23ème CONGRÈS NATIONAL DE LA SAARSIU

LE 14, 15 ET LE 16 DÉCEMBRE 2023

A L'HÔTEL MERCURE ALGER

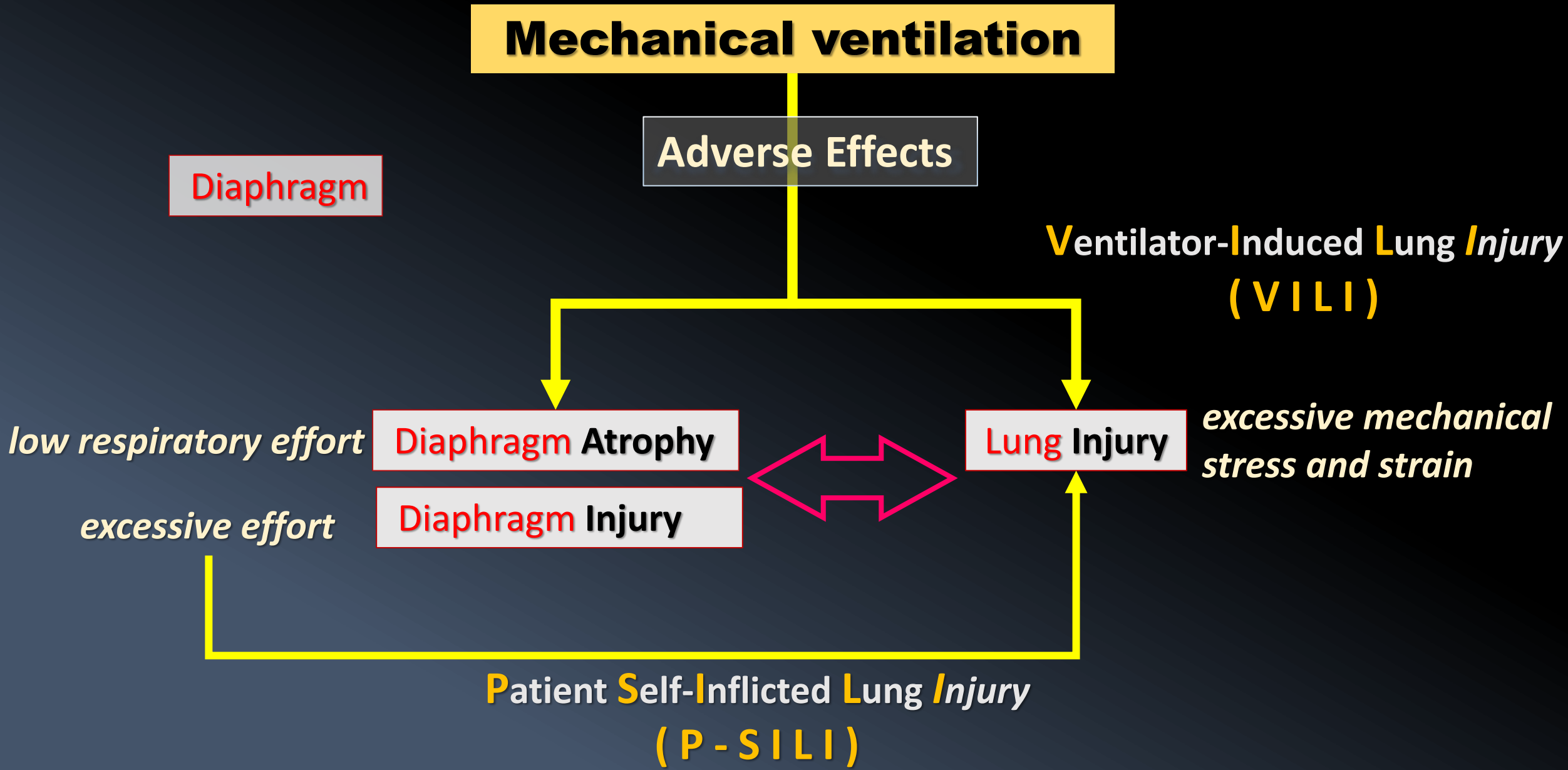
MEDICO MEDLINE

Ventilation Protectrice et Asynchronies

Dr Abad Salem

mindray

healthcare within reach



Slutsky AS, Ranieri VM. Ventilator-induced lung injury. N Engl J Med

Lung and Diaphragm-protective mechanical ventilation approach

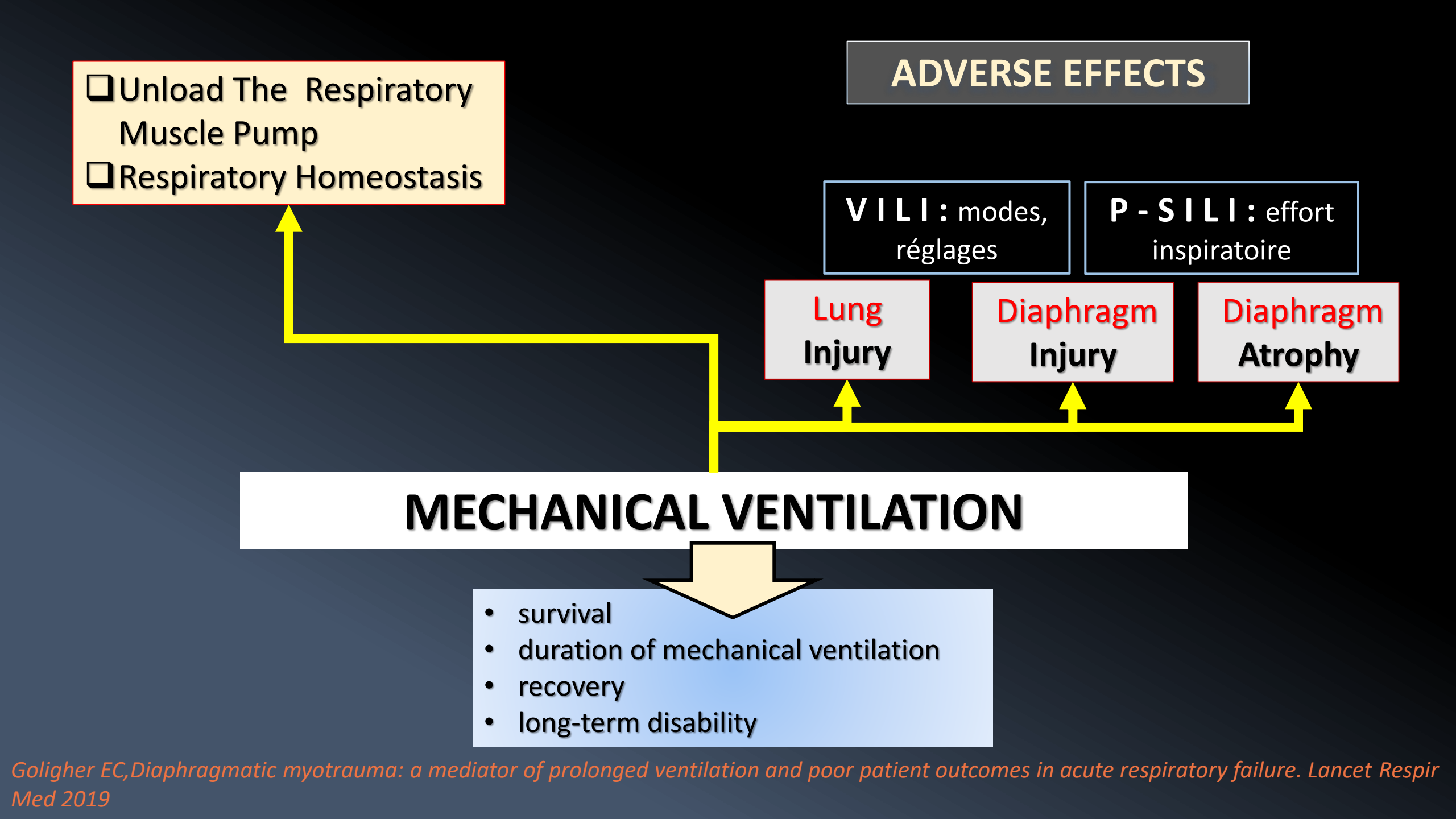
CHALLENGE…

Avoid
Lung And Diaphragm Injury

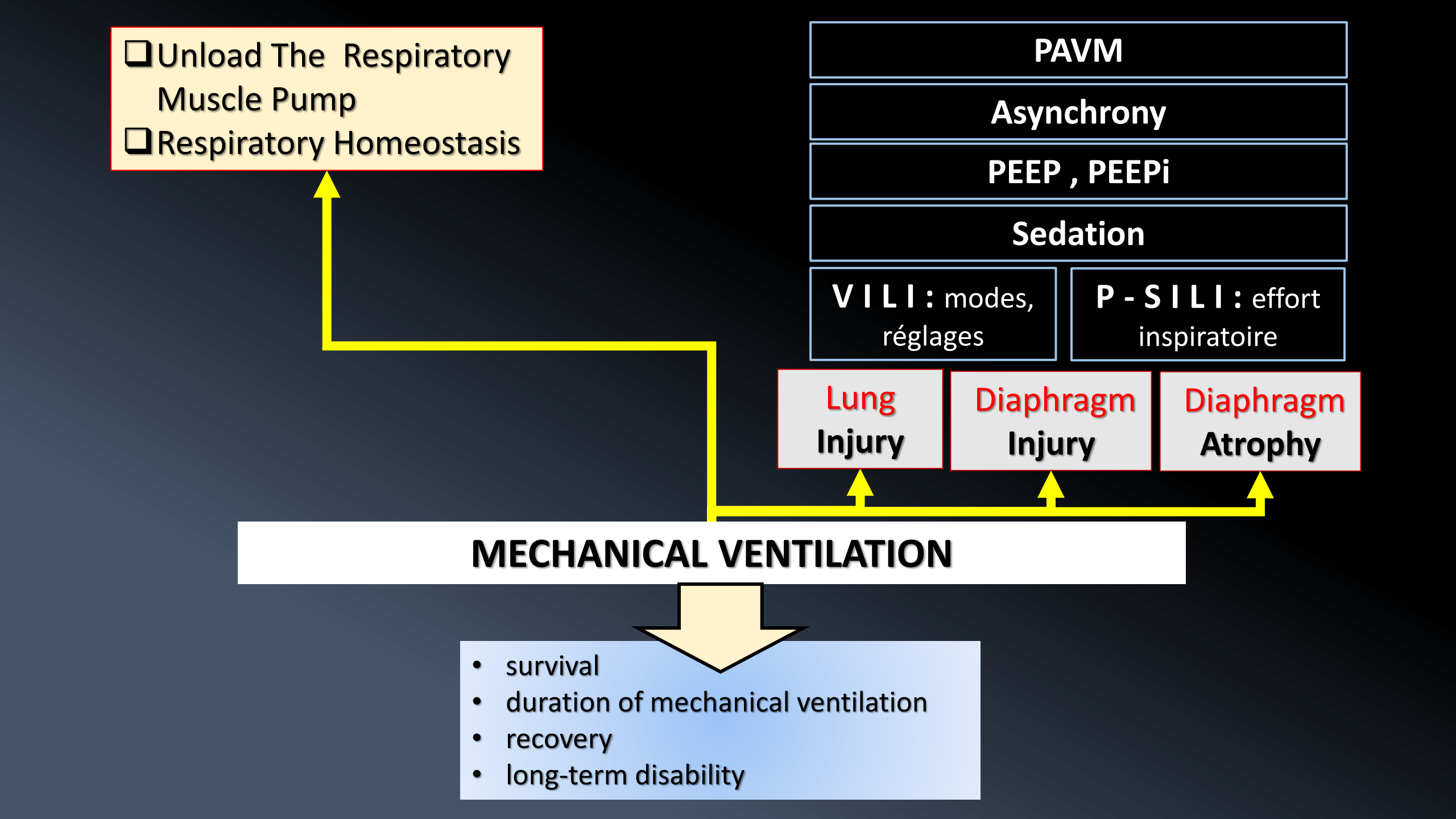
Maintaining
Respiratory Homeostasis

Optimizing Patient Respiratory Effort

Brochard L, Mechanical ventilation to minimize progression of lung injury in acute respiratory failure. Am J Respir Crit Care Med 2017



Goligher EC,Diaphragmatic myotrauma: a mediator of prolonged ventilation and poor patient outcomes in acute respiratory failure. Lancet Respir Med 2019


Unload The Respiratory Muscle Pump
Respiratory Homeostasis
PAVM
Asynchrony
PEEP , PEEPi
Sedation
V I L I : modes, réglages
P - S I L I : effort inspiratoire
Lung Injury
Diaphragm Injury
Diaphragm Atrophy
MECHANICAL VENTILATION
survival
duration of mechanical ventilation
recovery
long-term disability

Implementation **Lung** and **Diaphragm**-protective mechanical ventilation

PROTECTIVE VENTILATION PARAMETERS

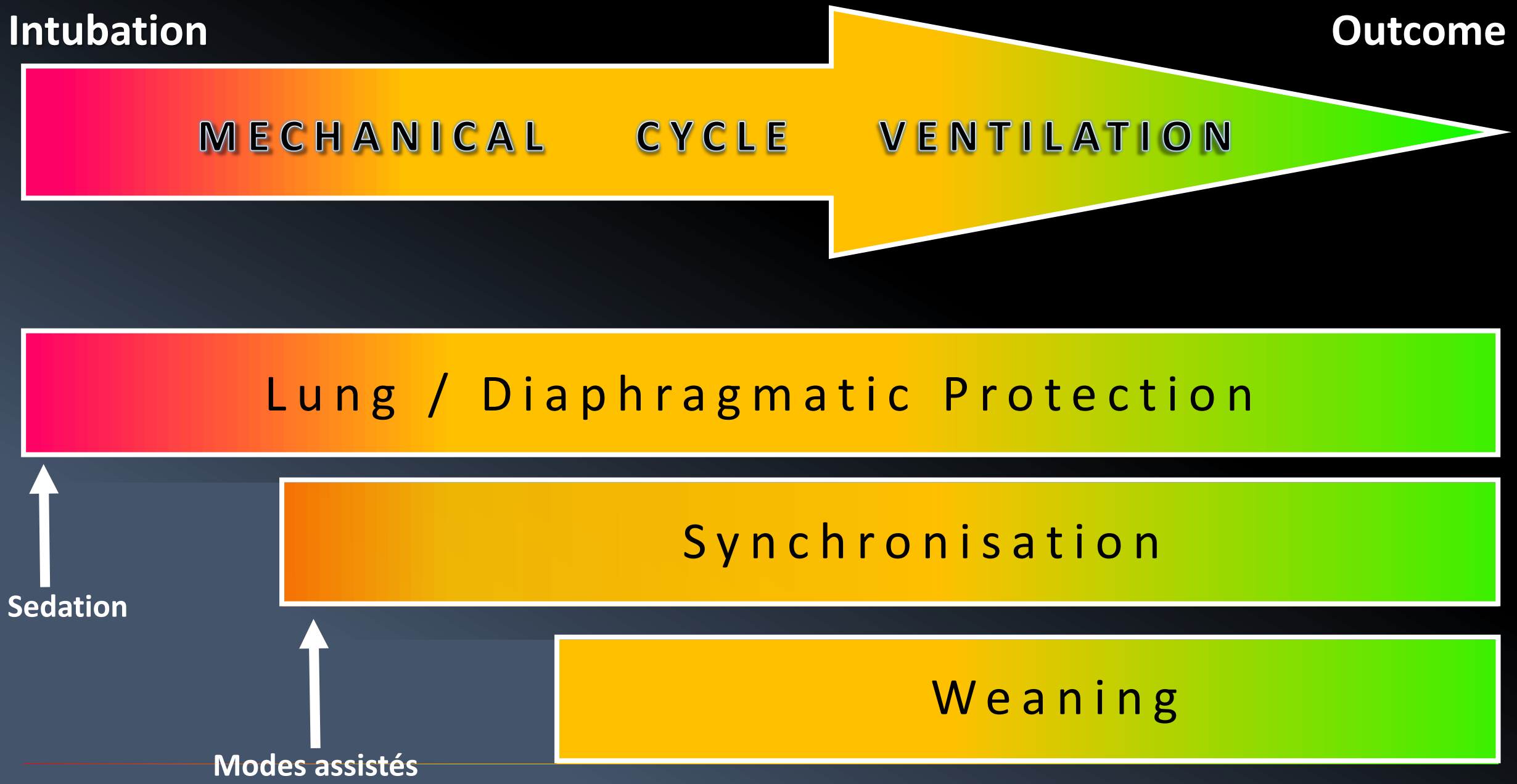
- ❑ **Lung Stress / Strain**
- ❑ **Modes ventilatoires**
- ❑ **Respiratory Effort And Drive**
- ❑ **Asynchrony**

mindray
healthcare within reach

Monitoring
Lung and Diaphragmatic Injury

Lung Protection

Diaphragm Protection


Intubation
Outcome
MECHANICAL CYCLE VENTILATION
Lung / Diaphragmatic Protection
Synchronisation
Weaning
Sedation
Modes assistés

Lung / Diaphragmatic Protection

Modes assistés contrôlés

- **High** Sedation
- **High** Ventilator Assistance
- **+/- High** PEEP
- **Low** Respiratory Effort And Drive

Avantages ?	Risques ?
▪ **Low** Asynchrony	▪ V I L I ▪ A t r o p h y

Levine S, Rapid disuse atrophy of diaphragm fibers in mechanically ventilated humans. N Engl J Med 2008

Lung / Diaphragmatic Protection

Synchronisation

Modes assistés contrôlés

- **High** Sedation
- **High** Ventilator Assistance
- **+/- High** PEEP
- **Low** Respiratory Effort And Drive

Avantages ?	Risques ?
▪ Low Asynchrony	▪ VILI ▪ Atrophy

Modes assistés

- **Low** Sedation
- **Low** Ventilator Assistance
- **+/- High** PEEP
- **High** Respiratory Effort And Drive

Avantages ?	Risques ?
▪ Atelectasis ▪ Oxygenation ▪ Pulm. Vasc. Resist. ▪ Atrophy	▪ VILI ▪ P-SILI ▪ Diaphr. Injury ▪ Asynchrony

Intensity of Inspiratory EFFORT..

Rittayamai N,. Effect of inspiratory synchronization during pressure controlled ventilation on lung distension and inspiratory effort. Ann Intensive Care 2017

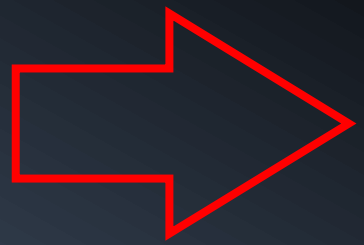
Synchronisation

Risques ?

Intensity of Inspiratory EFFORT..

Mechanisms

- **Distending Pressure and Tidal Volumes**
- **Pendelluft**
- **Patient–Ventilator Asynchrony**



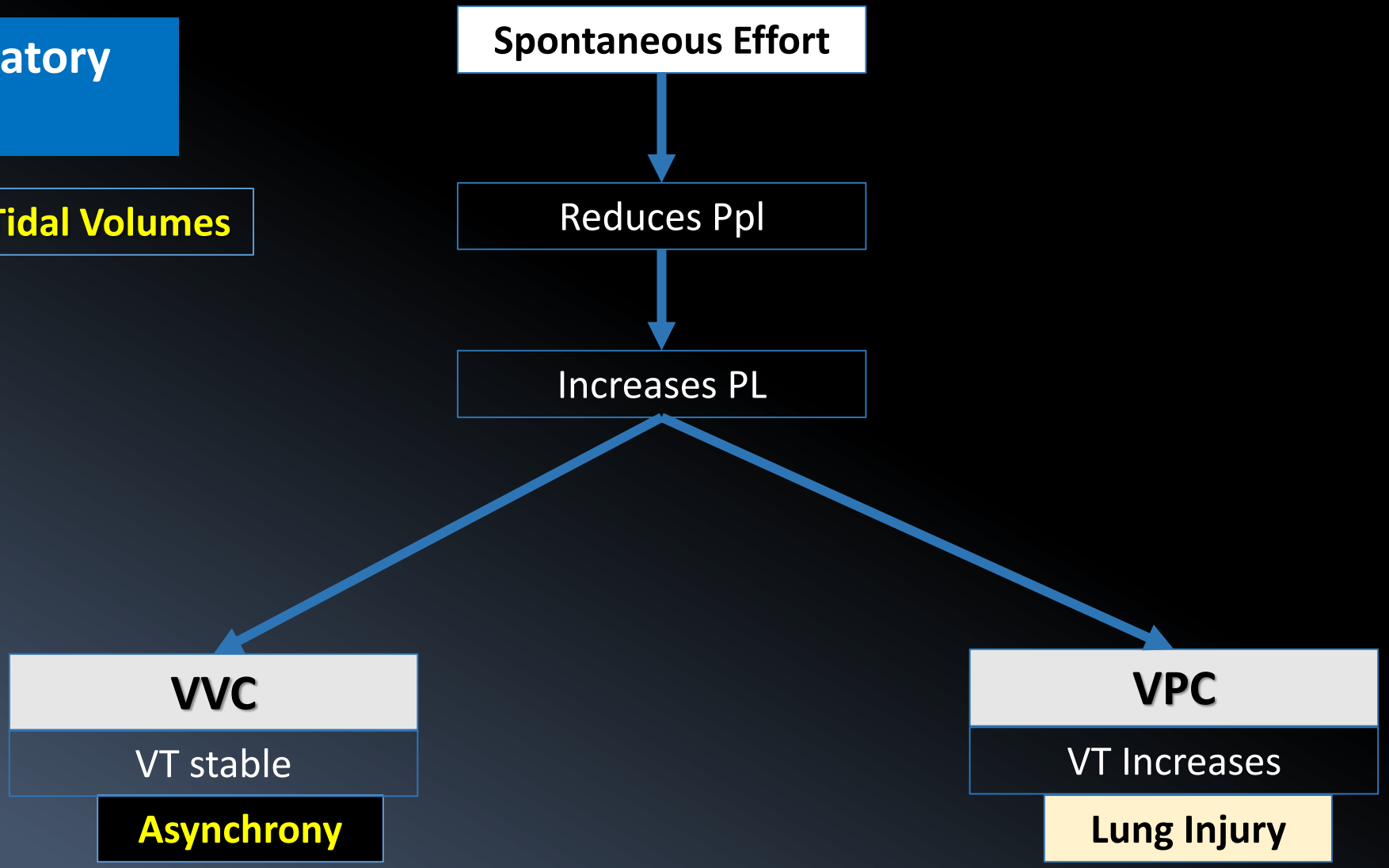
Consequences

- VILI
- P-SILI
- Diaphr. Injury
- Asynchrony

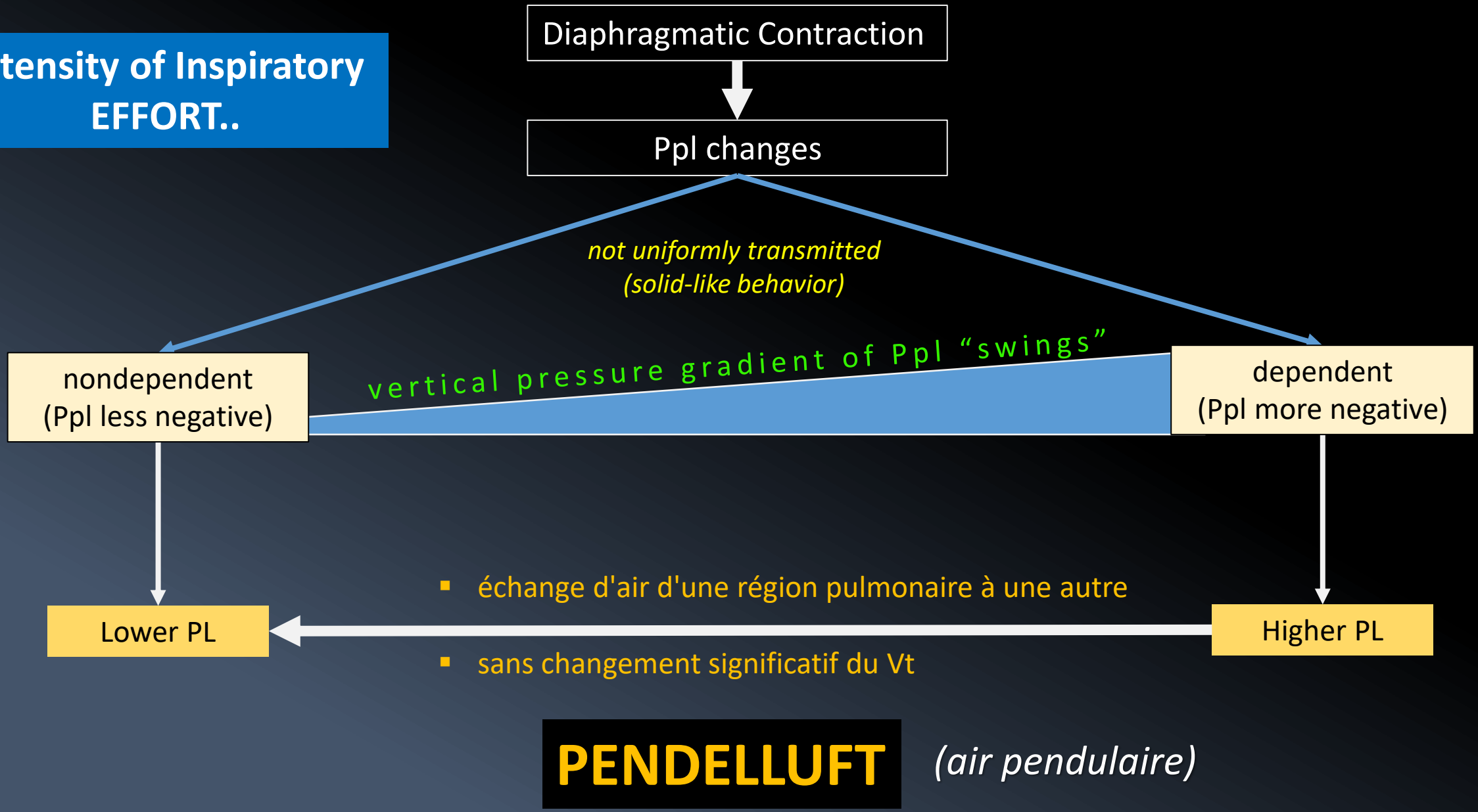
Yoshida T, Fifty years of research in ARDS: spontaneous breathing during mechanical ventilation. Risks, mechanisms, and management. Am J Respir Crit Care Med 2017

Intensity of Inspiratory EFFORT..

- **Distending Pressure and Tidal Volumes**



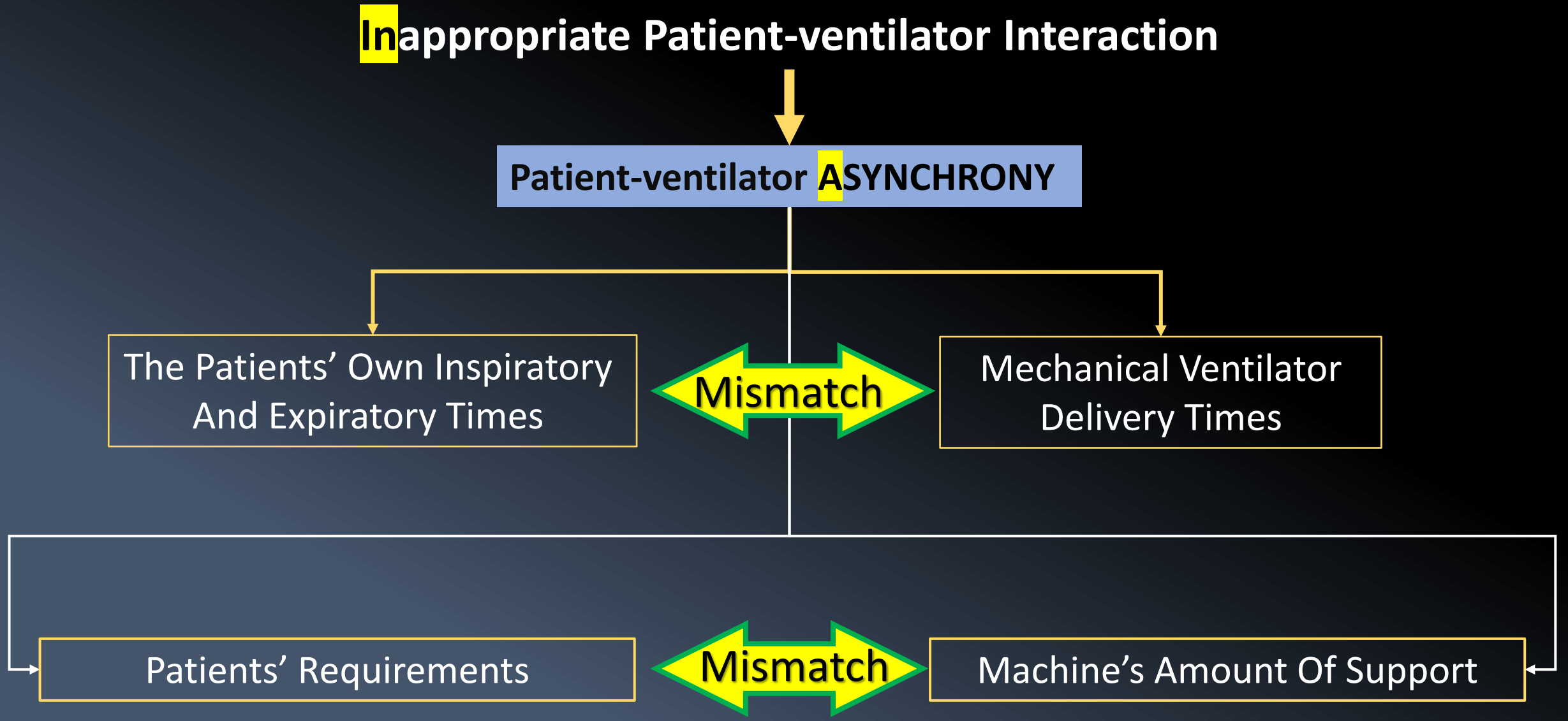
Intensity of Inspiratory EFFORT..

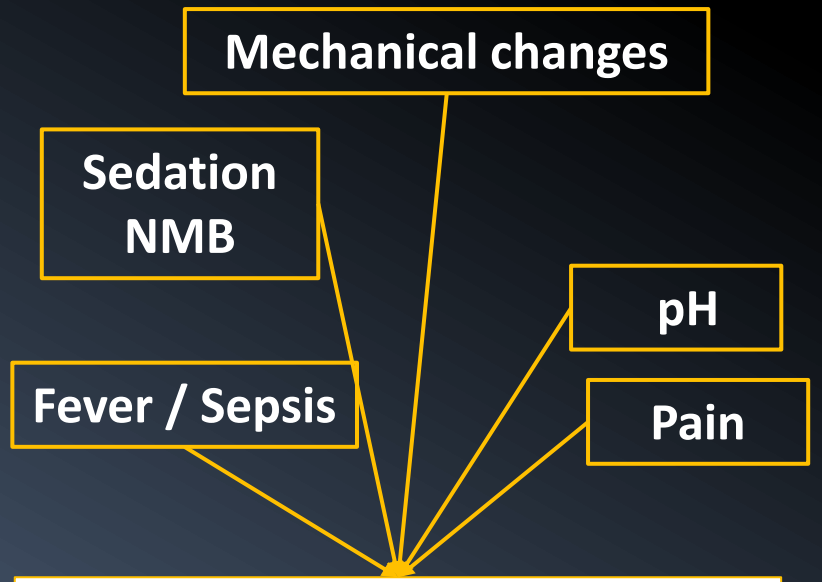


PENDELLUFT *(air pendulaire)*

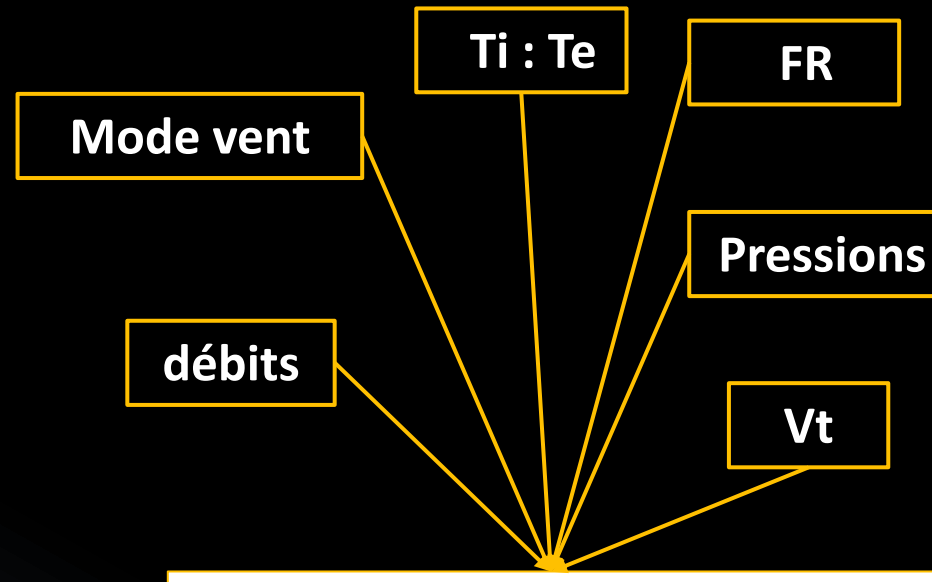
Yoshida T, Spontaneous effort causes occult pendelluft during mechanical ventilation. Am J Respir Crit Care Med 2013

Intensity of Inspiratory EFFORT..





