



VetAgro Sup
Campus Vétérinaire
de Lyon

Siamu

Ventilator management for non-cardiogenic pulmonary edema

Dr Céline Pouzot-Nevoret
DECVECC
Head of the ICU (SIAMU)
Lyon, France

JaVECCS
2025 TOKYO

Outline



- Quick overview of non-cardiogenic pulmonary oedema
- Particularities of ventilator management for patients with NCPE
 - Initial ventilator settings
 - Monitoring
 - Nursing care
 - Complications

Non-cardiogenic pulmonary oedema

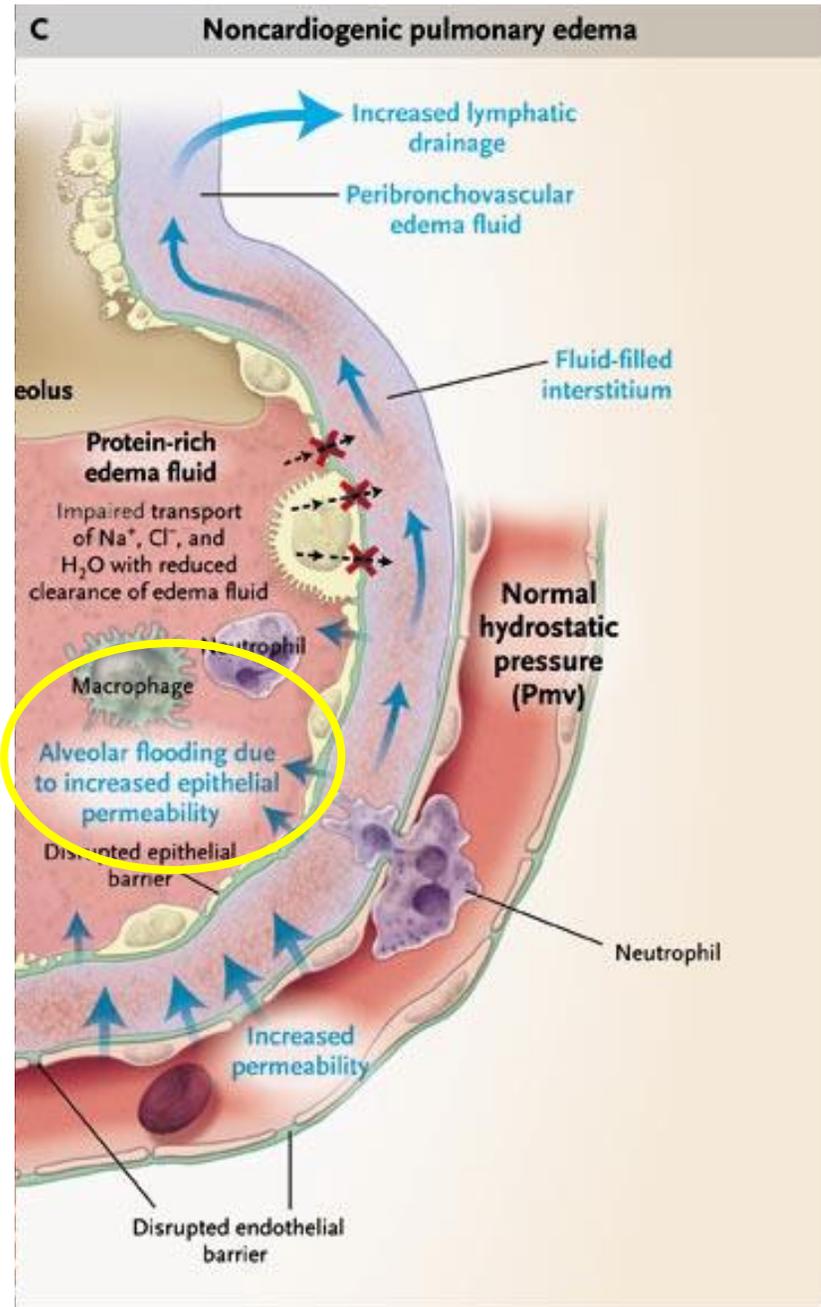


- Pathological accumulation of fluid in the extravascular space of the lungs, **not associated with elevated left cardiac pressure**
- **Various etiologies**
 - Upper airway obstruction
 - Electrocution - Near drowning – Fire/toxic inhalation
 - Neurogenic causes
 - Blood transfusion
 - Acute respiratory distress syndrome (ARDS)

TABLE 1. Summary of Dogs and Cats with Noncardiogenic Pulmonary Edema Included in the Study

	Dog	Cat
Postobstructive pulmonary edema	23	—
Tracheal collapse	10	—
Laryngeal paralysis	7	—
Brachycephalic airway obstructive syndrome	3	—
Strangulation	2	—
Direct lung injury	8	5
Fire smoke exposure	4	2
Toxin inhalation	4	3
Neurogenic edema	10	2
Seizures	9	1
Electrocution	1	1
Systemic disease	4	2
Neoplasia	2	1
Uremic syndrome	2	—
Pancreatitis	—	1
Near drowning	3	—
Blood transfusion	1	1
Anaphylaxis	—	1



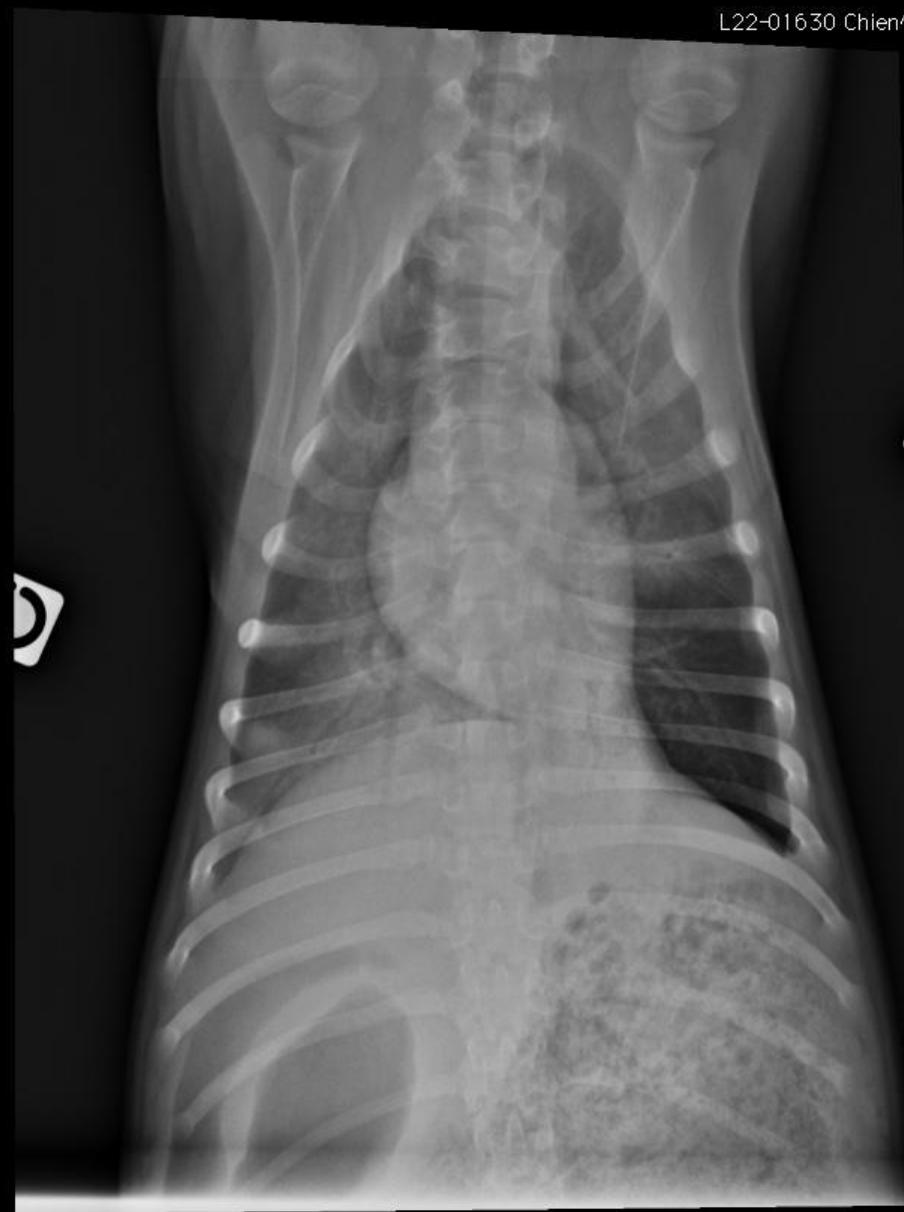
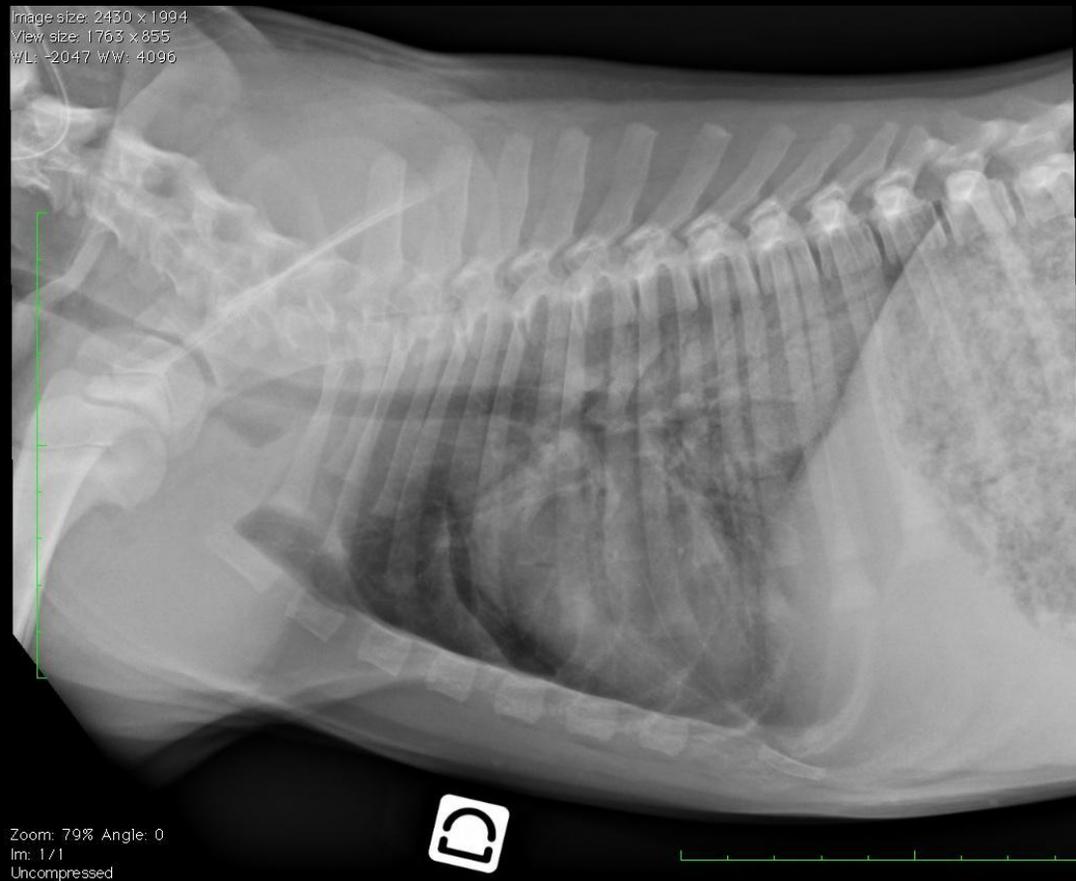


