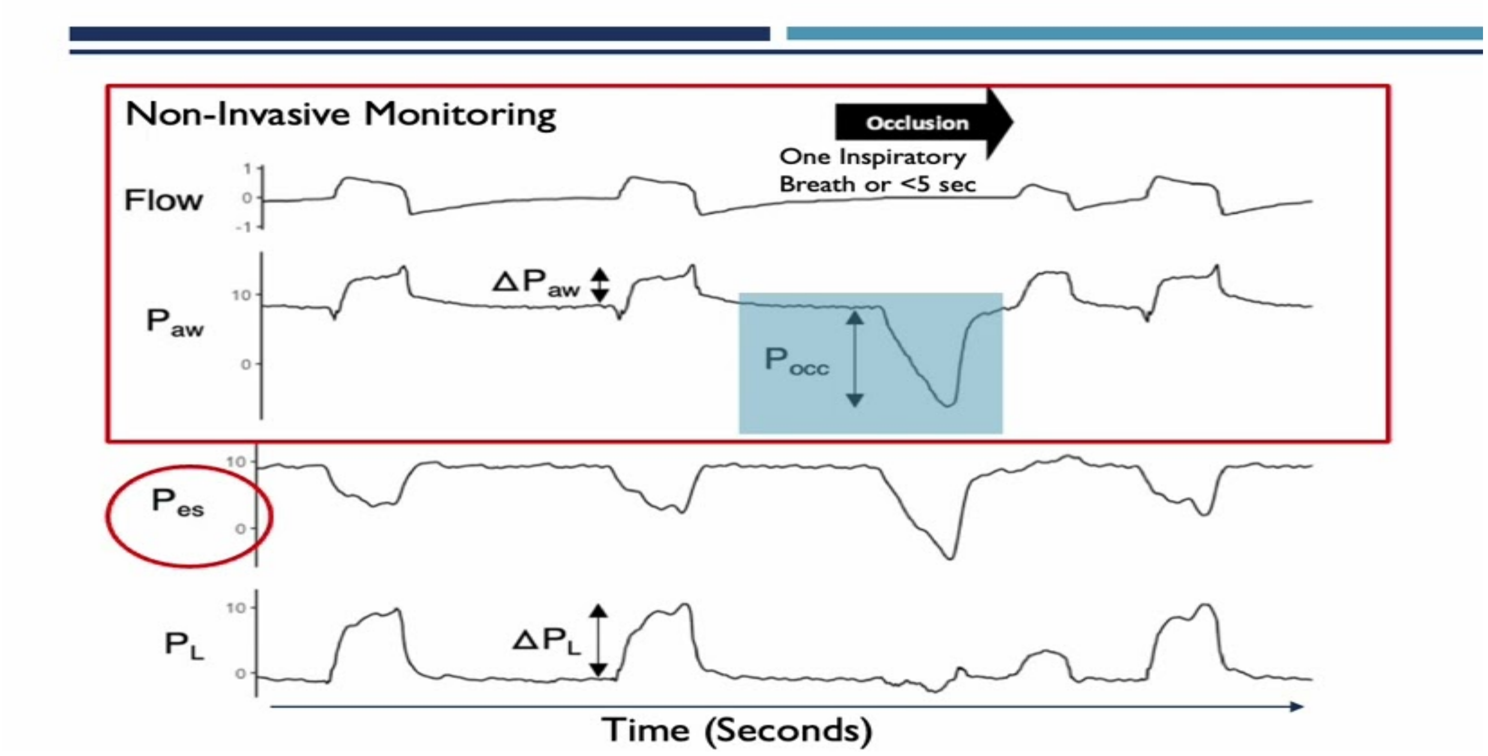
How much stress is the alveoli seeing?

Patrick McDonagh MS. RRT-NPS, ACCS, C-NPT.



Disclosures

No Disclosures to Report

Objectives

1. Noninvasive Monitoring of Transpulmonary Pressure
2. Sedation is Not Always The Answer

ARMA and PReVENT Trials

Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome

Author: The Acute Respiratory Distress Syndrome Network* Author Info & Affiliations

Published May 4, 2000 | N Engl J Med 2000;342:1301-1308 | DOI: 10.1056/NEJM200005043421801

VOL. 342 NO. 18

Pre ARMA: VT range 10-15ml/kg leading to stretch induced lung injury

ARMA: Compared 6 to 12ml/kg VT with plateaus < 30 mmHg

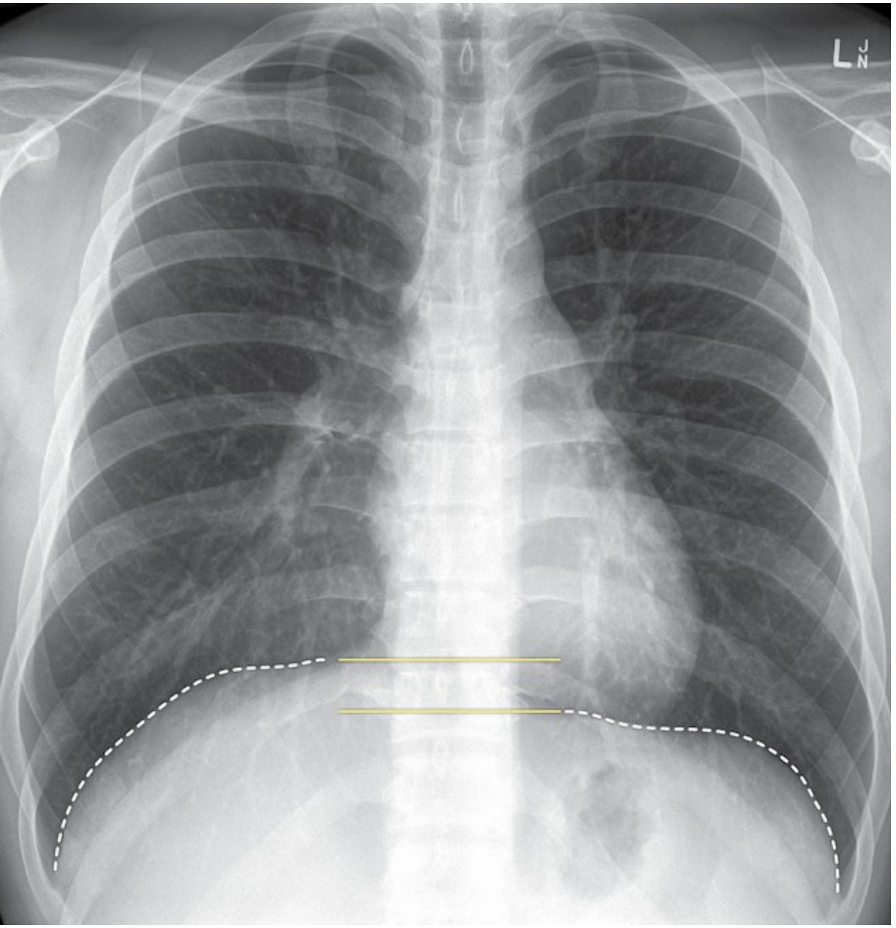
A prospective study on patients with acute lung injury and the acute respiratory distress syndrome, showing a lower tidal volume strategy results in decreased mortality and increases the number of days without ventilator use.