Challenge



Respiratory Drive

MODES ASSISTÉS

Reglages

Effort Patient

Ti Patient = Ti Ventilateur

Débit insp. Patient = Débit insp. Ventilateur

Ventilateur

Challenge

Respiratory Drive

Effort Patient

MODES ASSISTÉS

Ti Patient = **Ti Ventilateur**

Débit insp. Patient = **Débit insp. Ventilateur**

Reglages

Ventilateur

Premature Cycling

Delayed Cycling

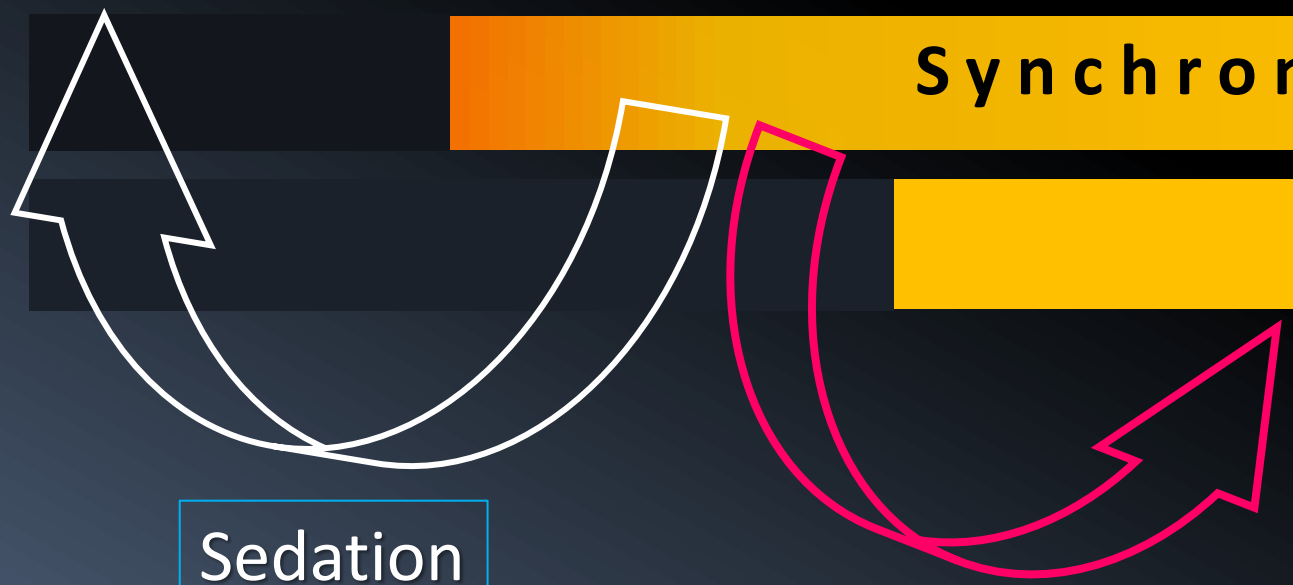
Excessive Inspiratory Flow

Insufficient Inspiratory Flow

Lung / Diaphragmatic Protection

Synchronisation

Weaning



Sedation

Often Possible

Adjustment of Ventilatory Parameters

Lower Sedation Requirements

Ventilator ?

Patient ?

Classification of Patient-Ventilator Asynchrony

❑ Trigger Asynchrony

- Ineffective Triggering
- Double Triggering
- Reverse Triggering
- Auto-triggering

❑ Flow Asynchrony

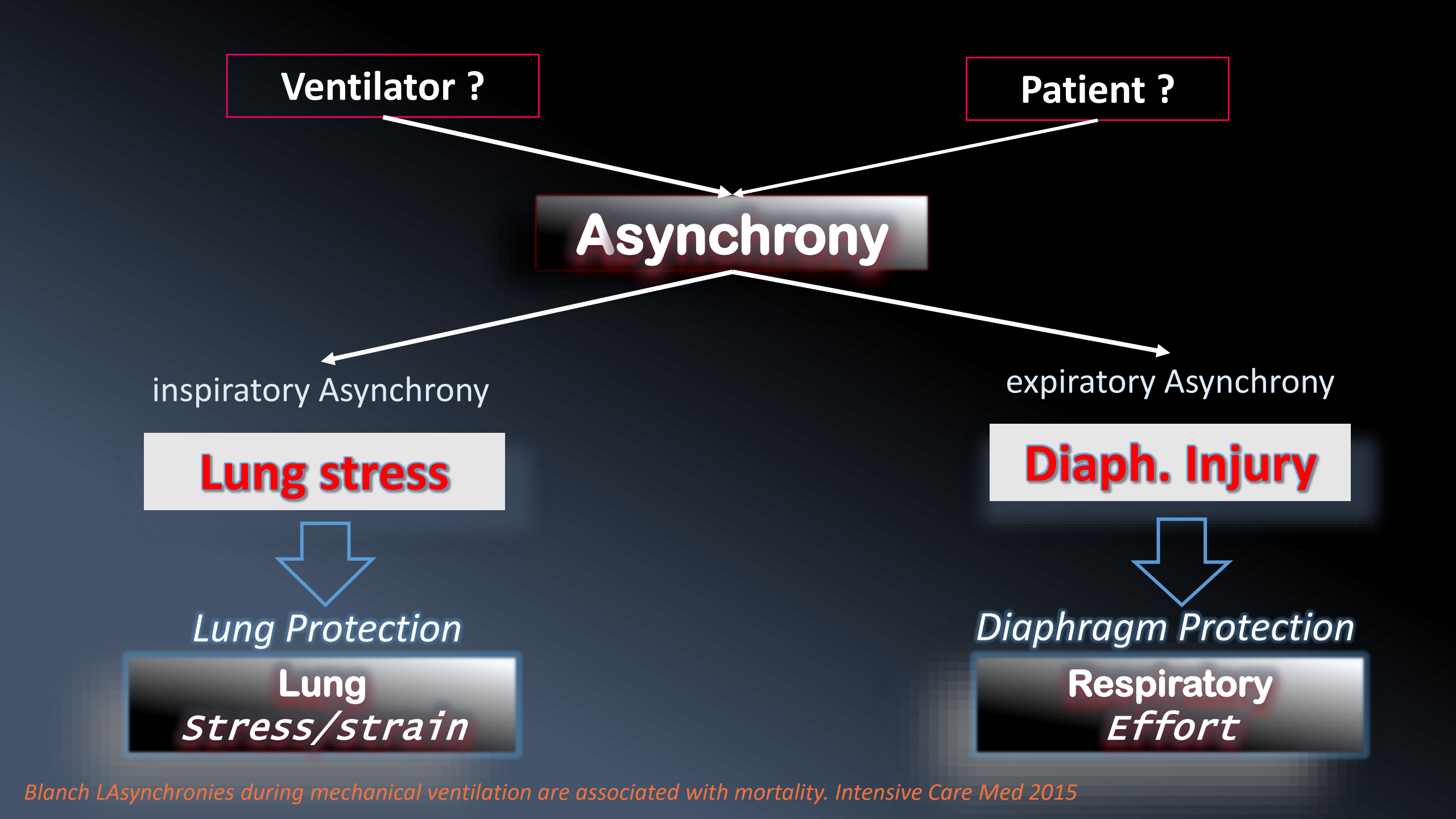
- Insufficient Inspiratory Flow
- Excessive Inspiratory Flow

❑ Cycling Asynchrony

- Premature Cycling
- Delayed Cycling

Ventilator ?

Patient ?



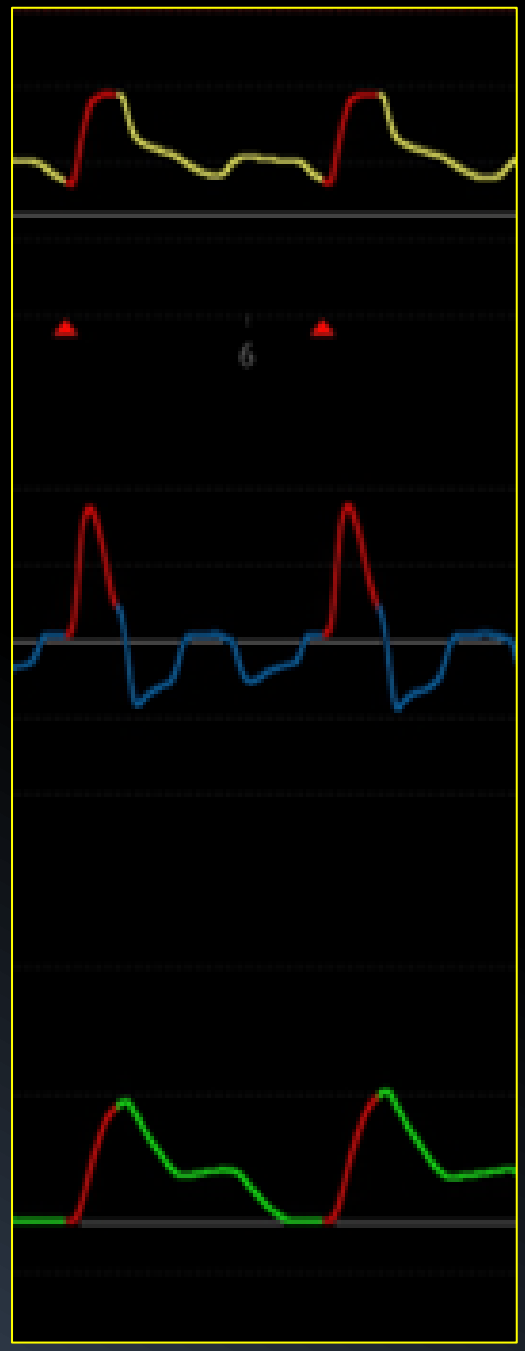
Blanch LAsynchronies during mechanical ventilation are associated with mortality. Intensive Care Med 2015

Ineffective Triggering

➔ *Effort unable to trigger the ventilator*

- **Eccentric contractions**
- **Erroneous display of respiratory rate**

Muscle Injury




Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
40
25.0
10.0
-5.0
-20
0 s
3
6
9
12
15
18
Débit
l/min
60
30
0
-30
-60
Volume
ml
500
250
0
-100
Pcrête
cmH2O
40
23
10
Pplat
cmH2O
20
PEP
cmH2O
9.4
VMe
l/min
10.0
6.35
3.0
Vte
ml
560
245
250
ftotal
/min
35
26
8
FiO2
vol.%
72
65
58
Ri
cmH2O/l/s
5
Vte/PCI
ml/kg
3.5
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
65
vol.%
PEP
10
cmH2O
PAI
13
cmH2O

➢ Fully Sedated Patients *(drive abolished)*

Reverse Triggering

Double-triggering

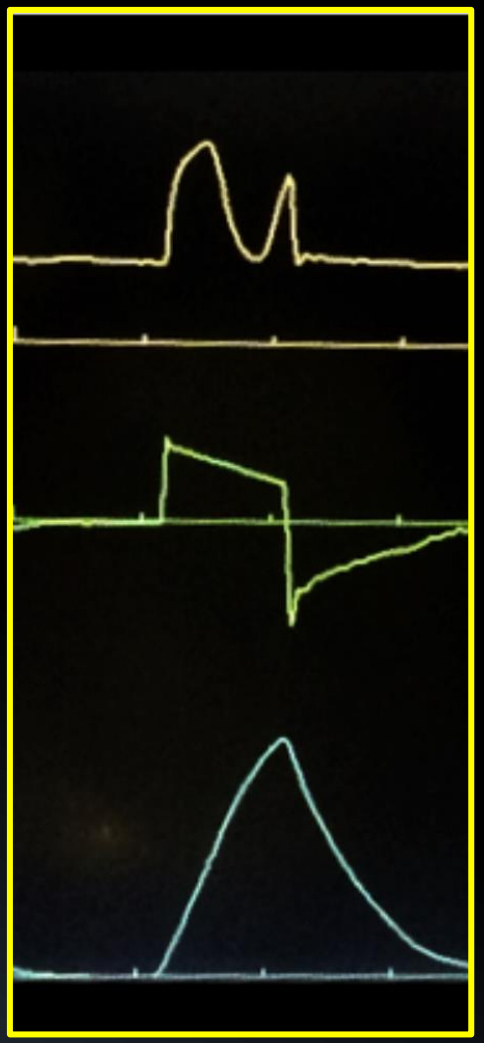
breath stacking

excessive tidal volumes

High Dynamic Lung Stress

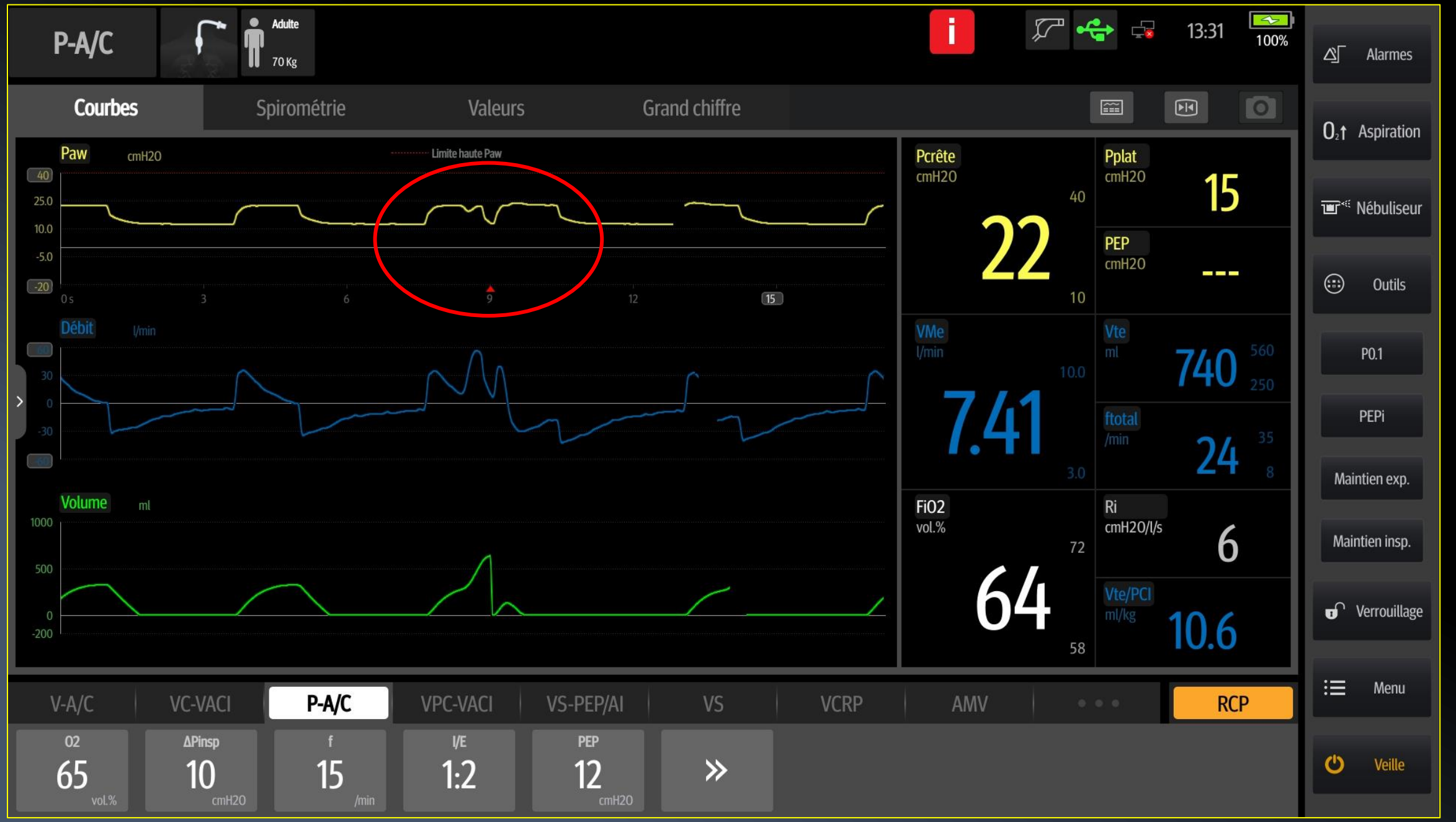
eccentric diaphragm loading conditions

Muscle Injury



Akoumianaki E, Mechanical ventilation–induced reverse-triggered breaths: a frequently unrecognized form of neuromechanical coupling. Chest 2013


VC-VACI
Adulte
70 Kg
22:17
100%
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
30
15
0
-6
0 s
3
6
9
12
15
Débit
l/min
60
30
0
-30
-60
Volume
ml
500
250
0
-100
Pcrête
cmH2O
40
20
10
Pplat
cmH2O
17
PEP
cmH2O
8.0
VMe
l/min
10.0
8.27
3.0
Vte
ml
560
421
250
ftotal
/min
35
19
8
FiO2
vol.%
57
49
43
RCexp
s
0.64
Vte/PCI
ml/kg
6.0
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
50
vol.%
Vt
420
ml
fVACI
19
/min
Tinsp
1.30
s
PAI
3
cmH2O
PEP
8
cmH2O


P-A/C
Adulte
70 Kg
13:31
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
PEPi
Maintien exp.
Maintien insp.
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
40
25.0
10.0
-5.0
-20
0 s
3
6
9
12
15
Débit
l/min
60
30
0
-30
-60
Volume
ml
1000
500
0
-200
Pcrête
cmH2O
40
22
10
Pplat
cmH2O
15
PEP
cmH2O

VMe
l/min
10.0
7.41
3.0
Vte
ml
740
560
250
ftotal
/min
24
35
8
FiO2
vol.%
72
64
58
Ri
cmH2O/l/s
6
Vte/PCI
ml/kg
10.6
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
65
vol.%
ΔPinsp
10
cmH2O
f
15
/min
I/E
1:2
PEP
12
cmH2O

Ti Patient

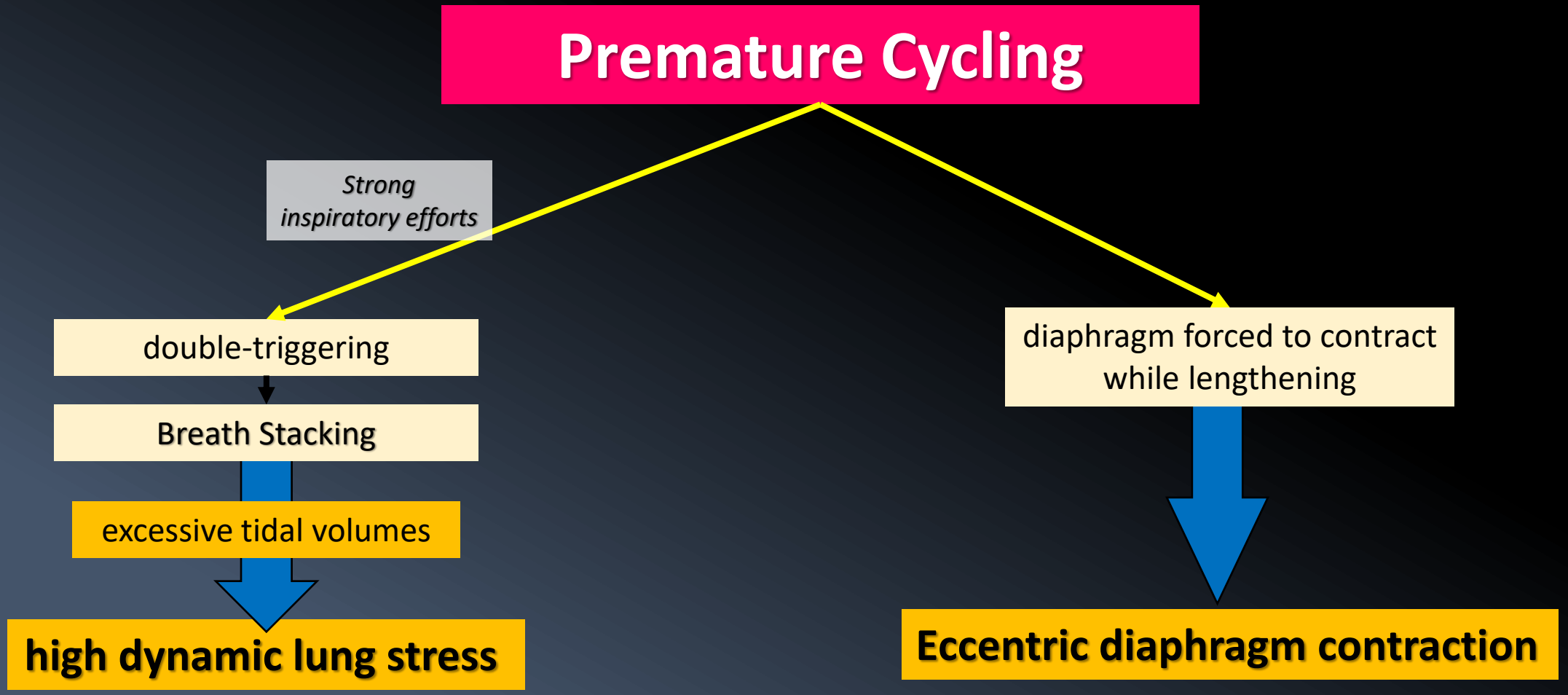
Ti Ventilateur

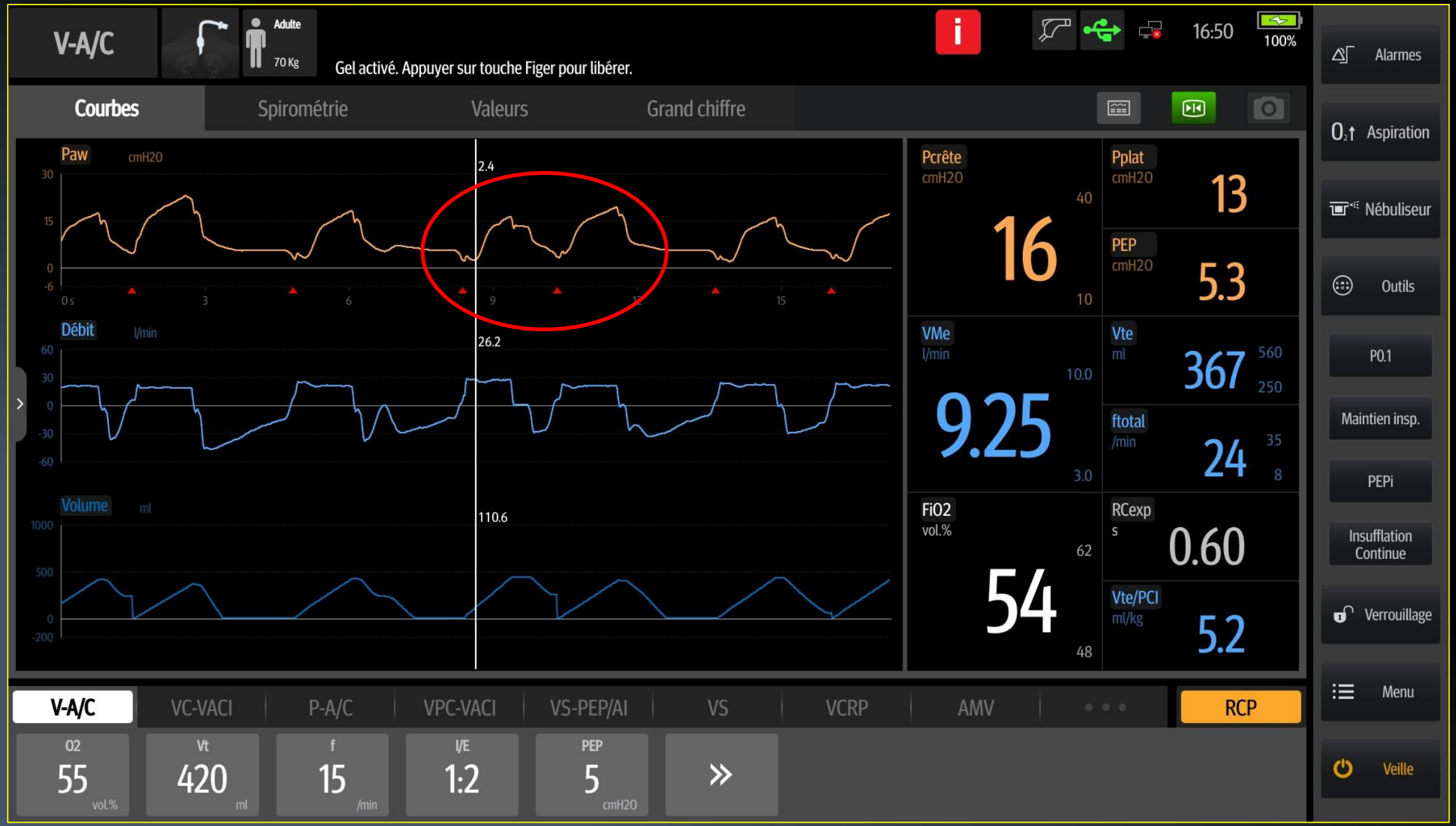
Premature Cycling

(Short cycles)

Continuation of inspiratory effort after the end of insufflation

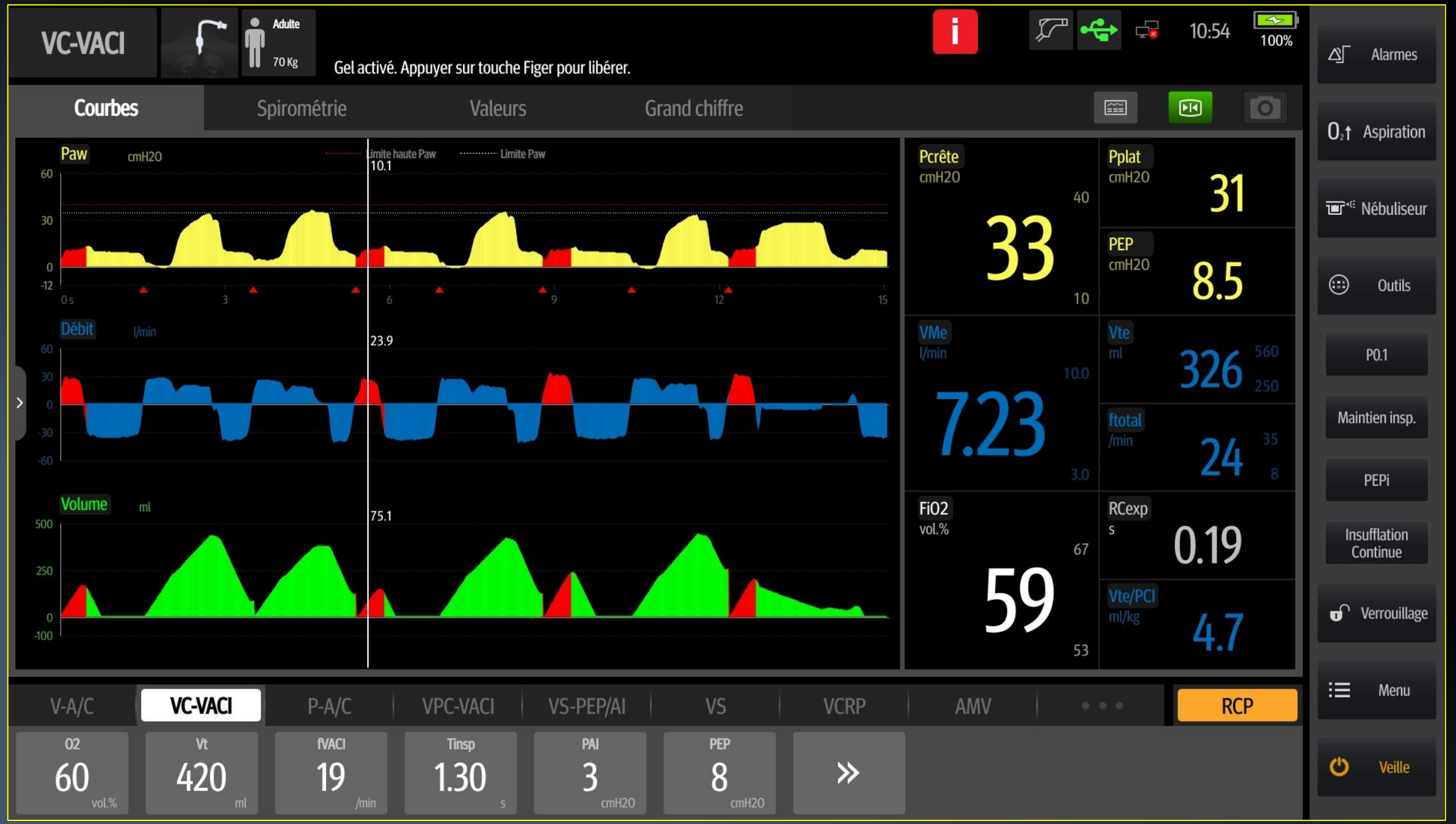
Neural Inspiration Time >>> Mechanical Inflation Time


Premature Cycling
Strong inspiratory efforts
double-triggering
Breath Stacking
excessive tidal volumes
high dynamic lung stress
diaphragm forced to contract while lengthening
Eccentric diaphragm contraction

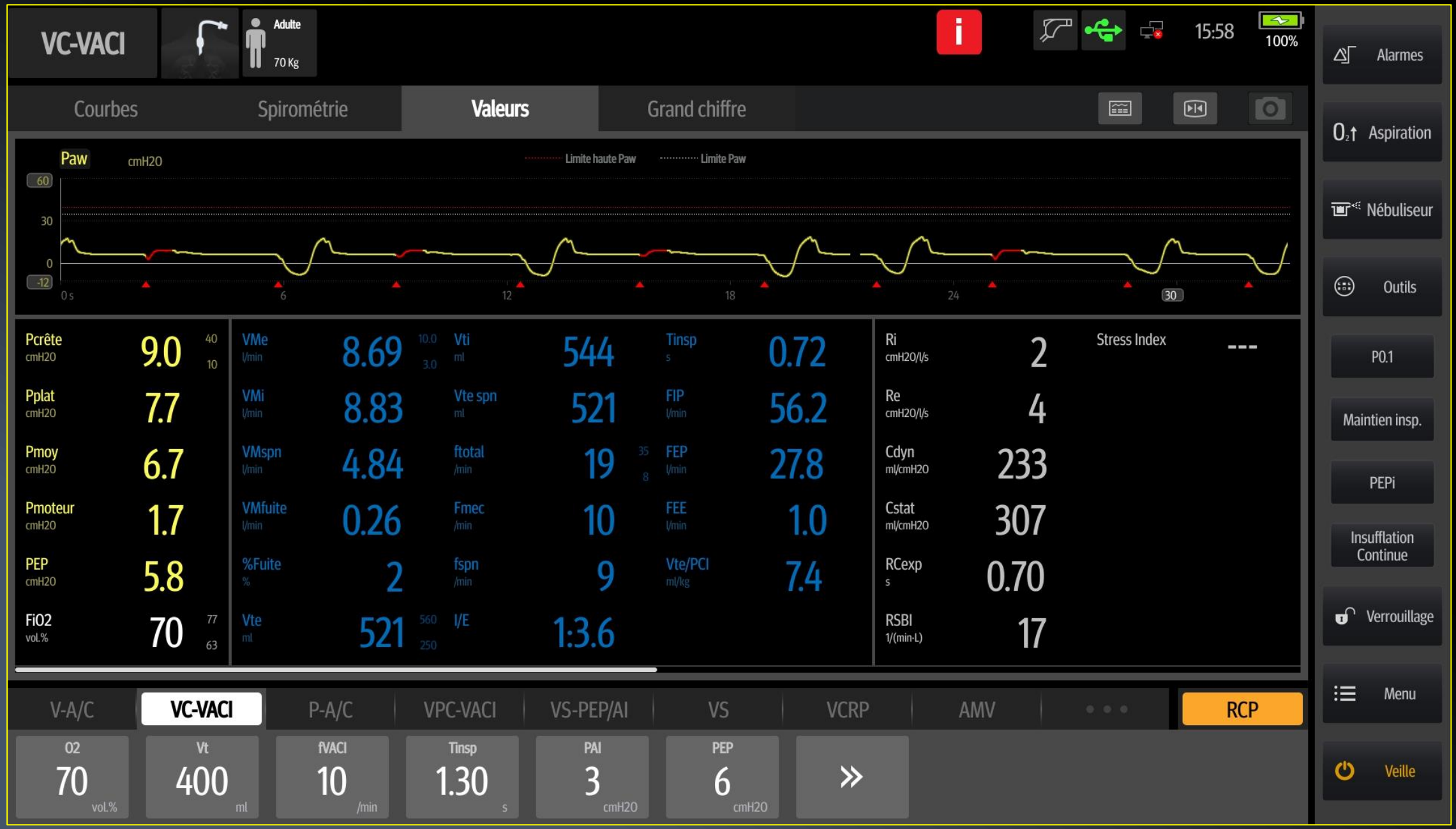

V-A/C
Adulte
70 Kg
Gel activé. Appuyer sur touche Figer pour libérer.
16:50
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
2.4
Débit
l/min
26.2
Volume
ml
110.6
Pcrête
cmH2O
16
Pplat
cmH2O
13
PEP
cmH2O
5.3
VMe
l/min
9.25
Vte
ml
367
ftotal
/min
24
FiO2
vol.%
54
RCexp
s
0.60
Vte/PCI
ml/kg
5.2
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
55
vol.%
Vt
420
ml
f
15
/min
I/E
1:2
PEP
5
cmH2O

Insufficient Inspiratory Flow

The Flow Received By The Patient Is Lower Than His Ventilatory Demand


VC-VACI
Adulte
70 Kg
Gel activé. Appuyer sur touche Figer pour libérer.
10:54
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
Limite Paw
10.1
Débit
l/min
23.9
Volume
ml
75.1
Pcrête
cmH2O
33
Pplat
cmH2O
31
PEP
cmH2O
8.5
VMe
l/min
7.23
Vte
ml
326
ftotal
/min
24
FiO2
vol.%
59
RCexp
s
0.19
Vte/PCI
ml/kg
4.7
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
60
vol.%
Vt
420
ml
fVACI
19
/min
Tinsp
1.30
s
PAI
3
cmH2O
PEP
8
cmH2O


VC-VACI
Adulte
70 Kg
16:20
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
30
15
0
-6
0 s
3
6
9
12
15
Débit
l/min
60
30
0
-30
-60
Volume
ml
500
250
0
-100
Pcrête
cmH2O
40
17
10
Pplat
cmH2O
15
PEP
cmH2O
7.8
VMe
l/min
10.0
7.44
3.0
Vte
ml
560
436
250
ftotal
/min
35
19
8
FiO2
vol.%
57
49
43
RCexp
s
0.56
Vte/PCI
ml/kg
6.2
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
50
vol.%
Vt
420
ml
fVACI
19
/min
Tinsp
1.30
s
PAI
3
cmH2O
PEP
8
cmH2O


VC-VACI
Adulte
70 Kg
15:58
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
Limite Paw
60
30
0
-12
0 s
6
12
18
24
30
Pcrête 9.0 cmH2O
Pplat 7.7 cmH2O
Pmoy 6.7 cmH2O
Pmoteur 1.7 cmH2O
PEP 5.8 cmH2O
FiO2 70 vol.%
VMe 8.69 l/min
VMi 8.83 l/min
VMspn 4.84 l/min
VMfuite 0.26 l/min
%Fuite 2 %
Vte 521 ml
Vti 544 ml
Vte spn 521 ml
ftotal 19 /min
Fmec 10 /min
fspn 9 /min
I/E 1:3.6
Tinsp 0.72 s
FIP 56.2 l/min
FEP 27.8 l/min
FEE 1.0 l/min
Vte/PCI 7.4 ml/kg
Ri 2 cmH2O/l/s
Re 4 cmH2O/l/s
Cdyn 233 ml/cmH2O
Cstat 307 ml/cmH2O
RCexp 0.70 s
RSBI 17 1/(min·L)
Stress Index ---
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2 70 vol.%
Vt 400 ml
fVACI 10 /min
Tinsp 1.30 s
PAI 3 cmH2O
PEP 6 cmH2O

Double Triggering

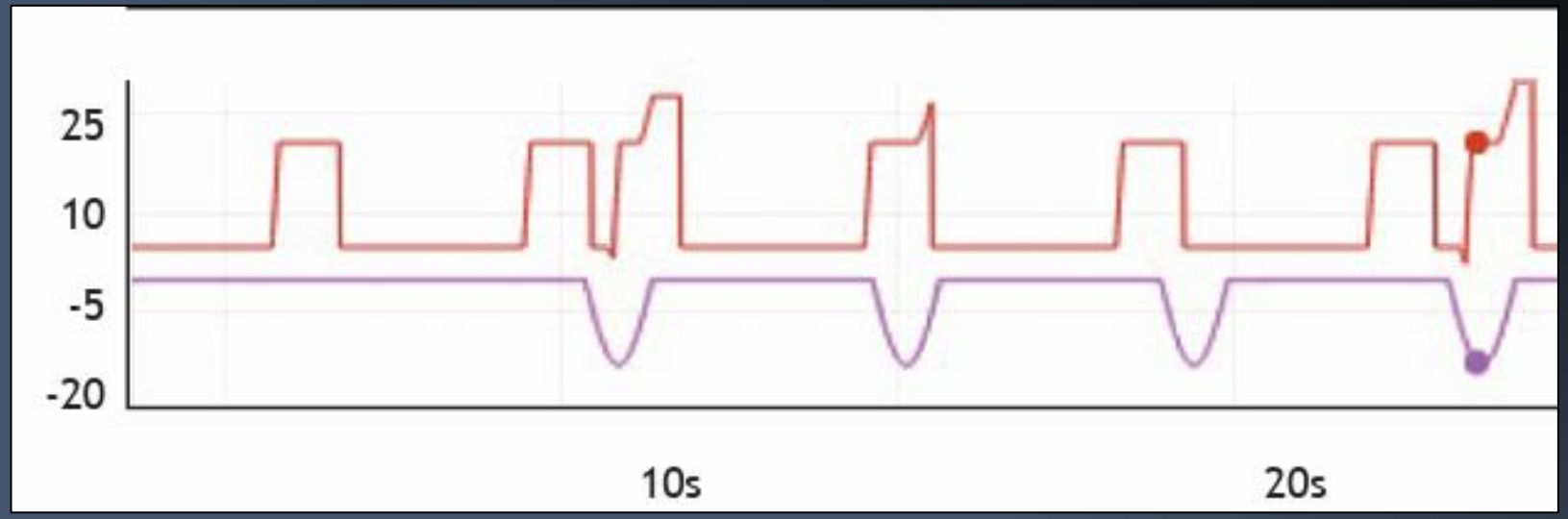
Premature cycling

REVERSE TRIGGERING

DOUBLE TRIGGERING

INSUFFICIENT INSPIRATORY FLOW

Premature cycling



REVERSE TRIGGERING

Lung / Diaphragmatic Protection

Synchronisation

Risques ?