Mechanism of NCPE

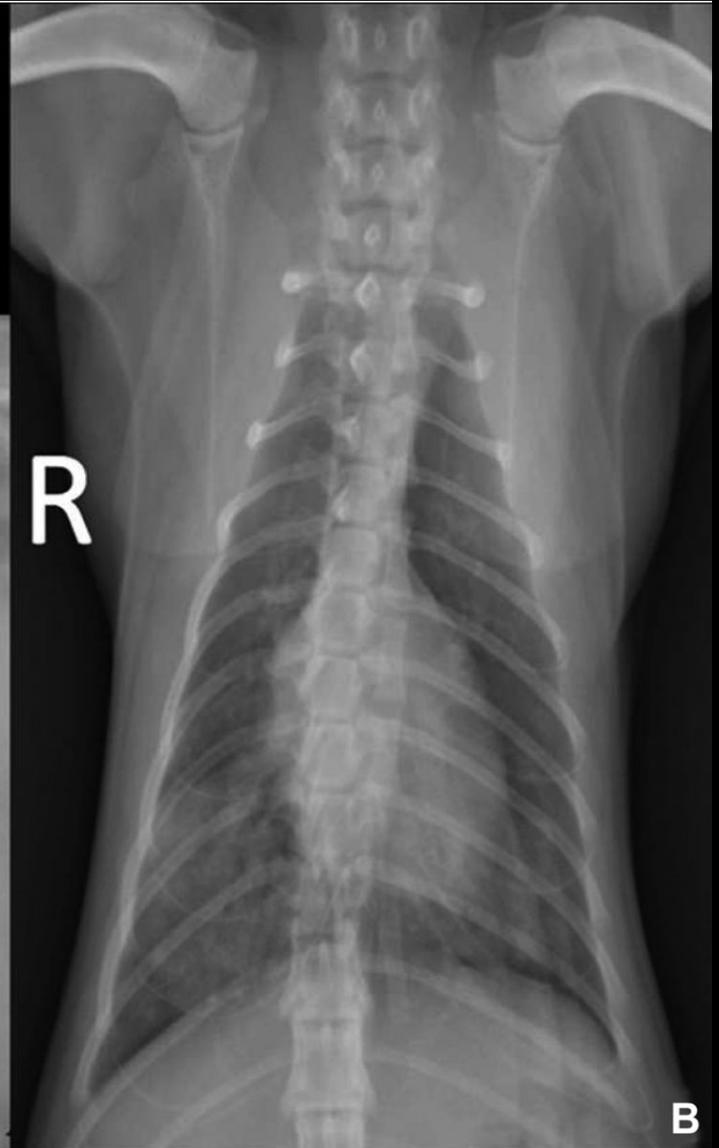


- Increased intrathoracic negative pressure
- Increased vascular permeability
- Damage of the respiratory membrane
- Volume and pressure overload in the pulmonary microvasculature

Diagnosis



25/02/2022 09:37:10
Made In Horos





Gén
S MB

2022 Fév 24 11:13



AbV

C11



69%

IM

0,4

ITM

0,2

A

B

5,2 °



Gén



0



MB Oui



Double

Page 1/2

Non-cardiogenic pulmonary oedema



- Treatment based on
 - Etiology
 - Oxygen therapy
- Mechanical ventilation for NCPE
 - Few data
 - MV associated with worst outcome
 - MV for 45h to 6 days

Mechanical ventilation



- Important treatment for patients with respiratory distress
- Invasive respiratory support
- Provide a **positive pressure**
- Perform part or all the work of breathing

Indications



- **Hypoxemia** not responsive to oxygen therapy
 - $\text{PaO}_2 < 60$ mm Hg with $\text{FiO}_2 > 60\%$
- **Hypercapnia**
 - $\text{PaCO}_2 > 60$ mm Hg
- **Increased work of breathing** with possible impending respiratory fatigue/arrest

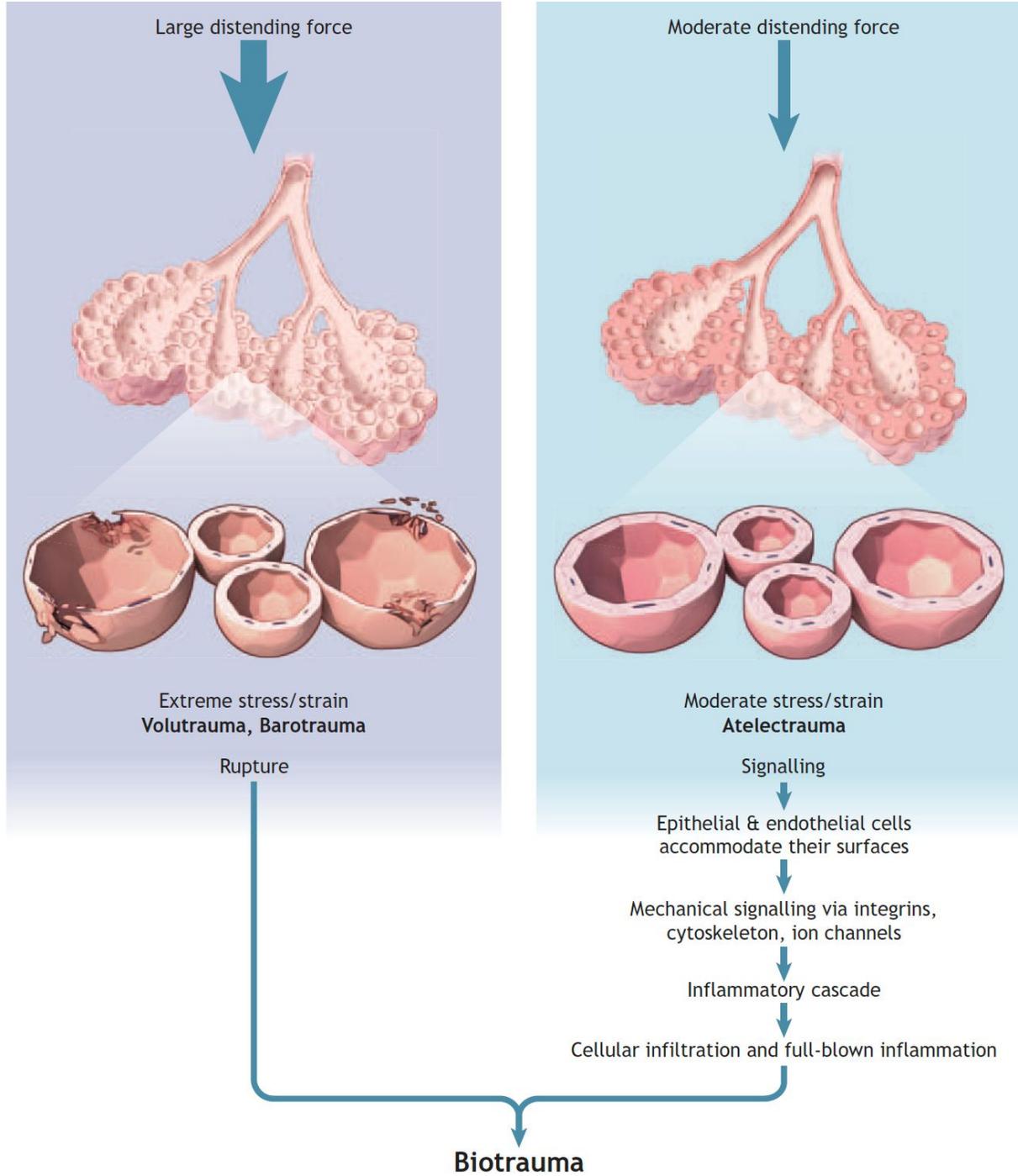
Goals of mechanical ventilation



Improve
Oxygenation and ventilation



Without inducing VILI



Ventilator-induced lung injury

Initiate mechanical ventilation



Set up your ventilator

Prepare your patient



Patient



- Pre-oxygenation
- IV Anesthesia
- Intubation
 - Sterile procedure
 - Humification
- Monitoring
 - SpO₂
 - Capnography
 - Arterial line
 - Temperature