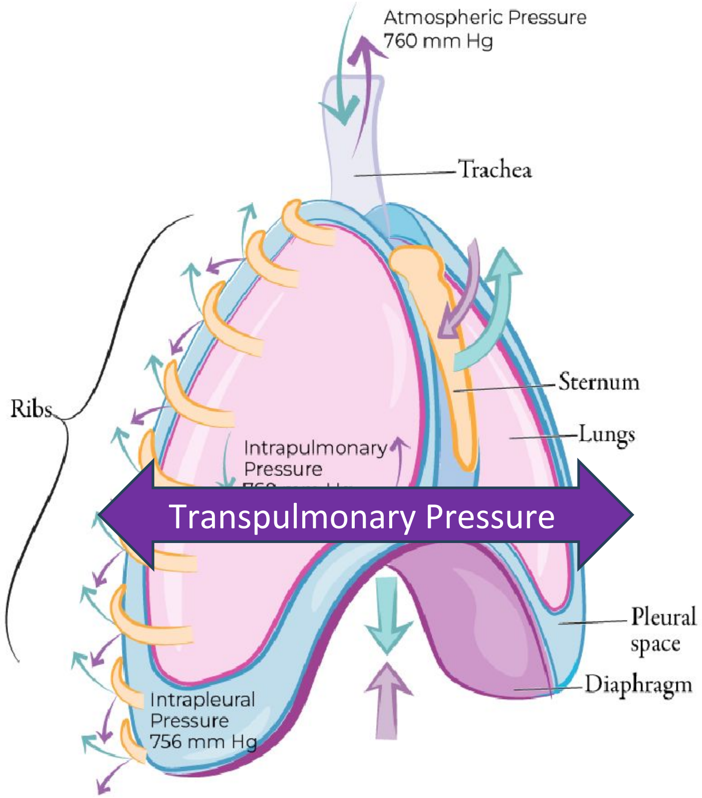
Effect of a Low vs Intermediate Tidal Volume Strategy on Ventilator-Free Days in Intensive Care Unit Patients Without ARDS. The PReVENT Trial

Simonis et al. JAMA 2018. Published online October 24, 2018. doi:10.1001/jama.2018.14280

Pendelluft phenomenon is defined as the displacement of gas from a more recruited nondependent (ND) lung region to a less recruited dependent (D) lung region. This phenomenon may cause lung injury.

Don't Allow This To Turn Into This





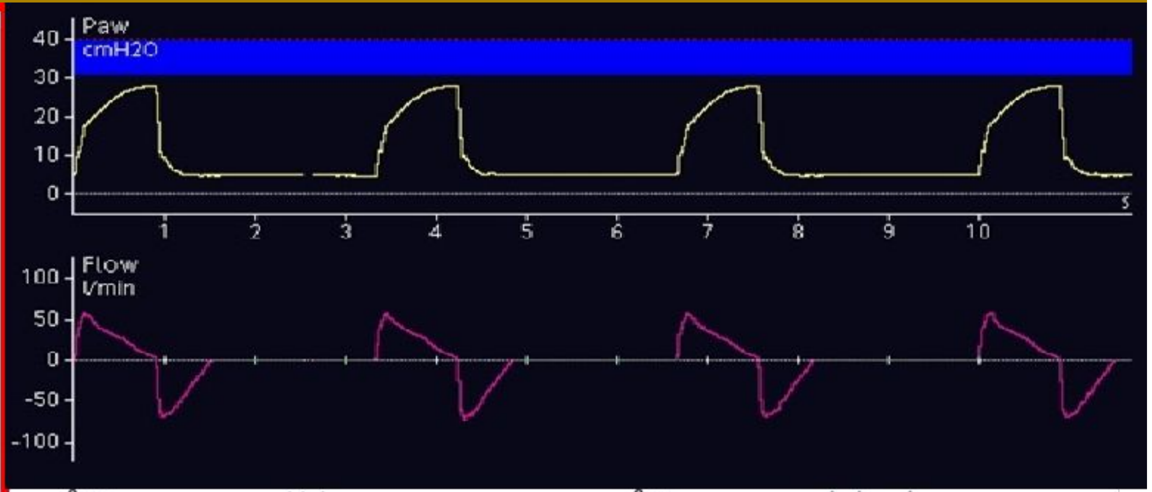
Asynchrony Variables: Flow, Volume, Pressure and Time

More Variables = Increased Asynchrony

How harmful is deep sedation?

Early Intensive Care Sedation Predicts Long-Term Mortality in Ventilated Critically Ill Patients

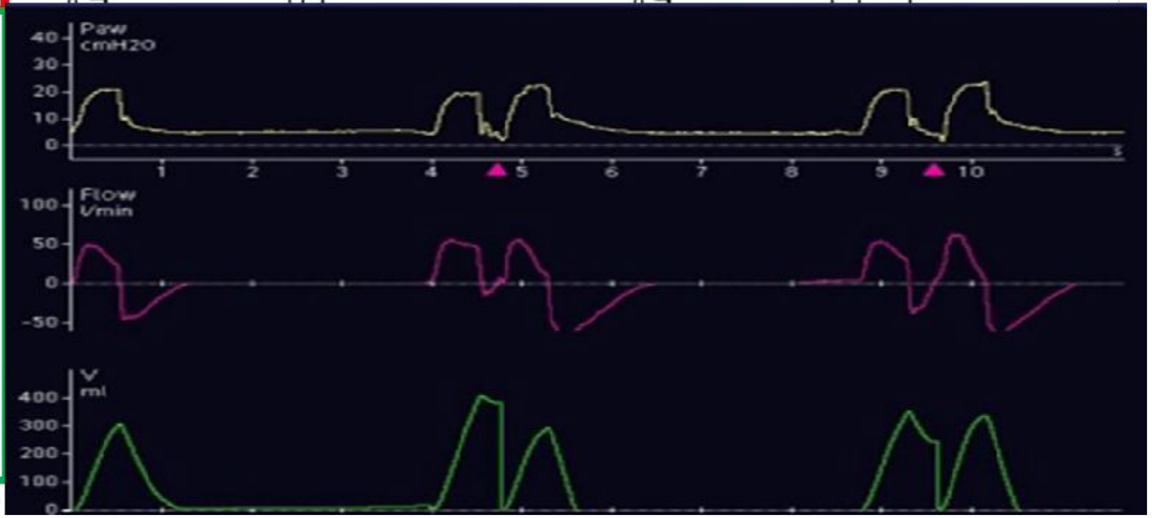
Yahya Shehabi[1,2], Rinaldo Bellomo[3,4,5,6], Michael C. Reade[7,8], Michael Bailey[5], Frances Bass[2], Belinda Howe[5], Colin McArthur[9], Ian M. Seppelt[10], Steve Webb[11,12], and Leonie Weisbrodt[13]; Sedation Practice in Intensive Care Evaluation (SPICE) Study Investigators and the ANZICS Clinical Trials Group*



RESEARCH — Open Access

Patient–ventilator asynchrony, impact on clinical outcomes and effectiveness of interventions: a systematic review and meta-analysis

Michihito Kyo[1*], Tatsutoshi Shimatani[1], Koji Hosokawa[2], Shunsuke Taito[3,5], Yuki Kataoka[4,5,6,7], Shinichiro Ohshimo[1] and Nobuaki Shime[1]



