RESPIRATORY PHYSIOLOGY

Two main forces oppose inflation of the balloon

Impedance to flow

...which represents resistance of the airways

Impedance to volumetric expansion

...which represents compliance of the chest wall

RESPIRATORY PHYSIOLOGY

RESISTANCE

Force against gas movement

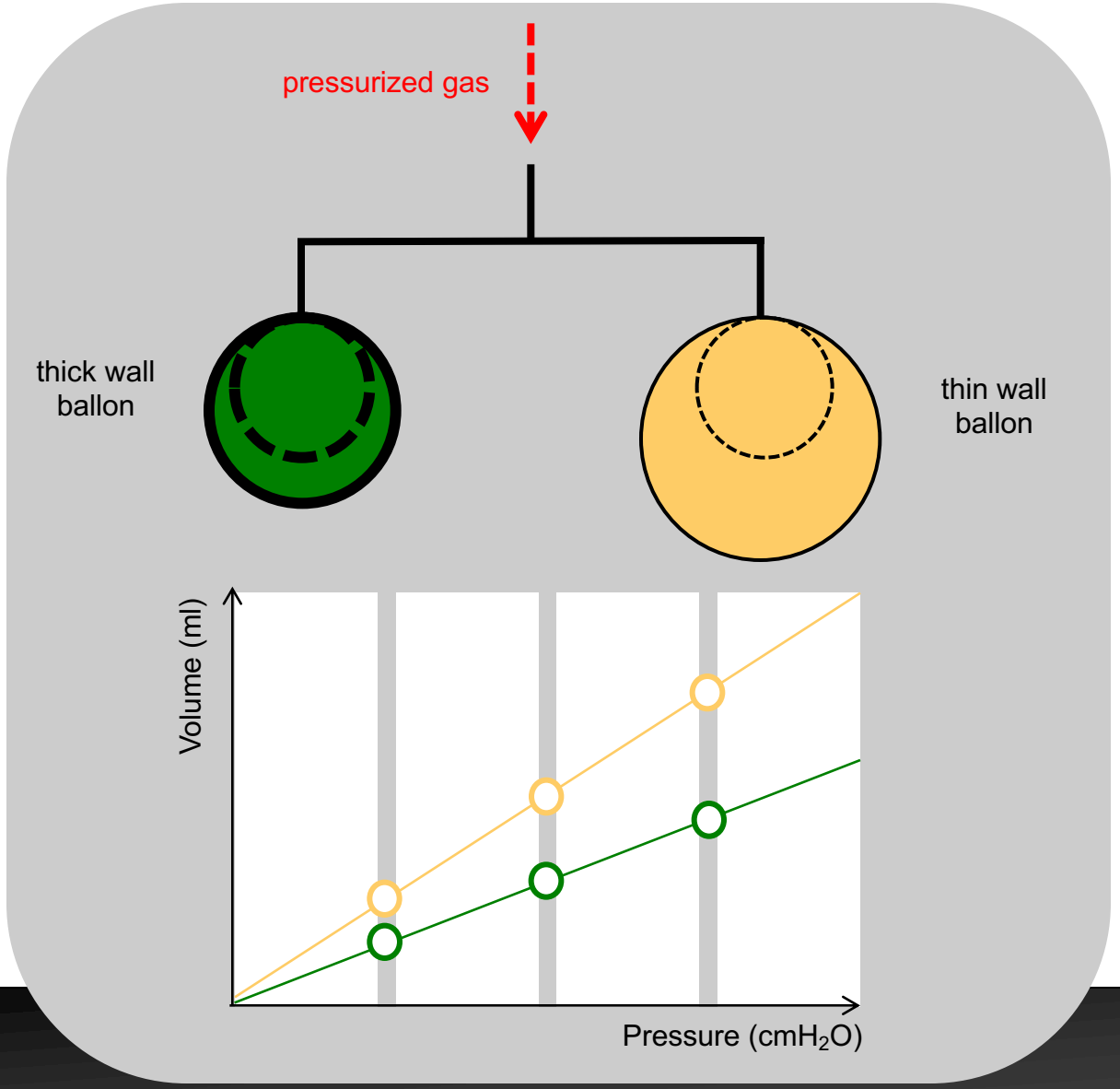
- When a gas moves through a tube, a resistance is generated
- Resistance depends on
  1. Properties of the tube
     (length, internal diameter, inner surface, curvature...)
  2. Properties of the passing gas
     (density, viscosity)
  3. Flow