- VILI
- Atrophy

Risques ? **Intensity of Inspiratory EFFORT..**

- VILI
- P-SILI
- Diaphr. Injury
- Asynchrony

Monitoring Lung Diaphragmatic Injury

Lung *Stress/strain*

Respiratory *Effort*

Lung

Stress/strain

Tidal Volume (Vt)

VT 4–6 ml/PBW

Lung Strain

VT/ (end expiratory lung volume)

inconvénients

- **VT alone** : not a precise measure of lung strain
- **Does not reflect lung stress**
- **does not correct for “baby lung” size**

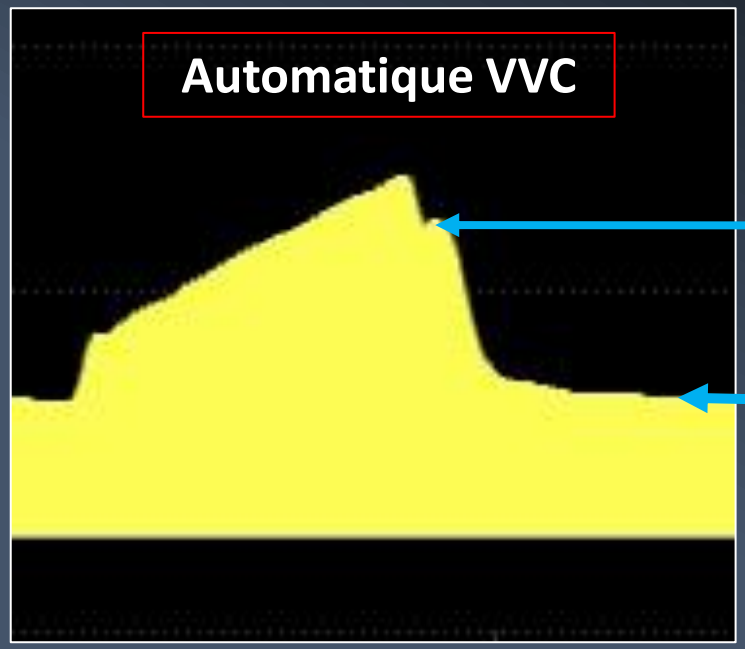
Plateau Pressure

Plateau Pressure < 30 cmH2O

Lung Stress *and* Strain (Tidal Volume)

- ✓ Réglages
- ✓ Mécanique respiratoire

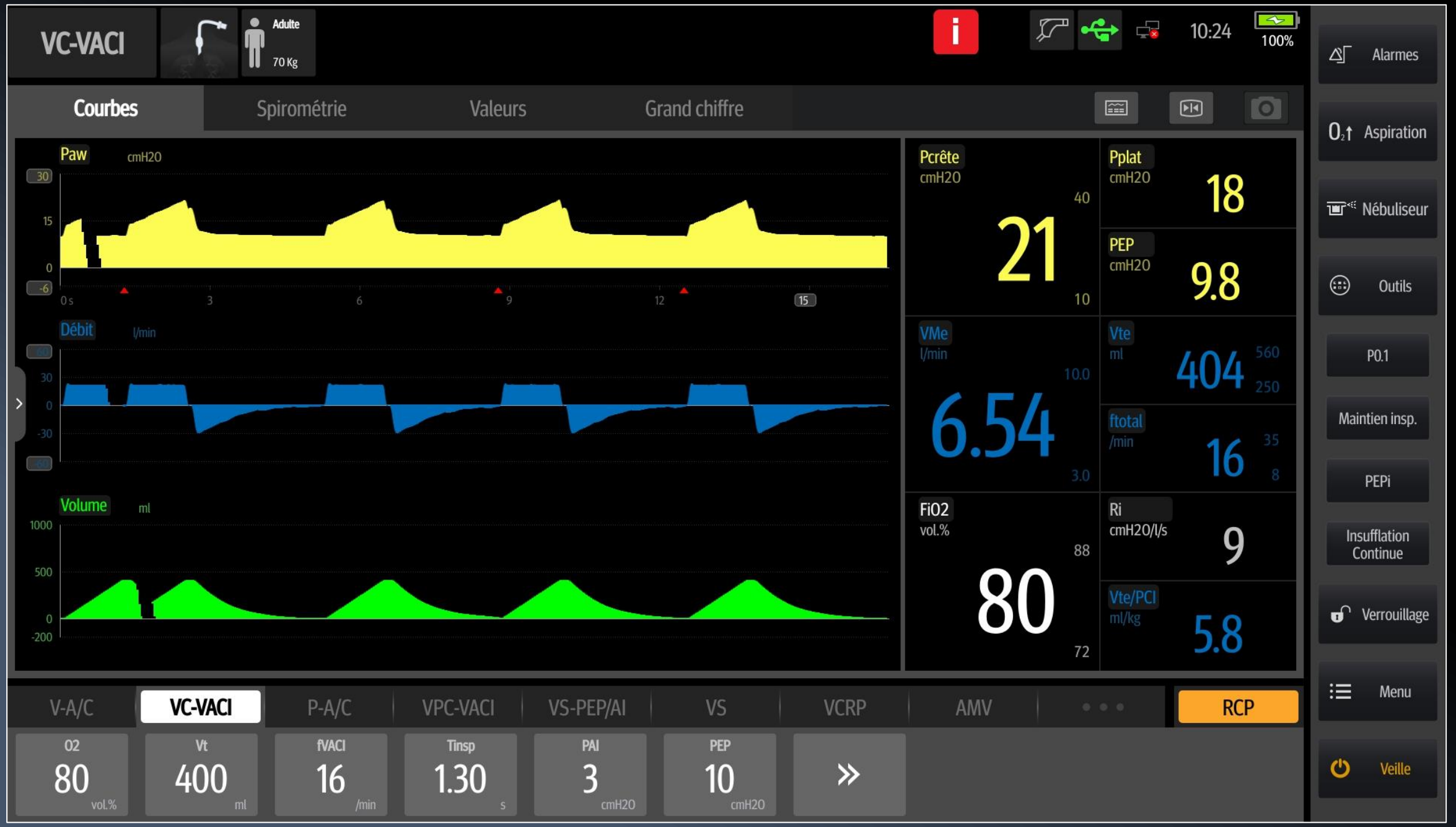
- **Pause inspiratoire → Débit nul : statique**
- **Estimation Pression Plateau (alvéolaire)**
- **Barotraumatisme +++**



inconvénients

- Depend : PEEP (Pression Élastique + PEEP)
- Depend : Compliance Pulmonaire et Thoracique
- Ne Reflète pas Les Variations Dynamiques
- Ne Permet pas Calcul Compliance

Plateau Pressure < TOUJOURS < Pression crête


VC-VACI
Adulte
70 Kg
10:24
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
30
15
0
-6
0 s
3
6
9
12
15
Débit
l/min
60
30
0
-30
-60
Volume
ml
1000
500
0
-200
Pcrête
cmH2O
40
21
10
Pplat
cmH2O
18
PEP
cmH2O
9.8
VMe
l/min
10.0
6.54
3.0
Vte
ml
404
560
250
ftotal
/min
16
35
8
FiO2
vol.%
88
80
72
Ri
cmH2O/l/s
9
Vte/PCI
ml/kg
5.8
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
80
vol.%
Vt
400
ml
fVACI
16
/min
Tinsp
1.30
s
PAI
3
cmH2O
PEP
10
cmH2O

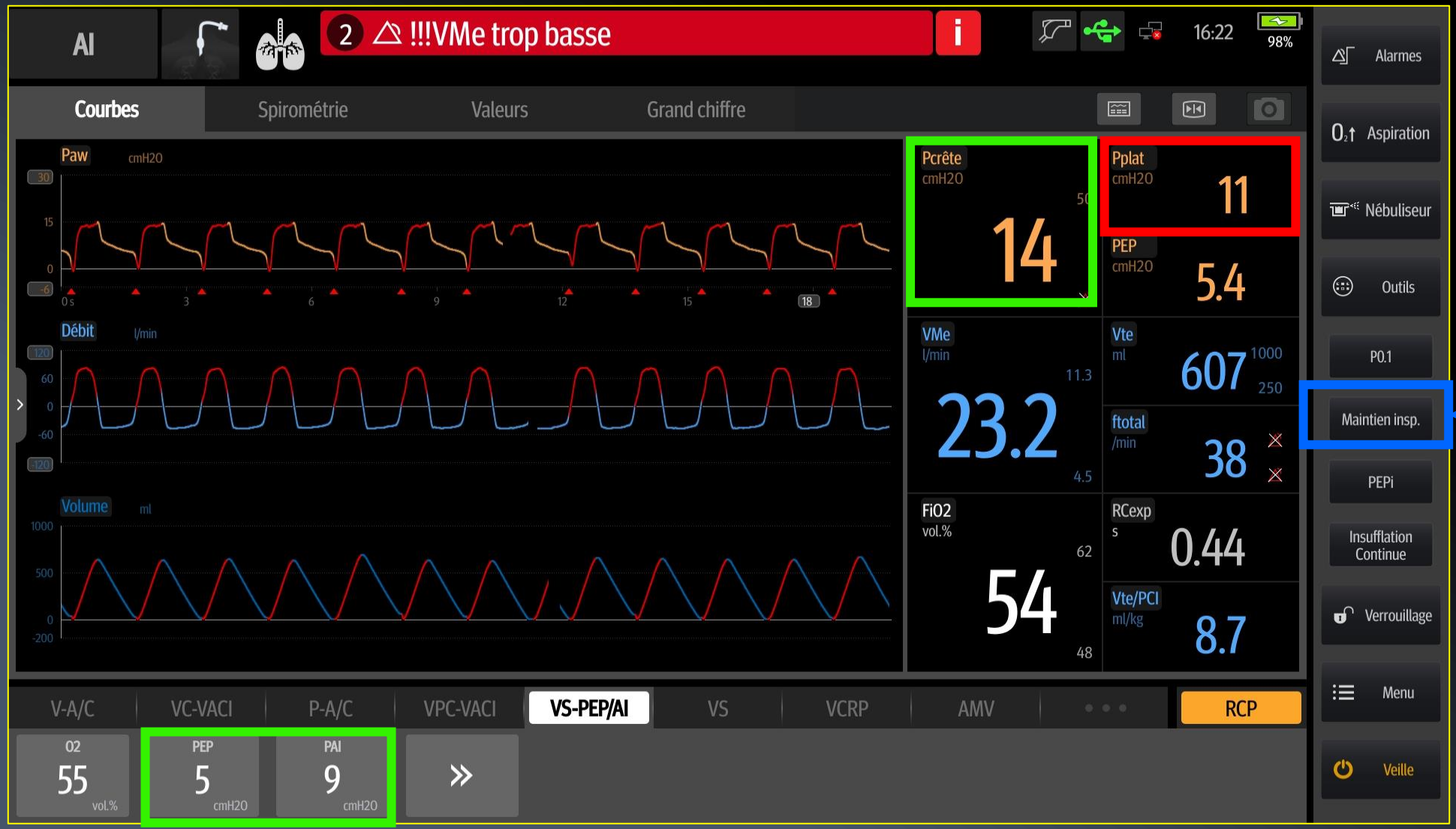
Plateau Pressure

Plateau Pressure < 30 cmH2O

Lung Stress *and* Strain (Tidal Volume)

VPC ?

Pause manuelle

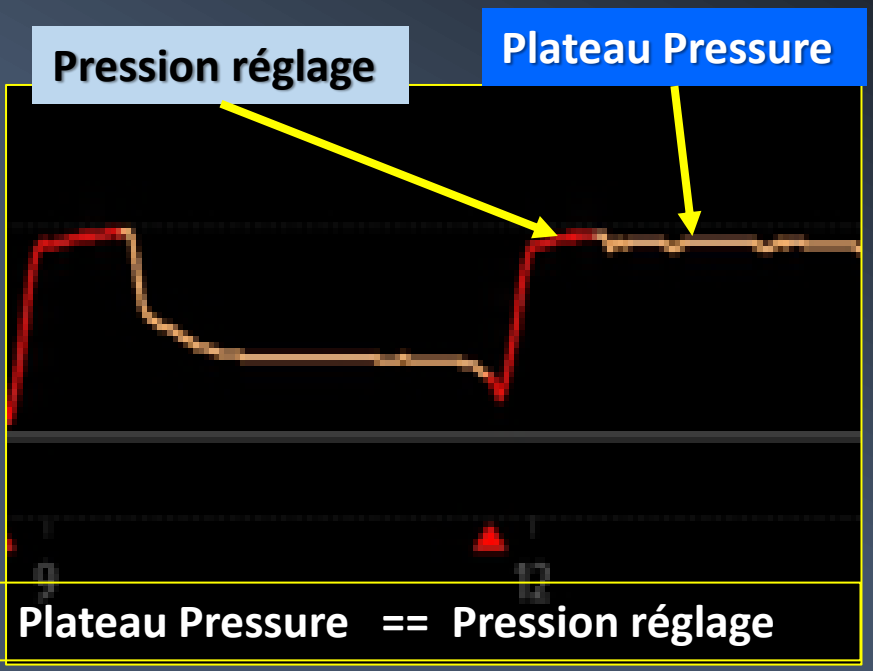


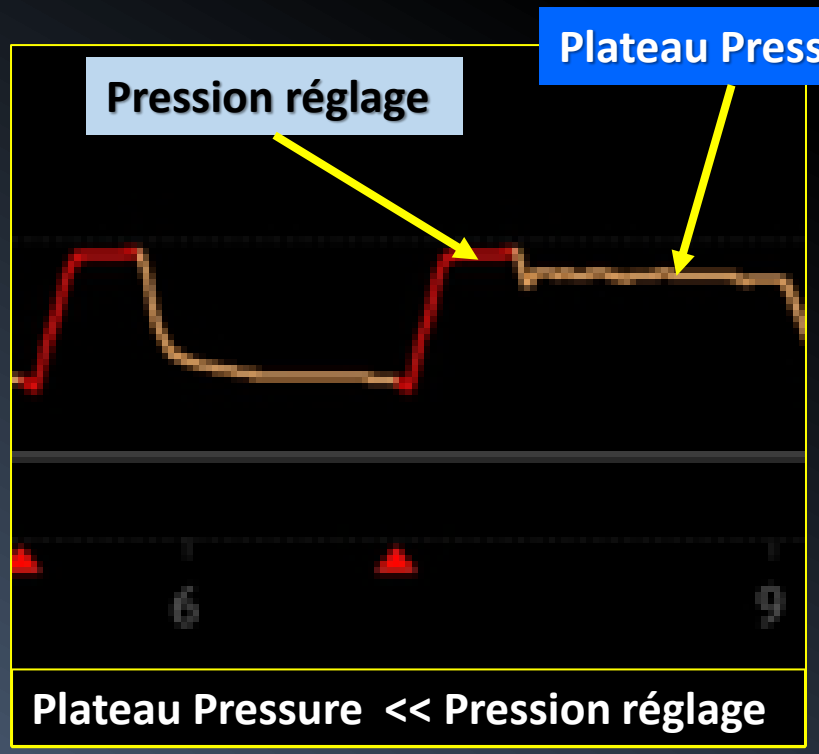
VPC ?

Plateau Pressure

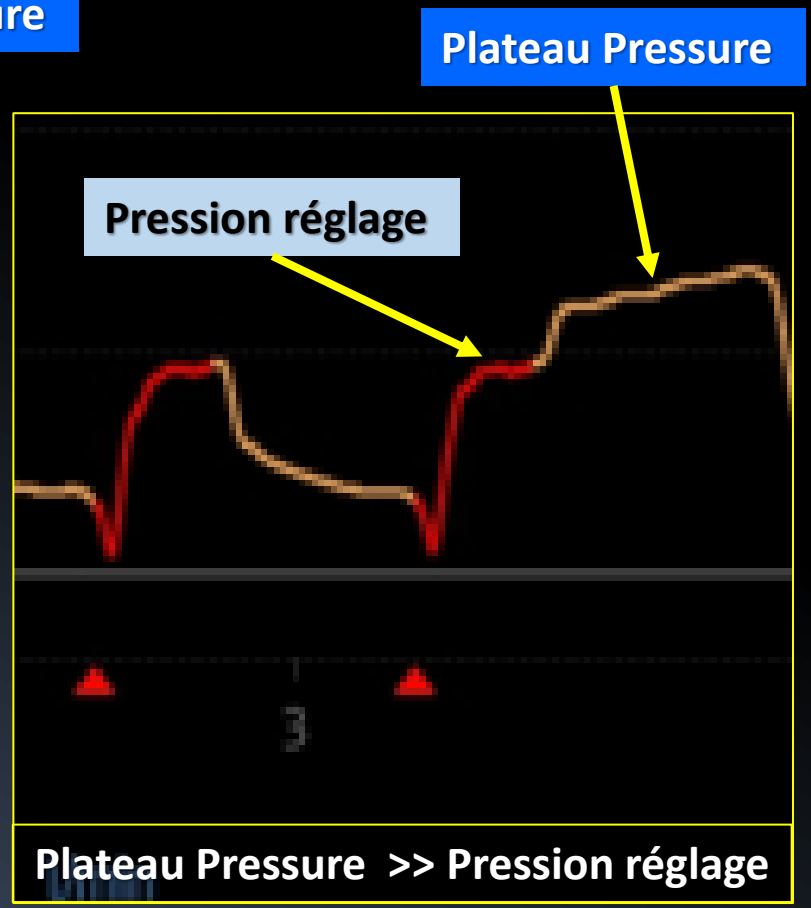
- ✓ Réglages
- ✓ Mécanique respiratoire
- ✓ Effort inspiratoire

Lung Stress *and* Strain (Tidal Volume)





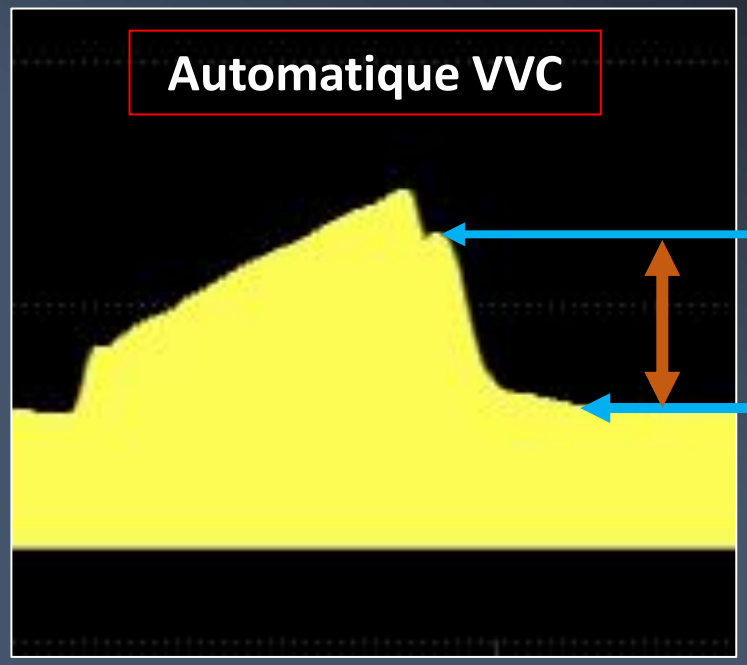
Surdistension



Airway driving pressure (ΔPaw)

ΔPaw < 15 cmH2O

- Pause inspiratoire ➔ Débit nul : statique
- Non dépendant de la PEEP
- Estimation **Pression motrice**
- Compliance Thoraco-Pulmonaire statique
- Barotraumatisme +++
- Mortalité +++



Lung Stress *and* Strain (Tidal Volume)

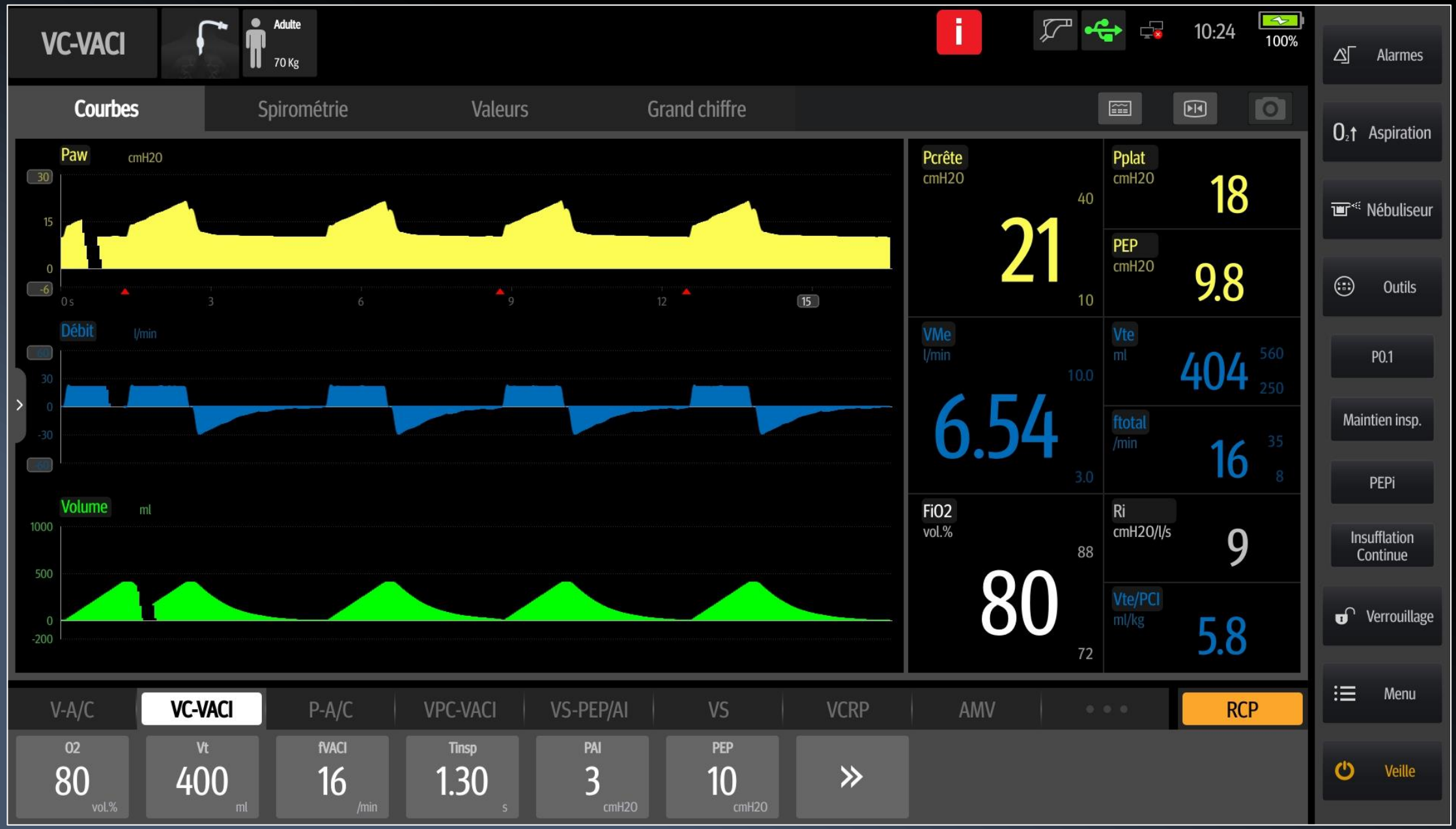
inconvénients

- depend de la compliance pulmonaire et thoracique
  - Overestimates the transpulmonary pressure :
  - ➢ *chest wall elastance increased*
  - ➢ *expiratory muscle activity*
- Ne reflète pas les variations dynamiques
  - Does not reflect regional lung stress :
  - ➢ *respiratory effort is high*

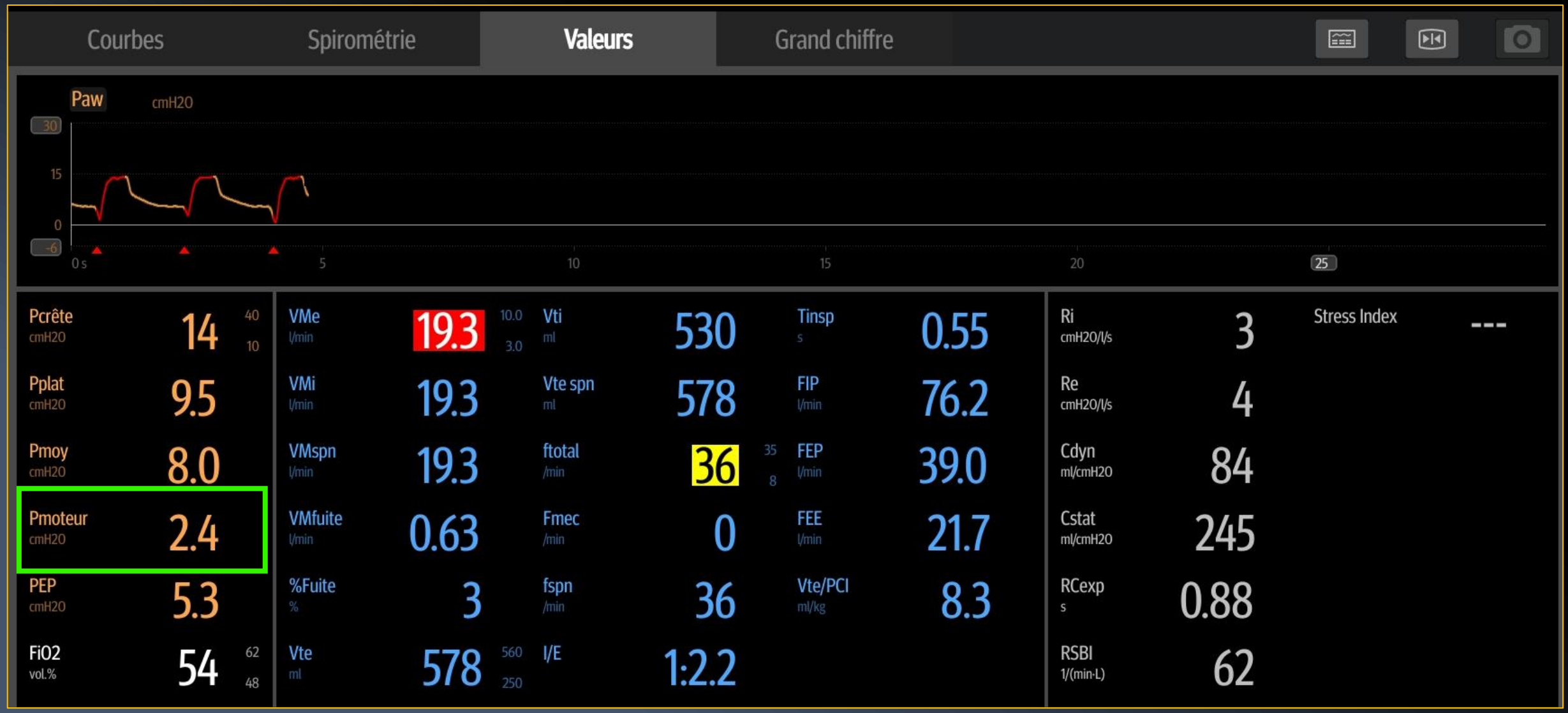
compliance thorax et poumon = $\frac{\text{Tidal Volume (Vt)}}{\text{respiratory system compliance (Crs)}}$

Amato MB,. Driving pressure and survival in the acute respiratory distress syndrome. N Engl J Med 2015

Automatique VVC



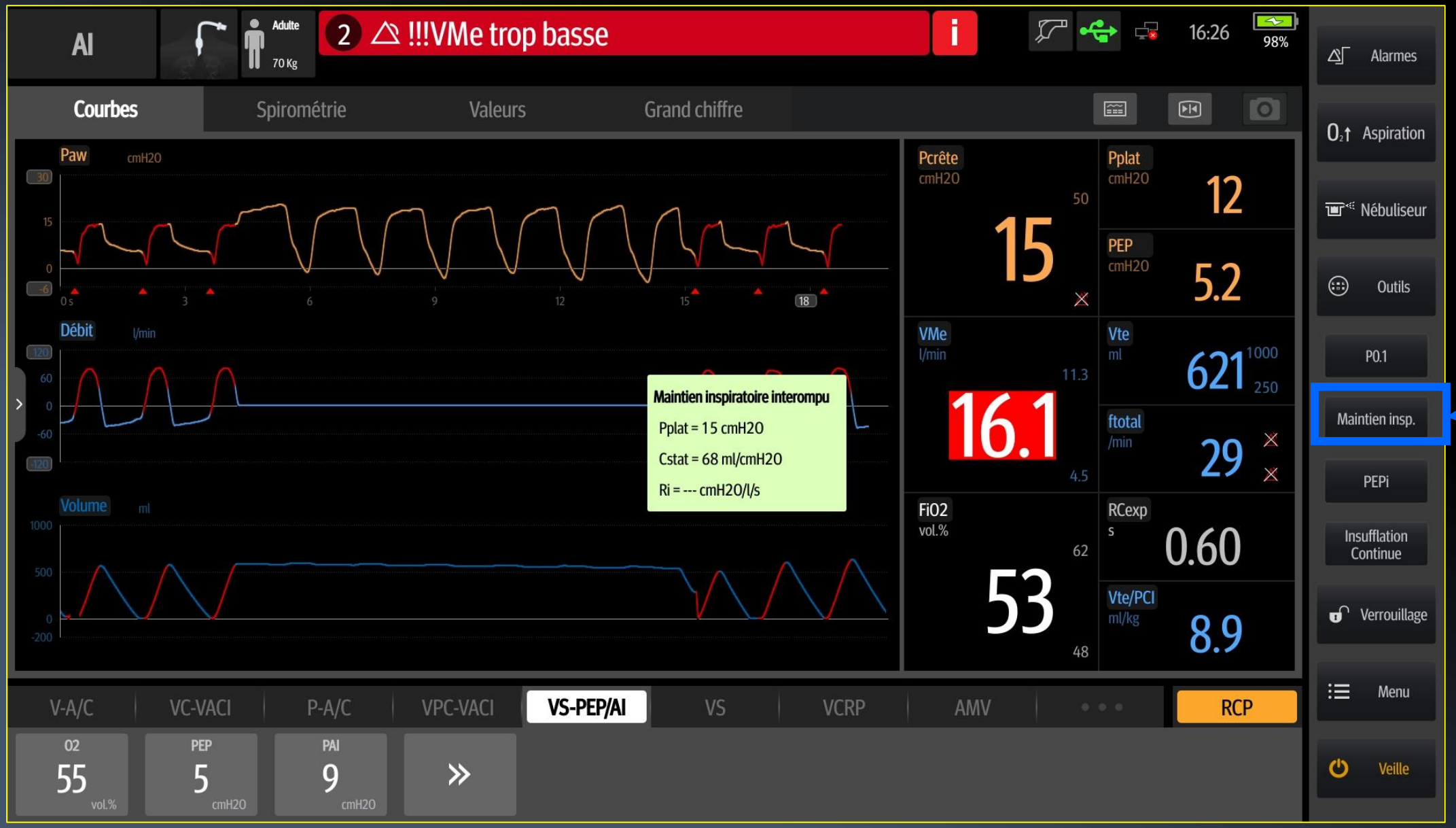
Automatique VVC



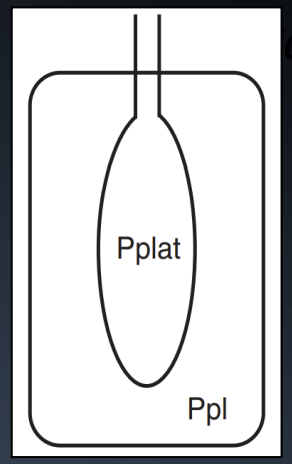
VPC ?