PMID: 34399855

Respiratory Equation of Motion

Pmus + Pvent = Resistance x Flow + Elastance x Volume

Breath Delivery = Airway Resistance + Lung Compliance

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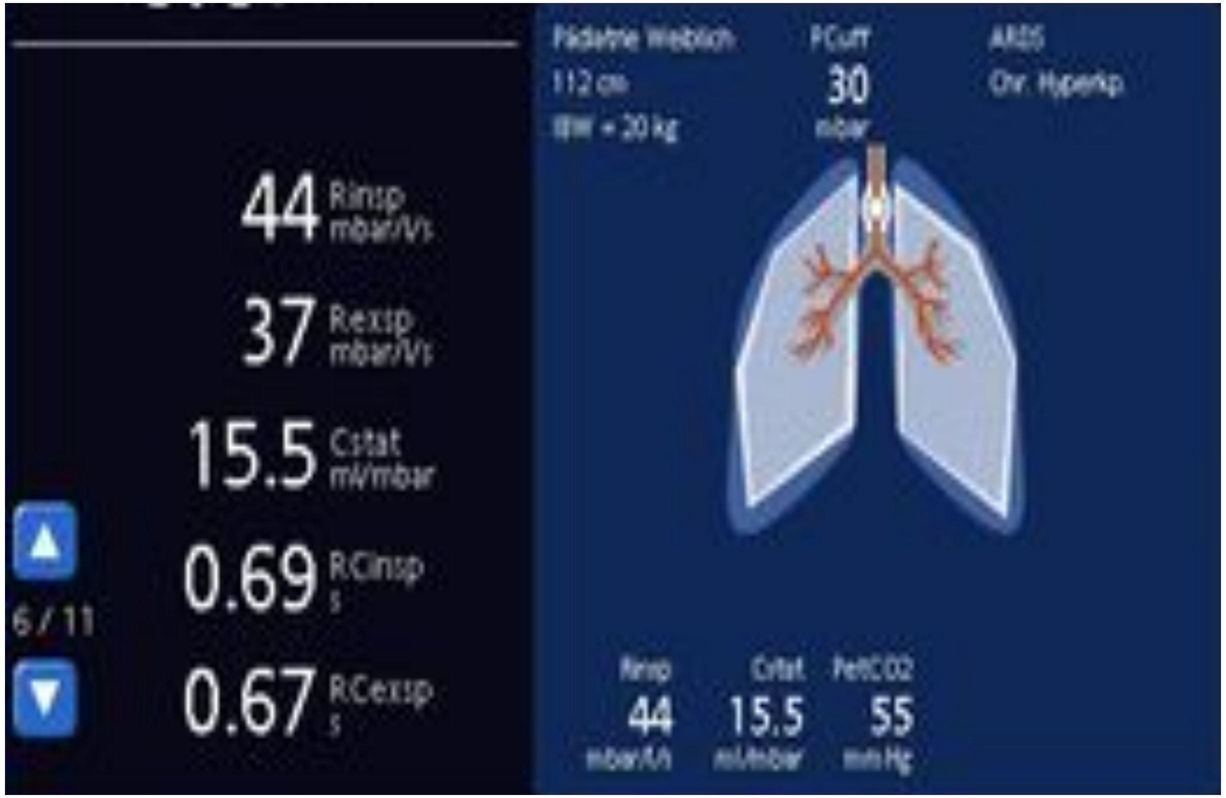
Ventilator-Induced Lung Injury (VILI)

Ajith Kumar AK; Fatima Anjum.

Author Information and Affiliations

Last Update: April 27, 2023.

Ventilator-induced lung injury is the acute lung injury inflicted or aggravated by mechanical ventilation during treatment and has the potential to cause significant morbidity and mortality. The potential morbidity and the mortality impact of ventilator-induced lung injury are increasingly recognized across the world.

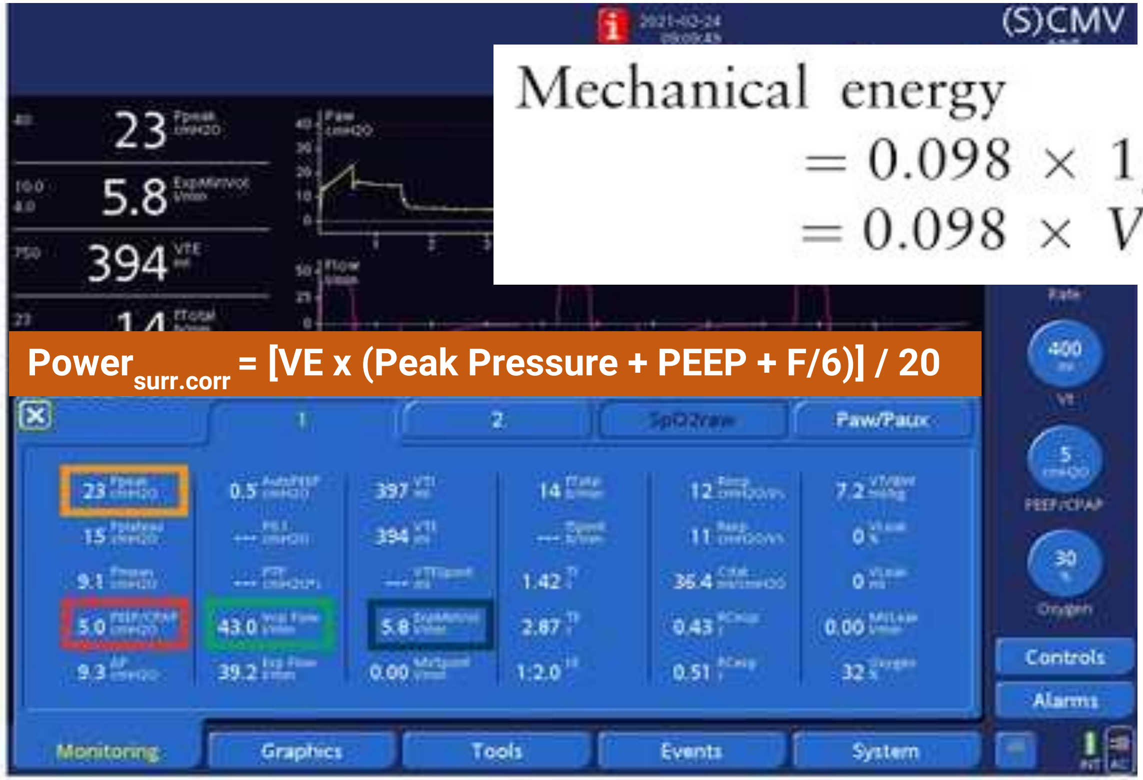


Mechanical Power: The Power of Each Delivered Breath

Mechanical power of ventilation is associated with mortality in critically ill patients: an analysis of patients in two observational cohorts.