$$\text{Resistance} = \frac{\Delta\,\text{Pressure}}{\text{Flow}}$$ mbar/L/min

Ohm's law

RESPIRATORY PHYSIOLOGY

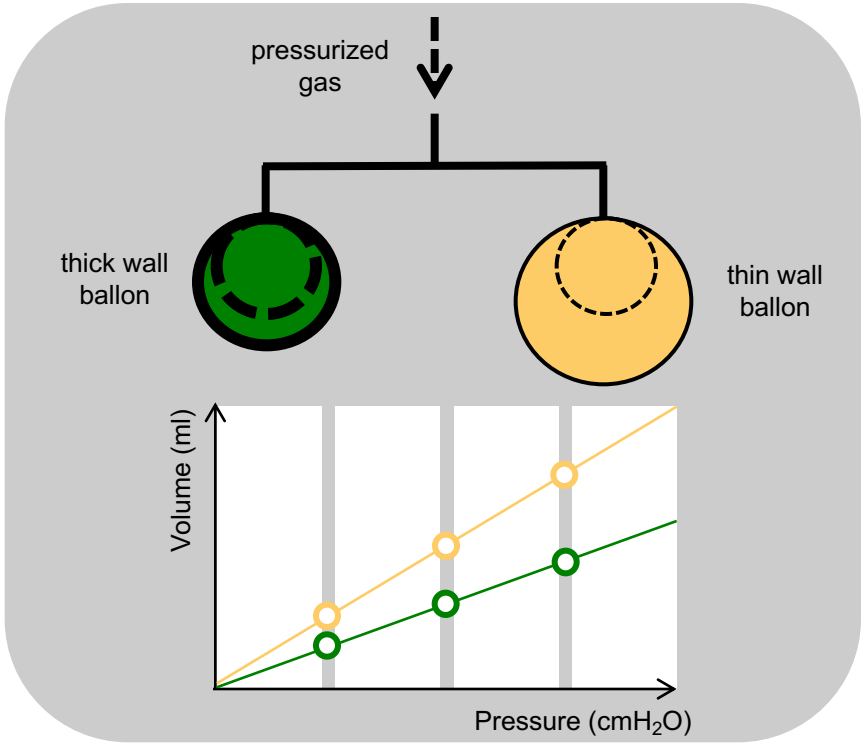
COMPLIANCE



Adapted from Hamilton Medical

RESPIRATORY PHYSIOLOGY

COMPLIANCE

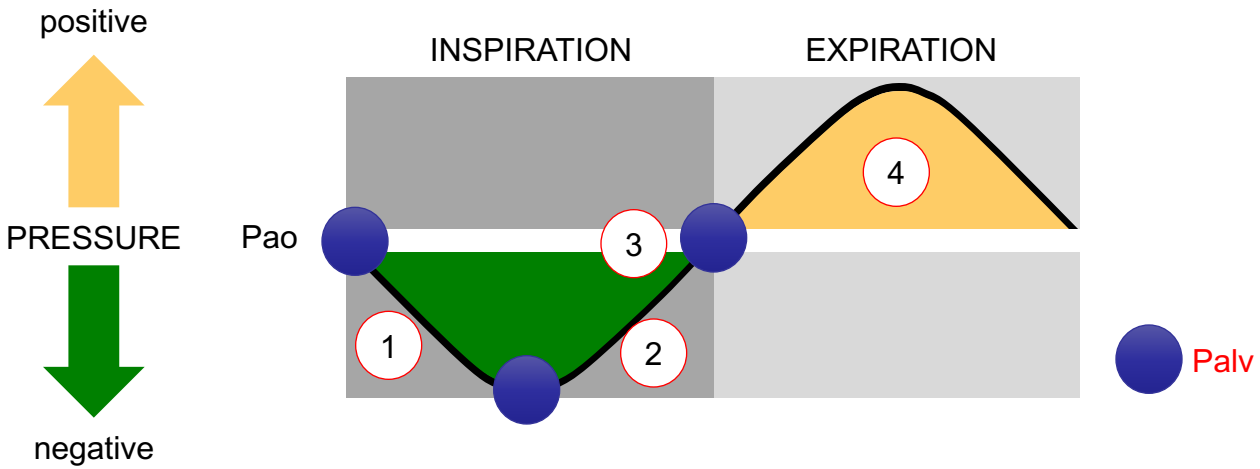


$$\text{Compliance} = \frac{\Delta\ \text{Volume}}{\Delta\ \text{Pressure}} \quad \text{mL/cmH}_2\text{O oder L/cmH}_2\text{O}$$

Adapted from Hamilton Medical

RESPIRATORY PHYSIOLOGY

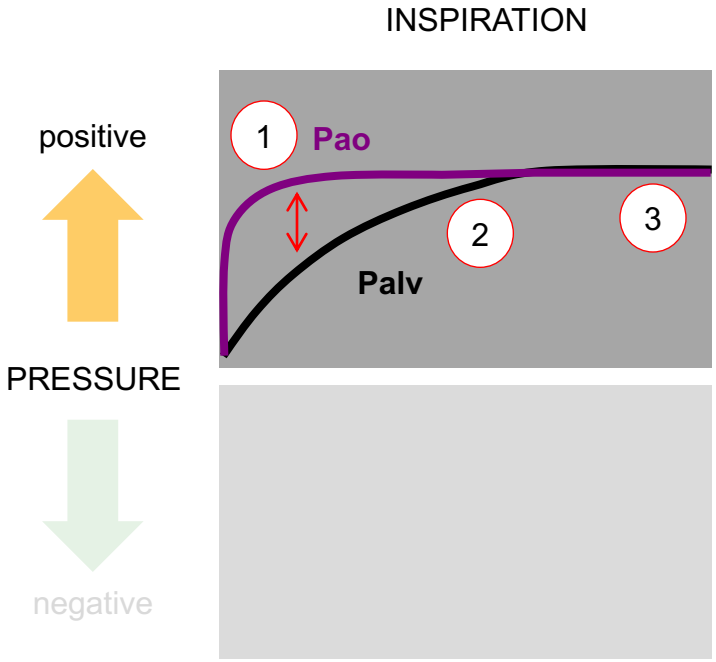
INSPIRATION AND EXPIRATION; SPONTANEOUS BREATHING



1	Downward movement of diaphragm	→	alveolar pressure drops below airway opening pressure
	Following the pressure gradient	→	air is sucked into the lung
2	Lungs are inflated with inspiratory flow over time	→	Alveolar pressure increases gradually
3	Alveolar pressure and airway opening pressure become equal	→	Flow stops
4	Relaxation of the diaphragm	→	Elastic recoil force of lungs and chest wall brings the enlarged lungs bach to their resting position (FRC)