Initiate mechanical ventilation



Set up your ventilator

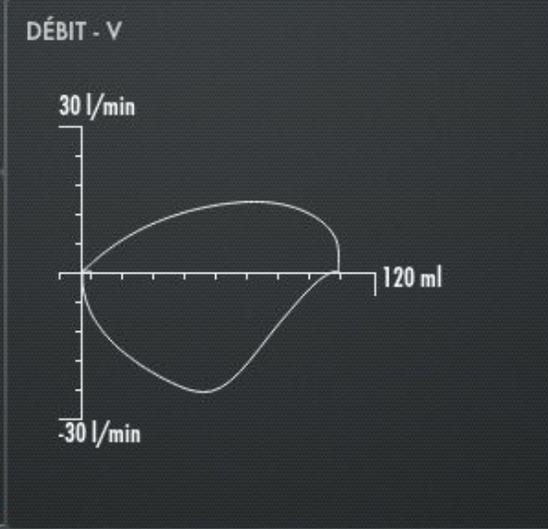
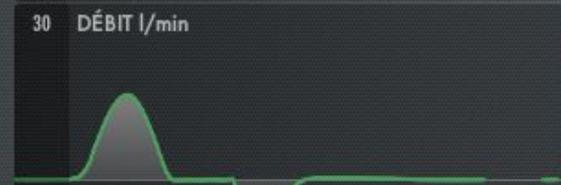
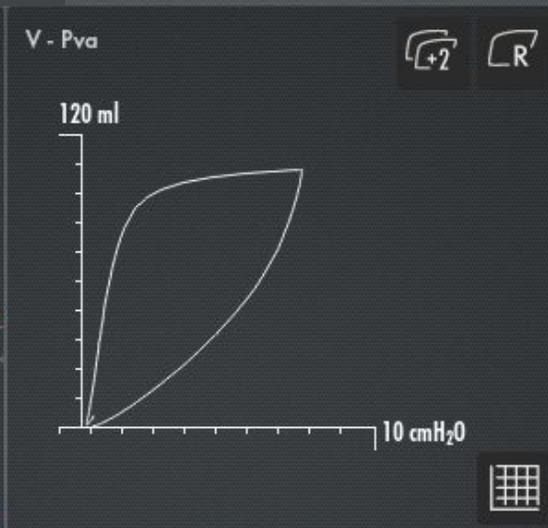
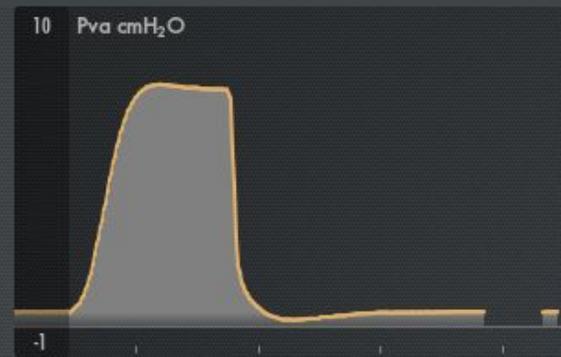
Prepare your patient





Pressure control

- ATTENTE
- DÉBRANCHEMENT
- MODES
- LIMITES D'ALARME
- TENDANCES & JOURNAUX
- MANŒUVRES
- AFFICHAGES
- VERROUILLER L'ÉCRAN
-



Pcrête 30
7
cmH₂O

Pmoy **2,3**
cmH₂O

PEP 15
0,5
cmH₂O

FR 50
15
resp/min

I:E **1 : 2,0**

Conc. O₂ **21**
%

VM_e 5,0
1,5
l/min

Vci 105
ml

Vce 101
ml

V_c/PC ...
ml/kg

C_{dyn} **14,6**
ml/cmH₂O

51
O₂ SUPP.

Conc. O₂ **21**

PEP **0,0**

F resp. **15**

Niv. PC sur PEP **6**



Initial settings

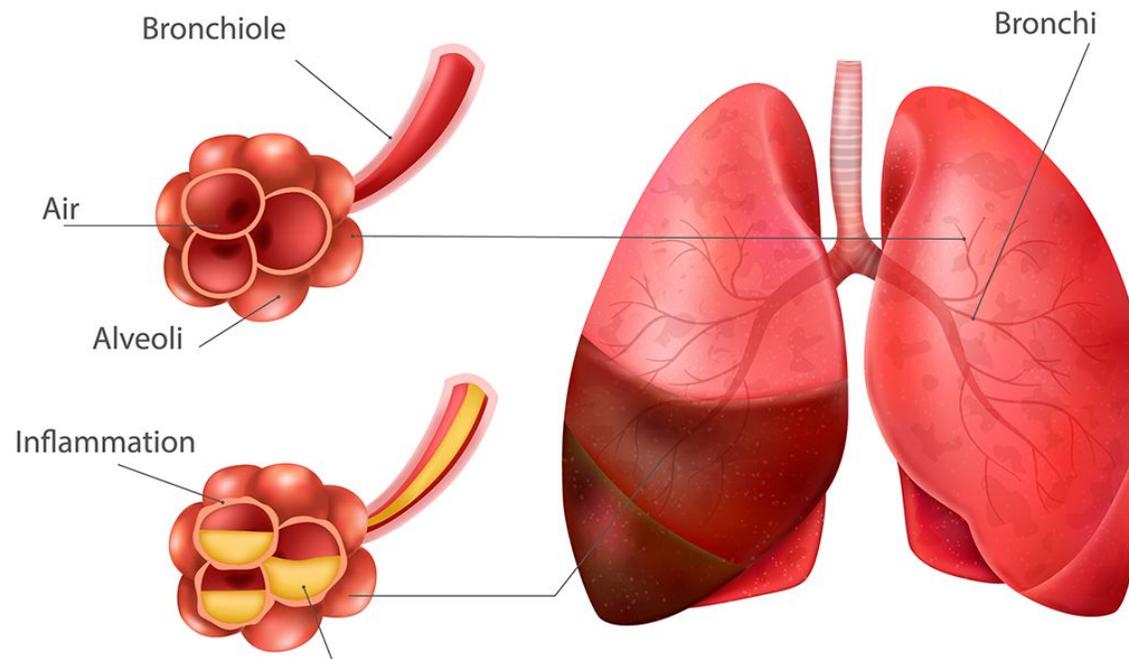


- Ventilation mode
- FiO_2
- Tidal volume
- Respiratory rate
- Flow rate
- PEEP
- Inspiratory to expiratory ratio
- Inspiratory trigger
- ...

Initial settings



- Important question: normal or abnormal lungs?



Patients with NCPE



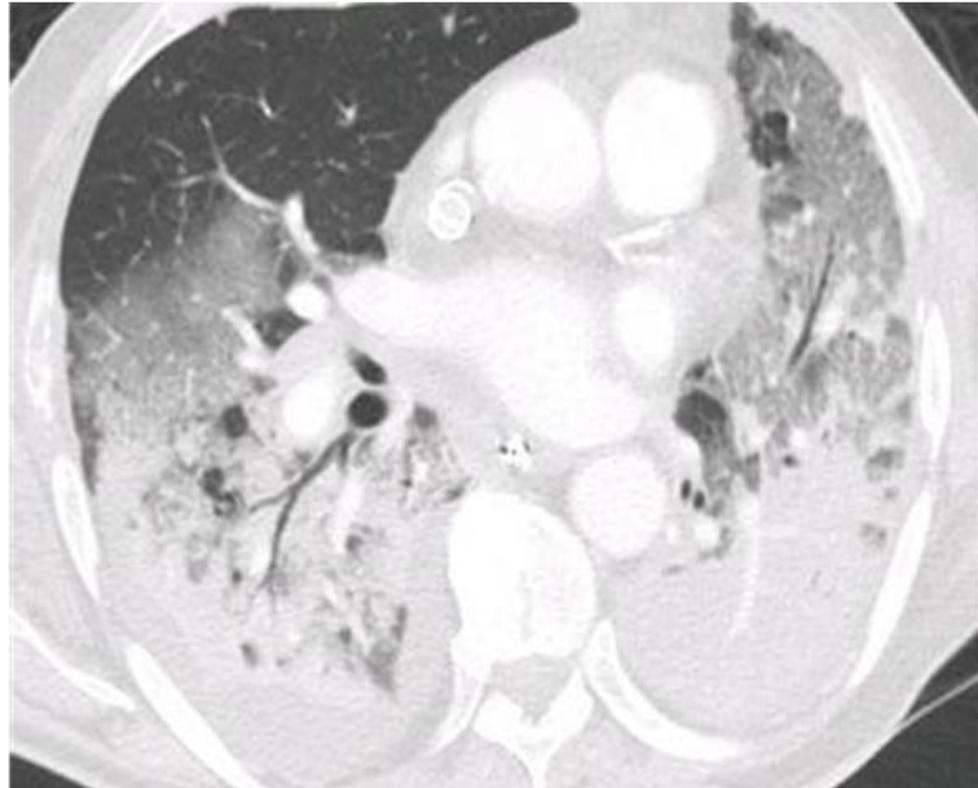
- Decreased compliance
- Increased resistance
- Increased intra-pulmonary shunt
- Heterogeneous repartition of ventilation