Serpa Neto A, Deliberato RO, Johnson AEW, et al. Mechanical power of ventilation is associated with mortality in critically ill patients: an analysis of patients in two observational cohorts. Intensive Care Med. 2018;44(11):1914-1922. doi:10.1007/s00134-018-5375-6

As the understanding of VILI grows, there is a greater focus on mechanical power (MP) as a potential predictor of negative outcomes. Data currently suggests that a MP of >17.0 J/min is associated with higher risk of death

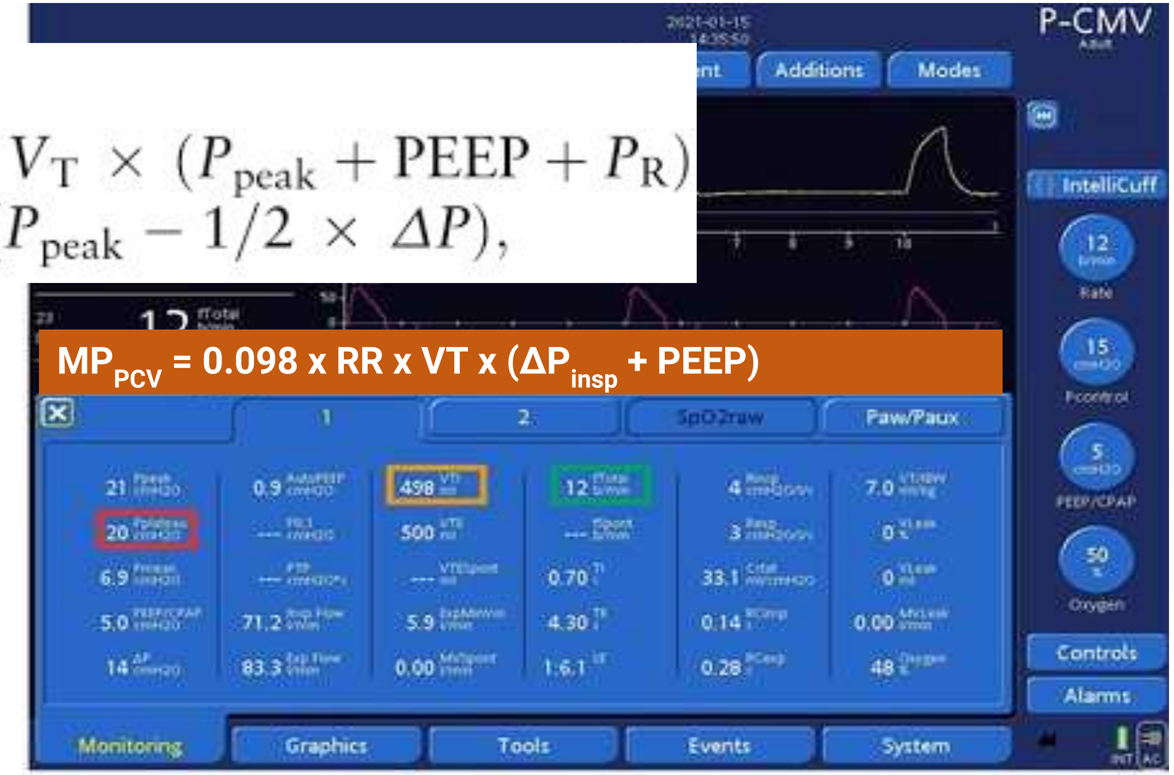


Mechanical energy

$$= 0.098 \times 1/2 \times V_T \times (P_{peak} + PEEP + P_R)$$
$$= 0.098 \times V_T \times (P_{peak} - 1/2 \times \Delta P),$$

$Power_{surr.corr}$ = [VE x (Peak Pressure + PEEP + F/6)] / 20

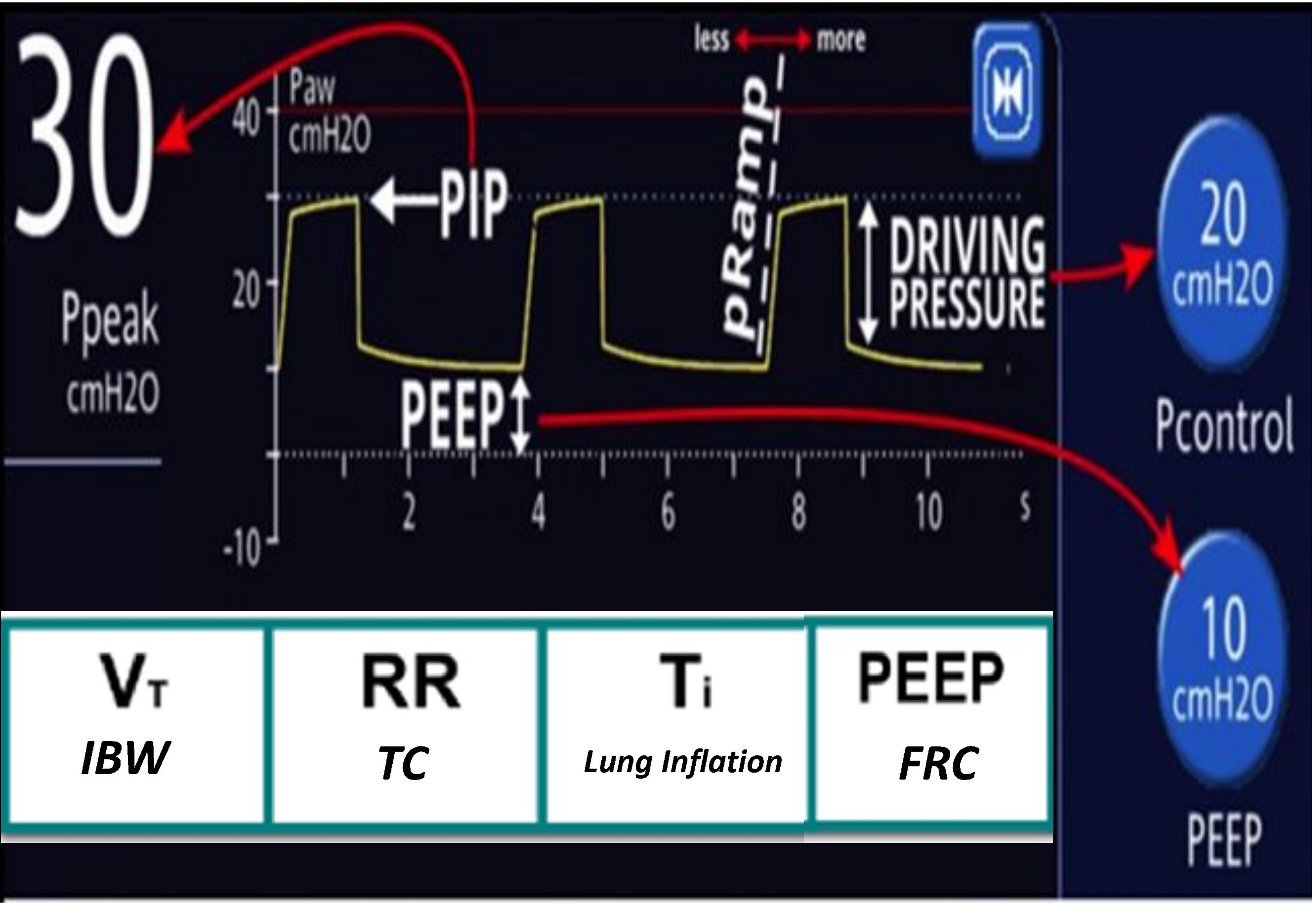
$$\frac{5.8 \times (23 + 5 + 43/6)}{20} = 10.2 \text{ J/min}$$