RESPIRATORY PHYSIOLOGY

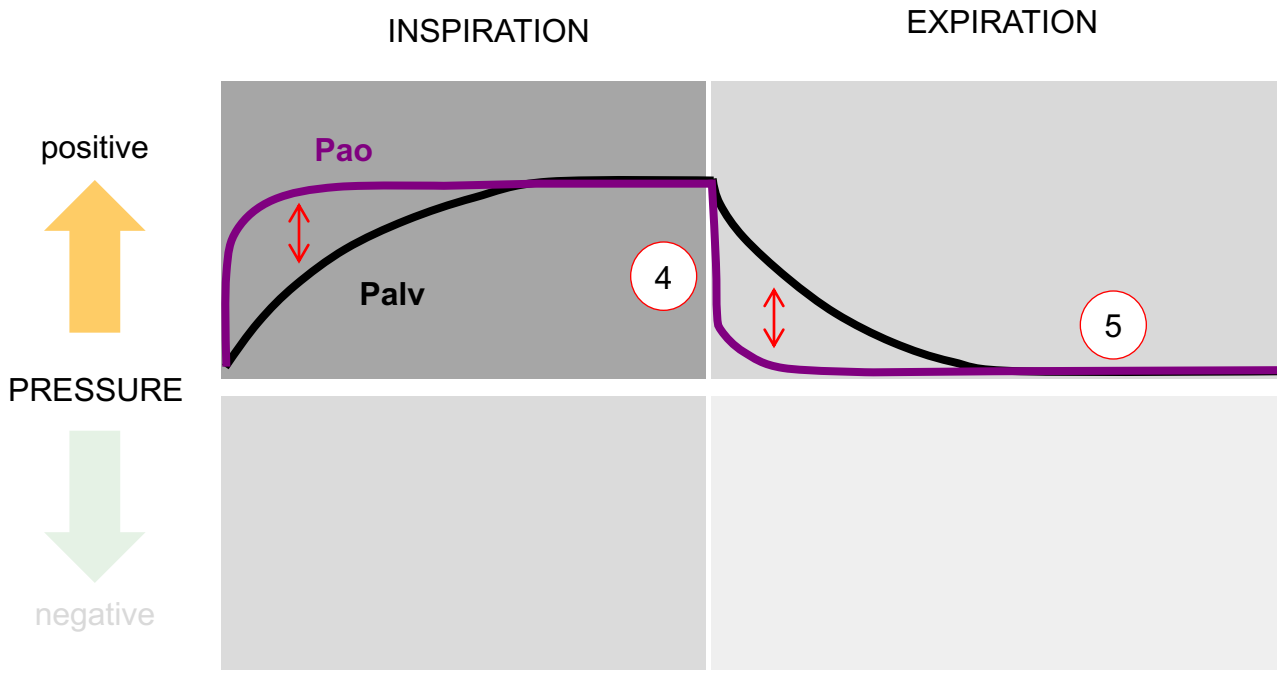
INSPIRATION AND EXPIRATION; ARTIFICIAL LUNG VENTILATION



1	Ventilator raises Pao from pressure baseline to peak pressure	→	This generates a temporary gradient between Pao and Palv
		→	The gas is pushed into the lungs
2	Lungs are inflated with inspiratory flow over time	→	Alveolar pressure increases gradually
3	Alveolar pressure and airway opening pressure become equal	→	Flow stops

RESPIRATORY PHYSIOLOGY

INSPIRATION AND EXPIRATION; ARTIFICIAL LUNG VENTILATION



4 Ventilator lowers Pao from peak pressure baseline to baseline pressure → This generates a temporary gradient between Pao and Palv

→ The elastic recoil force of the lung-chest wall pushes the gas out of the lungs

5 Alveolar pressure and airway opening pressure become equal → Flow stops

RESPIRATORY PHYSIOLOGY

INSPIRATION AND EXPIRATION

- Flow is defined as change of volume over time
- It takes time to complete a course of volume change (inflation or deflation)
- Inflation: if time available for lung inspiration is too short, tidal volume decreases
- Deflation: if time available for lung exhalation is shorter than required, gas volume is trapped in the lungs and alveolar pressure rises

How to know or estimate objectively and individually the required time to complete a course of volume change?