Concept of baby-lung



Normally aerated

Non aerated



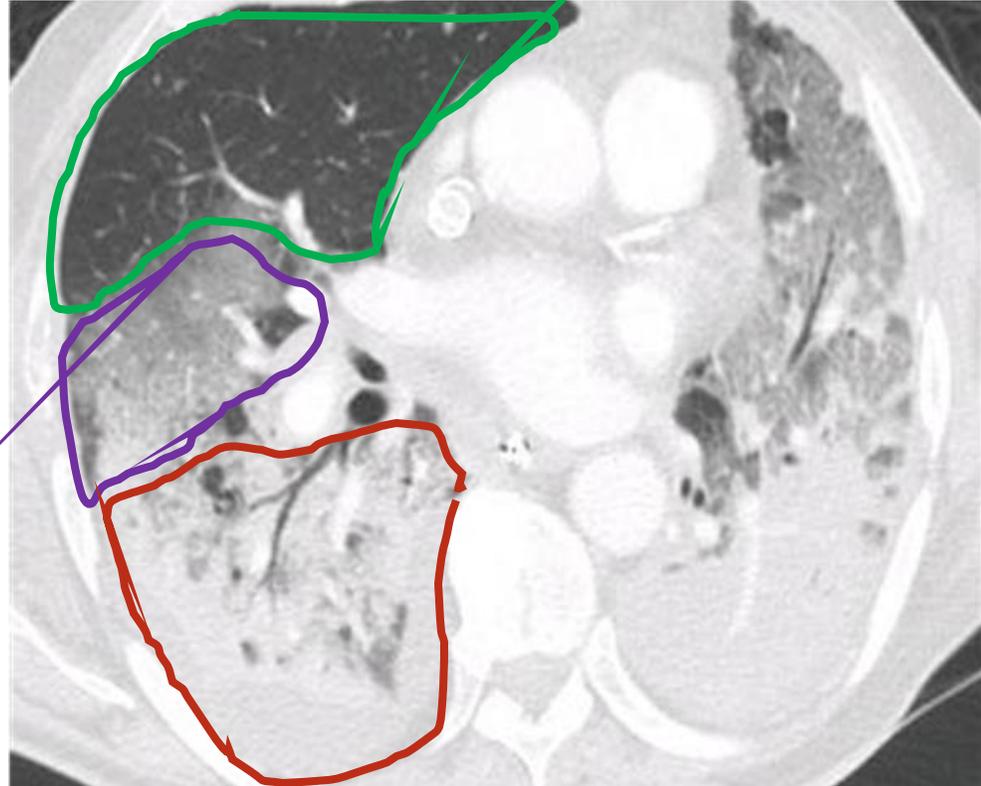
Concept of baby-lung



High risk of volo/barotrauma

High risk of atelectrauma

No ventilation



Initial settings



- Ventilation mode
- FiO_2
- Tidal volume
- Respiratory rate
- Flow rate
- PEEP
- Inspiratory to expiratory ratio
- Inspiratory trigger
- ...

Protective ventilation

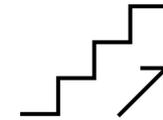
Protective ventilation



Low VT



Limit Pplat



Apply PEEP

Tidal volume



- Recommended VT in people: 6-8 ml/kg

The New England Journal of Medicine

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VOLUME 342

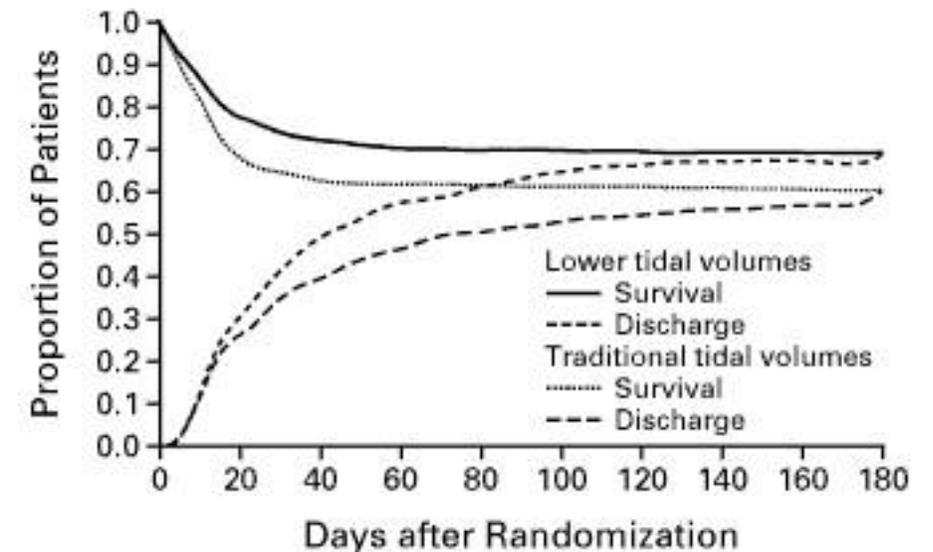
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NUMBER 18



VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH
TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY
AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*



Low VT in vet med?



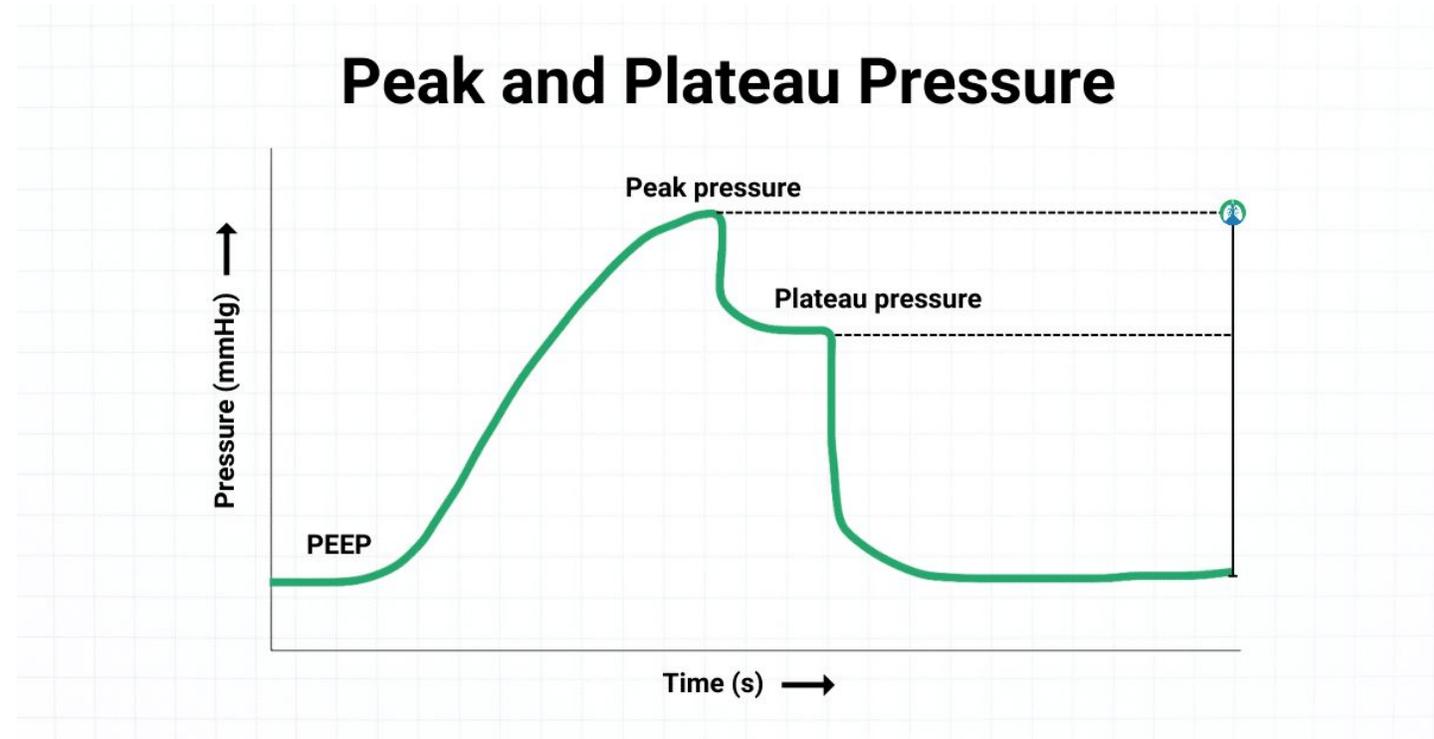
- Patients with pulmonary disease are ventilated with **lower VT** compared to non pulmonary disease
- Median VT:
 - At initial stabilization: 9-10 ml/kg
 - Average: 8-12 ml/kg