Airway driving pressure (ΔPaw)

Lung Stress *and* Strain (Tidal Volume)



Pause manuelle



Transpulmonary Pressure (PL)

Gold Standard

Lung Stress *and* Strain (Tidal Volume)

PL = Airway Pressure (Paw) - Pleural Pressure (Ppl)

❑ **POSITIVE PRESSURE VENTILATION with :**

- **muscle paralysis,**
- **chest wall compliance not impaired**

Ppl → minor contributor

Ppat == Paw == PL

❑ **POSITIVE PRESSURE VENTILATION with :**

- **chest wall compliance seriously impaired (Ppl très positive)**
- **spontaneous effort (Ppl très négative)**

Ppl ↑ ↘

Ppat == Paw ≠ PL

Definition

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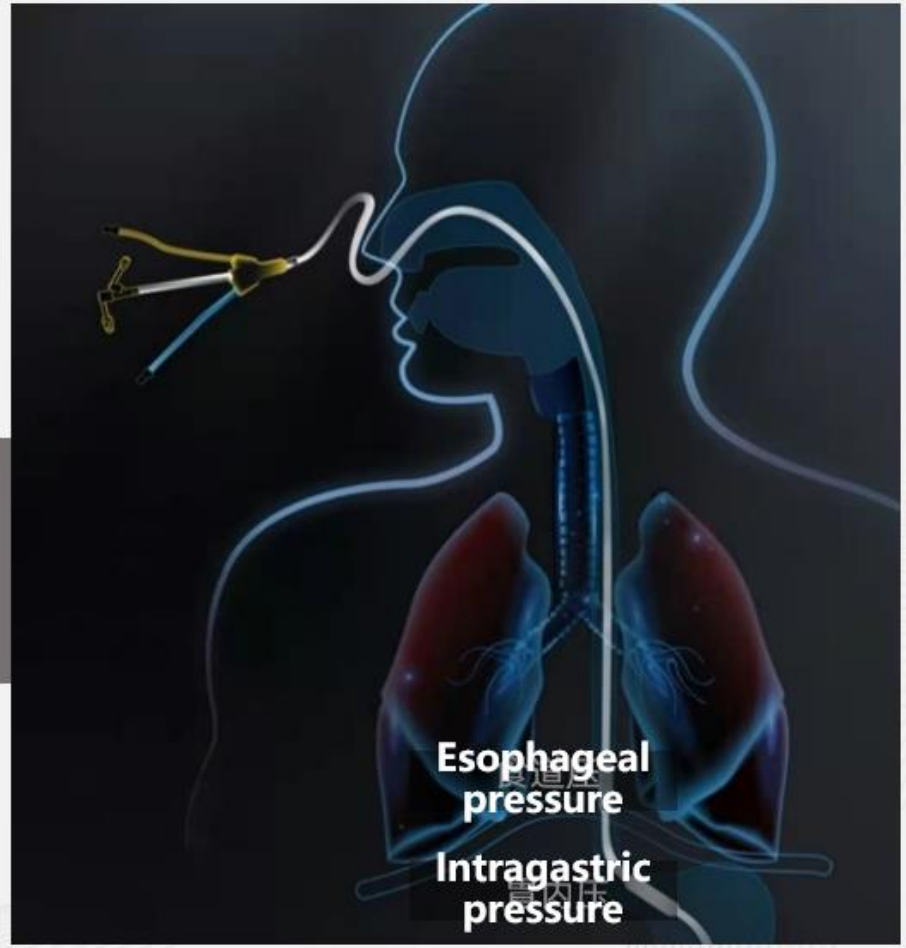
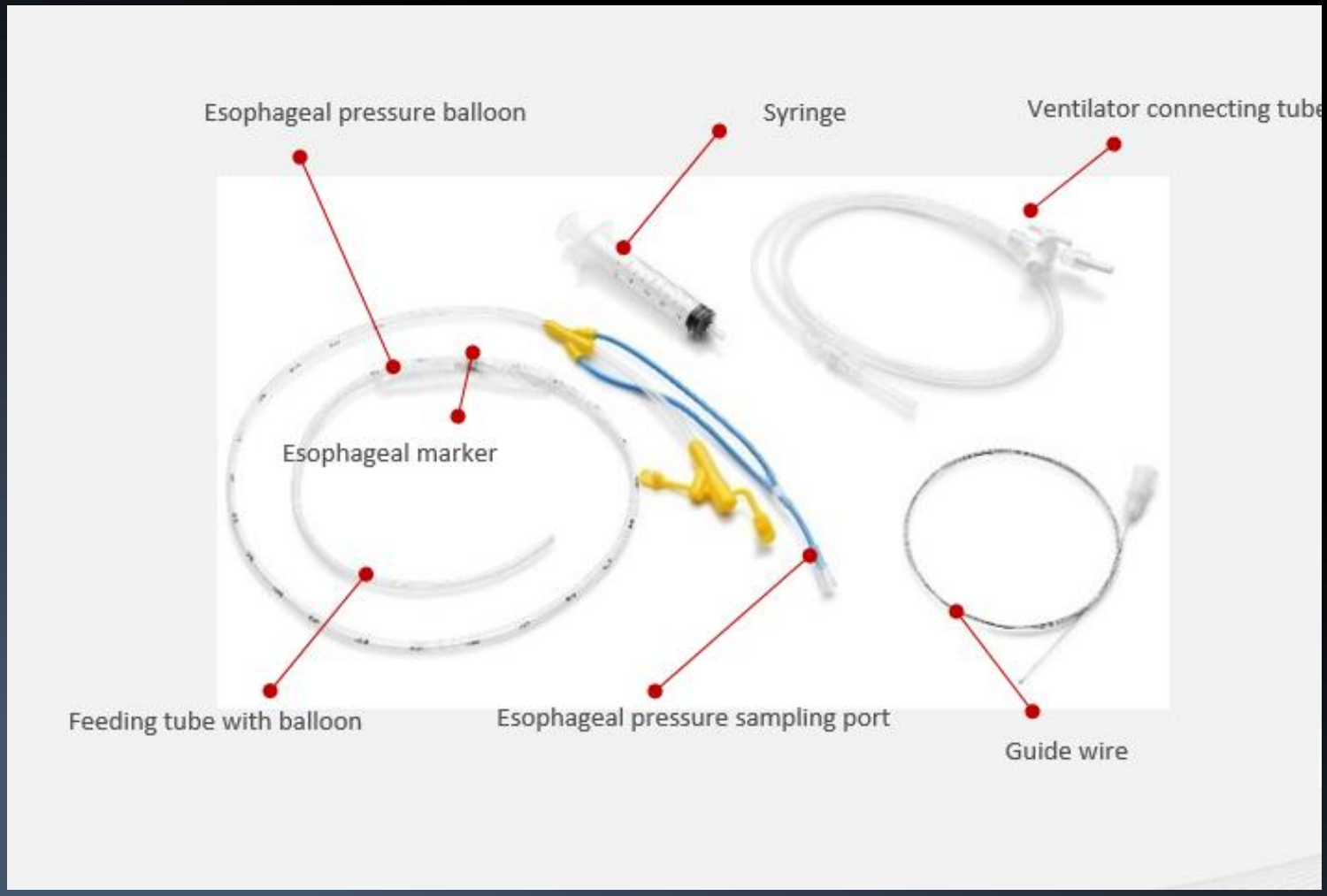
Global Clinical Institute

Dual channel auxiliary pressure

- **Esophageal pressure (Pes)** → **Transpulmonary pressure (Ptp)**
  - Ptp =Paw-Pes
- **Intragastric pressure (Pg) (Paux2)** → **Trans-diaphragmatic pressure (Pdi) (Paux2-Paux1)**
  - Pdi =Pg-Pes
    Paux2-Paux1




Esophageal pressure balloon
Syringe
Ventilator connecting tube
Esophageal marker
Feeding tube with balloon
Esophageal pressure sampling port
Guide wire

Workflow of auxiliary pressure

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Catheterization | Balloon inflation | Location | Maintain | Remove

Patient Preparation

Open package inspection

Balloon examination

Lubricate the catheter

Depth prediction

Insert the tube into the stomach

Confirm in stomach

Connect the ventilator

Positioning process of catheter

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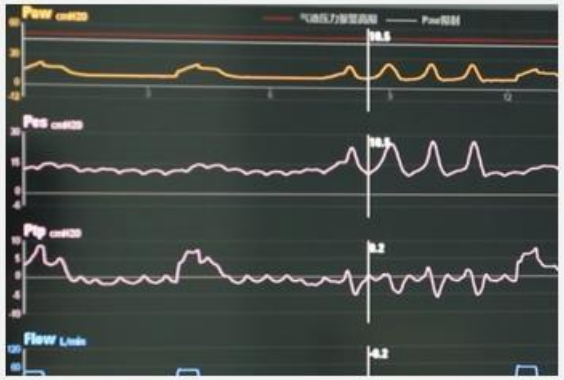
Slow retracement → See the heartbeat notch → Exhalation occlusion → Calculate △Paw/△Pes → Repeat adjustment → Fixed catheter

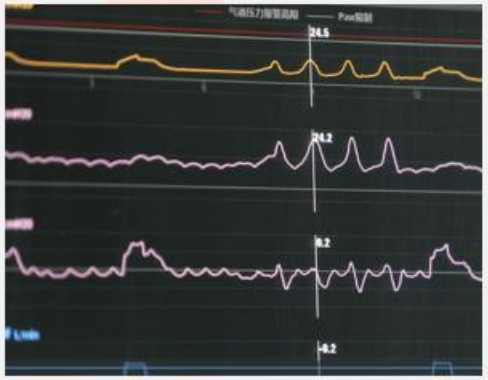
Judge spontaneous breathing;

Yes - ask the patient to inhale

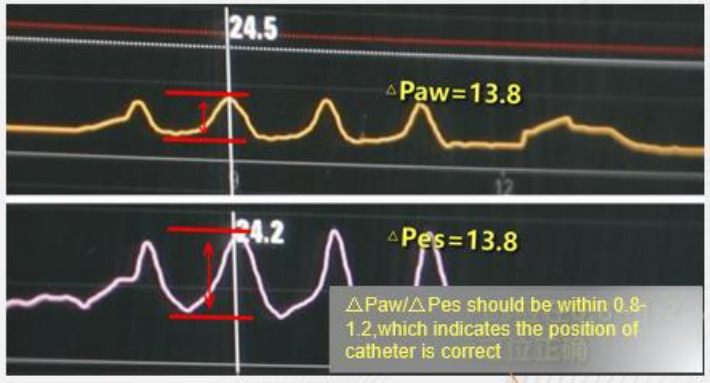
None - press chest lightly



- Select waveform
- Record the trough value of airway pressure
- Record the trough value of esophageal pressure



- Record the peak airway pressure
- Record the peak esophageal pressure



- Calculate airway pressure fluctuation
- Calculate esophageal pressure fluctuation
- The above two values are divided to judge the positioning

If not, repeat the previous process

Challenges of esophageal technique in clinical practice

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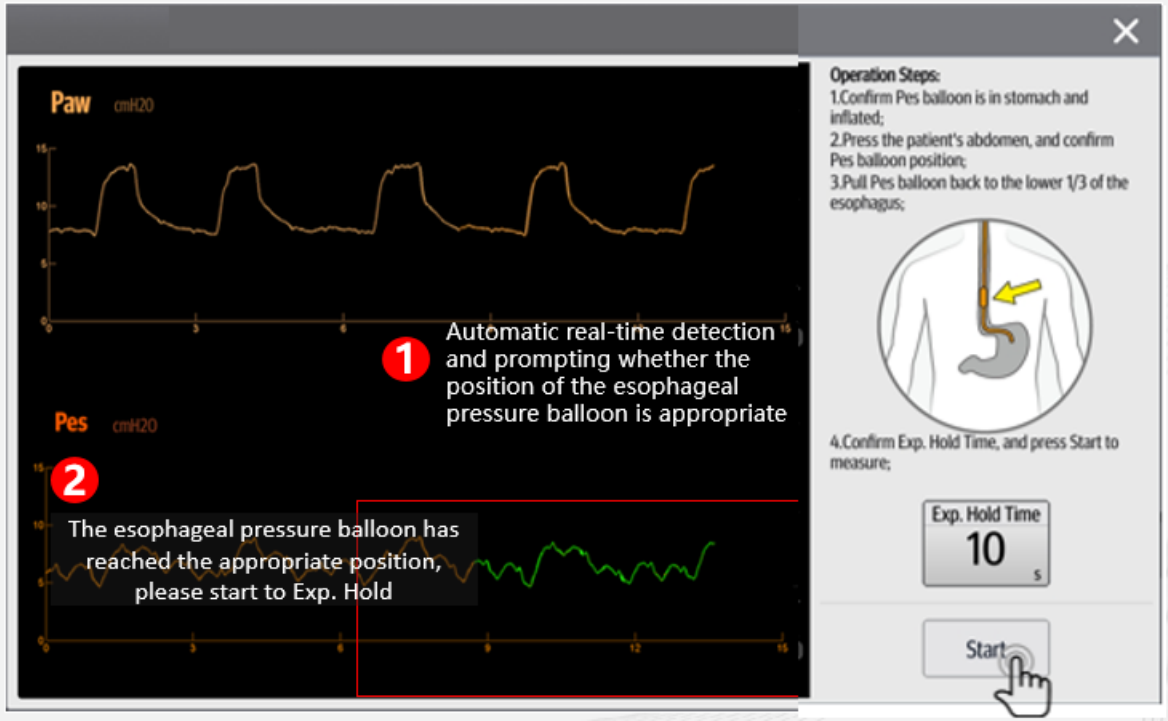
Auxiliary pressure advanced catheterization tool greatly simplifies the catheterization process

Intelligent Algorithm

1 Automatically detect and prompt suitable location

2. One-click automatic location confirmation



Esophageal pressure waveform interference filtering

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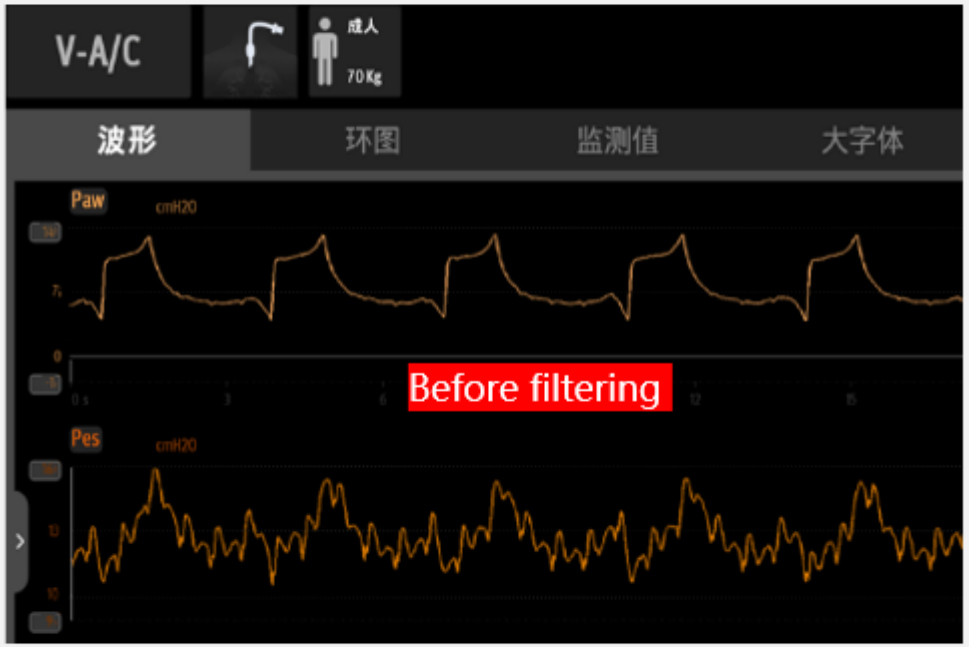
Intelligent esophageal pressure filter function - automatic real-time filtering of esophageal pressure waveform interference



- The patented intelligent algorithm, the industry's exclusive innovative functions
- Automatic and real-time filtering of heartbeat notch interference in esophageal pressure, restoring the patient's true esophageal pressure waveform

Patent

Esophageal pressure waveform interference filtering

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Intelligent esophageal pressure filter function - automatic real-time filtering of esophageal pressure waveform interference

- The patented intelligent algorithm, the industry's exclusive innovative functions
- Automatic and real-time filtering of heartbeat notch interference in esophageal pressure, restoring the patient's true esophageal pressure waveform

Patent

Esophageal pressure error correction

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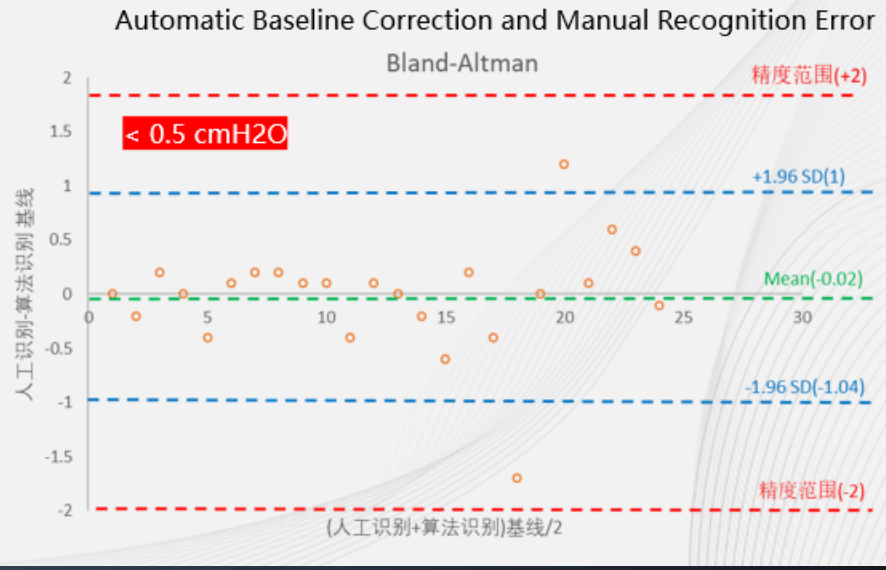
Esophageal pressure baseline correction function - automatically identify and remove esophageal pressure baseline deviation

Patent

One-click automatic correction without manual intervention



Mindray esophageal pressure summary

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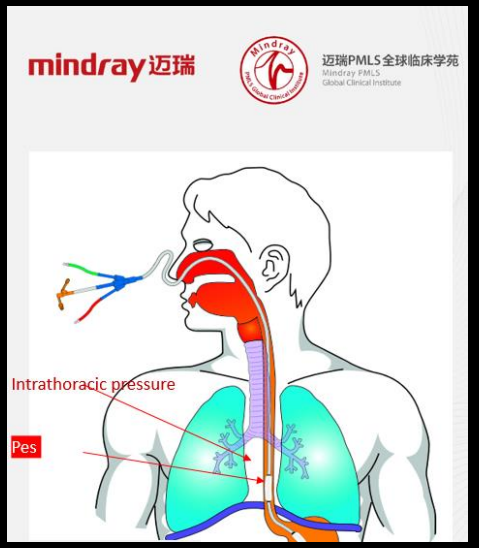
Auxiliary pressure accessories → Assisted pressure-based catheter placement → **Manual repeated adjustment to confirm the position of the catheter** → **Inability to filter out esophageal pressure waveform interference** → **Manual baseline correction**

↓

Mindray's esophageal pressure– easy to ues

Auxiliary pressure accessories → Assisted pressure-based catheter placement → **Intelligent Assisted Pressure Advanced Catheterization Function** → **Auto filter function** → **Auto baseline correction function**

PL = Airway Pressure (Paw) - Pleural Pressure (Ppl)



ΔPaw

Transpulmonary Driving Pressure (ΔPL)

changes in lung elastance affect ΔPaw,
with affecting lung stress

Ex: SDRA ➔ ***HIGH PLATEAU PRESSURE***
(pulmonary edema)
➔ *high ΔPaw*

VILI, S-PILI

Barotrauma

and

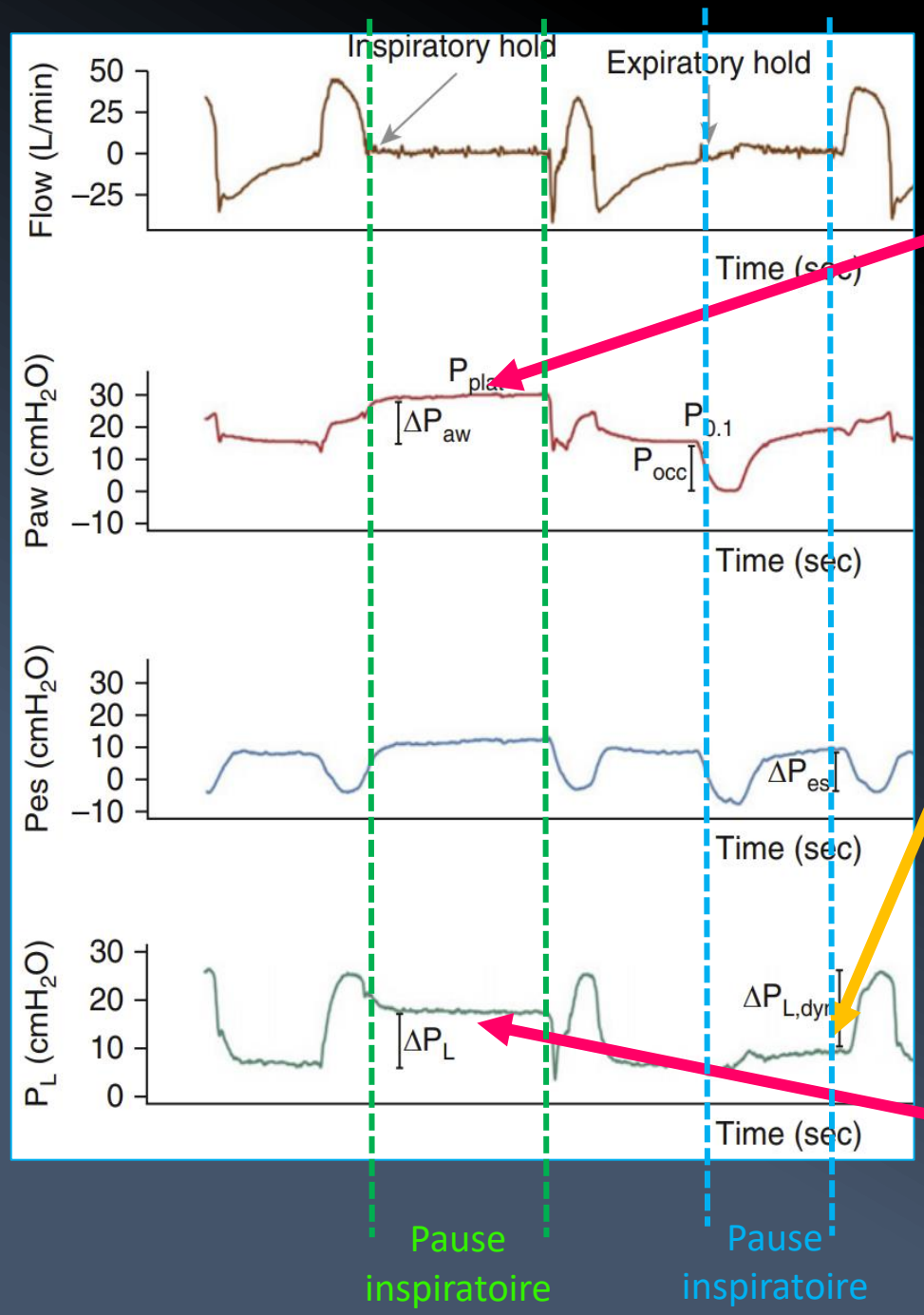
Driving Pressure Across The Chest Wall (ΔPcw)

changes in chest wall elastance affect ΔPaw,
without affecting lung stress

Ex: Obese patients ➔ ***HIGH PLATEAU PRESSURE***
(weight imposed by the chest wall)
➔ *high ΔPaw*

Barotrauma
inspiratory

Hypoventilation, atélectasie
expiratory



PLATEAU PRESSURE EN FIN D'INSPIRATION

↓

Pression Trans- Thoraco-Pulmonaire statique

↓

Compliance Thoraco-Pulmonaire statique

Δpaw

Trans-Thoraco-Pulm

PLATEAU PRESSURE en fin *expiration*

Pression Trans-Pulmonaire statique

Hypoventilation, atélectasie

PLATEAU PRESSURE EN FIN D'INSPIRATION

↓

Pression Trans-Pulmonaire statique

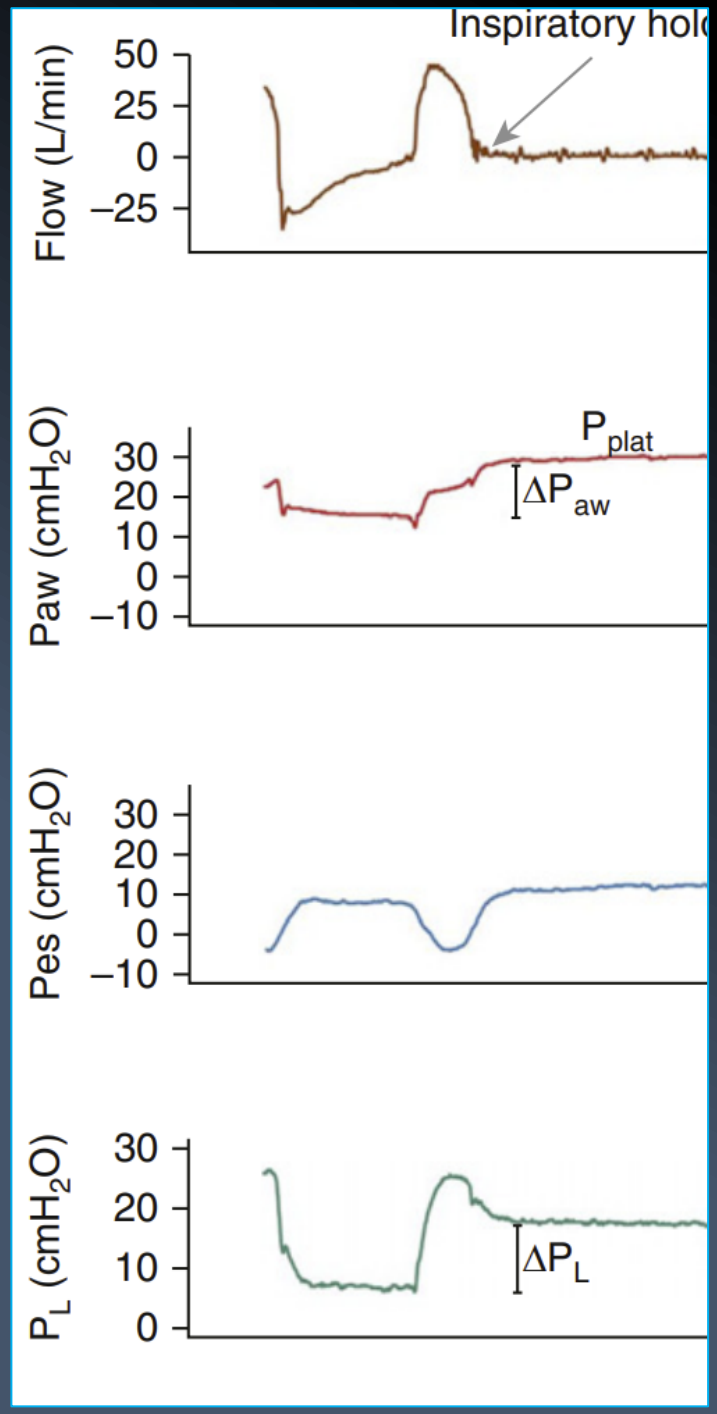
↓

Compliance Pulmonaire statique

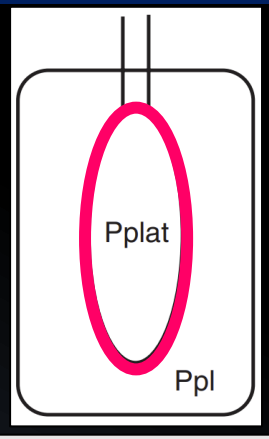
Δpaw

Trans-Pulm

Δpaw Trans-Pulm << Δpaw Trans-Thoraco-Pulm



Baisse Compliance pulmonaire



Vt = 400 ml

PEP = 2 mmHg

Pplat = 20 mmHg

ΔPaw = 20 – 2 = 18 mmHg

Compliance thoraco-pulmonaire
400 /18 = **22.2 mmHg**

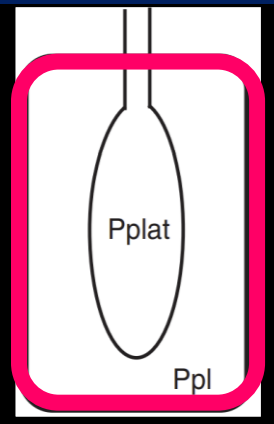
P pleur = 4 mmHg

PTP = 18 – 4 = 14 mmHg

Compliance pulmonaire
400 / 16 = **25 mmHg**

Compliance thoracique
400 / 4 = **100 mmHg**

Baisse Compliance thoracique



Pplat = 20 mmHg

ΔPaw = 20 – 2 = 18 mmHg

Compliance thoraco-pulmonaire
400 /18 = **22.2 mmHg**

P pleur = 14 mmHg

PTP = 18 – 14 = 4 mmHg

Compliance pulmonaire
400 / 6 = **66.6 mmHg**

Compliance thoracique
400 / 14 = **28.6 mmHg**

Transpulmonary Pressure (PL) = Airway pressure (Paw) - pleural pressure (Ppl)

STATIC
Transpulmonary Pressure

(ΔPL)< 15 cmH2O

- Pause inspiratoire ➔ Débit nul : statique
- Non dépendant de la PEEP
- Estimation Pression motrice
- Compliance ***Pulmonaire*** statique
- Barotraumatisme +++
- Mortalité +++

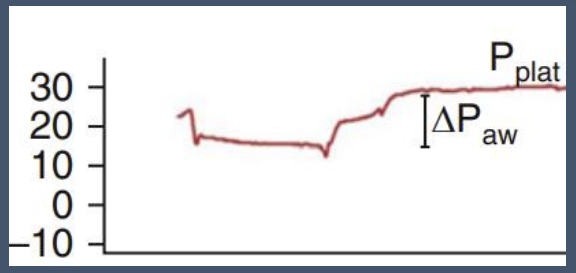
Chest Wall Compliance

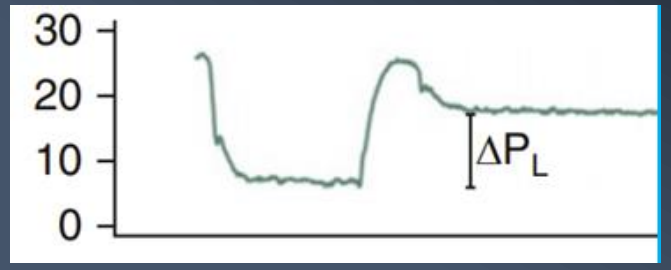
Not Impaired

Transpulmonary Driving Pressure = **ΔPaw**

Impaired (Ppl très positive)