Physics

P: Pressure

$\triangle P$: Pressure Gradient

V: Volume

$\dot{V}$: Gas Flow

R: Resistance

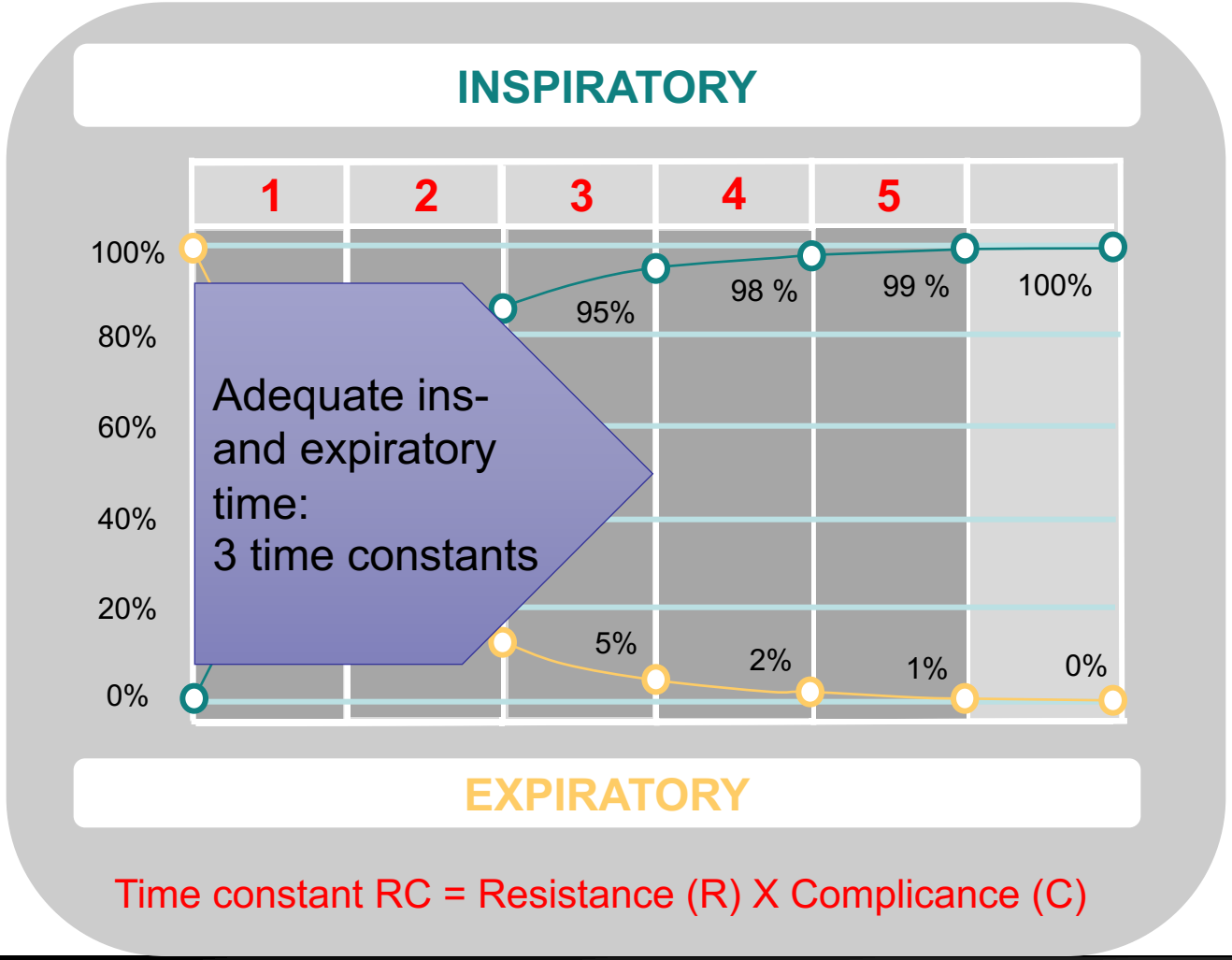
C: Compliance

RC: Time constant

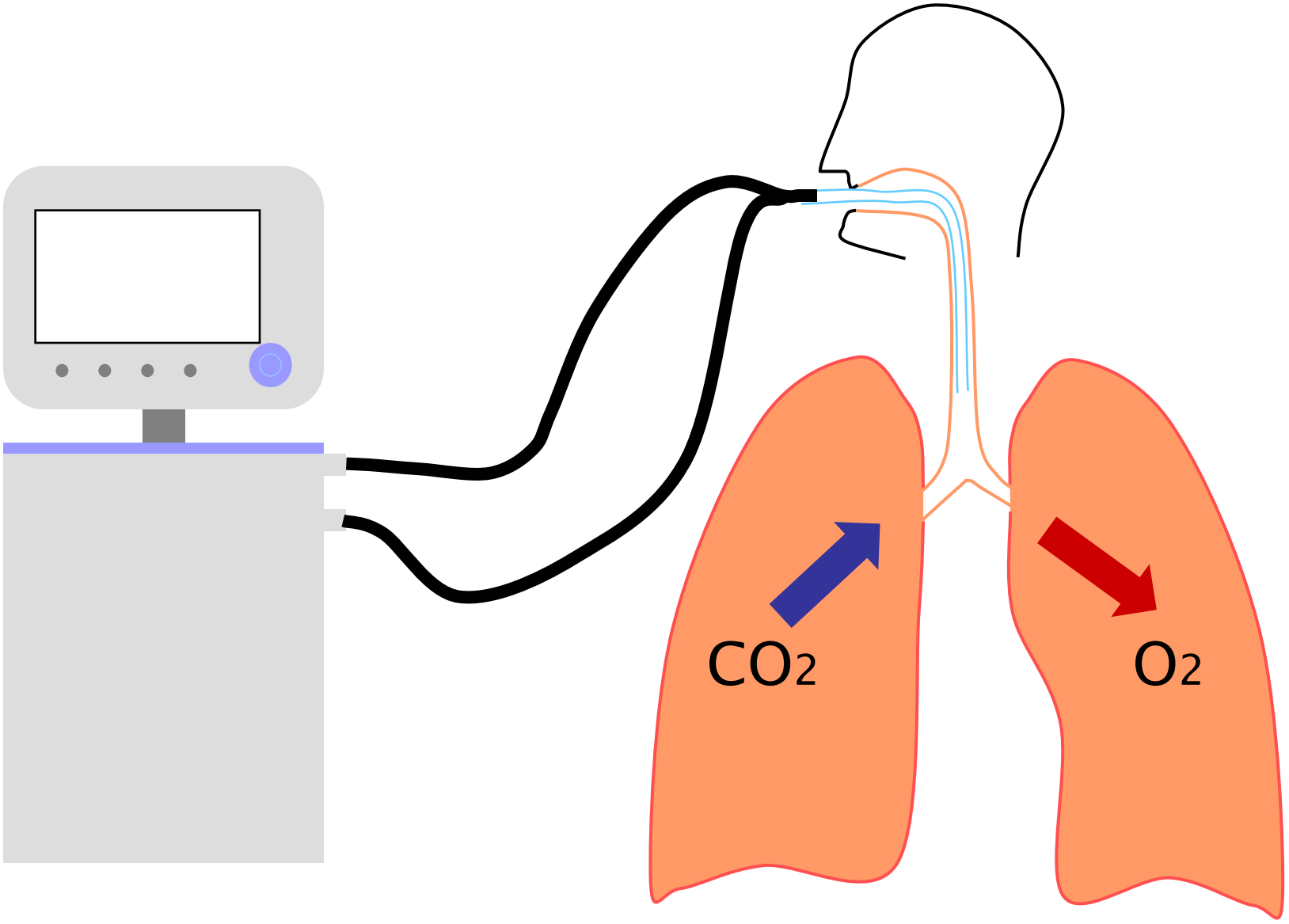
RESPIRATORY PHYSIOLOGY

TIME CONSTANT

Expressed in second



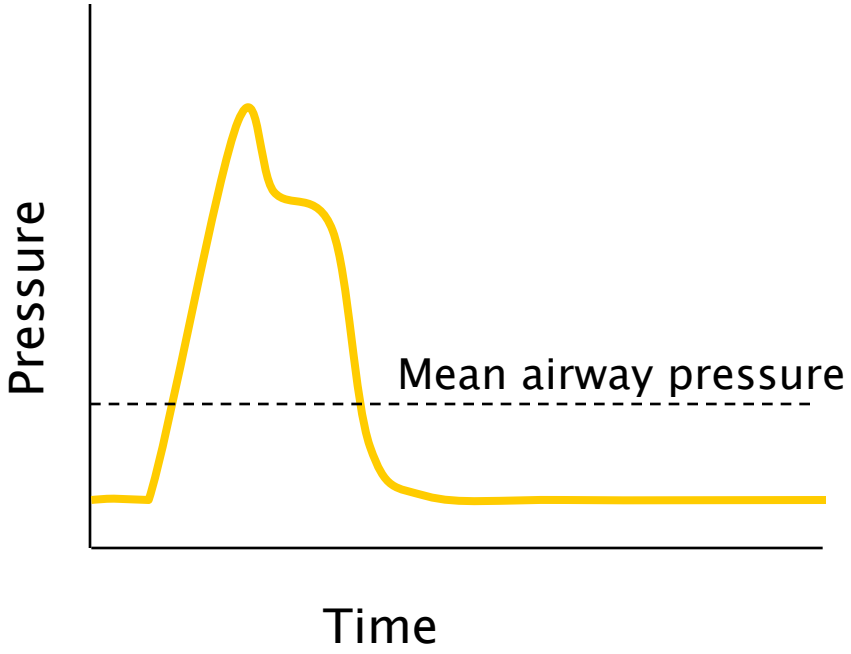