Initial VT settings
8-10 ml/kg

Limit Plateau pressure



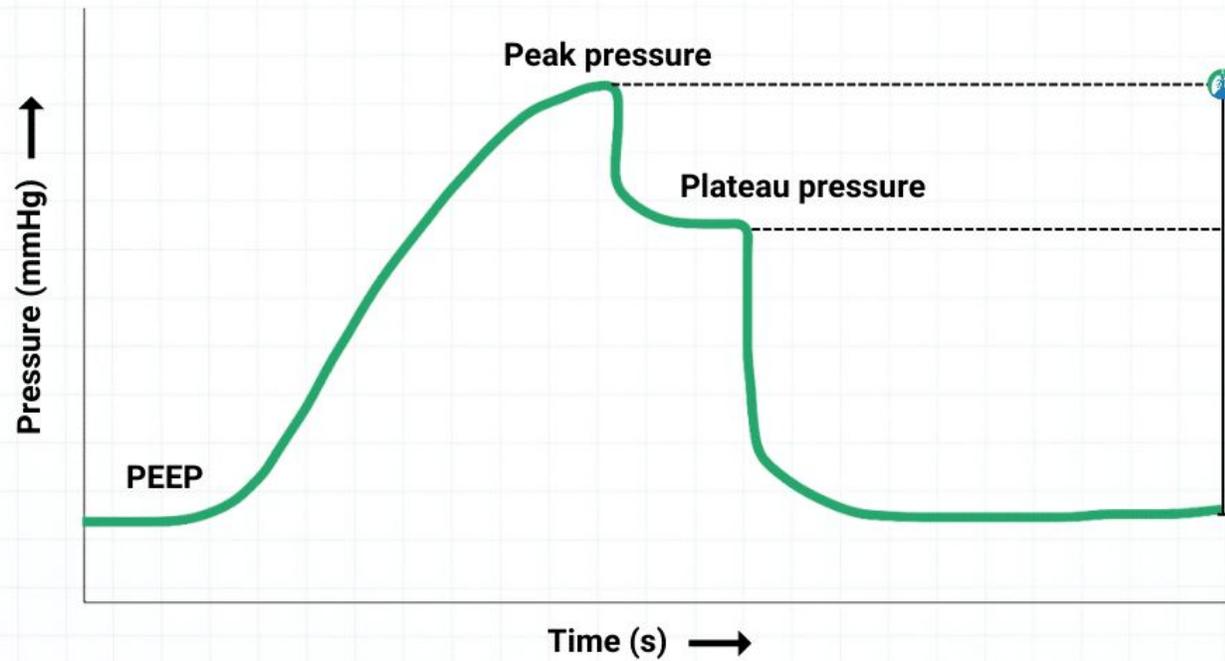
- Plateau pressure < 30 cm H₂O
- Reflet alveolar pressure



Use PEEP



Peak and Plateau Pressure





Benefits of PEEP



- Increases functional residual capacity by preventing atelectasis
- Improves alveolar recruitment
- Prevents atelectrauma
- Improves VQ matching

PEEP in Vet med?



- Patients with pulmonary disease are ventilated with **higher PEEP** compared to non pulmonary disease
- Median PEEP
 - 6-7 cm H₂O
 - Up to 14 cm H₂O

Initial PEEP settings
6-8 cm H₂O

Protective ventilation – Initial settings



Low VT

8-10 ml/kg



Limit Pplat

$P_{plat} < 30 \text{ cm H}_2\text{O}$



Apply PEEP

PEEP 6-8 cm H₂O

Initial settings



- **Pressure or Volume, assisted/synchronized**
- Respiratory rate: 15-30 mpm
- I:E ratio: 1:1 – 1:2
- FiO_2 : 100%

Monitor

Monitor oxygenation



- Targets
 - PaO₂: 80-120 mm Hg
 - SpO₂: 85-100%
- Adapt FiO₂ and PEEP
- Goal: FiO₂ < 60% to avoid oxygen toxicity

Monitor ventilation



- Targets
 - PaCO₂: 35-50 mm Hg
 - EtCO₂
- Change minute ventilation (VT x RR)

Monitor ventilation



- Targets
 - PaCO₂: 35-50 mm Hg
 - EtCO₂
- Change minute ventilation (VT x RR)
- Permissive hypercapnia in ARDS patients