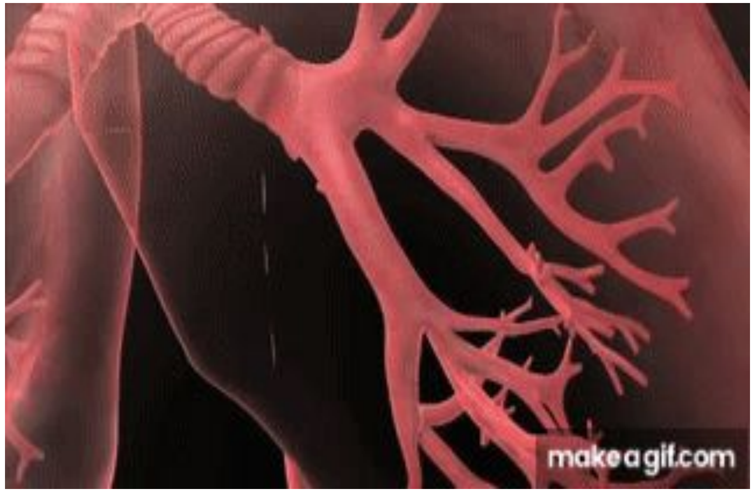


MP_{PCV} = 0.098 x RR x VT x (ΔP_{insp} + PEEP)

0.098 x 12 x 0.498 x 20 = 11.71 J/min

The Mean Airway Pressure





Cstat: Static Compliance

Indian Journal of Critical Care Medicine
Official Publication of Indian Society of Critical Care Medicine
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Indian J Crit Care Med. 2021 Jan; 25(1): 10–11.
doi: 10.5005/jp-journals-10071-23700
PMCID: PMC7874283
PMID: 33603294

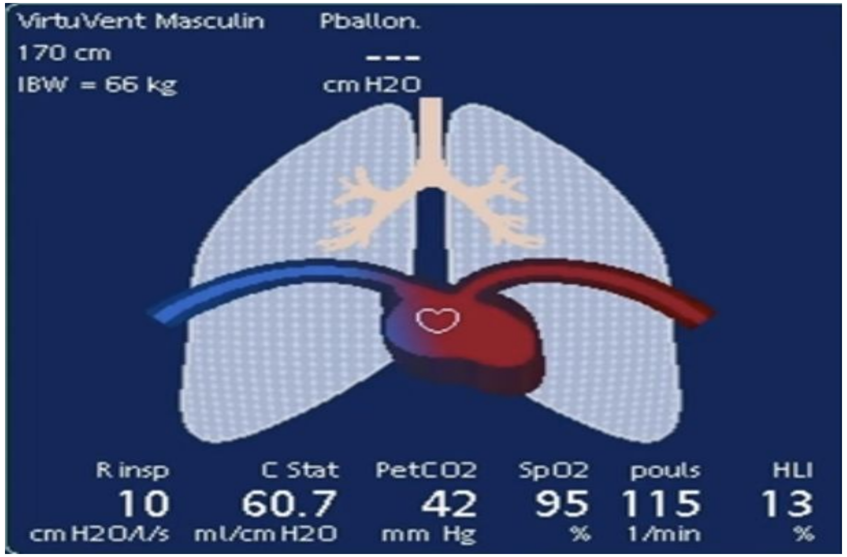
Respiratory Mechanics: To Balance the Mechanical Breaths!!

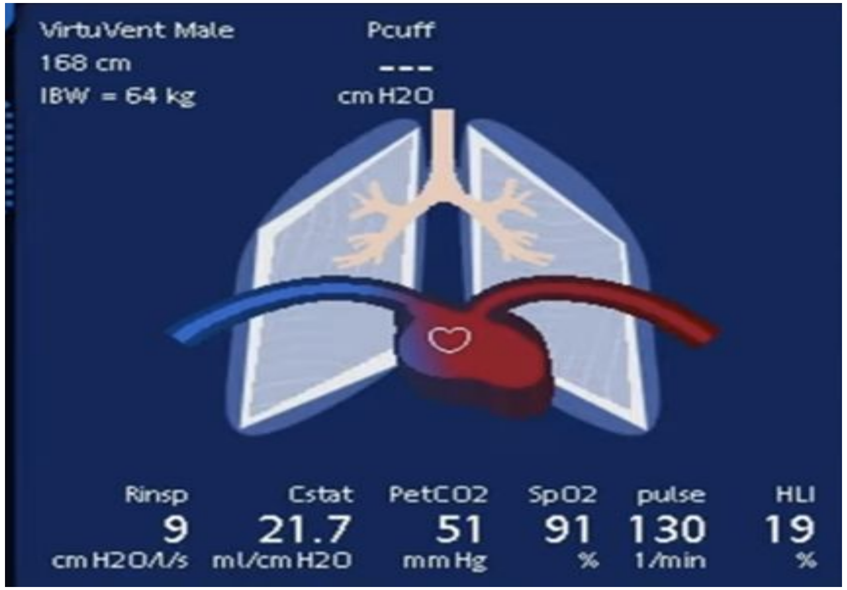
Manu Sundaram[1] and Manjush Karthika[2]

Author information Copyright and License information PMC Disclaimer

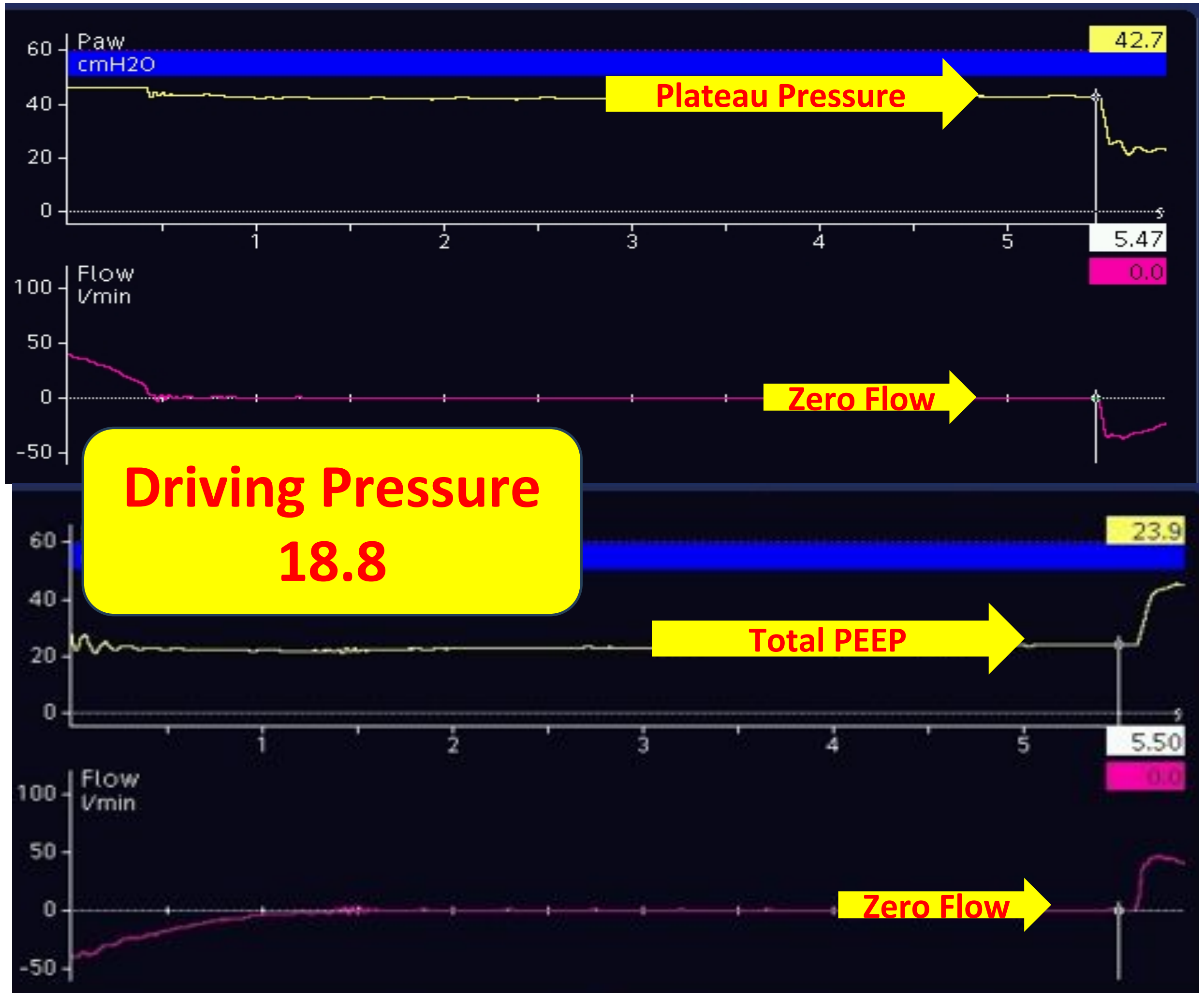
C_{STAT} is best explained when transpulmonary pressure equals the elastic recoil pressure of the lungs, hence it only measures the elastic resistance.