Time constant RC = Resistance (R) X Complicance (C)

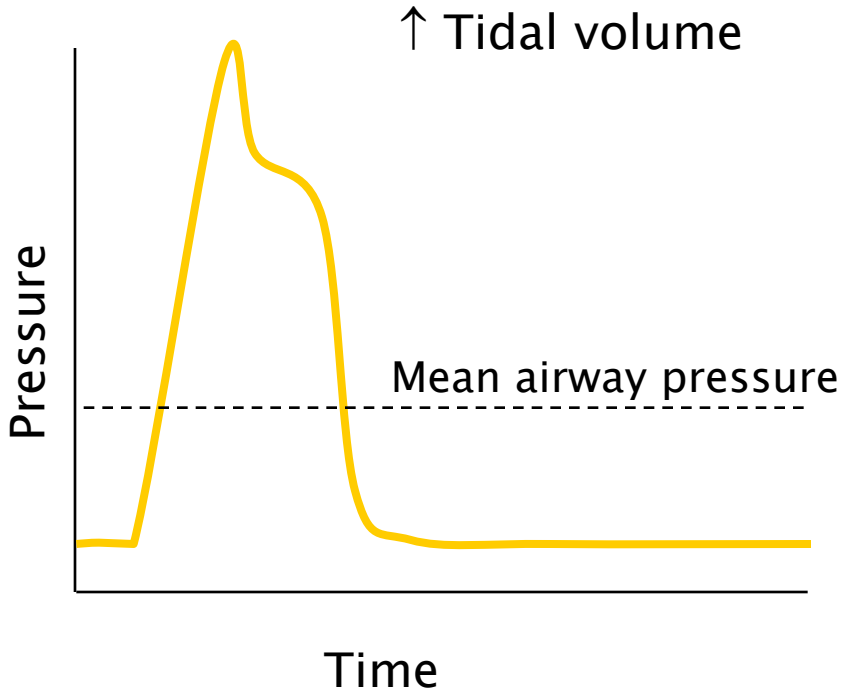

CO2
O2

Main determinants

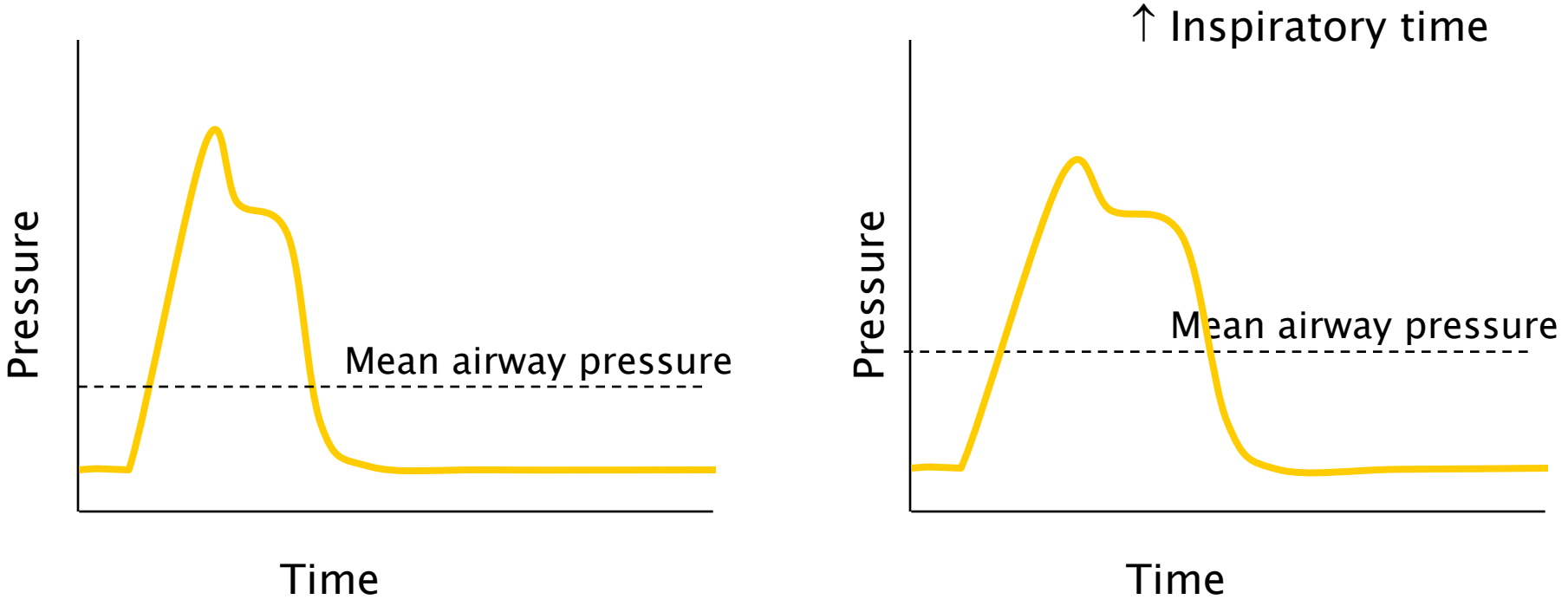
- Oxygen in
  - ↑ F_IO_2
  - ↑ mean alveolar pressure
  - PEEP
    - Re-open alveoli and ↓ shunt
- Carbon dioxide out
  - ↑ ventilation
    - ↑ RR
    - ↑ tidal volume