Monitor lung's mechanics



Compliance

Resistance

Equation of motion



$$P_{aw} = P_{vent} + P_{musc}$$

$$= P_0 + \text{Resistive pressure} + \text{Elastic pressure}$$

PEEP

Resistance x
Flow

Volume x Elastance
or
Volume / Compliance



Compliance = 1/Elastance

Equation of motion



$$P_{aw} = P_{vent} + P_{musc}$$

$$= P_0 + \text{Resistive pressure} + \text{Elastic pressure}$$

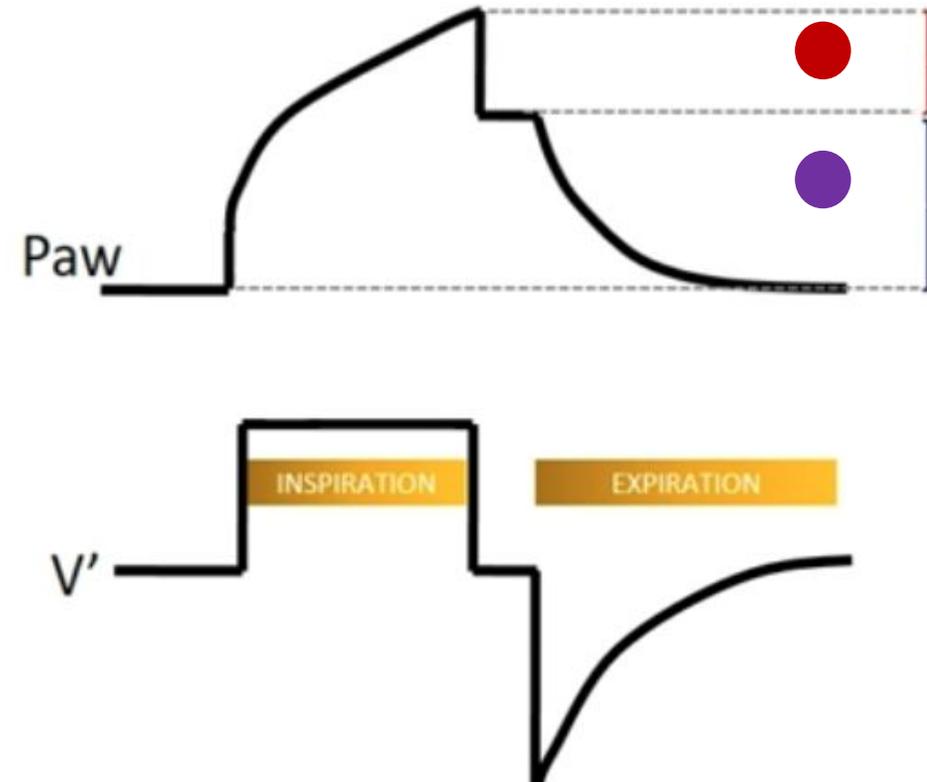
PEEP

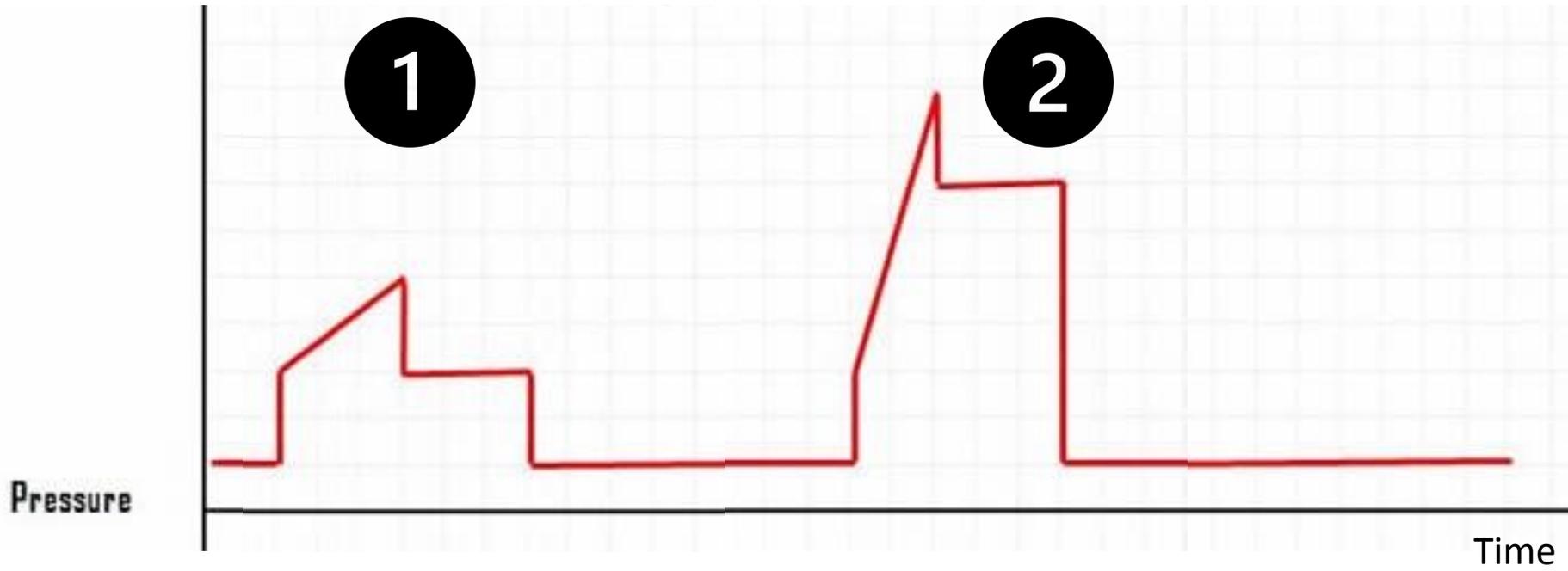
Resistance x
Flow

Volume x Elastance
or
Volume / Compliance

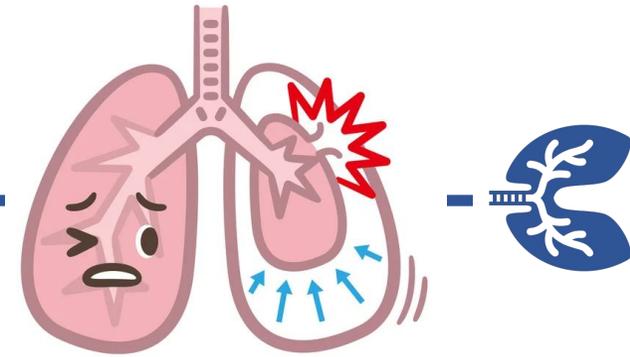


Compliance = 1/Elastance

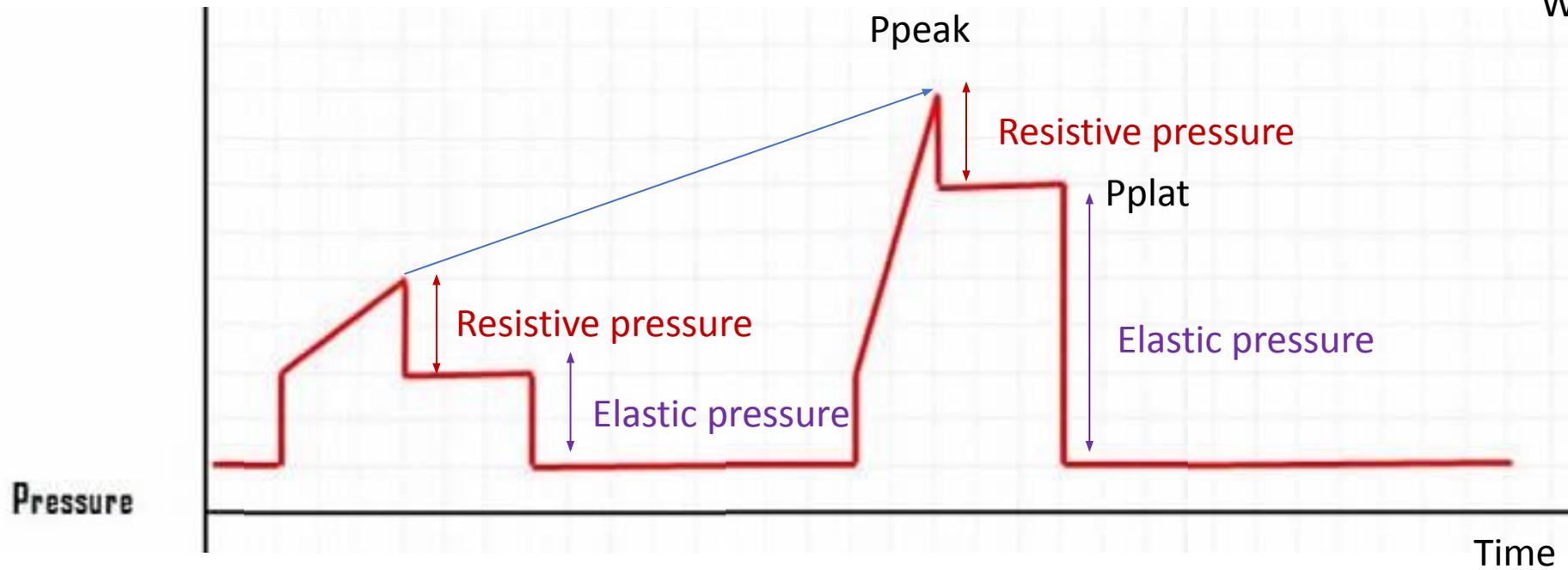


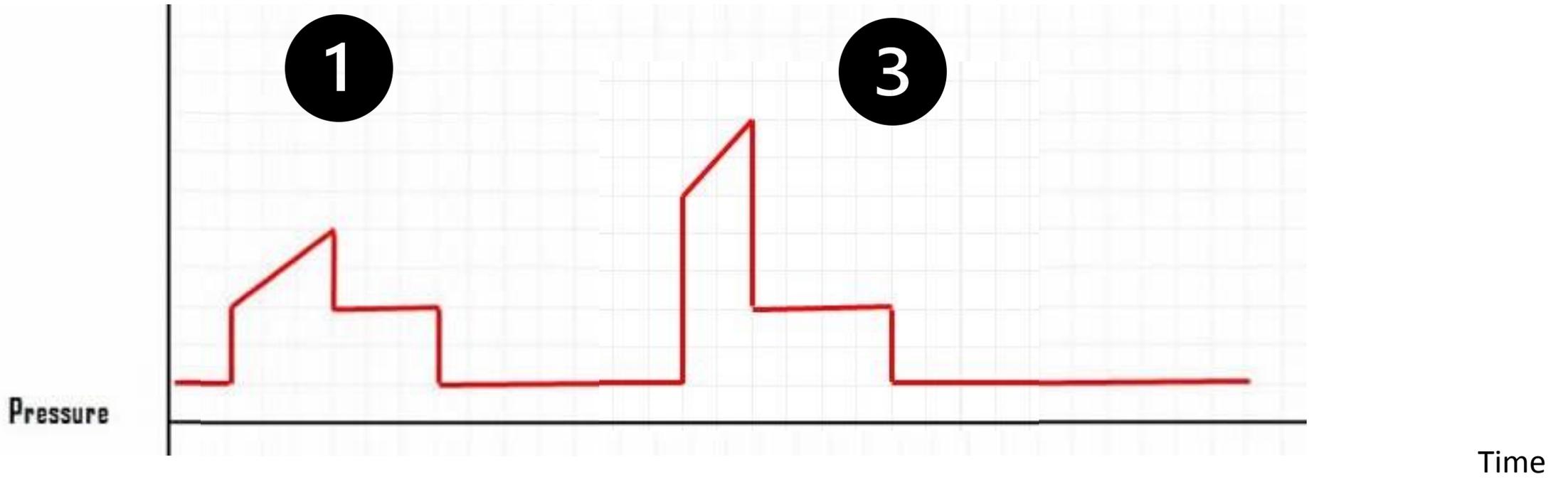


Decreased compliance

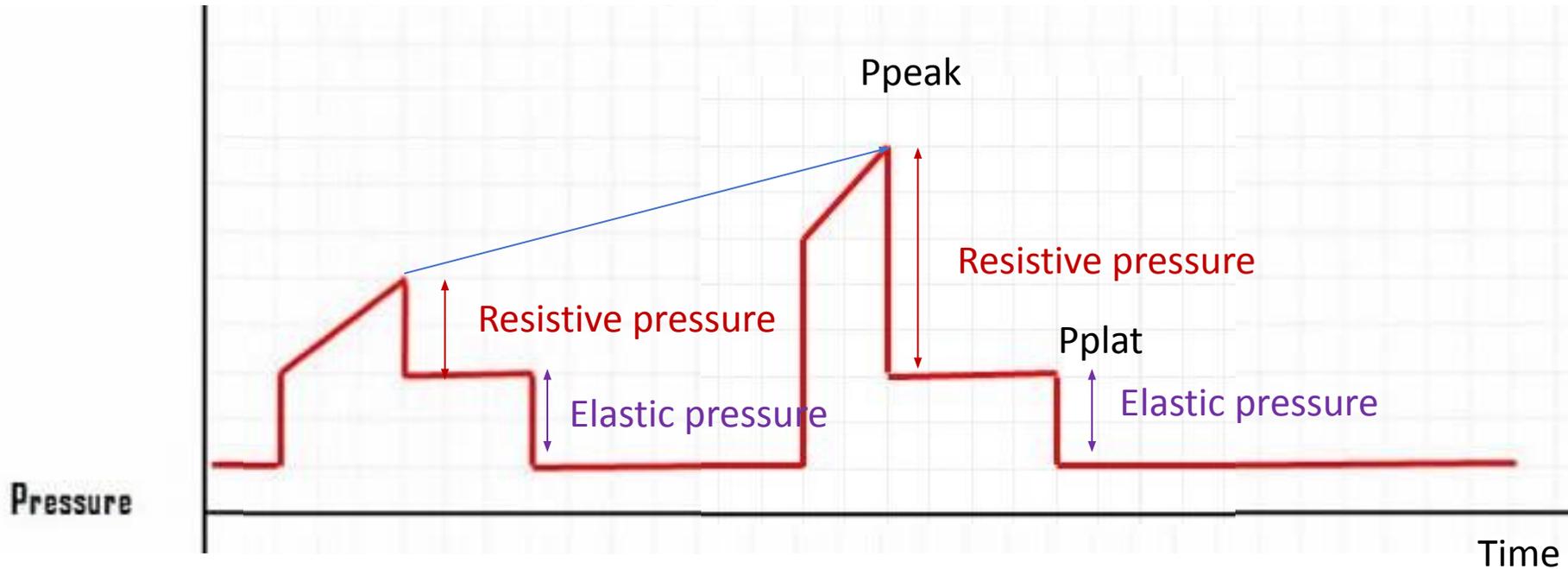
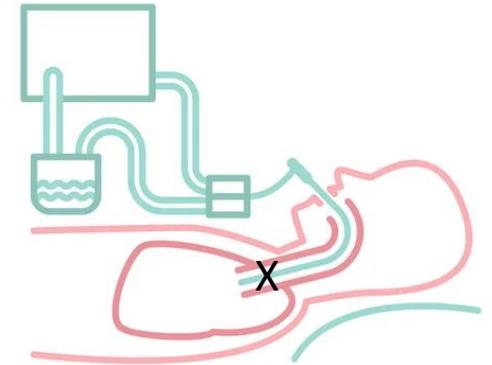