Transpulmonary Driving Pressure < **ΔPaw**





inconvénients

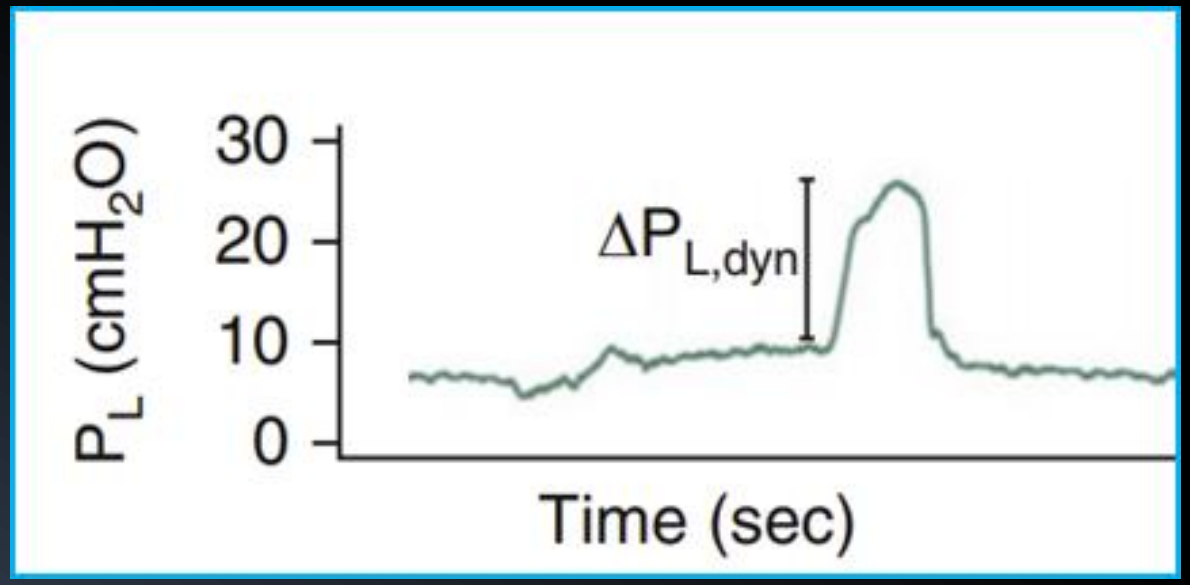
- Ne reflète pas les variations dynamiques
- Does not reflect regional lung stress :
  - ➢ *respiratory effort is high*

Transpulmonary Pressure (PL) = Airway pressure (Paw) - pleural pressure (Ppl)

DYNAMIC
Transpulmonary Pressure

DYNAMIC

ΔPL,dyn<15–20 cmH2O



spontaneous effort
(Ppl très négative)

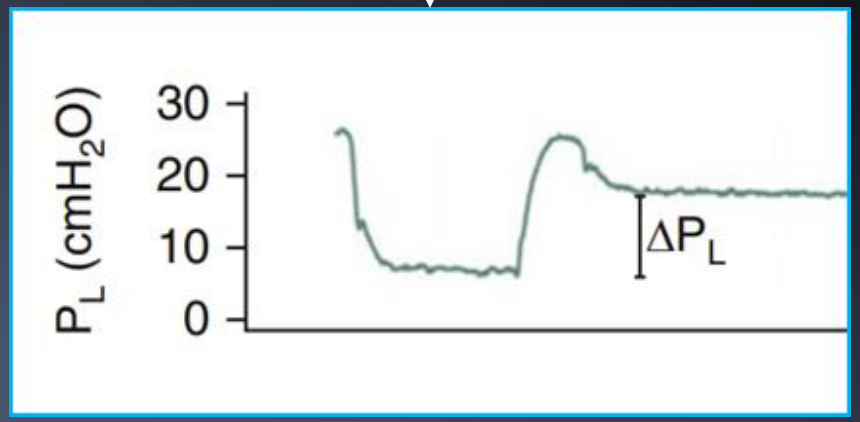
Regional Lung Stress

Magnitude Of Its Change
During Inspiration

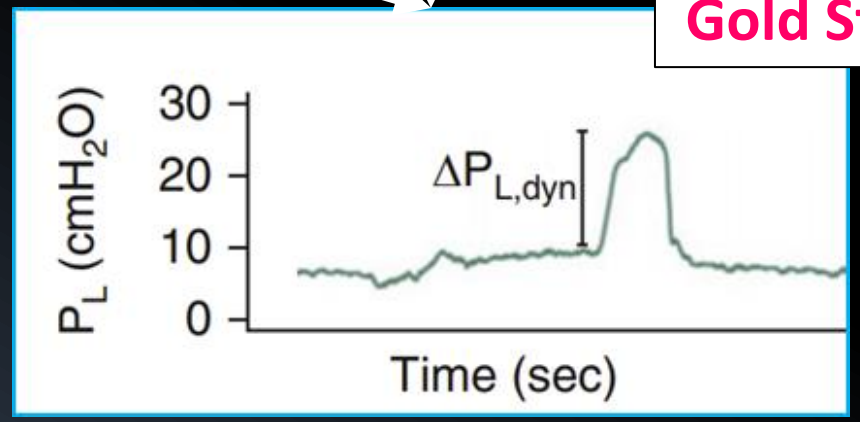
Akoumianaki E, (2014) The application of esophageal pressure measurement in patients with respiratory failure. Am J Respir Crit Care Med

Chest Wall Compliance Impaired
(Ppl très positive)

Spontaneous Effort
(Ppl très négative)



Gold Standard



STATIC
Transpulmonary Pressure

DYNAMIC
Transpulmonary Pressure

Transpulmonary Driving Pressure< 15 cmH2O

ΔPL,dyn<15–20 cmH2O

Comprehensive monitoring parameters related to esophageal pressure

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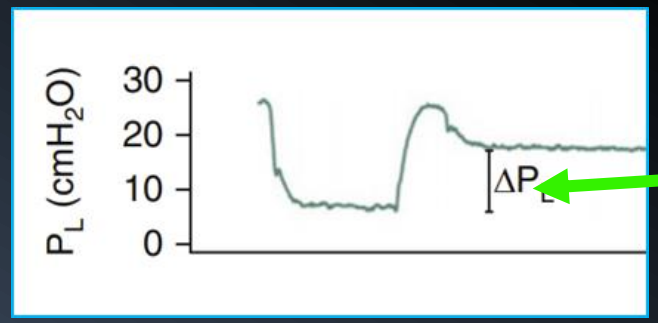
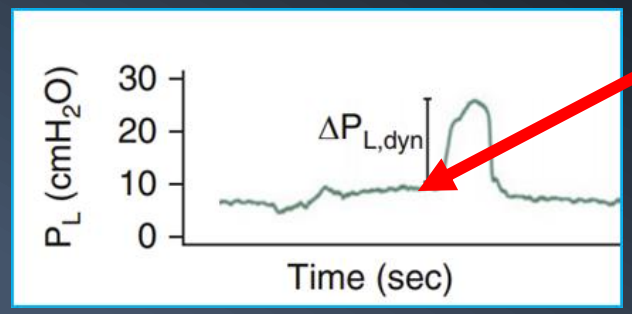
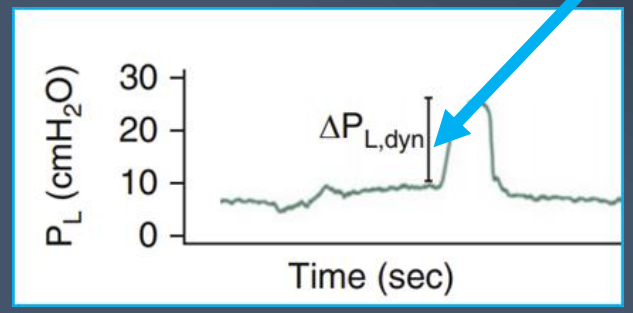
PtpI cmH2O	End-inspiration transpulmonary pressure
PtpE cmH2O	End-expiratory transpulmonary pressure
ΔPtp cmH2O	Transpulmonary pressure

PTPes cmH2O*s	Esophageal pressure pressure-time product
PTPes/min cmH2O*s/min	Esophageal pressure pressure-time product per minute
Paux2I cmH2O	End-inspiration Transpulmonary pressure 2
Paux2E cmH2O	End-expiratory Transpulmonary pressure 2

Comprehensive monitoring parameters related to esophageal pressure







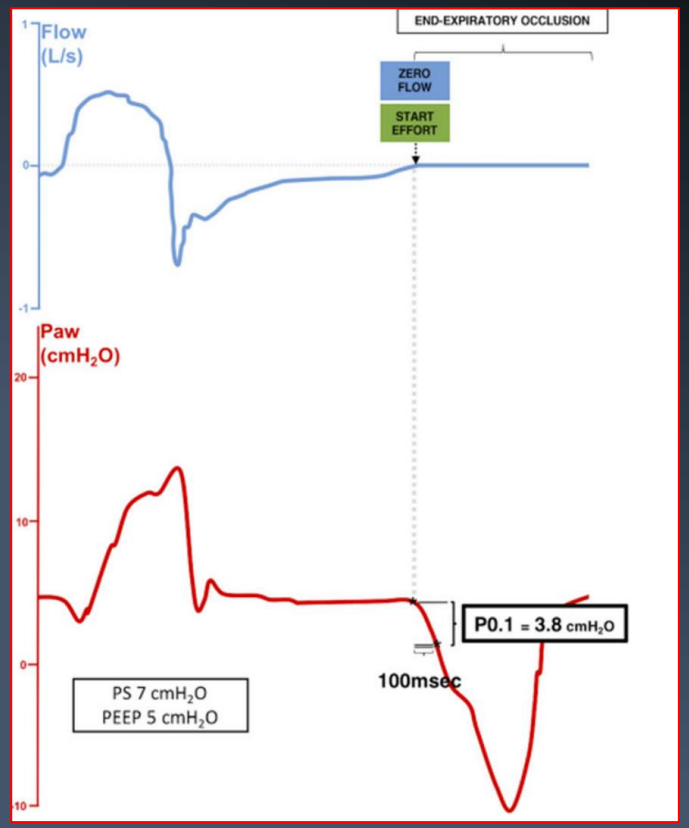
PtpI cmH2O	4.7	PTPes cmH2O*s	0.0
PtpE cmH2O	-5.0	PTPes/min cmH2O*s/min	2.0
ΔPtp cmH2O	9.7	Paux2I cmH2O	41
PesI cmH2O	15	Paux2E cmH2O	6.3
PesE cmH2O	8.0	Ccw mL/cmH2O	72
ΔPes cmH2O	7.0	Clung mL/cmH2O	52

Respiratory *Effort*

Airway occlusion pressure (P0.1)

Pression d'occlusion des voies respiratoires

P0.1 : 1–4 cmH2O



→ **Respiratory Drive**

deflection in Paw during the first 0.1 s of an inspiratory effort against an occluded airway

detect :
- very low respiratory effort
- very high respiratory effort

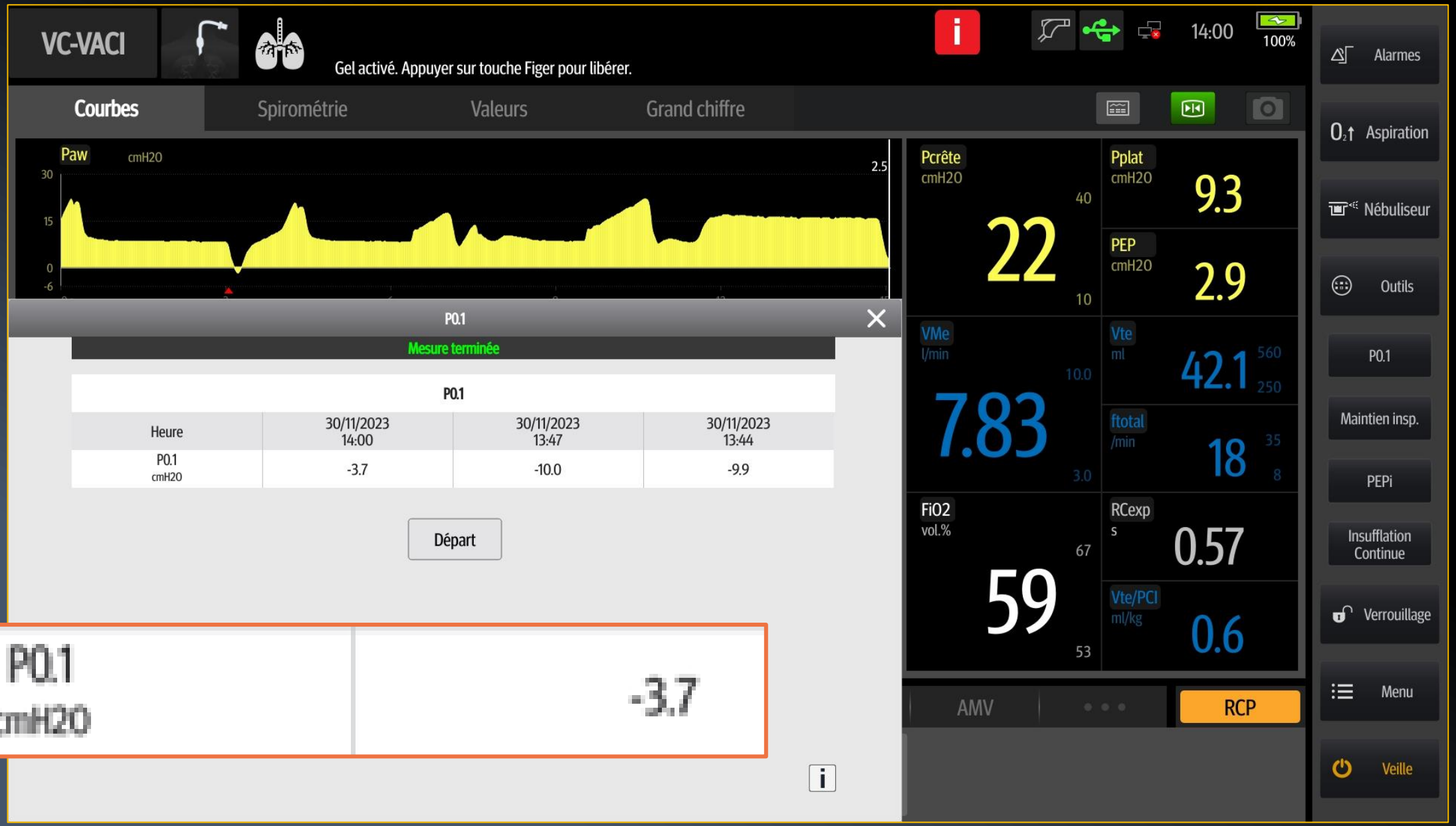
inconvénients

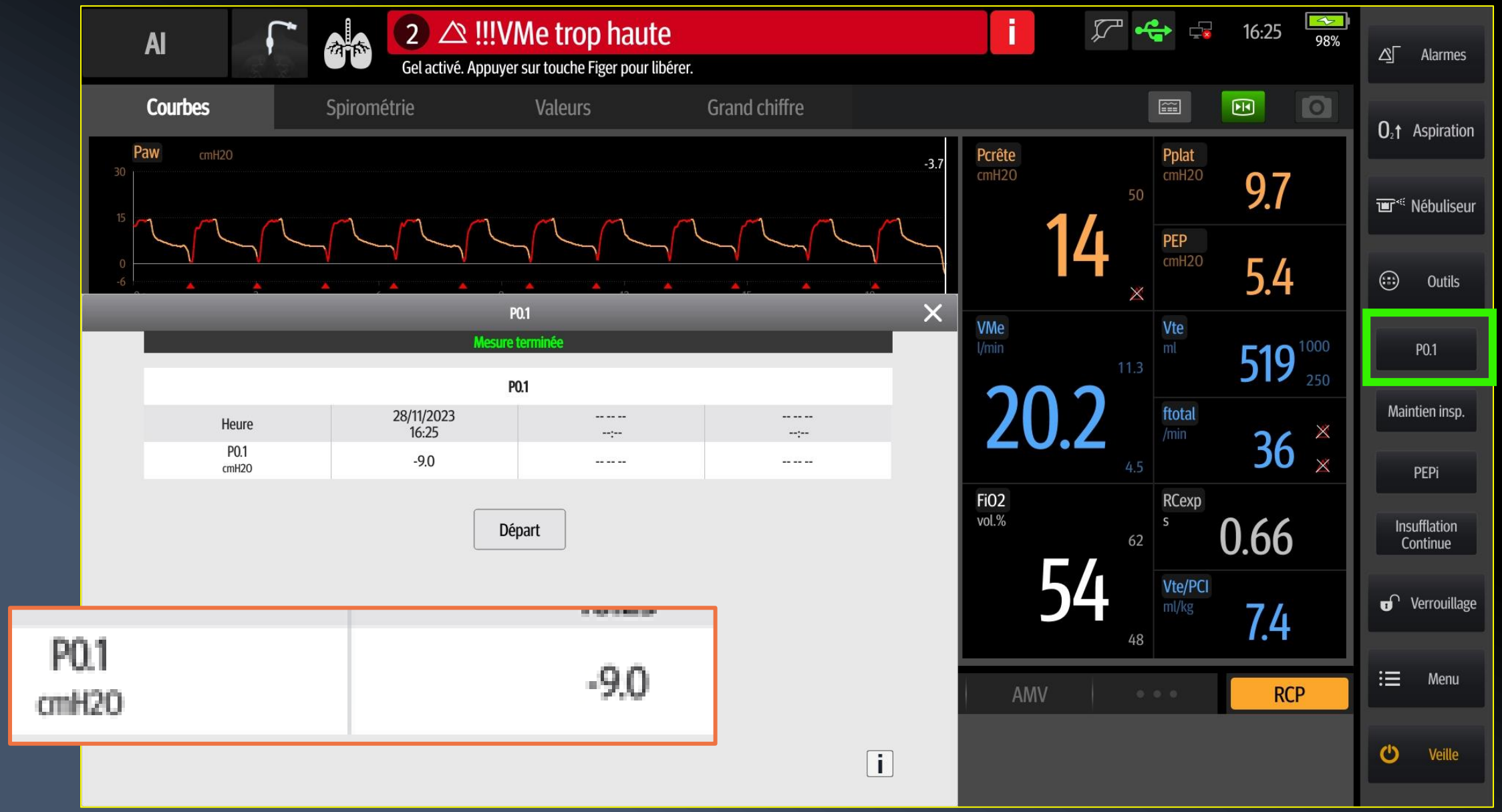
- muscle weakness
- short inspiratory time

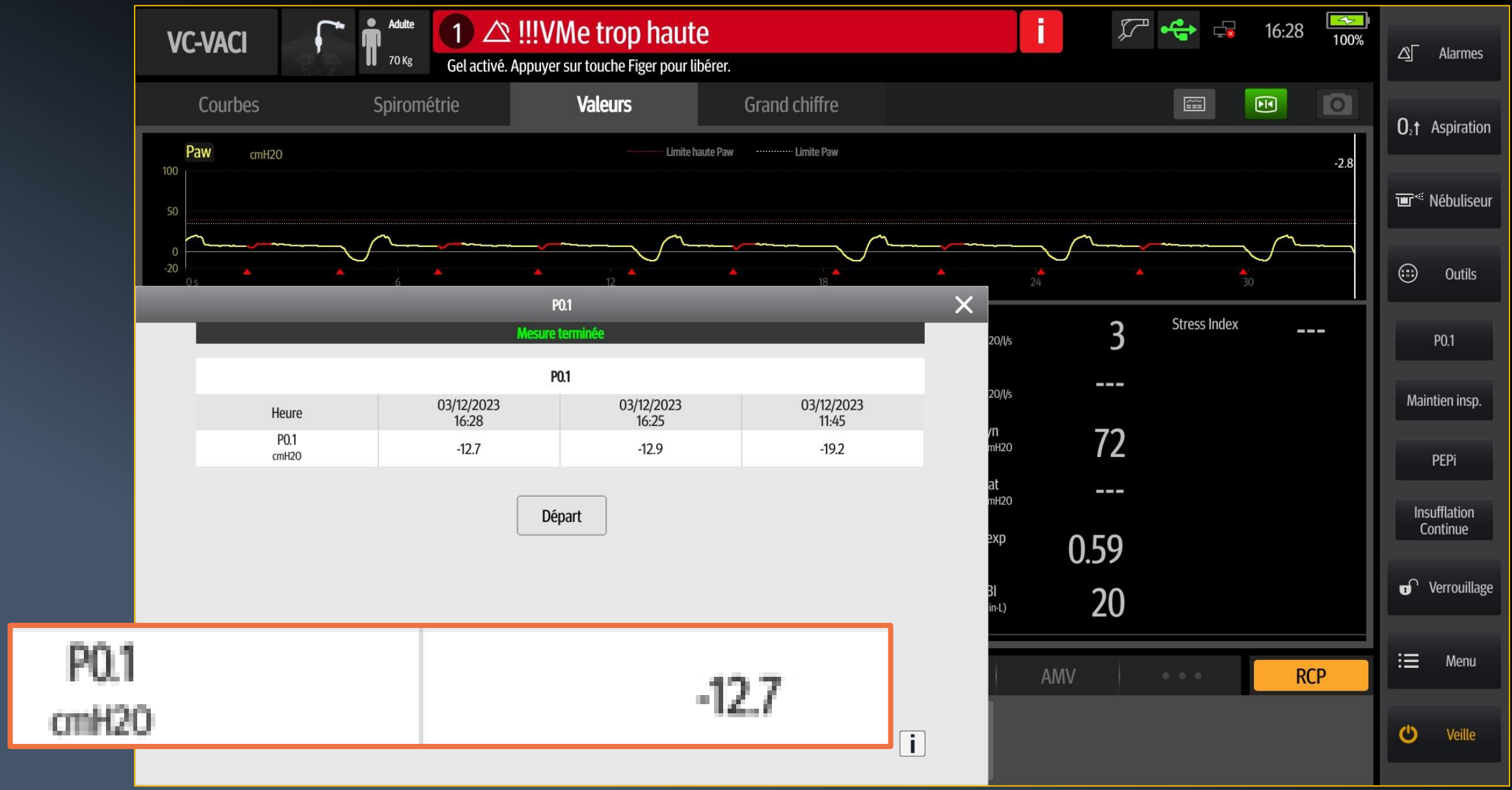
➢ Under estimates respiratory drive

Elevated respiratory drive does not always result in elevated respiratory effort

Telias I Airway occlusion pressure as an estimate of respiratory drive and inspiratory effort during assisted ventilation. Am J Respir Crit Care Med 2020


VC-VACI
Gel activé. Appuyer sur touche Figer pour libérer.
14:00
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
30
15
0
-6
2.5
P0.1
Mesure terminée
P0.1
Heure
30/11/2023 14:00
30/11/2023 13:47
30/11/2023 13:44
P0.1 cmH2O
-3.7
-10.0
-9.9
Départ
Pcrête cmH2O
22
40
10
Pplat cmH2O
9.3
PEP cmH2O
2.9
VMe l/min
7.83
10.0
3.0
Vte ml
42.1
560
250
ftotal /min
18
35
8
FiO2 vol.%
59
67
53
RCexp s
0.57
Vte/PCI ml/kg
0.6
AMV
RCP
P0.1
cmH2O
-3.7

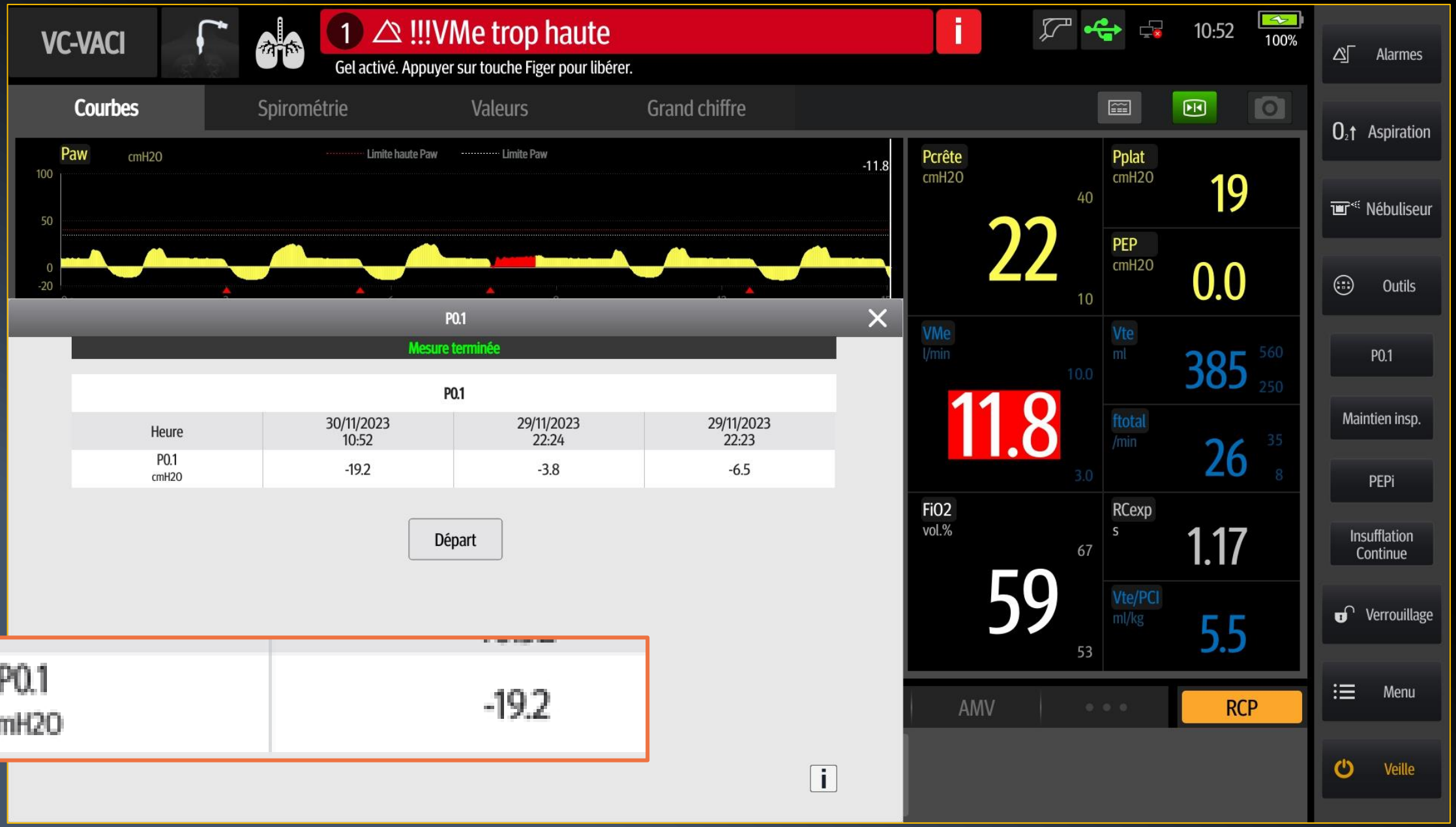

AI
2 !!!VMe trop haute
Gel activé. Appuyer sur touche Figer pour libérer.
16:25
98%
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
30
15
0
-6
-3.7
P0.1
Mesure terminée
P0.1
Heure
28/11/2023
16:25
P0.1
cmH2O
-9.0
Départ
Pcrête
cmH2O
14
50
Pplat
cmH2O
9.7
PEP
cmH2O
5.4
VMe
l/min
20.2
11.3
4.5
Vte
ml
519
1000
250
ftotal
/min
36
FiO2
vol.%
54
62
48
RCexp
s
0.66
Vte/PCI
ml/kg
7.4
AMV
RCP
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
P0.1
cmH2O
-9.0


VC-VACI
Adulte
70 Kg
1 !!!VMe trop haute
Gel activé. Appuyer sur touche Figer pour libérer.
16:28
100%
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
Limite Paw
-2.8
100
50
0
-20
0 s
6
12
18
24
30
P0.1
Mesure terminée
P0.1
Heure
03/12/2023 16:28
03/12/2023 16:25
03/12/2023 11:45
P0.1 cmH2O
-12.7
-12.9
-19.2
Départ
Stress Index

3

72

0.59
20
AMV
RCP
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
P0.1
cmH2O
-12.7


VC-VACI
1 !!!VMe trop haute
Gel activé. Appuyer sur touche Figer pour libérer.
10:52
100%
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
Maintien insp.
PEPi
Insufflation Continue
Verrouillage
Menu
Veille
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
Limite Paw
-11.8
100
50
0
-20
P0.1
Mesure terminée
P0.1
Heure
30/11/2023 10:52
29/11/2023 22:24
29/11/2023 22:23
P0.1 cmH2O
-19.2
-3.8
-6.5
Départ
Pcrête cmH2O
22
40
10
Pplat cmH2O
19
PEP cmH2O
0.0
VMe l/min
11.8
10.0
3.0
Vte ml
385
560
250
ftotal /min
26
35
8
FiO2 vol.%
59
67
53
RCexp s
1.17
Vte/PCI ml/kg
5.5
AMV
RCP
P0.1
cmH2O
-19.2

Diaphragm inspiratory thickening fraction (TFdi)

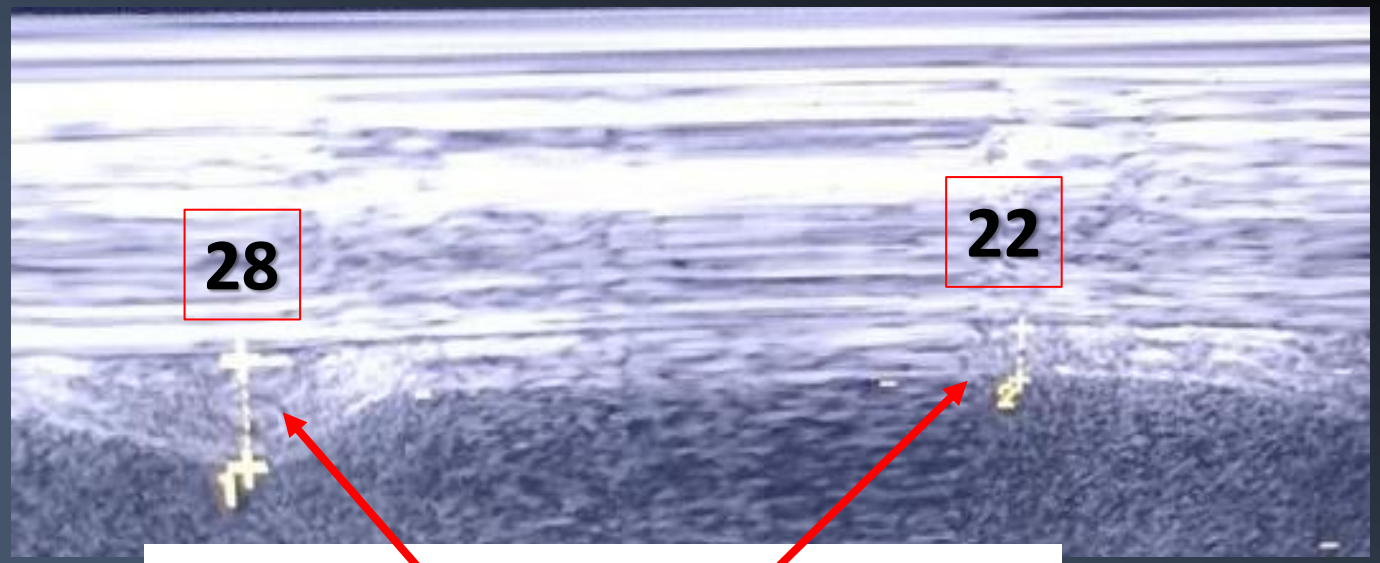
Diaphragmatic Effort (tidal TFdi)

Diaphragmatic Function (Maximal TFdi)

ULTRASOUND

TFdi 15–30%

- *Non-invasive assessment of diaphragmatic contractility*
- *Diaphragmatic Function (Maximal TFdi)*



Tfdi = Tei - Tee / Tee

Tfdi = 27 %

inconvénients

- Requires equipment and training
- Continuous monitoring is not feasible

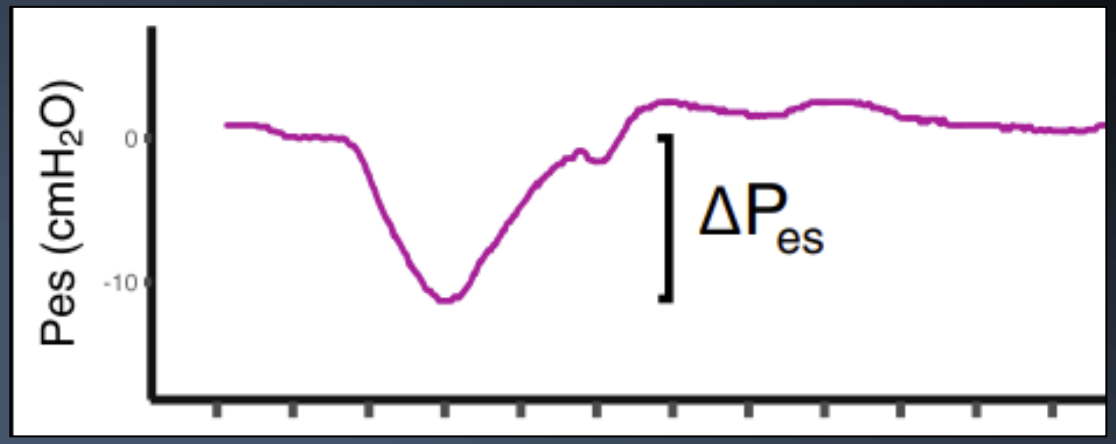
Tuinman PR, Respiratory muscle ultrasonography: methodology, basic and advanced principles and clinical applications in ICU and ED patients a narrative review. Intensive Care Med 2020

Esophageal pressure (Pes)

Gold Standard

Respiratory Effort

ΔPes : 3–15 cmH2O
(Diaphragm Protective)



inconvénients

- do not take into account the effects of time, the elastance of chest wall, and PEEPi
- difficult to assess the energy expenditure of the respiratory muscles

Work of Breathing (WOB J/L)

Respiratory Effort

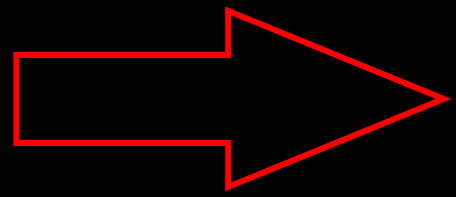
change of volume caused by pressure during breathing

$$\mathrm{WOB} = \mathrm{P} \times \mathrm{V} = \int P dv.$$

inconvénients

- cannot reflect changes in isovolumic contraction
- does not consider the effect of time

Pressure time product (PTP)