Mean airway pressure





Mean airway pressure



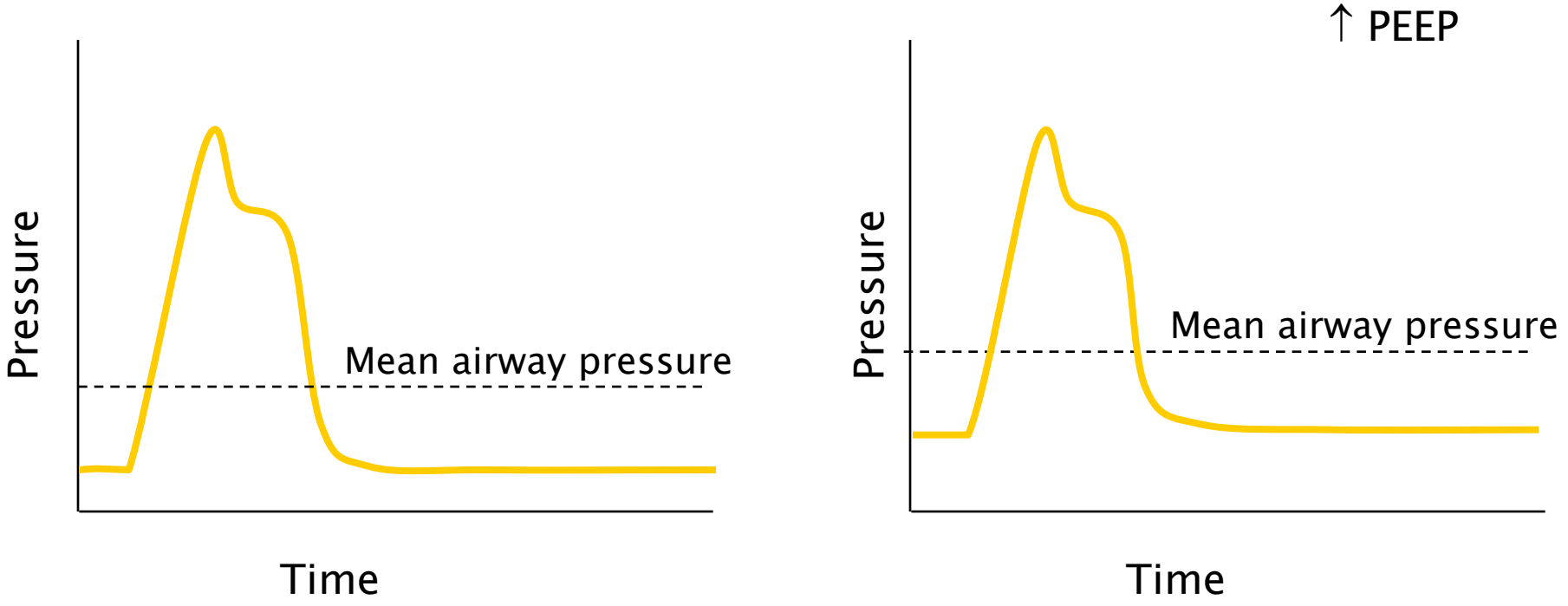
Inspiratory time

- Set as:
  - % of respiratory cycle
  - I:E ratio
  - Fixed time
  - Indirectly, by setting flow
- Expiratory time not set
  - Remaining time after inspiration before next breath

Inspiratory time

- Increased inspiratory time
  - Improved oxygenation
  - Unnatural pattern of breathing
    - Deeper sedation
  - Increased risk of gas trapping