Pneumothorax
Worthening of the disease



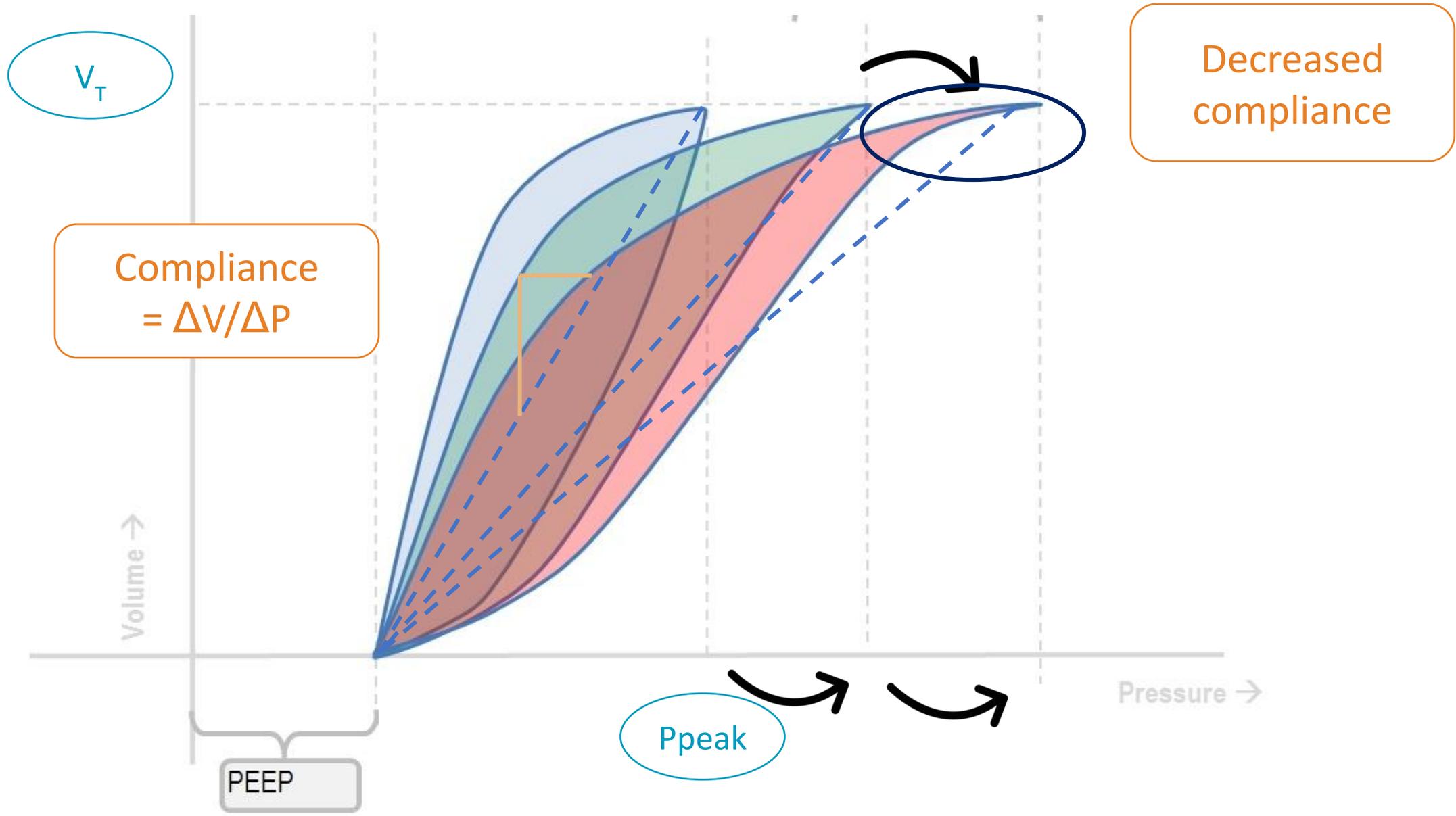


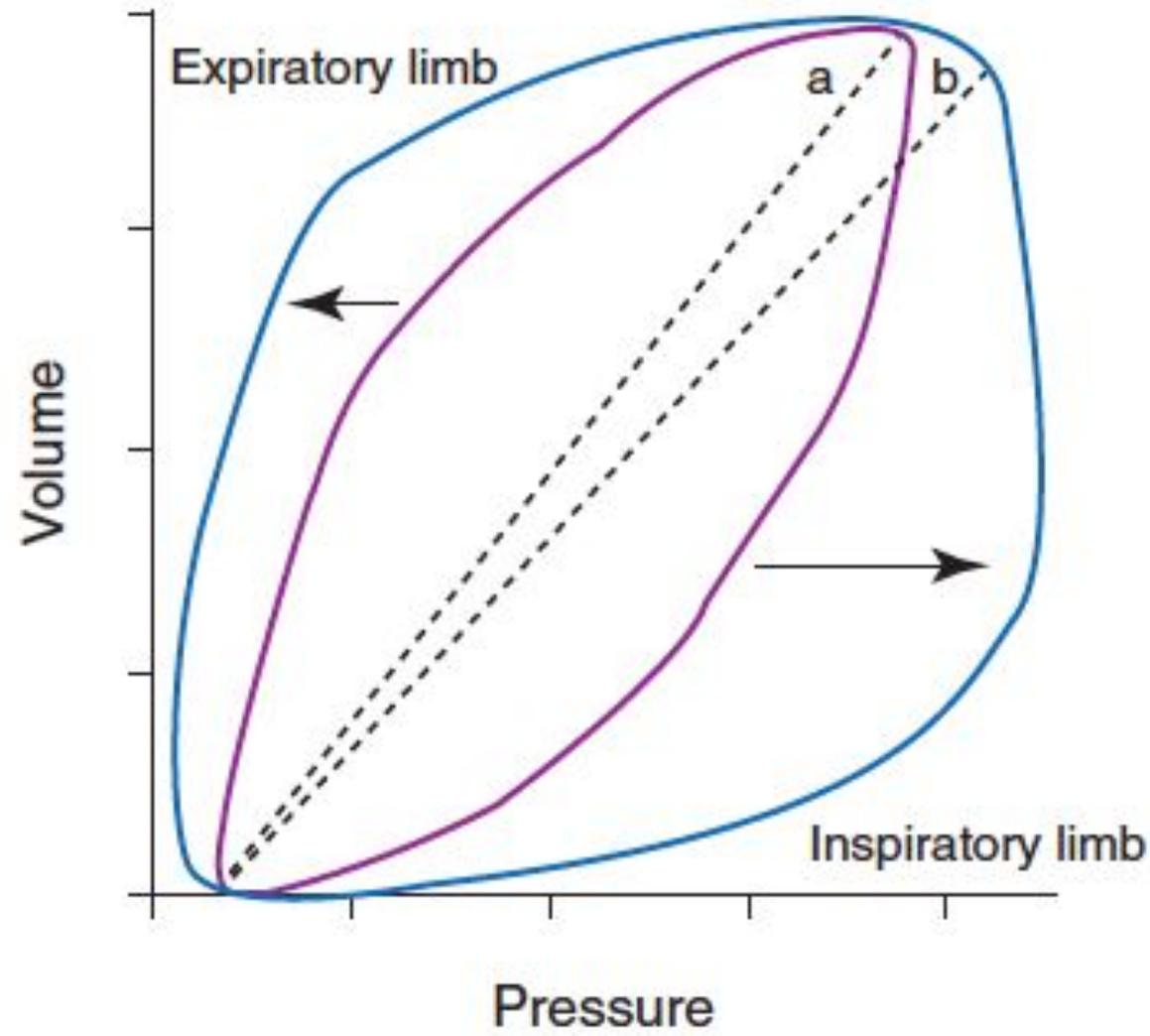
Increased resistance



Circuit/airway obstruction

Bronchospasm





Increased
resistance

I

Monitor lung's mechanics



- Address any acute changes in compliance or resistance
- Follow the trends to evaluate evolution of your lung disease
- Check for overdistension

Monitor complications of long term MV



Caggle JVECC 2023

Complication	Percent occurrence n (%)
Equipment Problems	
Leaky endotracheal tube cuff	10 (15%)
Obstructed endotracheal tube	4 (6%)
Overfilled humidifier	3 (4%)
Accidental dislodgement of tracheostomy tube	2 (3%)
Circuit leaks	2 (3%)
Tubing failure	1 (1%)
Hypoxemia due to endobronchial intubation	1 (1%)
Machine failure	1 (1%)
Pulmonary complications	
Ventilator-associated pneumonia (n = 41)	5 (12%)
Pneumothorax	3 (4%)
Renal complications	
Oliguria (n = 62)	5 (8%)
Acute kidney injury (n = 62)	4 (6%)

Gastrointestinal complications	
Regurgitation	8 (12%)
Cardiovascular complications	
Arrhythmias	33 (49%)
Hypotension	39 (58%)
Cardiopulmonary arrest	6 (9%)
Patient care-related problems	
Fluid overload	31 (46%)
Hypothermia	41 (61%)
Elevated body temperature	25 (37%)
Oral lesions	25 (37%)
Ulcerations (n = 25)	2 (8%)
Tongue swelling (n = 25)	20 (80%)
Ranula formulation (n = 25)	12 (48%)
Corneal ulcerations	24 (36%)

Retrospective

28



9



Nursing strategy



- Very important to prevent complications
- Ideally 1 nurse/care provider for 1 patient
- Importance of check-list and training