Normal Range
< 50 mL/cmH2O = Decreased Compliance
> 80 mL/cmH2O = Increased Compliance





Plateau Pressure & Driving Pressure



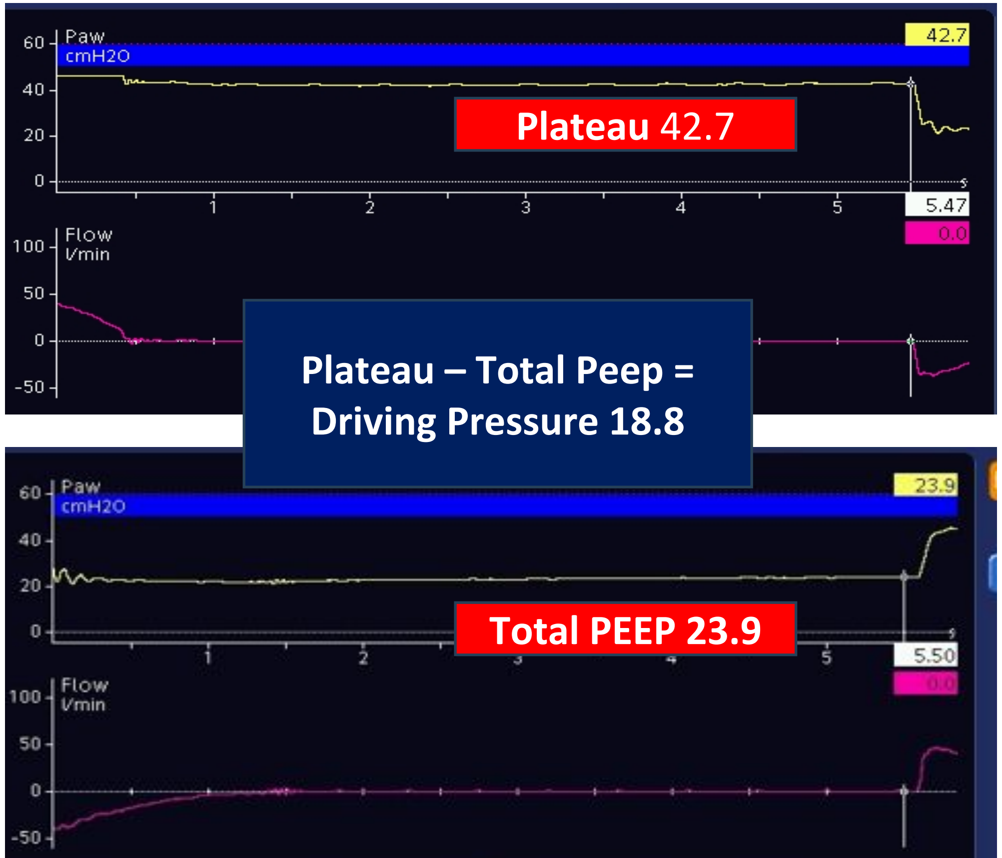
Active Patients: Driving Pressure & Plateau

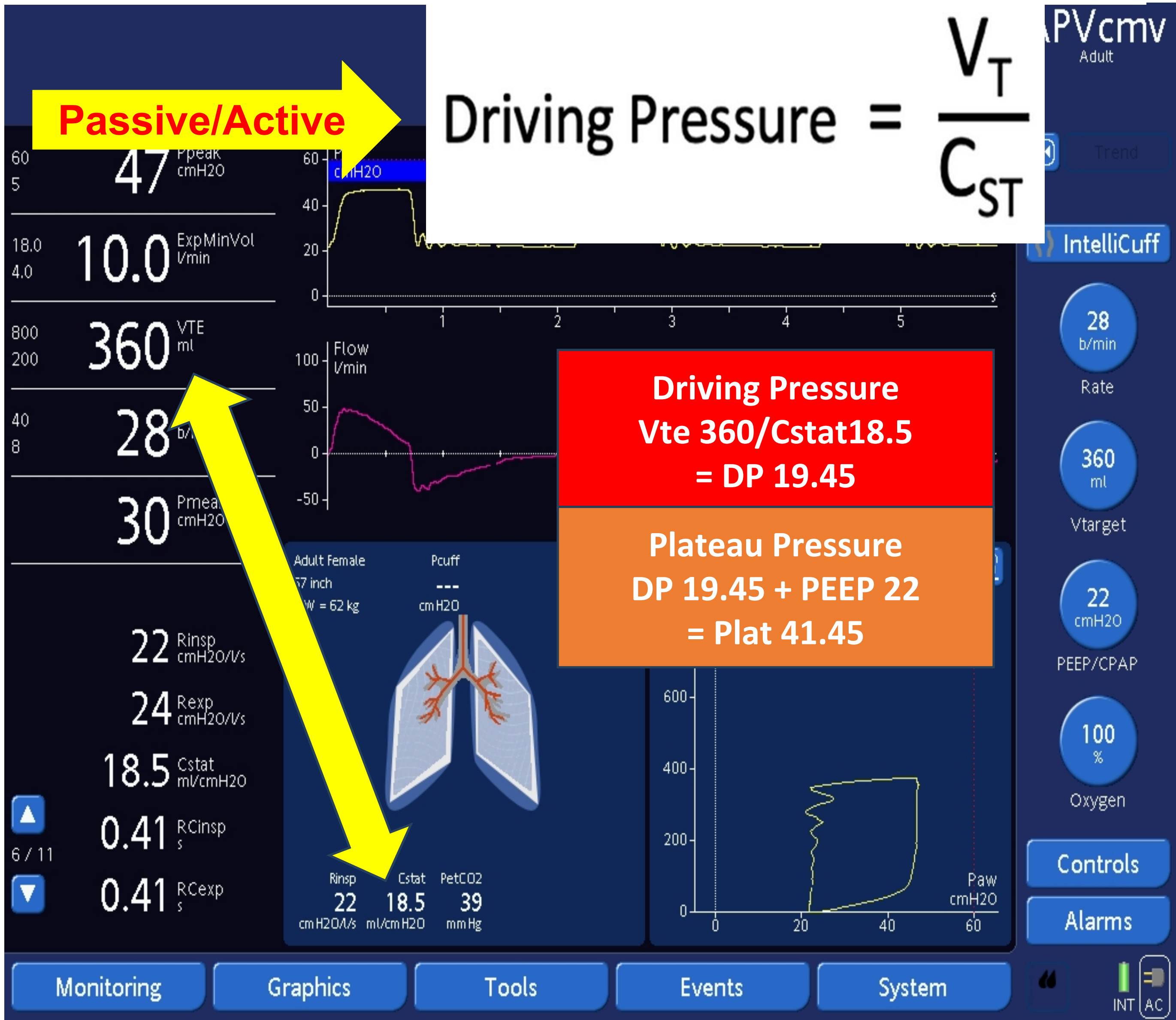
Korean J Anesthesiol. 2020 Jun; 73(3): 194–204. PMCID: PMC7280884
Published online 2020 Feb 26. doi: 10.4097/kja.20041 PMID: 32098009