Mean airway pressure



PEEP

- Improves oxygenation
  - ↑ mean alveolar pressure
  - ↓ shunting

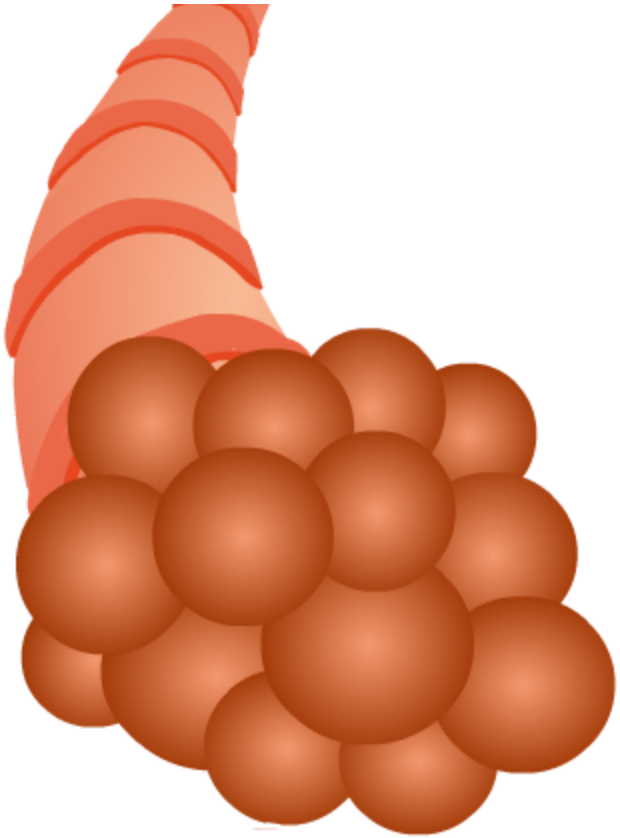
Respiratory complications

- Nosocomial pneumonia
- Ventilator-associated lung injury
- Gas trapping

Ventilator associated lung injury

- High pressures (barotrauma)
- High volumes (volutrauma)
- Shear injury

Gas trapping



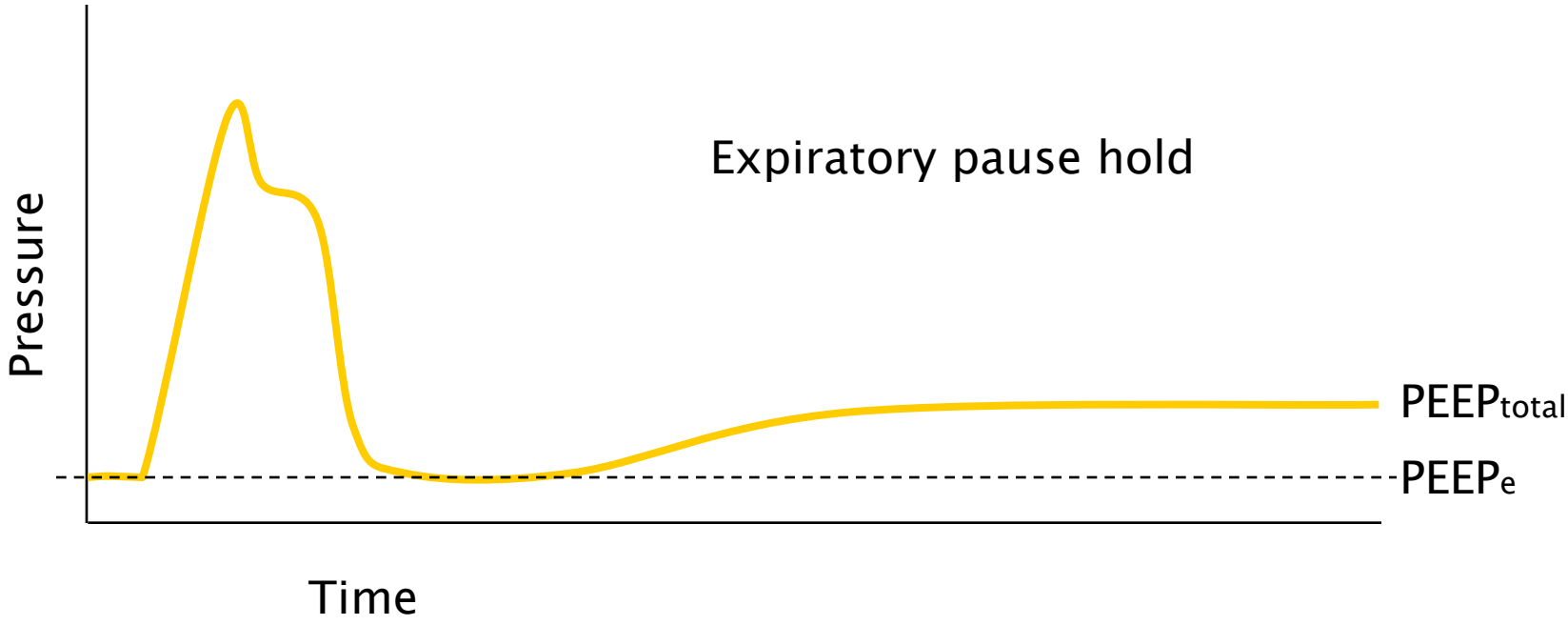
Gas trapping

- Predisposing factors:
  - Asthma or COPD
  - Long inspiratory time ($\Rightarrow$ expiratory time short)
  - High respiratory rate ($\Rightarrow$ absolute expiratory time short)
  - Large tidal volume

Gas trapping

- Effects
  - progressive hyperinflation of alveoli
  - progressive rise in end-expiratory pressure (intrinsic PEEP)

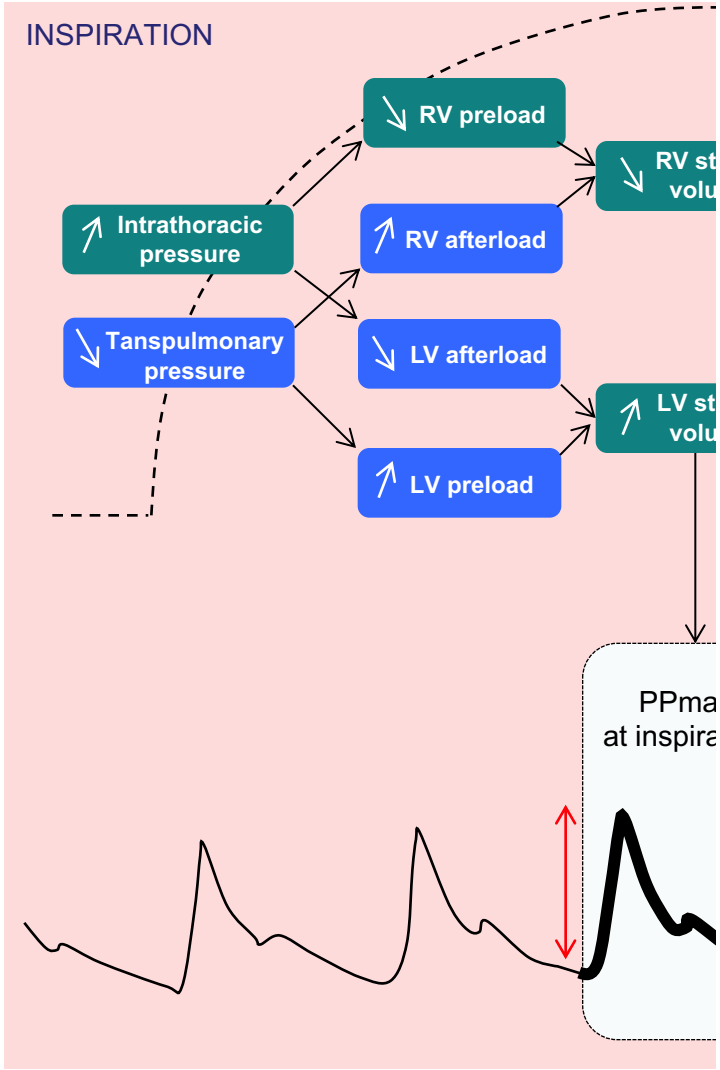
Intrinsic PEEP (PEEPi)