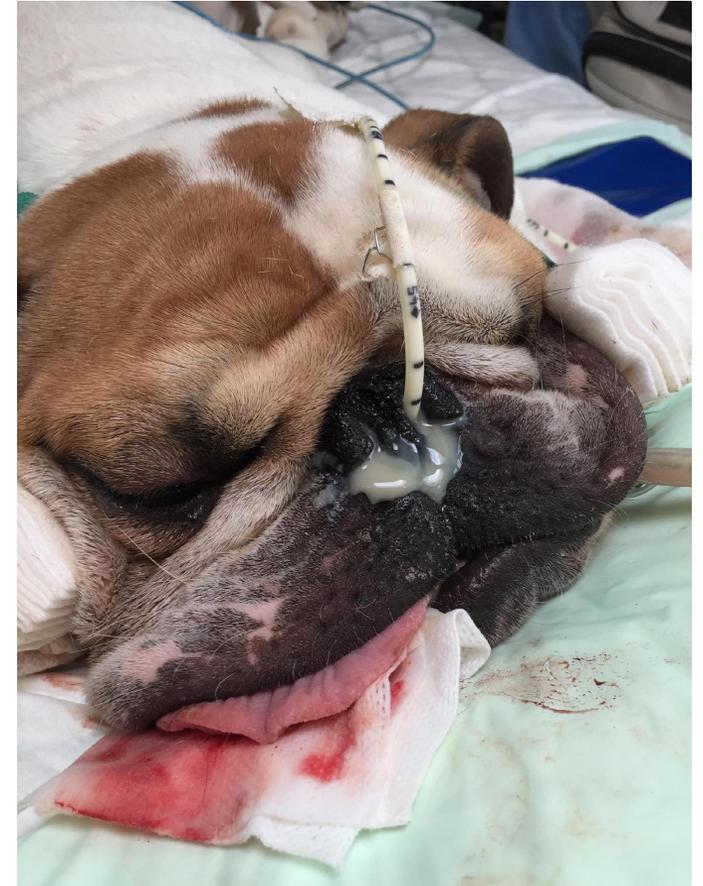
Mode: 1) A/C 2) SIMV 3) Spont.		Type: 1) PC 2) VS 3) PS 4) VS 5) TS 6) TC 7) CPAP				Trigger: p or 		IBW:		
ET Tube size:		Centimeter mark:		Diagnosis:			Clinician:			
Desired Range:		ETCO ₂	PaCO ₂	PaO ₂	SpO ₂		Code Status: Green Yellow Red			
		Time:								
Patient Monitoring	Temperature									
	Heart Rate									
	SAP/DAP									
	MAP									
	Invasive (I) Doppler (D)									
	SPO ₂									
	ETCO ₂									
Ventilator Settings	Ventilator Mode:									
	F									
	PI									
	TI									
	VT									
	Vmax									
	FiO ₂									
	PEEP									
	p or  trig									
Patient Ventilator Data	P support									
	E sens									
	Ppeak									
	Pmean									
	PEEP									
	I:E ratio									
	fTOT									
	VTE									
	VETOT									
	R STAT (cmH ₂ O/L/sec)									
	C STAT (ml/cmH ₂ O)									
	Pplateau									
	Leak									
<i>Spontaneous Breathing Trial</i>										
Initials										
Notes										

F = mandatory respiratory rate, PI = inspiratory pressure, TI = inspiratory time, VT = tidal volume, Vmax = peak inspiratory flow, FiO₂ = fraction inspired oxygen,
 PEEP = positive end expiratory pressure,  = flow, VTE = mandatory minute ventilation, VETOT = exhaled minute ventilation, RSTAT = resistance, CSTAT = compliance

Prevention of ventilator-associated pneumonia



- Pneumonia that arises > 48 hours after endotracheal intubation and mechanical ventilation
- Not present at the time of intubation



Prevention of ventilator-associated pneumonia



- **Non pharmacologic**

- Use of strict alcohol-based hand hygiene
- Minimize time of intubation
- Do not change ventilatory circuit unless contamination occurs
- Aspiration of subglottic secretions
- Maintain ET cuff pressure ≥ 25 cm H₂O

- **Pharmacologic**

- Perform oral care with dilute chlorhexidine
- Avoid increasing gastric pH prophylactically

Eye care

		Time:																		
ET/Trach tube	Suction ET/trach tube	q4h																		
	Reposition ET tube/ties	q4h																		
	Record cuff pressure	q4h																		
	Change tube ties	q24h																		
	Change ET/trach tube	PRN																		
Oral Care	Saline wipe of mucosa	q4h																		
	Brush teeth	q4h																		
	Suction oral cavity	q4h																		
Eye Care	Flush eyes with saline	q4h																		
	Lube eyes	q2h																		
	Floroscein stain	q24h																		
Nursing Care	Physiotherapy	q4h																		
	Change sides	q4h																		
	Monitor for scald/sores	q4h																		
	Move limb padding	q4h																		
	Perianal care PRN	q4h																		
	Reposition probes/lines	q4h																		
	Flush unused IVC/ports	q4h																		
	Flush arterial line	q1h																		
	Central line care	q4h																		
	Monitor insertion sites	q8h																		
Urinary catheter care	q8h																			
Fluid Monitoring	Urine specific gravity																			
	Urine output (ml/kg/hr)																			
	Monitor GRV																			
	Total fluid out																			
	Total fluid in																			
	PCV/TS																			
	Blood Glucose																			
	Lactate																			
Blood Gas	pH																			
	PaCO ₂																			
	PaO ₂																			
	HCO ₃																			
	BE																			



Nursing care

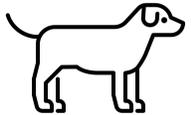
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Blood Gas	pH																			
	PaCO ₂																			
	PaO ₂																			
	HCO ₃																			
	BE																			



Positioning and lung injury



- Prone position
 - Improvement in V/Q matching
 - Decrease mortality in severe ARDS



- Improved oxygenation and reduce VILI compared to dorsal recumbency
 - Usually, ventilation in sternal recumbency...
- Try sternal or lateral recumbency and assess your patient

Fluid monitoring

		Time:																		
ET/Trach tube	Suction ET/trach tube	q4h																		
	Reposition ET tube/ties	q4h																		
	Record cuff pressure	q4h																		
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Blood Gas	Lactate																			
	pH																			
	PaCO ₂																			
	PaO ₂																			
	HCO ₃																			
BE																				



Fluid overload



Fluid therapy

Enteral nutrition



SIAHS

Medications

AKI

Prevention fluid overload



In = Out

Weight

Urine output



Conservative
Fluid management

Furosemide

Criteria to wean



- Improvement in the primary disease process
- Improvement of oxygen parameters
 - P/F ratio > 150-200 with $\text{FiO}_2 < 0.5$
- PEEP ≤ 5 cm H₂O
- Adequate respiratory drive
- Hemodynamic stability
- Absence of major organ failure

Weaning process



- Decrease anesthesia
- Spontaneous breath trials
 - Leave the patient connected to the machine, spontaneous mode
 - + Monitoring
 - - Increased resistance so WOB => add CPAP and/or PSV (2-5 cm H₂O)
 - Disconnecting the patient from the machine
- Switch to NIV technique after extubation

Conclusion



- NCPE includes a large variety of disease
- Some patient will require mechanical ventilation
- Monitoring and nursing care are mandatory

Thank you for your attention

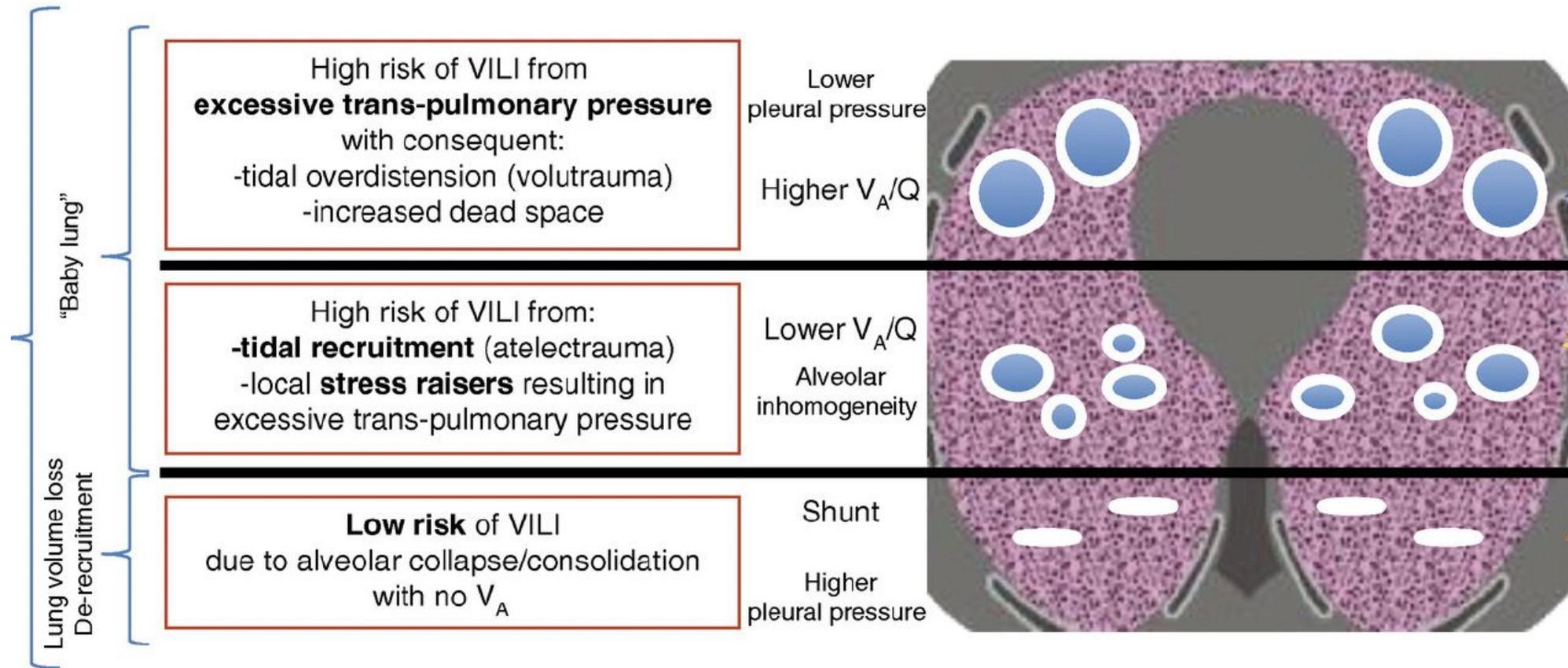


Enteral nutrition



- Benefits
 - Decrease GI bleeding and
 - Prevent villous atrophy
 - Reduce bacterial translocation risk
- Risks
 - Increase risk of reflux and aspiration pneumonia
- Delivered via NG, gastrostomy or jejunostomy tube
- Bolus or CRI

Heterogeneous lungs





A

Normal lung