Respiratory Effort

- *integral of pressure over time* 50–100 $cmH_2O/s/min$

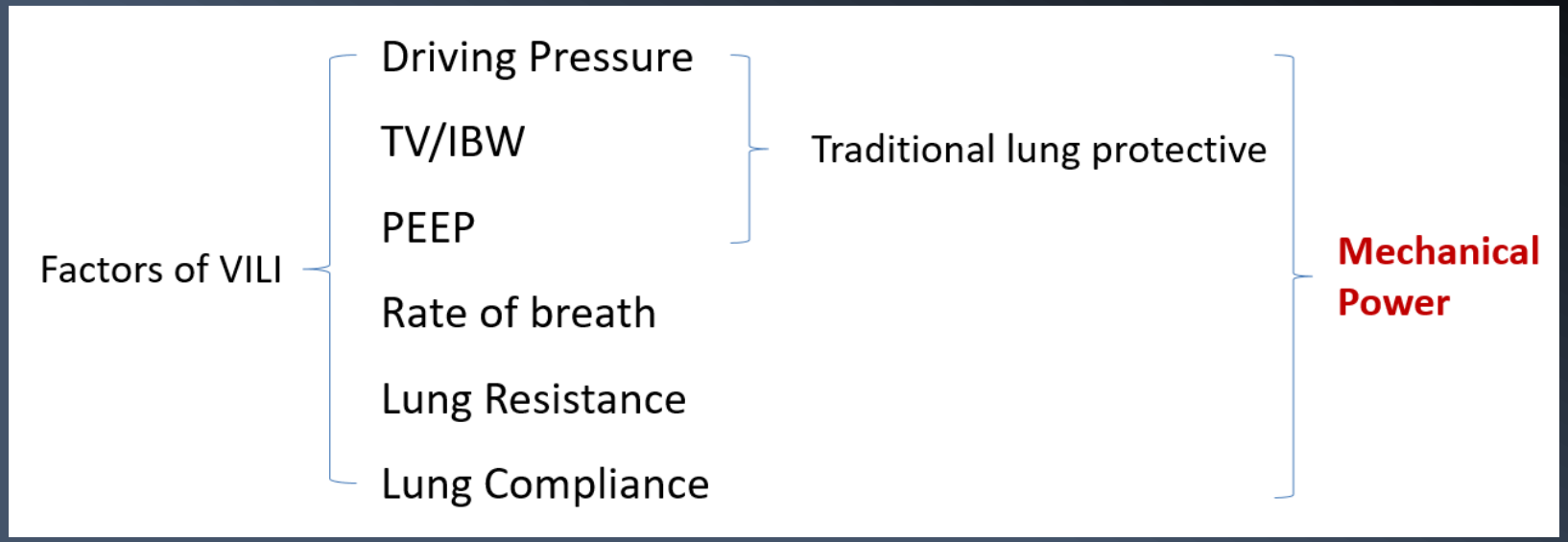
- *PTP calculated by Pes (PTPes)* ➔ *assess overall respiratory muscle activity*
- *Compared with WOB, PTP integrates time parameters*
- *good correlation with energy consumption*
- *can calculate changes in muscle during isovolumetric contraction*
  (ineffective spontaneous breathing efforts with asynchronous and PEEPi

Mechanical Power (MP)

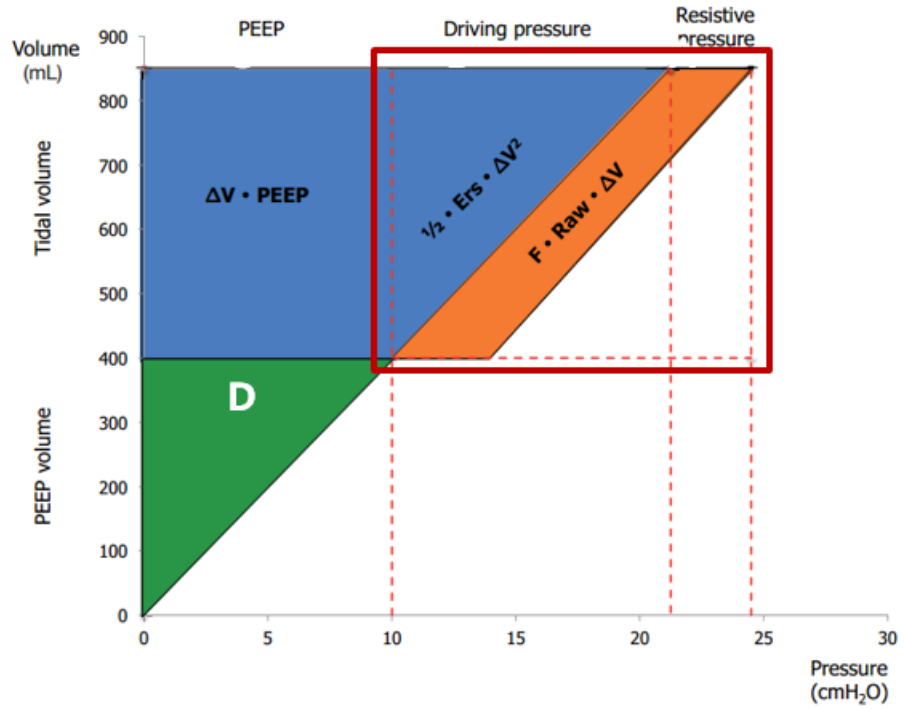
*Combining **WOB** with **respiratory rate***

17J/min

- integrates several parameters of pressure, volume, and time
- well reflect the energy consumption of respiratory muscles
- increase in MP is related to the occurrence of VILI



WOB not consider the effect of PEEP



		Mechanical power	WOB
Diff.	unit	J/min	J/min or J·L
	Scenario	Only for mandatory breathing patient	Can be separate as WOB by ventilator or by patient
	Definition	Include potential energy	Not included potential energy
Common		When PEEP equal to zero, there is no different	

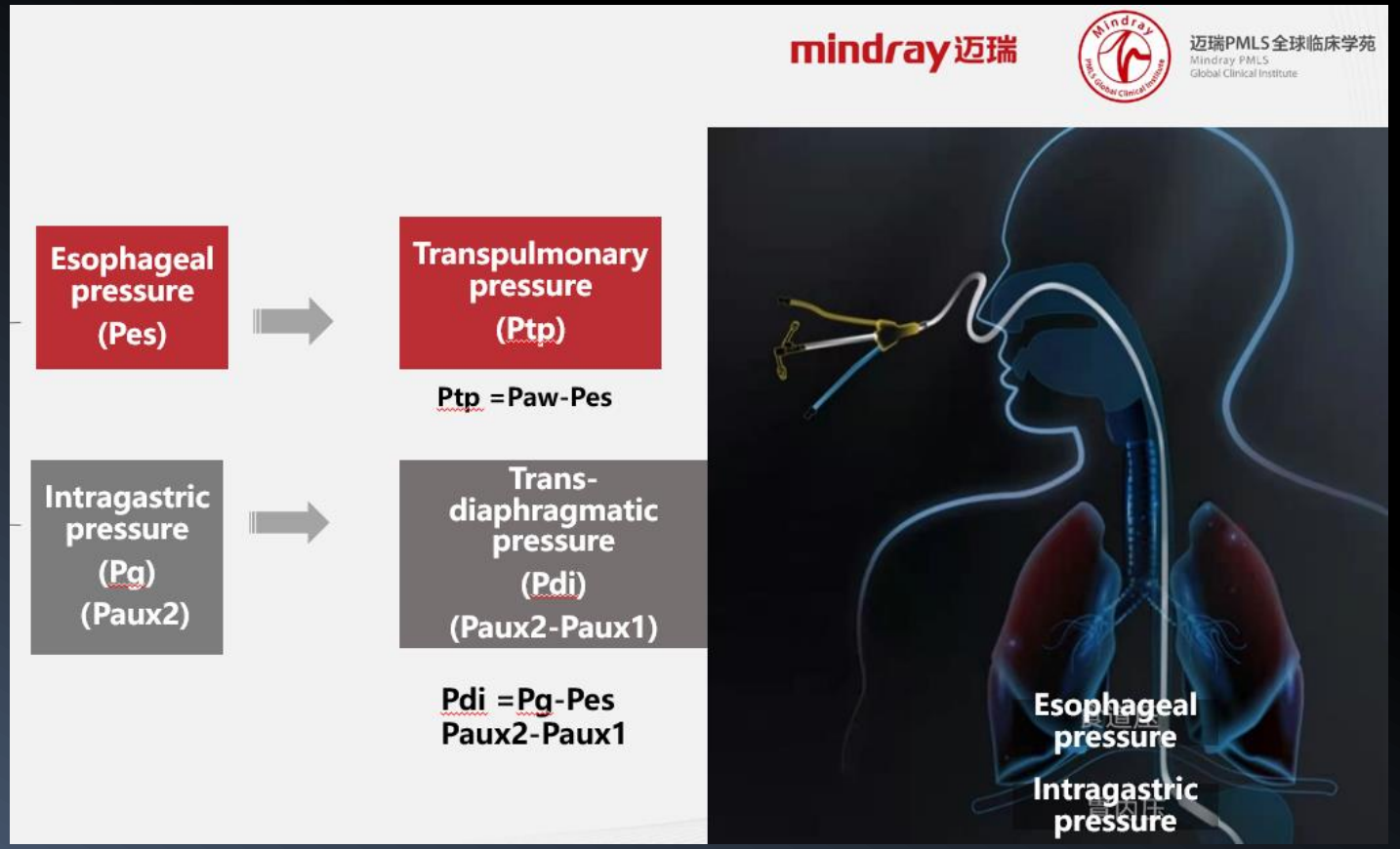
Tonetti T, Ann Transl Med 2017

Transdiaphragmatic pressure swing (ΔPdi)

ΔPdi–15 cmH2O

Respiratory Effort

- *Provides direct measurement of diaphragmatic effort*
- *Provides information about expiratory muscle activity*



Comprehensive monitoring parameters related to esophageal pressure

mindray 迈瑞

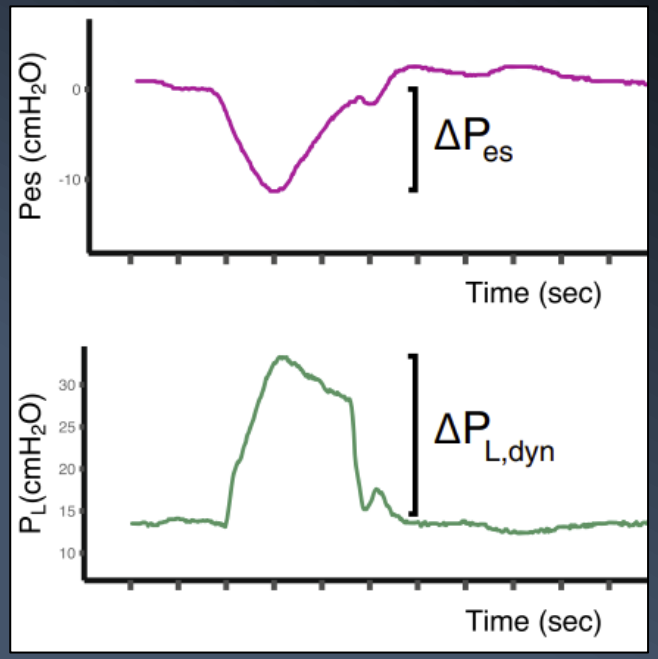
迈瑞PMLS全球临床学苑
Mindray PMLS
Global Clinical Institute

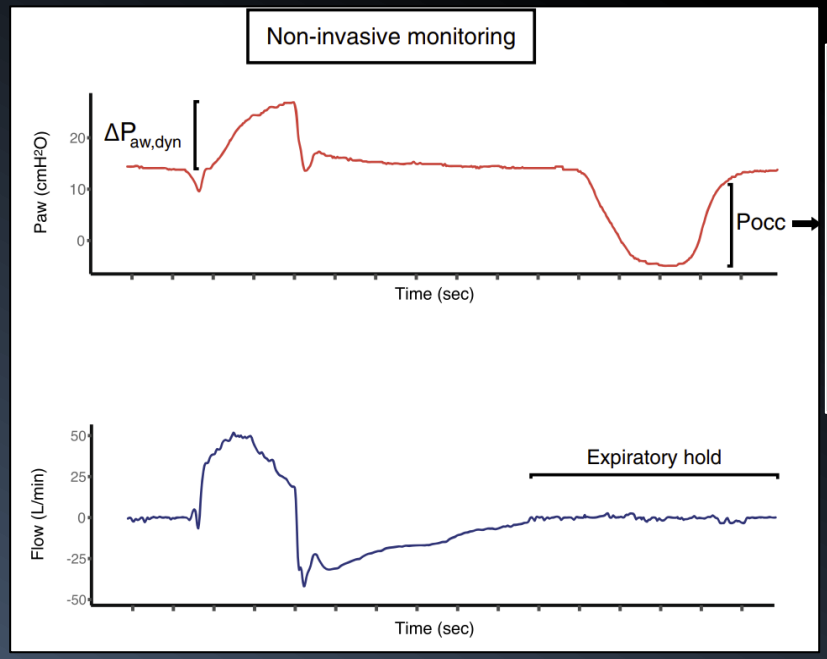
WHOLE BREATH OCCLUSION

Airway pressure swing (ΔPocc)

- Predicted Pmus 5–10 cmH2O (ΔPocc 8–20 cmH2O)
- Predicted ΔPL,dyn < 15–20 cmH2O

- **Respiratory Effort**
- **Tidal Lung Stress**





- *Non-invasive*
- *Easily measured at the bedside*
- *Can predict respiratory muscle effort (Pmus) and transpulmonary pressure swing (ΔPL,dyn)*
- *Detect apnea, auto-triggering*
- *Differentiate different forms of Asynchrony*

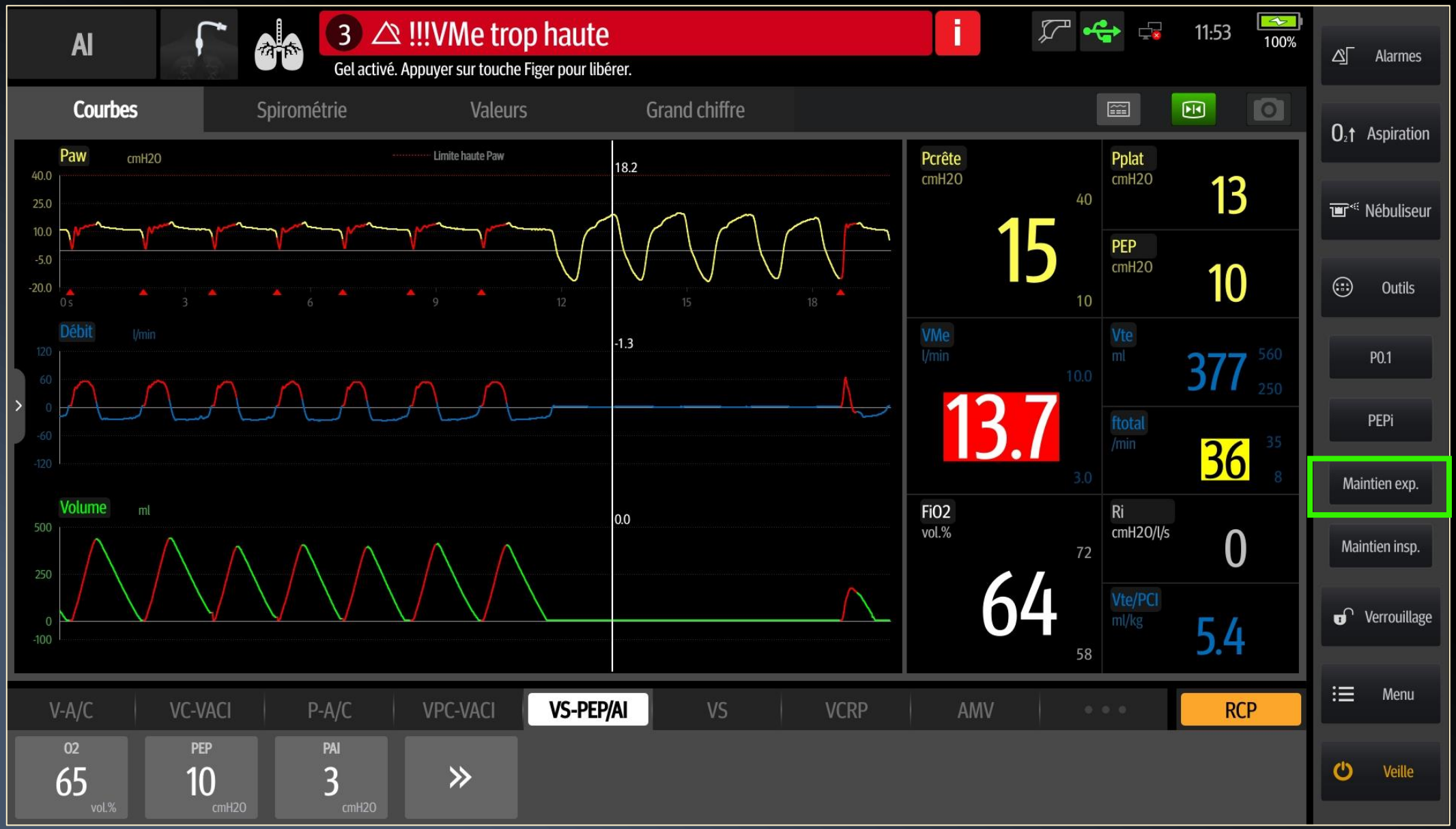
inconvénients

- not sufficiently accurate to replace direct measurement

$$\text{Predicted } P_{mus} = -3/4 \times Pocc$$

$$\text{Predicted } \Delta P_{L,dyn} = \Delta P_{aw,dyn} - 2/3 \times Pocc$$

(Peak airway pressure - PEEP)


AI
3 !!!VMe trop haute
Gel activé. Appuyer sur touche Figer pour libérer.
11:53
100%
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
18.2
Débit
l/min
-1.3
Volume
ml
0.0
Pcrête
cmH2O
15
Pplat
cmH2O
13
PEP
cmH2O
10
VMe
l/min
13.7
Vte
ml
377
ftotal
/min
36
FiO2
vol.%
64
Ri
cmH2O/l/s
0
Vte/PCI
ml/kg
5.4
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
PEPi
Maintien exp.
Maintien insp.
Verrouillage
Menu
Veille
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
65
vol.%
PEP
10
cmH2O
PAI
3
cmH2O

- Predicted Pmus 5–10 cmH2O (ΔPocc 8–20 cmH2O)
- Predicted ΔPL,dyn < 15–20 cmH2O

P0.1 cmH2O	-16.4

ΔPocc = 18 - (-15.6) = 23.6 cmH2O

$$\text{Predicted } P_{mus} = -3/4 \times Pocc$$

$$\text{Predicted } \Delta P_{L,dyn} = \Delta P_{aw,dyn} - 2/3 \times Pocc$$

Predicted Pmus = 3/4 . 23.6 = **17.7**

Predicted ΔPL,dyn = 3 . 2/3 . 23.6 = **47.2**

- Predicted Pmus 5–10 cmH2O (ΔPocc 8–20 cmH2O)
- Predicted ΔPL,dyn < 15–20 cmH2O

Titration : sédation

P0.1 cmH2O	-1.8

ΔPocc = 13.5 - (-3.5)= 17 cmH2O

$$\text{Predicted } P_{mus} = -3/4 \times Pocc$$

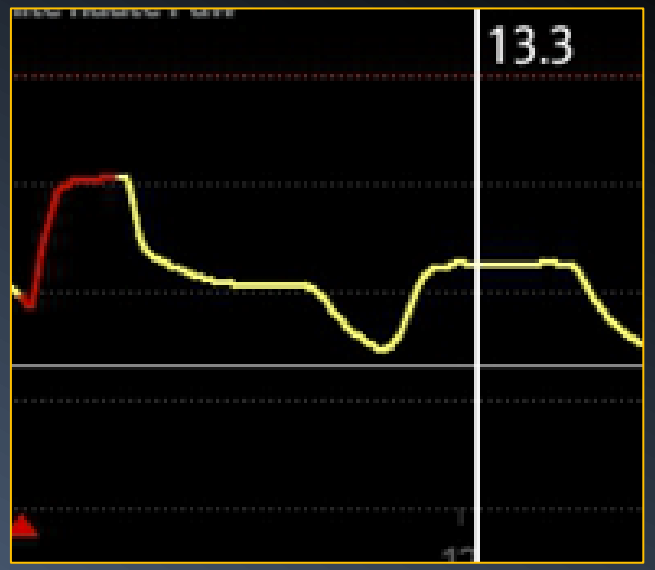
$$\text{Predicted } \Delta P_{L,dyn} = \Delta P_{aw,dyn} - 2/3 \times Pocc$$

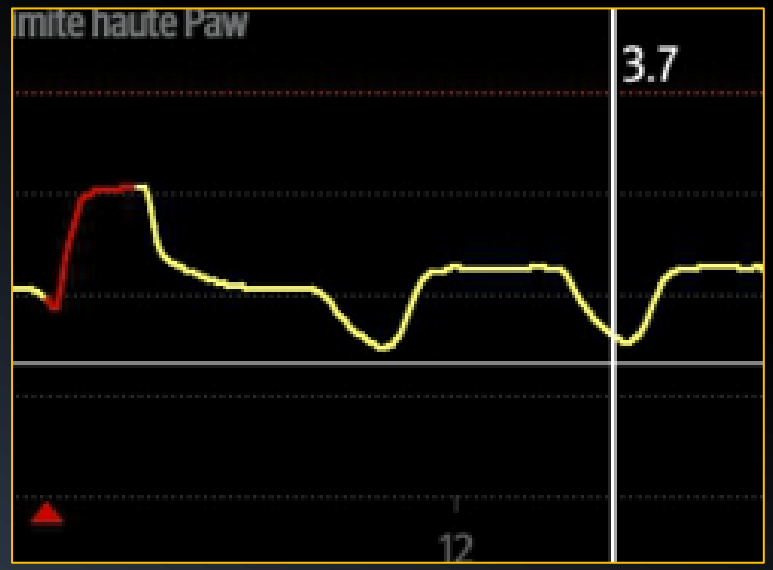
Predicted Pmus = 3/4 . 17 = **12.75**

Predicted ΔPL,dyn = 3 . 2/3 . 17 = **34**

- Predicted Pmus 5–10 cmH2O (ΔPocc 8–20 cmH2O)
- Predicted ΔPL,dyn < 15–20 cmH2O

Titration : sédation





P0.1 cmH2O	-2.5

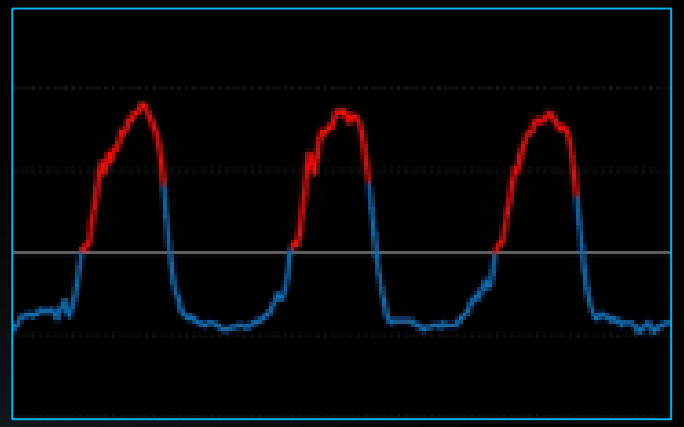
ΔPocc = 13. 3 - (+3.7)= 9.6 cmH2O

$$\text{Predicted } P_{mus} = -3/4 \times Pocc$$

$$\text{Predicted } \Delta P_{L,dyn} = \Delta P_{aw,dyn} - 2/3 \times Pocc$$

Predicted Pmus = 3/4 . 9.6= **7.2**

Predicted ΔPL,dyn = 3 . 2/3 . 9.6 = **19.2**



❑ AutoPEEP (PEEP intrinsèque)

Lung *Stress/strain*

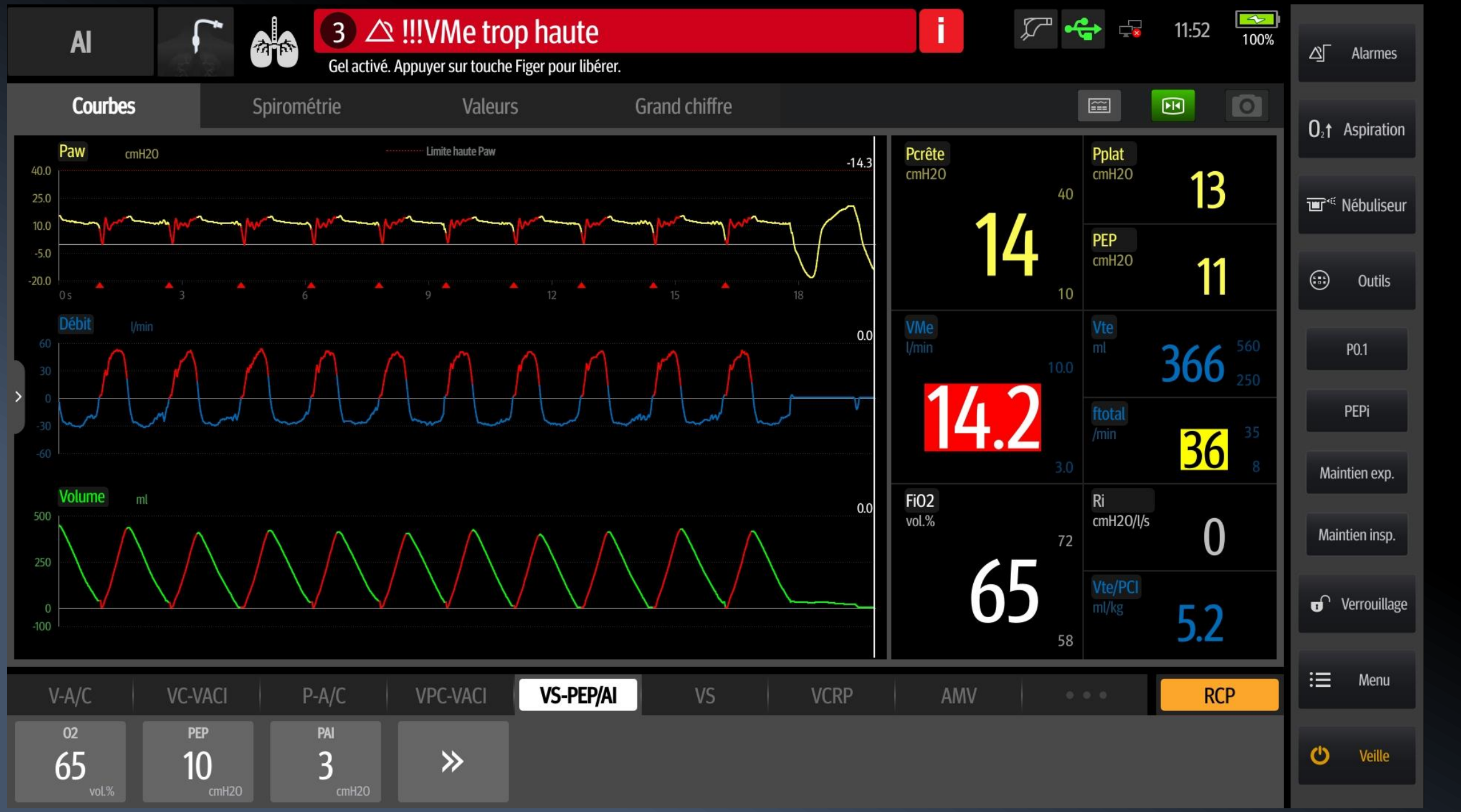
- Barotrauma
- volutauma

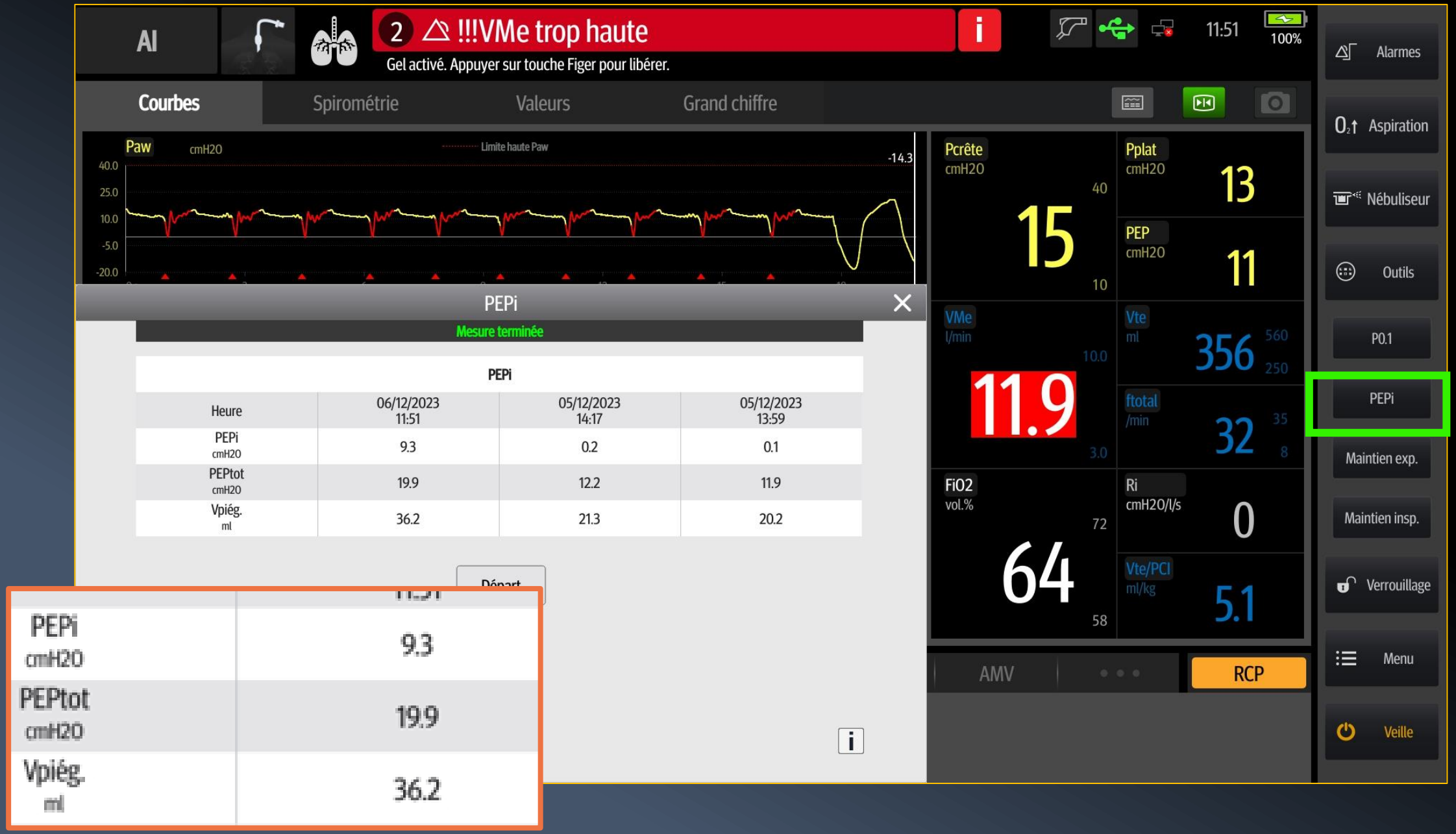
Hémodynamique

- Cœur pulmonaire

Respiratory *Effort*

- Trigger inefficace

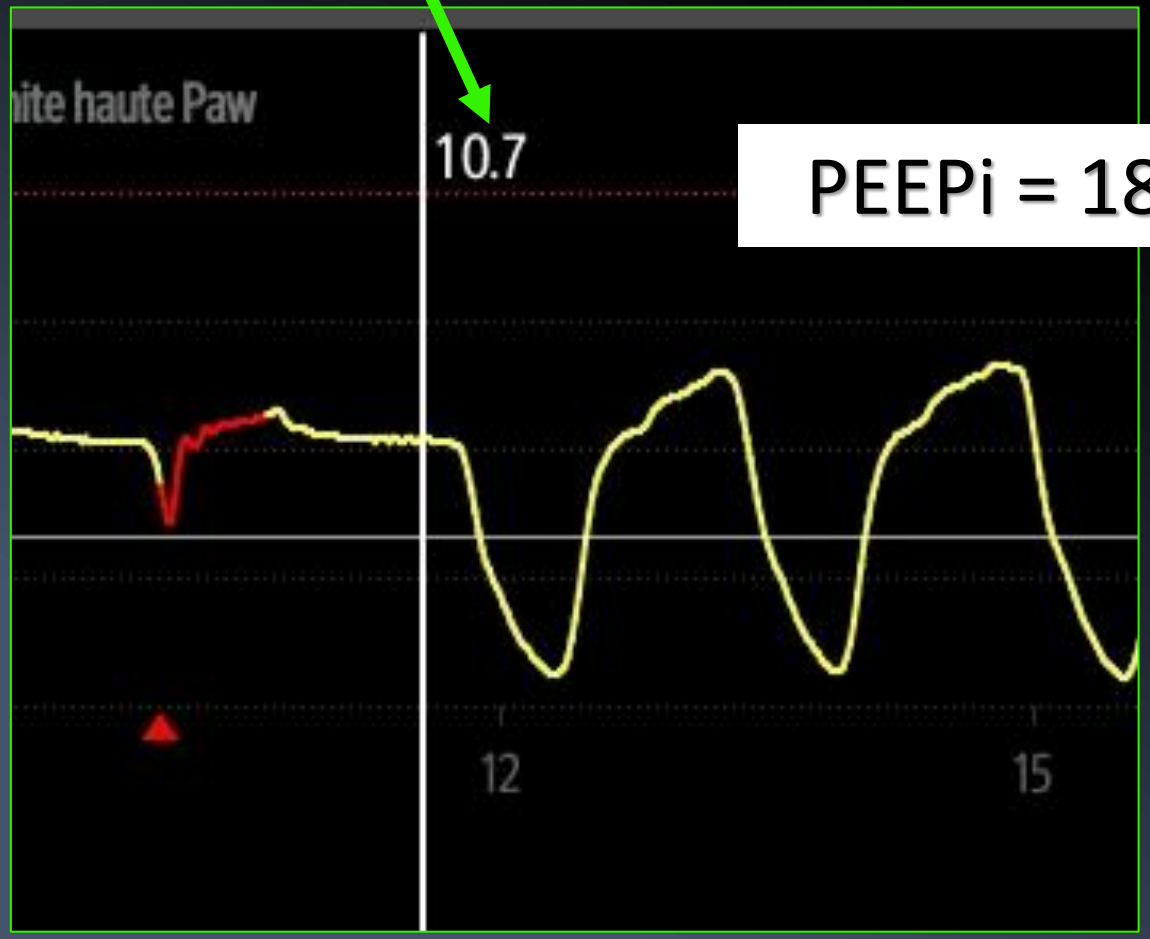

AI
3 !!!VMe trop haute
Gel activé. Appuyer sur touche Figer pour libérer.
11:52
100%
Courbes
Spirométrie
Valeurs
Grand chiffre
Paw
cmH2O
Limite haute Paw
-14.3
Débit
l/min
0.0
Volume
ml
0.0
Pcrête
cmH2O
14
Pplat
cmH2O
13
PEP
cmH2O
11
VMe
l/min
14.2
Vte
ml
366
ftotal
/min
36
FiO2
vol.%
65
Ri
cmH2O/l/s
0
Vte/PCI
ml/kg
5.2
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
PEPi
Maintien exp.
Maintien insp.
Verrouillage
Menu
Veille
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
65
vol.%
PEP
10
cmH2O
PAI
3
cmH2O