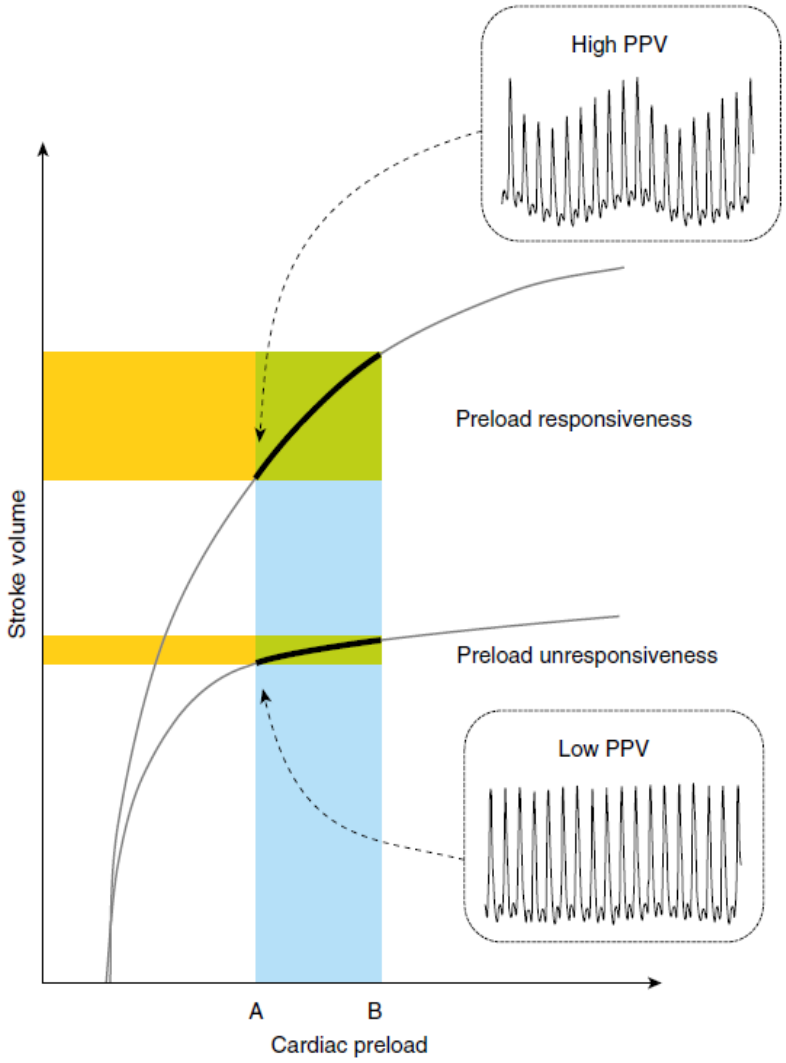


Gas trapping

- Adverse effects
  - Barotrauma
  - Cardiovascular compromise

Cardiovascular effects

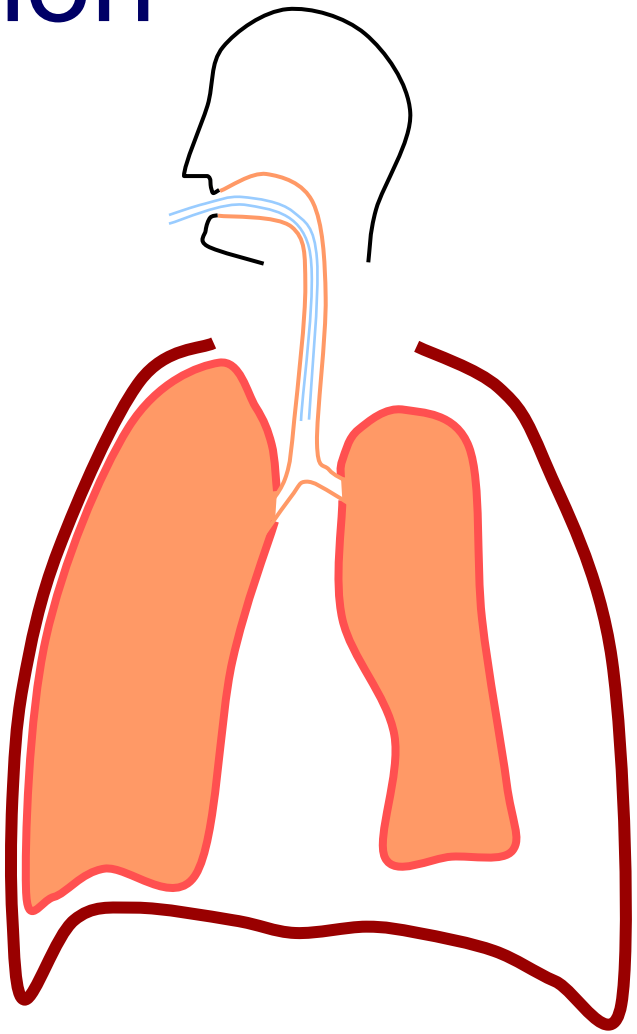




Teboul JL. Arterial pulse pressure variation with mechanical ventilation. Am J Respir Crit Care Med 2019

Hypotension

- Consider
  - Drug induced
  - Gas trapping
  - Tension pneumothorax



Summary I

- Physics: P, ΔP, $\dot{V}$, R, C, RC
- PaO_2 determined by
  - $F_I O_2$
  - Mean airway pressure (PEEP, I:E ratio)
- $PaCO_2$ determined by
  - Alveolar minute ventilation (RR, V_T)

Summary II

- Complications include
  - Hypotension
  - Ventilator-associated lung injury
  - Gas trapping