Driving pressure guided ventilation

Hyun Joo Ahn,[1] MiHye Park,[1] Jie Ae Kim,[1] Mikyung Yang,[1] Susie Yoon,[2] Bo Rim Kim,[2] Jae-Hyon Bahk,[2] Young Jun Oh,[3] and Eun-Ho Lee[4]

Driving pressure is [Pplat – PEEP] and is the pressure required for the alveolar opening [17]. Static lung compliance (Cstat) is expressed as [V_T / (Pplat – PEEP)]. Thus, driving pressure is also expressed as [V_T / Cstat]. Driving pressure has an inverse relationship with Cstat and an orthodromic relationship with V_T according to this formula. High driving pressure indicates poor lung condition with decreased lung compliance.





Expiratory Time Constant

Critical Care BMC

Crit Care. 2013; 17(1): R23. PMCID: PMC4056774

Published online 2013 Feb 5. doi: 10.1186/cc12500 PMID: 23384402

Expiratory time constant for determinations of plateau pressure, respiratory system compliance, and total resistance

Nawar Al-Rawas,[1] Michael J Banner,[✉1] Neil R Euliano,[2] Carl G Tams,[2] Jeff Brown,[1] A Daniel Martin,[1,3] and Andrea Gabrielli[1,4]

Author information Article notes Copyright and License information PMC Disclaimer

Normal Range

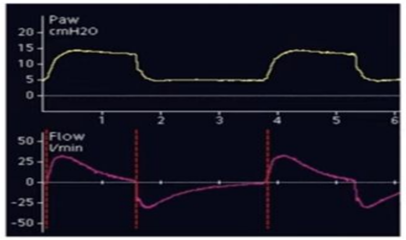
< 0.5 sec = Decreased Compliance

> 0.7 sec = High Rinsp and/or Compliance

Psuedo Normal

High Rinsp and and low Cstat

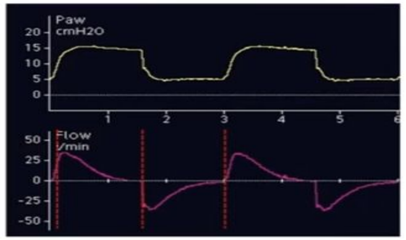
Expiratory time constant (RCexp) is a measurement of how long it takes for a person to exhale. It's a product of airway resistance and lung compliance, and it's used to assess the mechanical properties of the respiratory system.