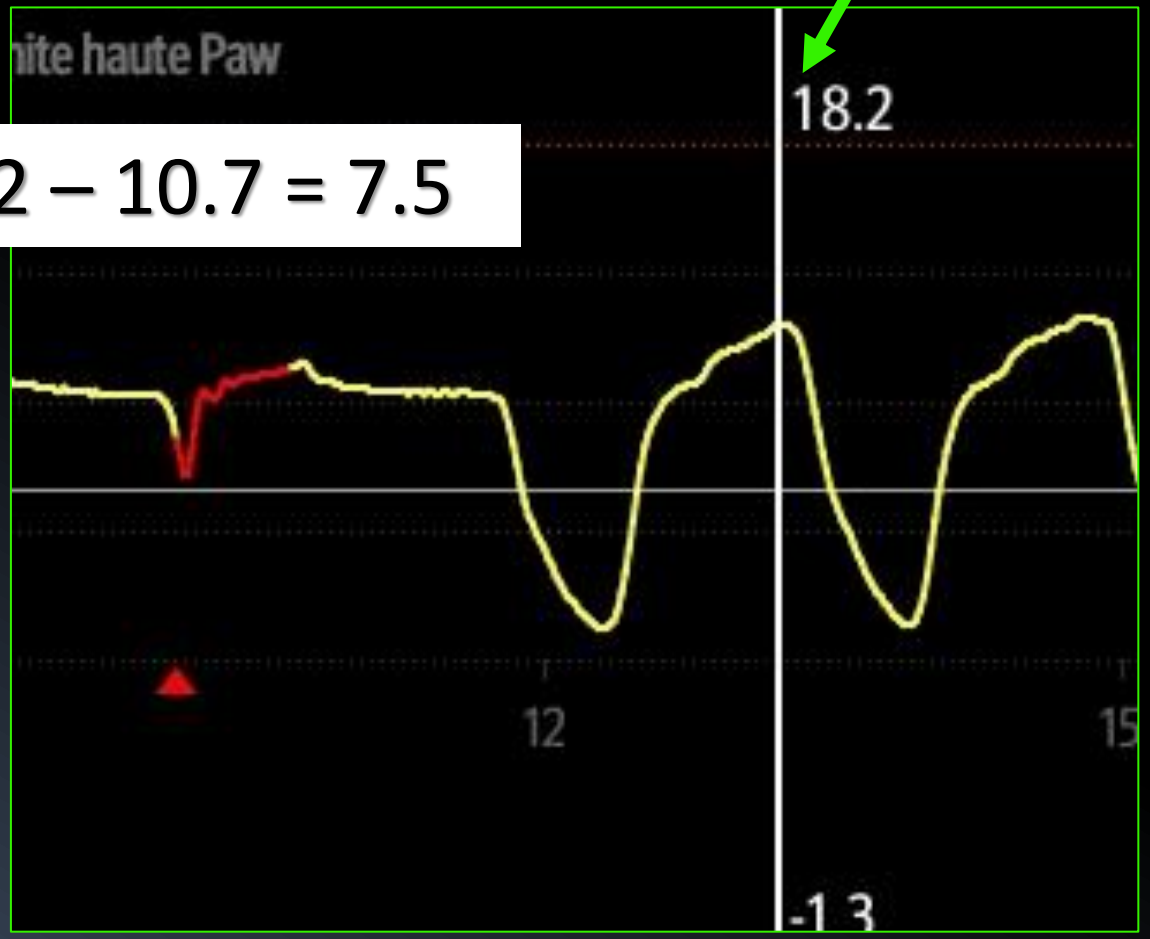
PEPi cmH2O	9.3
PEPtot cmH2O	19.9
Vpiég. ml	36.2

PEEP réglée

PEEP Totale = PEEP + PEEPi



PEEPi = 18.2 – 10.7 = 7.5

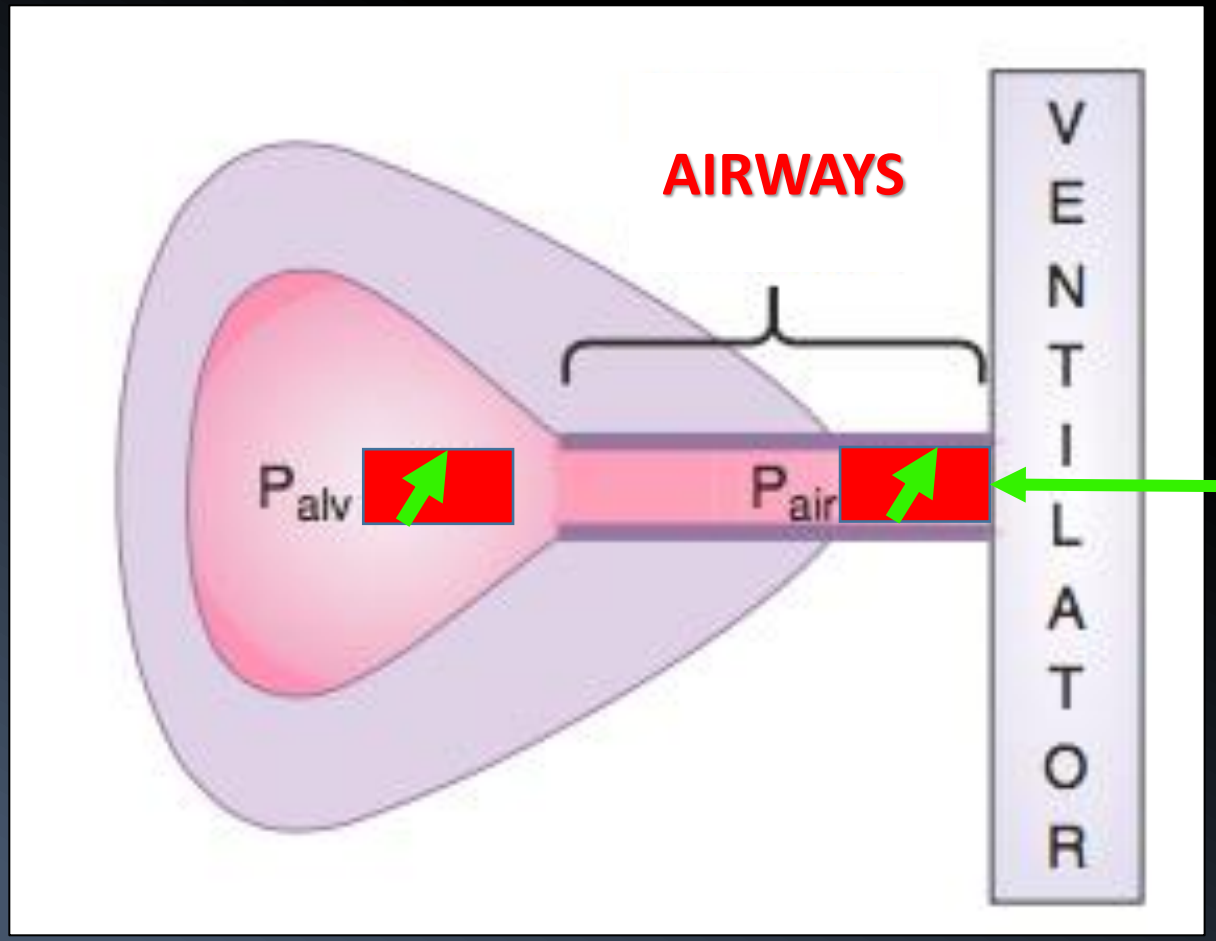


PEEPi = PEEP Totale - PEEP

INEFFECTIVE TRIGGERING

Auto-PEEP ?

- **OUI**
  - WATERFFALL EFFECT ??
    - **NON**
      - *decrease the respiratory rate*
      - *Decrease airway resistance*
    - **OUI**
      - *PEEP Extrinseque (75 % de la PEEP Intrinseque)*
- **NON**
  - ➢ *Reduce trigger thresholds*
  - ➢ *Promote respiratory drive*

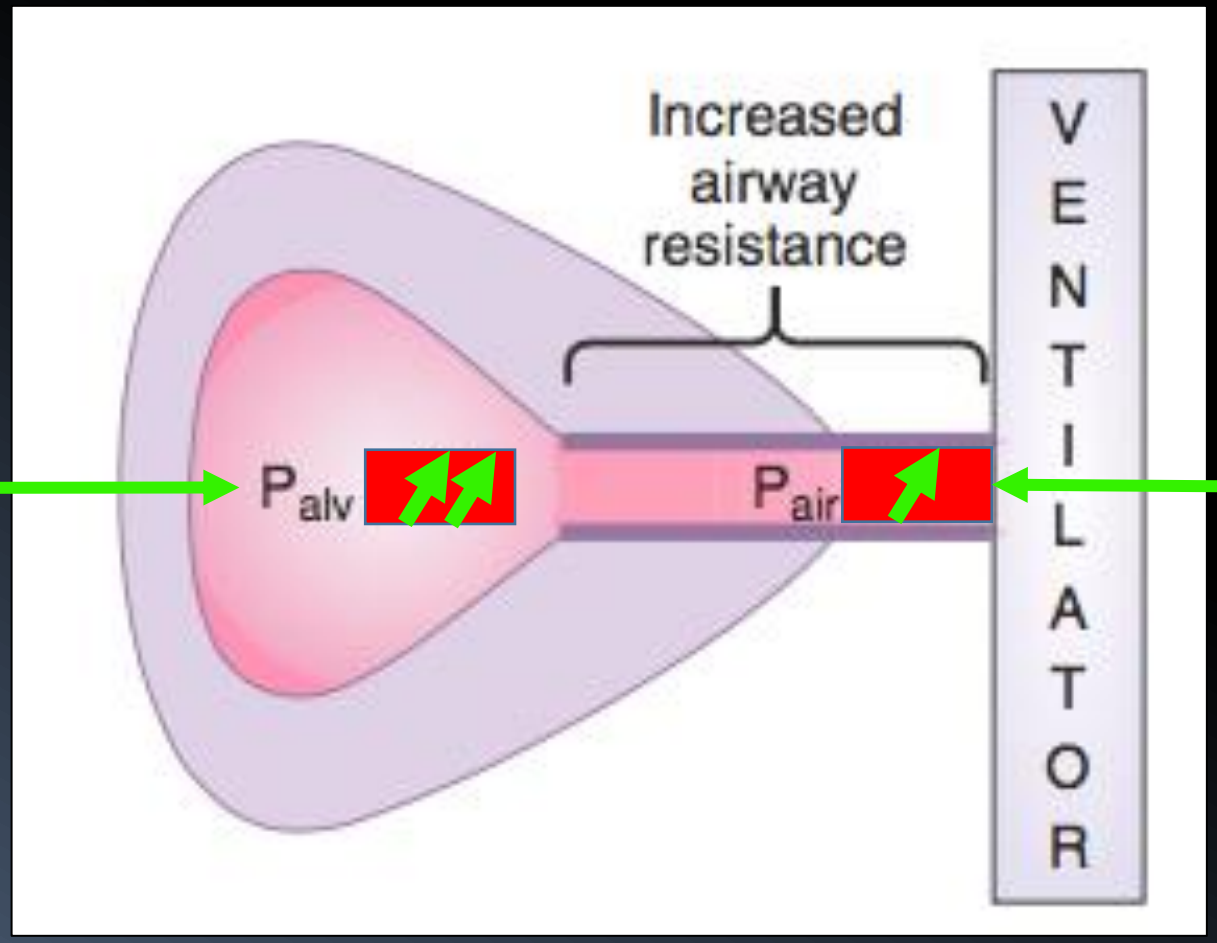


Thérapeutique

PEEP

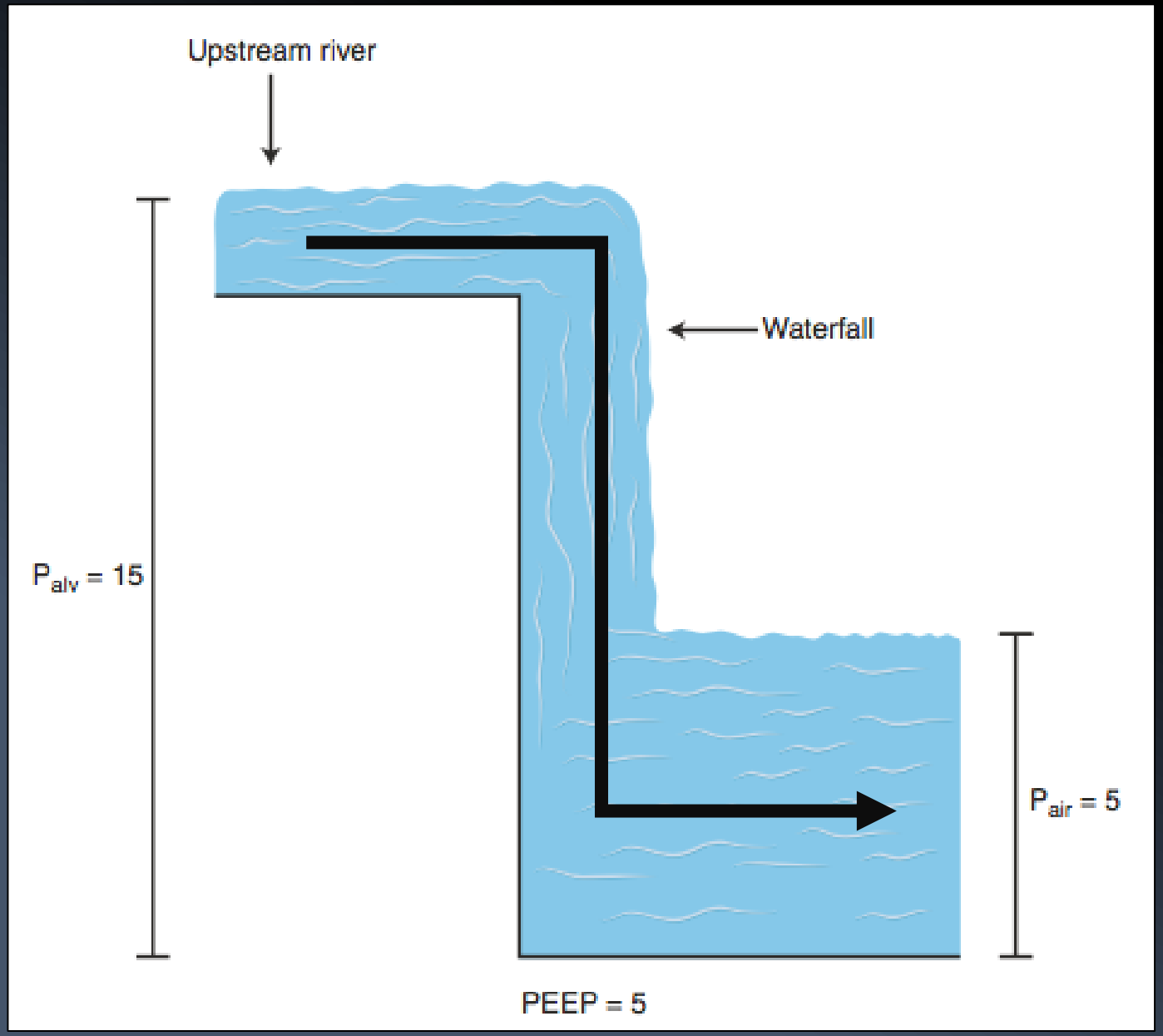
Pathologie

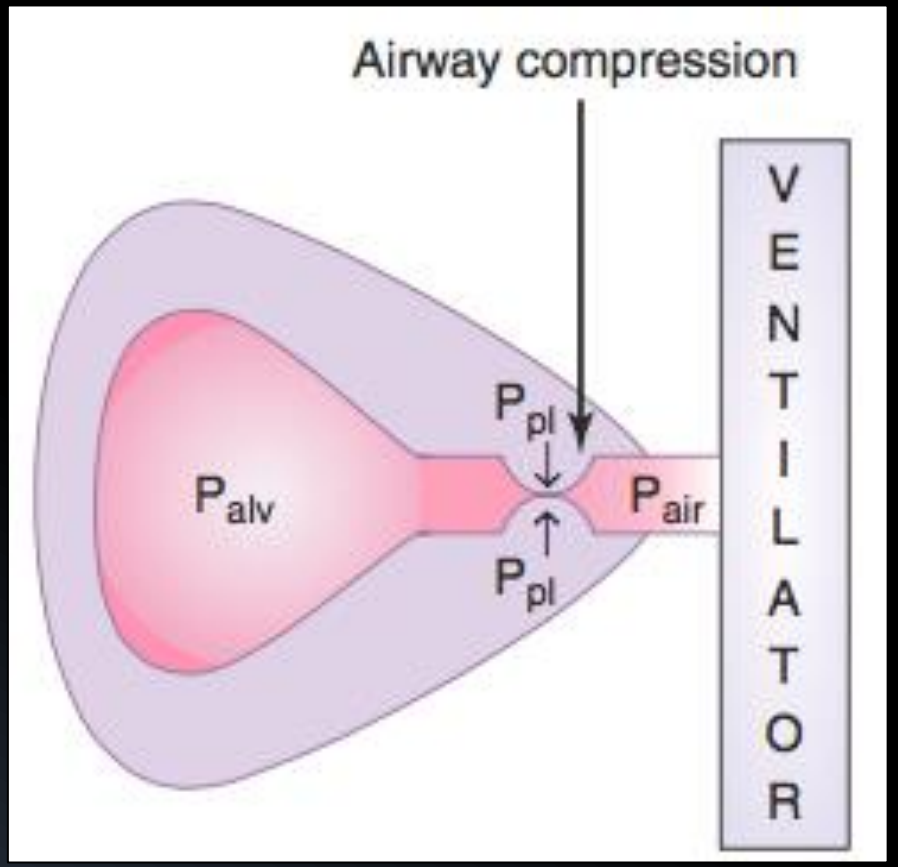
Auto-PEEP



Thérapeutique

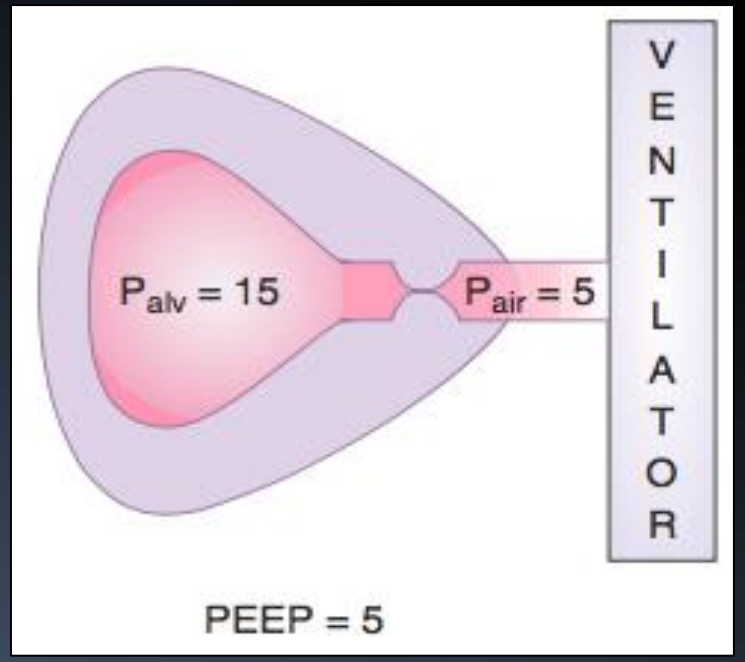
PEEP

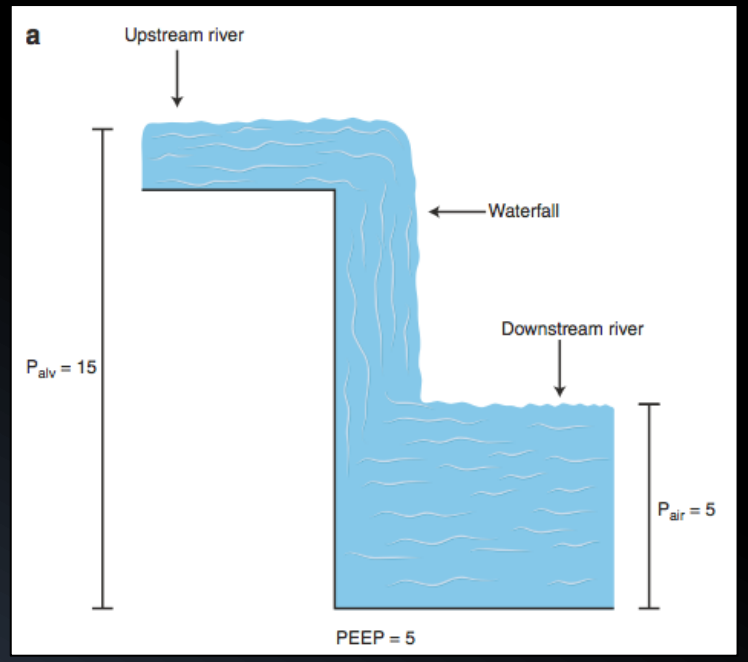


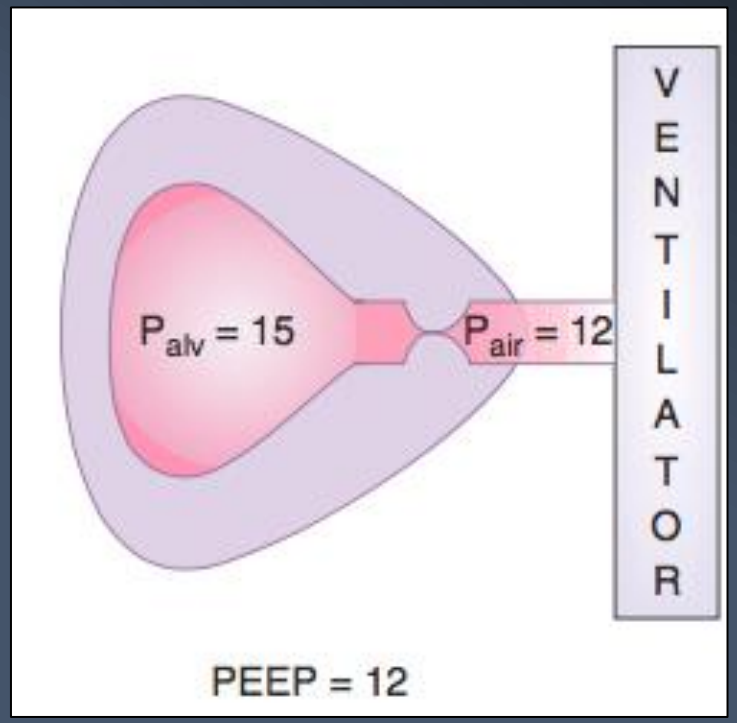


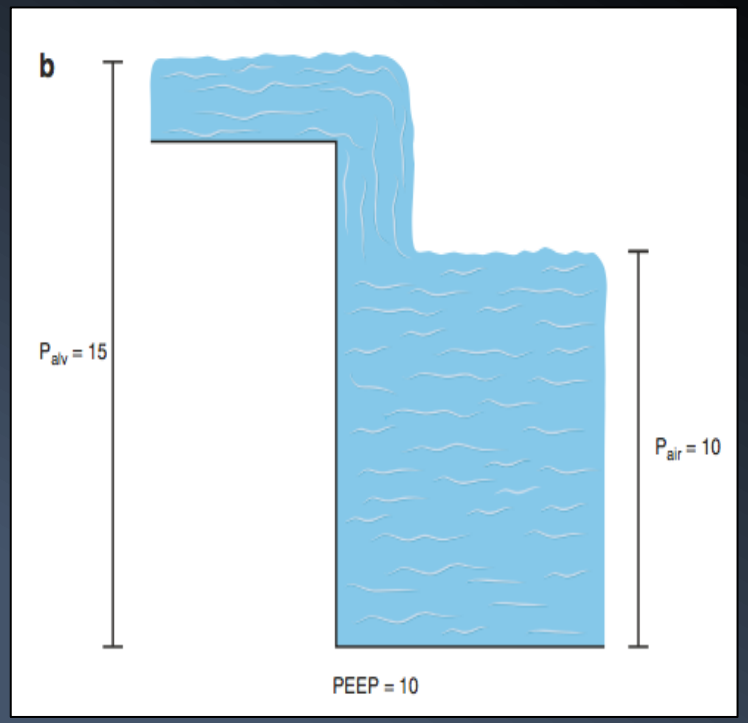
Limitation Du Débit Expiratoire

BPCO



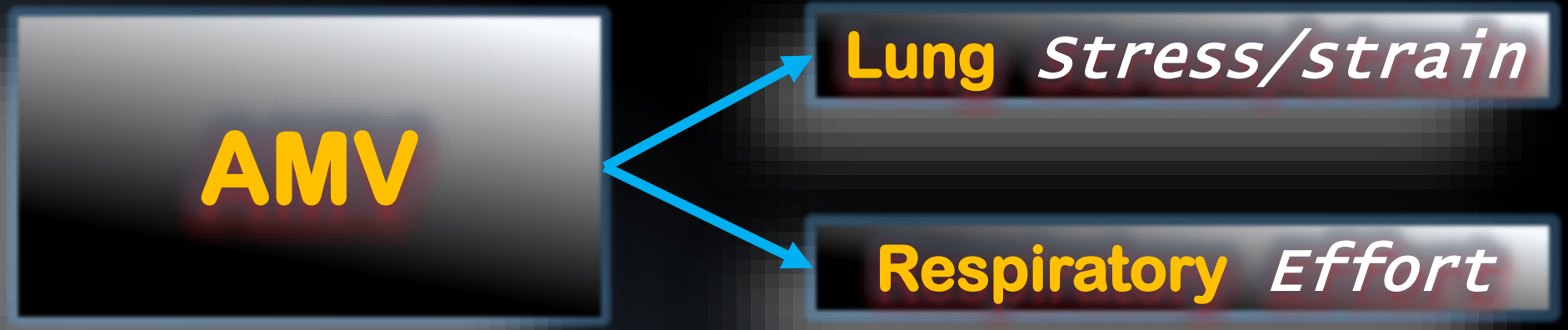




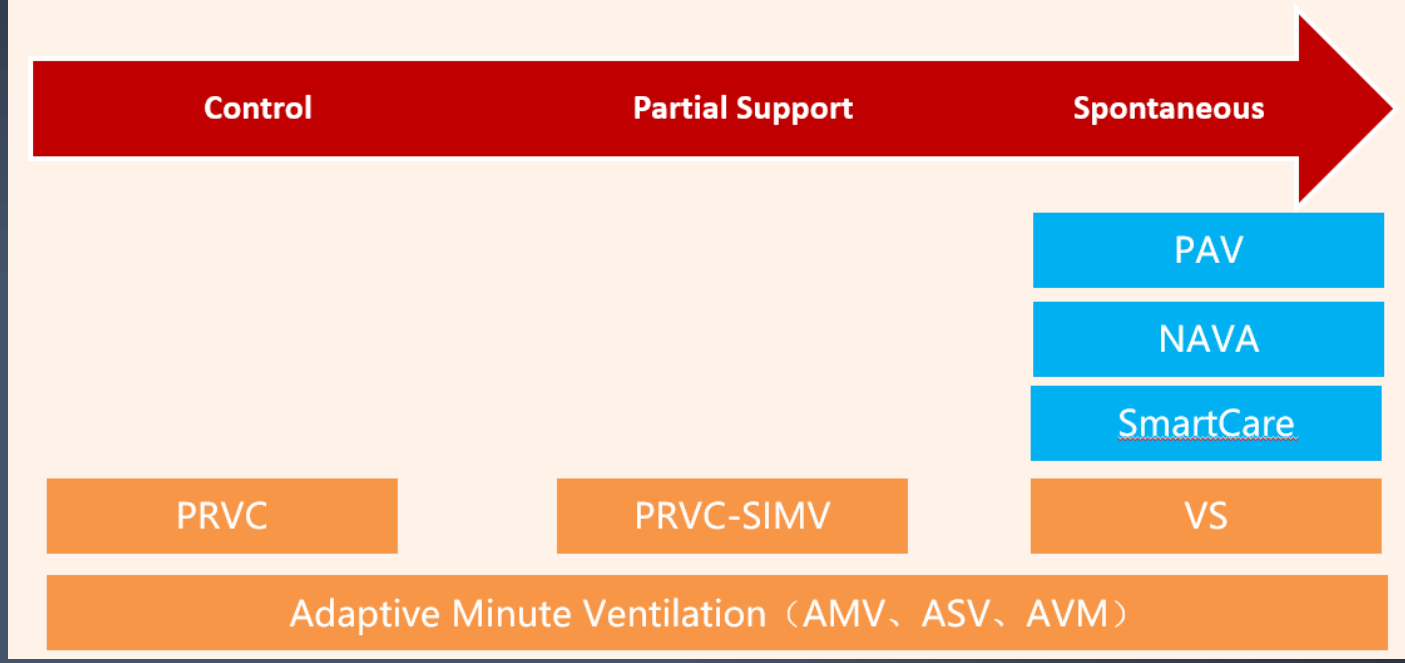


PEEP = approximately 75% of the measured autoPEEP

➔ Amélioration gradient pression motrice
➔ Amélioration débit expiratoire

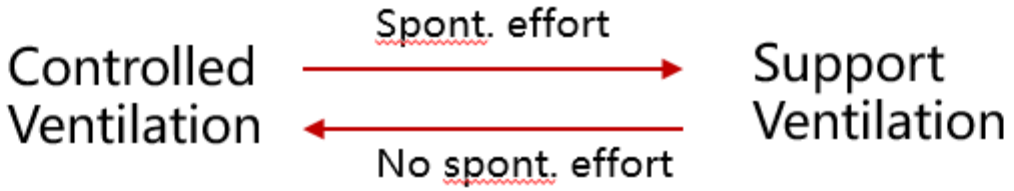


Common Closed-loop Systems



AMV Advantages

1 Base on patient's spont. effort， automatically switching between support ventilation and controlled ventilation ， improving patient comfort.



2 Base on change in resistance & compliance， automatically adjust resp. rate & Vt on the basis of setting the target MV, prevent barotrauma, & achieve minimal WOB。

Resp. Rate= F(Airway Resistance, Compliance) → minimal WOB base on Otis formula

Tidal Volume = Target MV/Resp. Rate

3 Ease of use， simplified ventilation settings, only need to set MV%, PEEP & FiO2。

AMV Operating Procedures

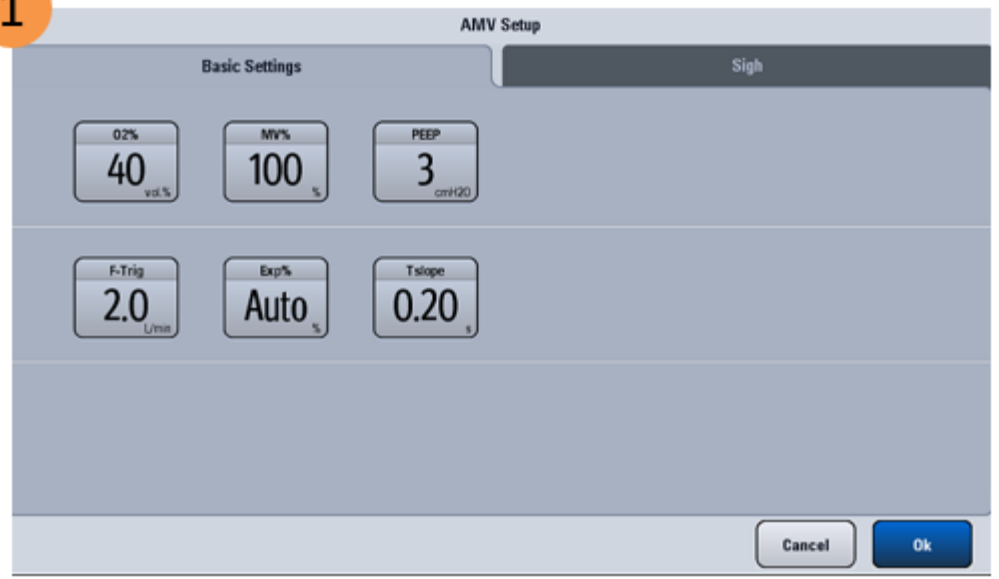
① Enter AMV mode interface;

② Select patient sex, height， system automatically calculate IBW;

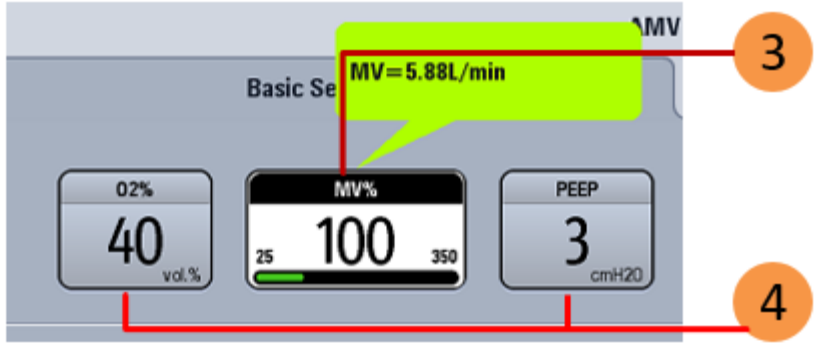
③ Set MV%;

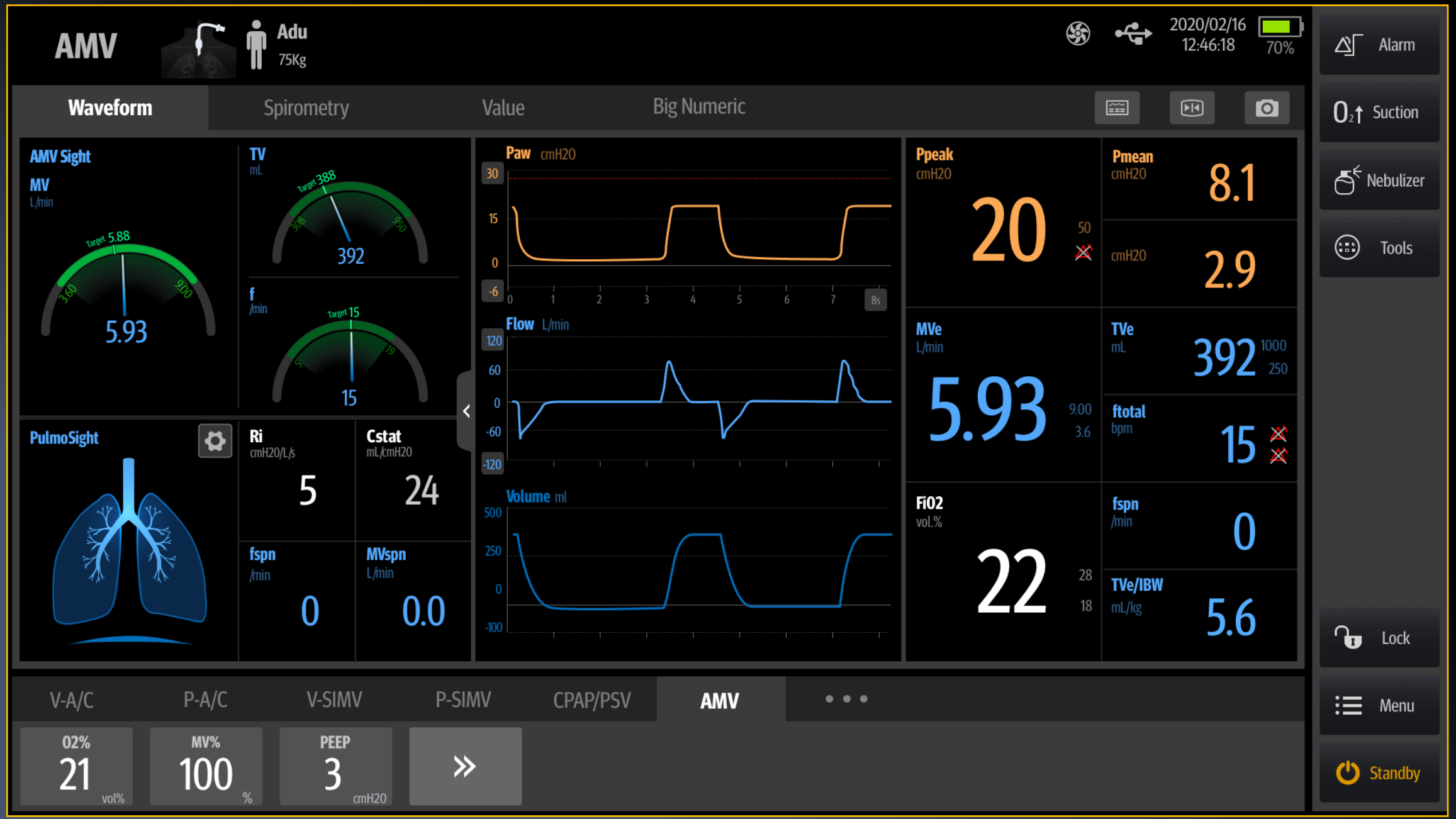
④ Set PEEP， FiO2。

1

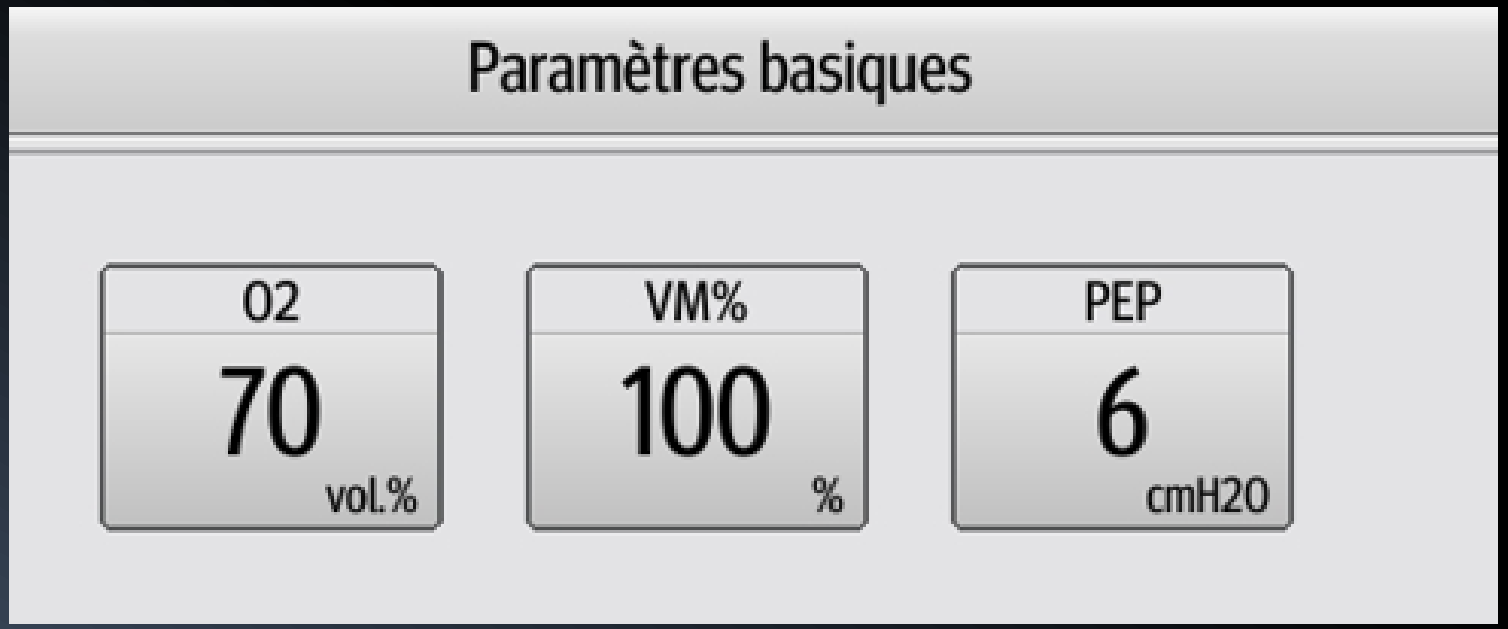


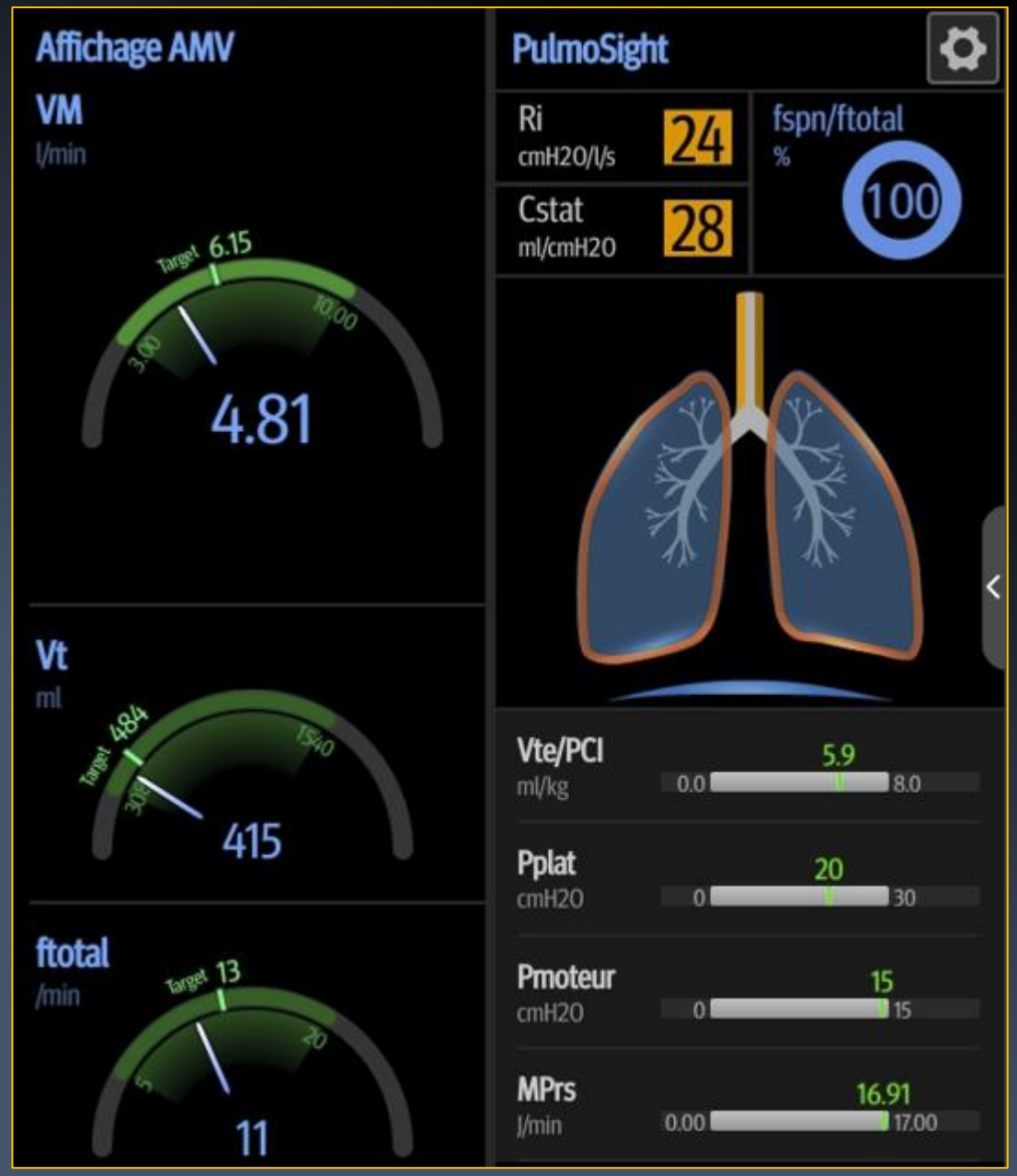
2

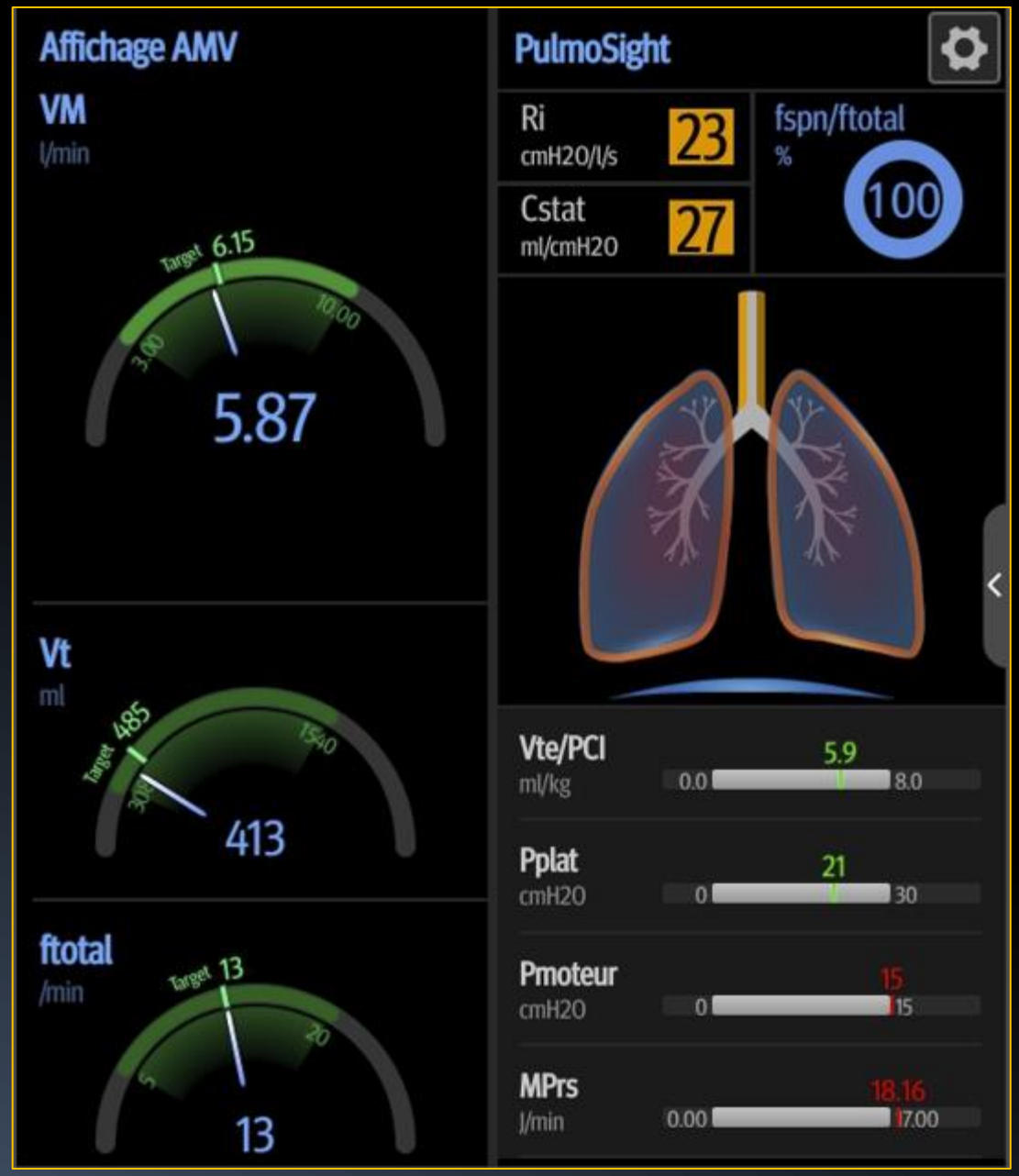



AMV
Adu
75Kg
2020/02/16
12:46:18
70%
Alarm
Suction
Nebulizer
Tools
Lock
Menu
Standby
Waveform
Spirometry
Value
Big Numeric
AMV Sight
MV
L/min
Target 5.88
3.60
9.00
5.93
TV
mL
Target 388
308
950
392
f
/min
Target 15
5
19
15
PulmoSight
Ri
cmH2O/L/s
5
Cstat
mL/cmH2O
24
fspn
/min
0
MVspn
L/min
0.0
Paw cmH2O
30
15
0
-6
0 1 2 3 4 5 6 7 8s
Flow L/min
120
60
0
-60
-120
Volume ml
500
250
0
-100
Ppeak
cmH2O
20
50
Pmean
cmH2O
8.1
cmH2O
2.9
MVe
L/min
5.93
9.00
3.6
TVe
mL
392
1000
250
ftotal
bpm
15
FiO2
vol.%
22
28
18
fspn
/min
0
TVe/IBW
mL/kg
5.6
V-A/C
P-A/C
V-SIMV
P-SIMV
CPAP/PSV
AMV
• • •
02%
21
vol%
MV%
100
%
PEEP
3
cmH2O
»


Affichage AMV
VM
l/min
Target 4.54
3.00
10.00
4.95
Vt
ml
Target 456
305
1540
556
ftotal
/min
Target 10
5
15
10


Paramètres basiques
02
70
vol.%
VM%
100
%
PEP
6
cmH2O


Affichage AMV
VM
l/min
Target 6.15
3.00
10.00
4.81
Vt
ml
Target 484
300
1540
415
ftotal
/min
Target 13
5
20
11
PulmoSight
Ri
cmH2O/l/s
24
Cstat
ml/cmH2O
28
fspn/ftotal
%
100
Vte/PCI
ml/kg
0.0
5.9
8.0
Pplat
cmH2O
0
20
30
Pmoteur
cmH2O
0
15
15
MPrs
J/min
0.00
16.91
17.00

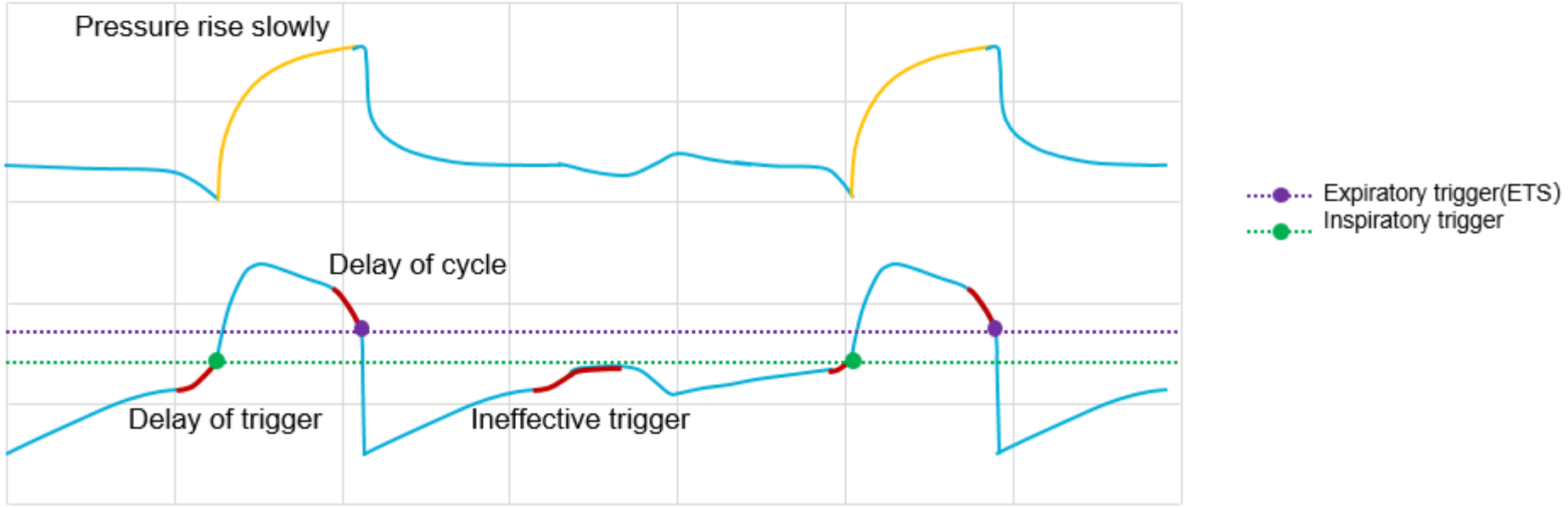

Affichage AMV
VM
l/min
Target 6.15
3.00
10.00
5.87
Vt
ml
Target 485
300
1540
413
ftotal
/min
Target 13
5
20
13
PulmoSight
Ri
cmH2O/l/s
23
Cstat
ml/cmH2O
27
fspn/ftotal
%
100
Vte/PCI
ml/kg
0.0
5.9
8.0
Pplat
cmH2O
0
21
30
Pmoteur
cmH2O
0
15
15
MPrs
J/min
0.00
18.16
17.00

IntelliCycle → Synchronization → Lung *Stress/strain*

Synchronization → Respiratory *Effort*

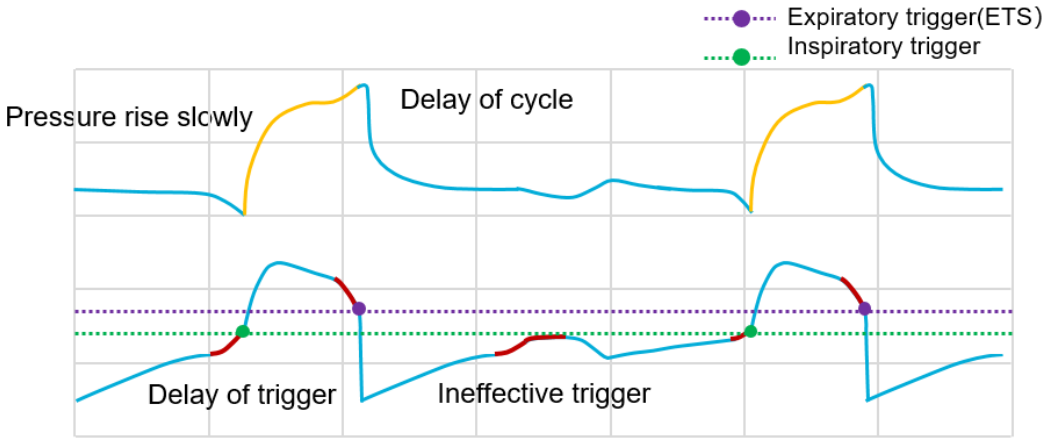
Asynchronization is harmful for patient

Fixed trigger/ Inspiratory pressure rise time /ETS easily lead to patient-ventilator asynchrony

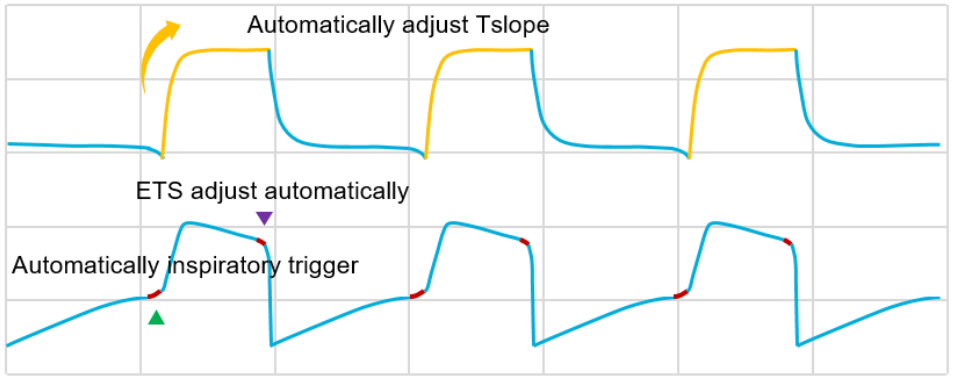


How IntelliCycle Pro Improve Synchronization

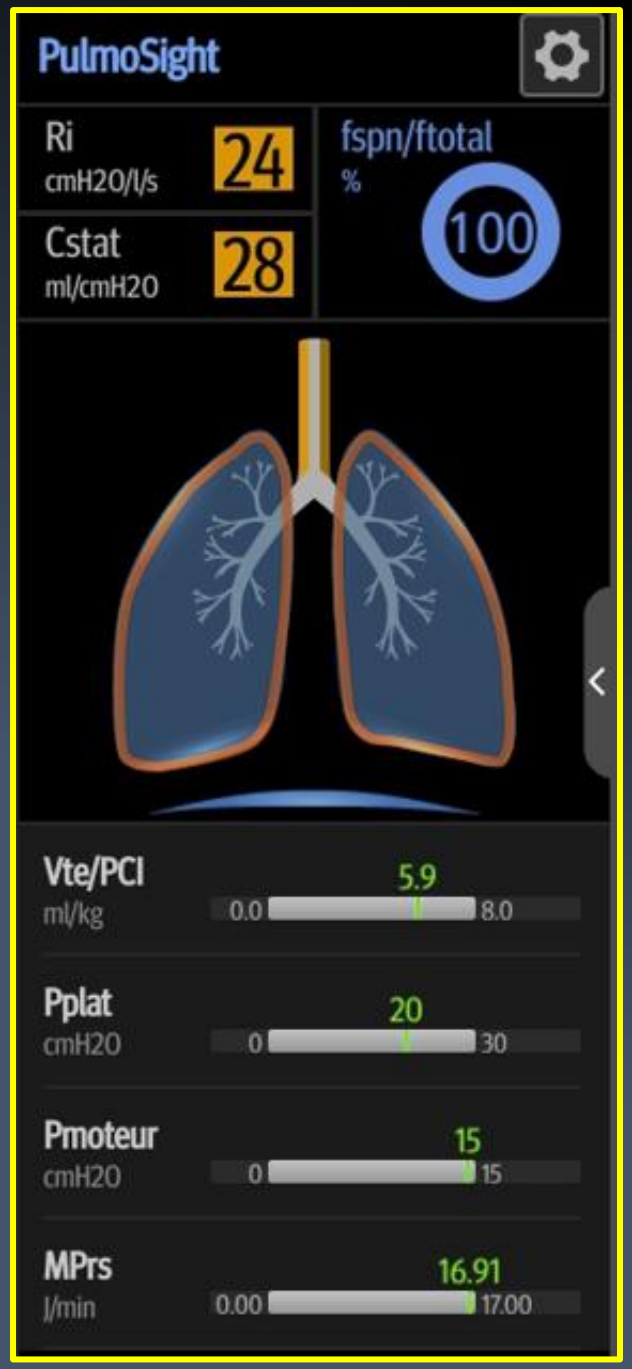
Trigger	Detect inspiratory effort, reduce delay of triggering and ineffective trigger;
Pressure Rise	Adjust the inspiratory pressure rise time to avoid flow starvation or overshooting
Cycle	Determine and adjusts appropriate ETS to reduce early/delay of cycle



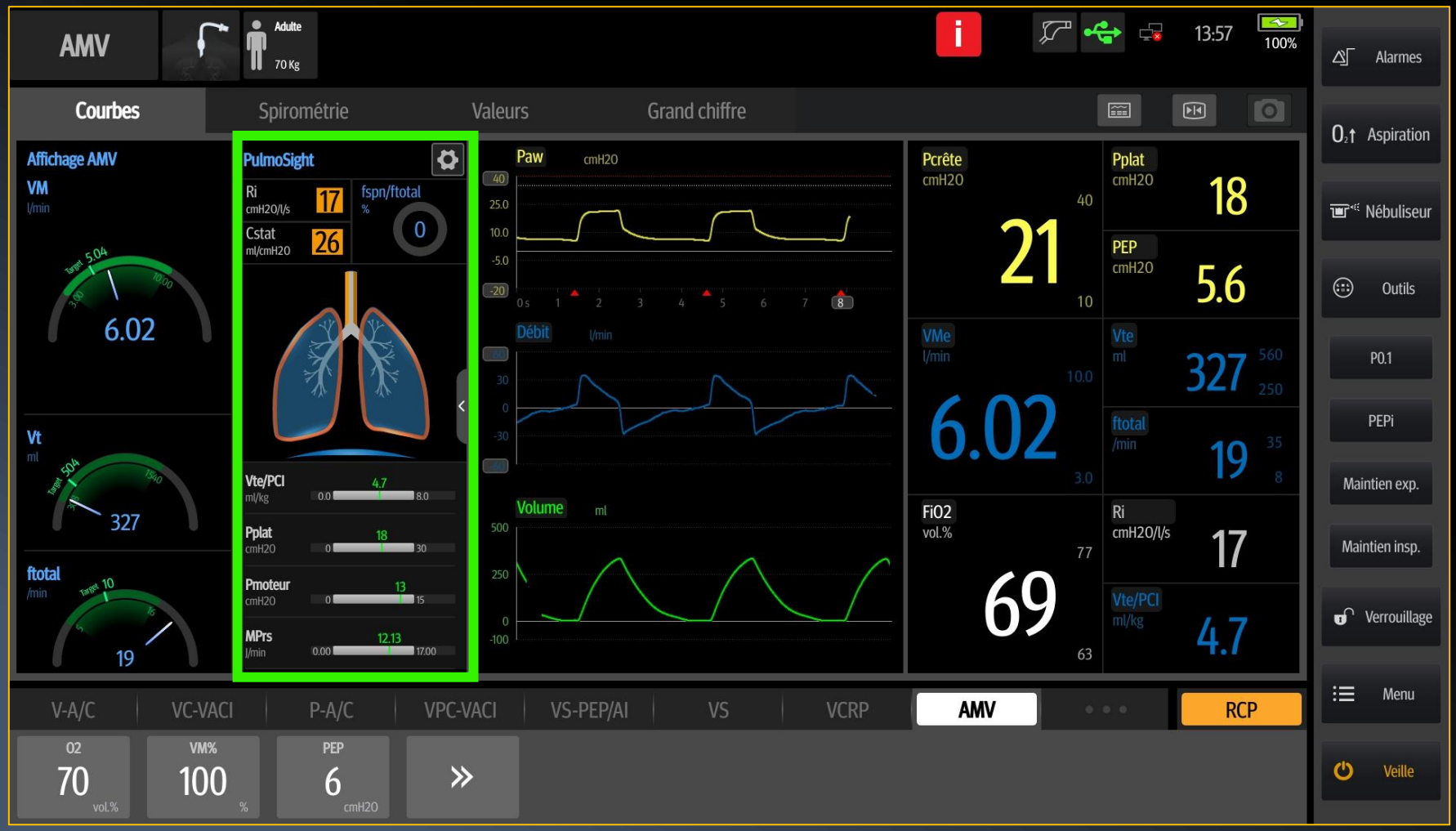
IntelliCycle **OFF**



IntelliCycle **ON**


PulmoSight
Ri
cmH2O/l/s
24
fspn/ftotal
%
100
Cstat
ml/cmH2O
28
Vte/PCI
ml/kg
5.9
0.0
8.0
Pplat
cmH2O
20
0
30
Pmoteur
cmH2O
15
0
15
MPrs
J/min
16.91
0.00
17.00

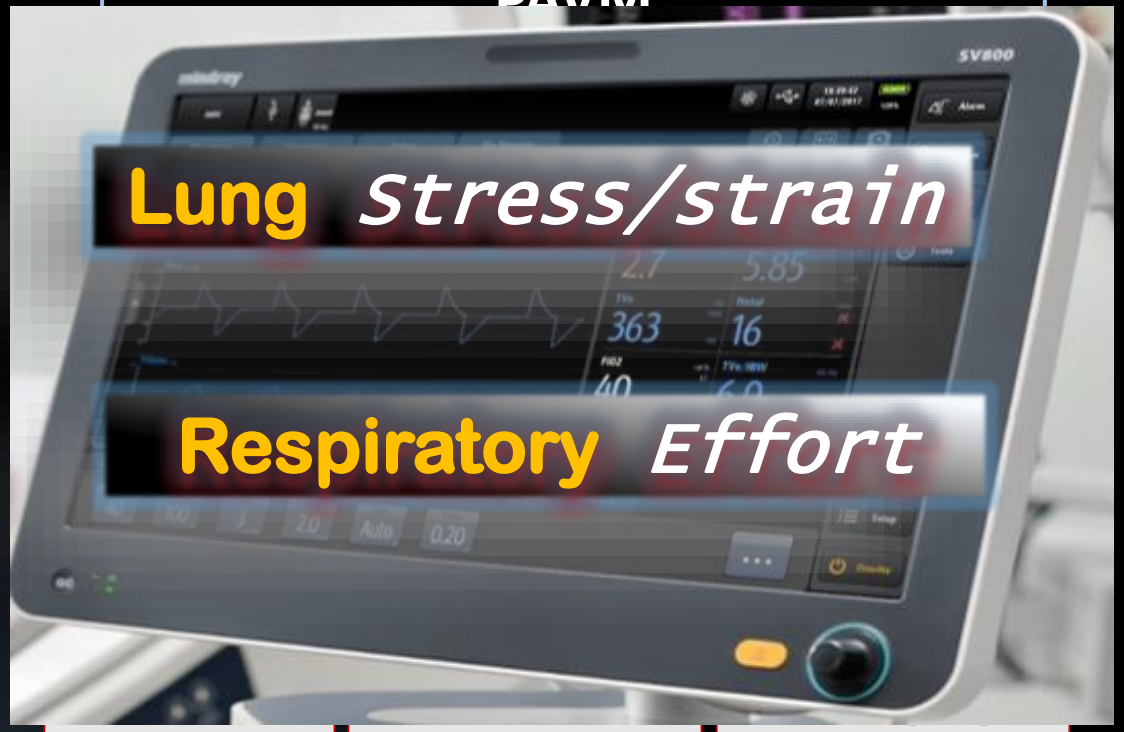
PulmoSight


AMV
Adulte
70 Kg
13:57
100%
Courbes
Spirométrie
Valeurs
Grand chiffre
Affichage AMV
VM
l/min
6.02
Vt
ml
327
ftotal
/min
19
PulmoSight
Ri
cmH2O/l/s
17
fspn/ftotal
%
0
Cstat
ml/cmH2O
26
Vte/PCI
ml/kg
4.7
Pplat
cmH2O
18
Pmoteur
cmH2O
13
MPrs
J/min
12.13
Paw
cmH2O
Débit
l/min
Volume
ml
Pcrête
cmH2O
21
Pplat
cmH2O
18
PEP
cmH2O
5.6
VMe
l/min
6.02
Vte
ml
327
ftotal
/min
19
FiO2
vol.%
69
Ri
cmH2O/l/s
17
Vte/PCI
ml/kg
4.7
Alarmes
Aspiration
Nébuliseur
Outils
P0.1
PEPi
Maintien exp.
Maintien insp.
Verrouillage
Menu
Veille
V-A/C
VC-VACI
P-A/C
VPC-VACI
VS-PEP/AI
VS
VCRP
AMV
RCP
O2
70
vol.%
VM%
100
%
PEP
6
cmH2O

CONCLUSION

- Unload The Respiratory Muscle Pump
- Respiratory Homeostasis

PAVM



- Unload The Respiratory Muscle Pump
- Respiratory Homeostasis

MECHANICAL VENTILATION

CONCLUSION

- survival
- duration of mechanical ventilation
- recovery
- long-term disability


SAARSIU
MEDICO MEDLINE
mindray
healthcare within reach
THANK YOU
mindray
SV800
21
8.9
2.7
5.85
40
100
3
2.0
Auto
0.20