Normal

Normal Cstat and Rinsp or combination of decreased Cstat and increased Rexp

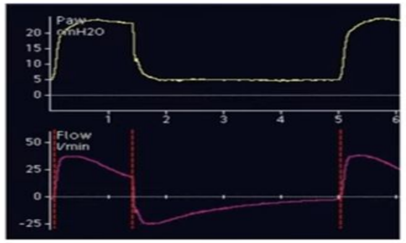
Cstat = 60 ml/cmH2O



Restrictive disease

Decreased Cstat: ARDS, atelectasis, chest wall stiffness

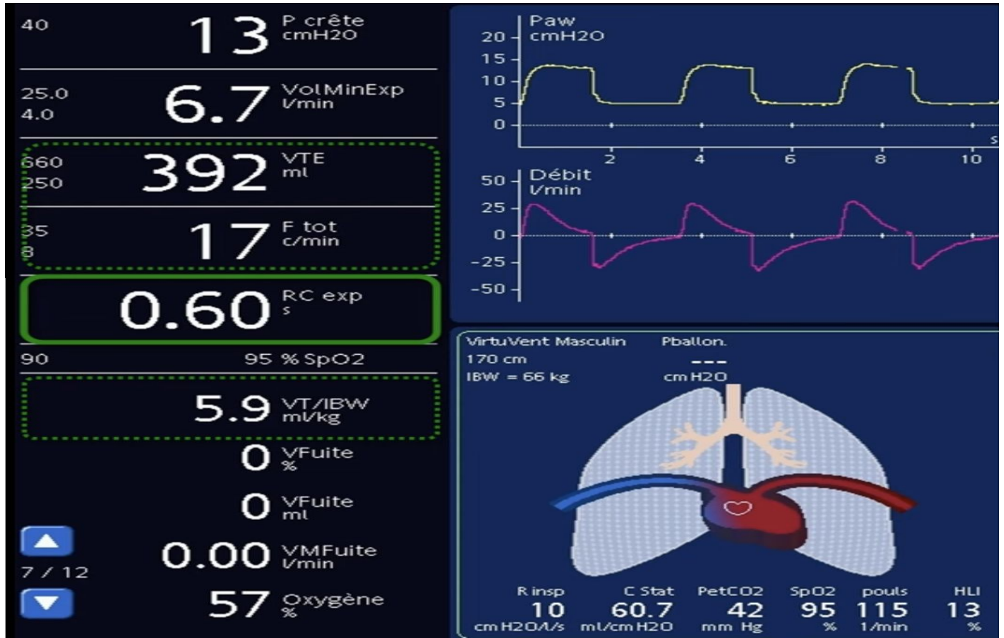
Cstat = 22 ml/cmH2O



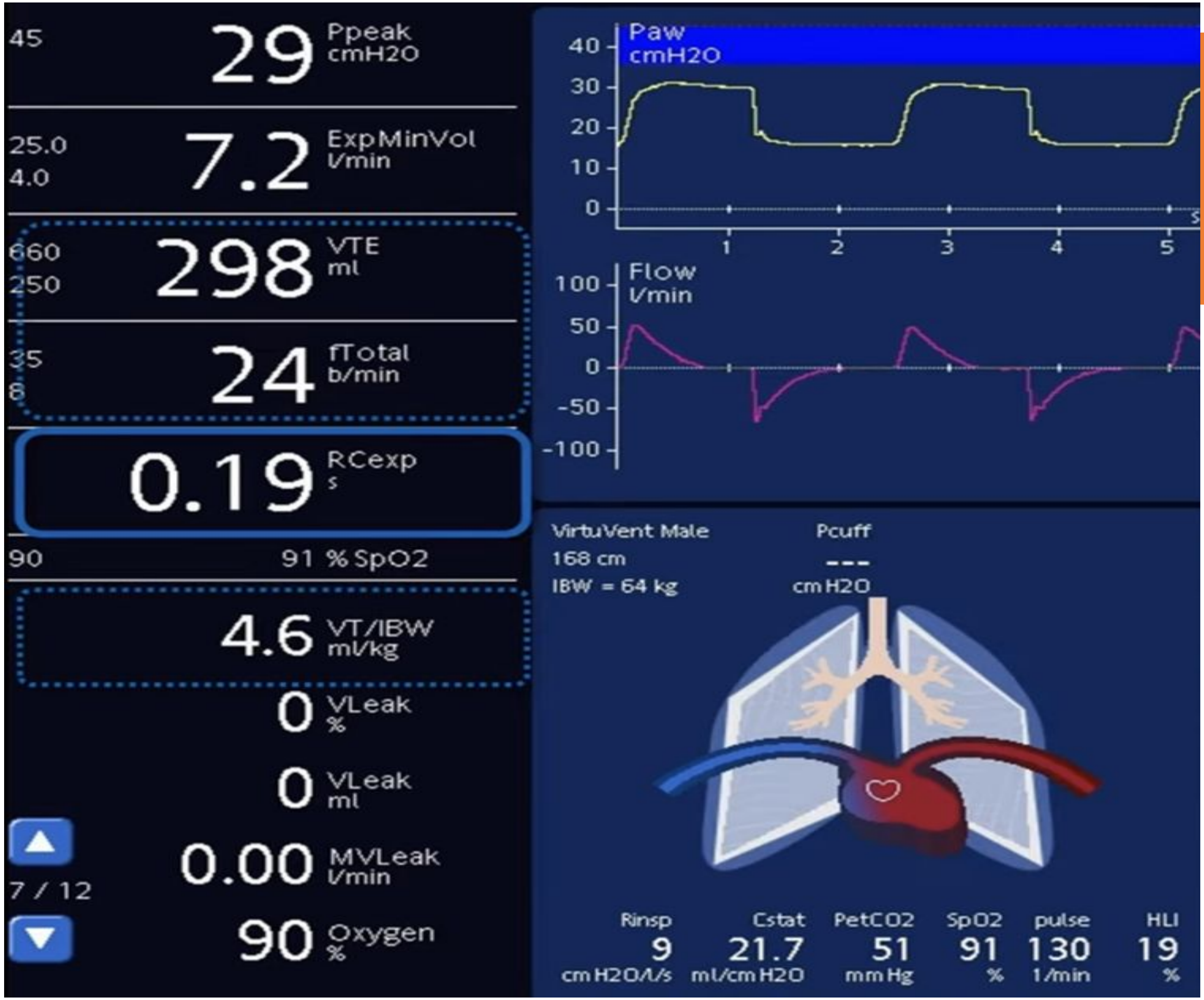
Obstructive disease

Increased Rexp: COPD, asthma, or bronchospasm, ETT obstruction or incorrect positioning

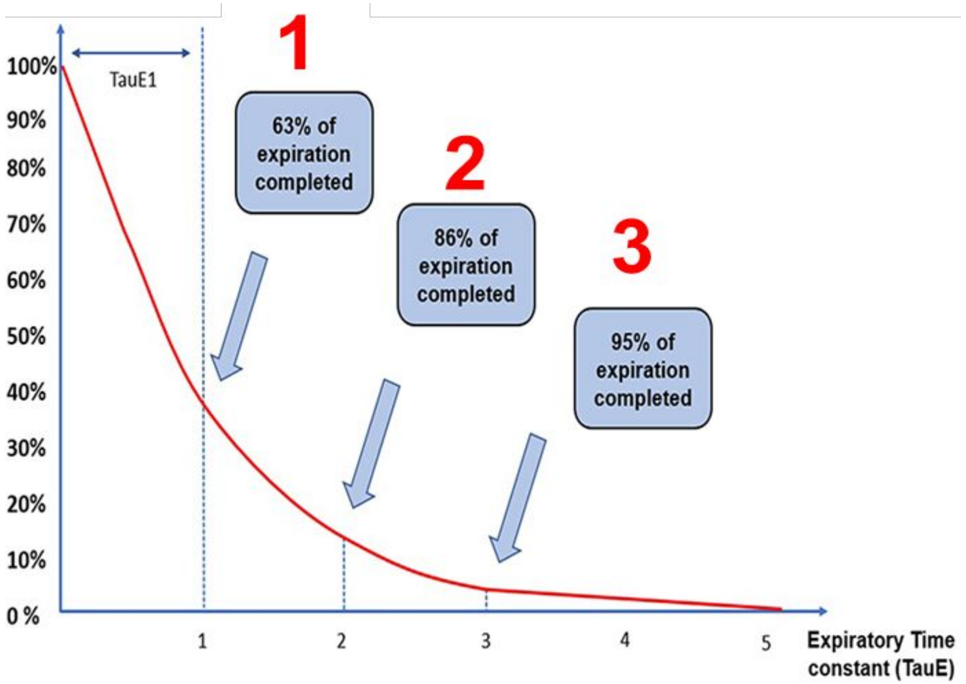
Cstat = 70 ml/cmH2O



What is the RCexp and minimum exhalation time?



RCexp: 0.19	**RR Set 24**
Min etime:	**TCT = 2.5 sec:**
0.19 x 2 = 0.38	Ti(2.5– 0.38) = 2.12
0.19 x 3 = 0.57	Ti(2.5– 0.57) = 1.93
0.19 x 4 = 0.76	Ti(2.5– 0.76) = 1.74
0.19 x 5 = 0.95	Ti(2.5– 0.95) = 1.55



Calculating Airway Pressures

Driving Pressure

Vte/Cstat

360/18.5

= DP 19.45

Estimated Plateau Pressure

DP + PEEP

19.45 + 22

= Plateau 41.45

Min Expiratory Time

RCexp x Desired Time Constant

0.41 x 3 = 1.23 secs

Max Inspiratory Time

TCT = 2.14 sec (60secs/RR28)

TCT 2.14 secs – Min Te 1.23 secs

= Max Ti: 0.91

Synchrony and Asynchrony with Safe Pressures can still be Injurious

Airway Occlusion Pressure As an Estimate of Respiratory Drive and Inspiratory Effort during Assisted Ventilation

Irene Telias[1,2,3], Detajin Junhasavasdikul[1,2,4], Nuttapol Rittayamai[1,2,5], Lise Piquilloud[6], Lu Chen[1,2], Niall D. Ferguson[1,3,7,8], Ewan C. Goligher[1,3,8], and Laurent Brochard[1,2*]

[1]Interdepartmental Division of Critical Care Medicine and [7]Institute of Health Policy, Management, and Evaluation, University of Toronto, Toronto, Ontario, Canada; [2]Keenan Research Centre, Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Ontario, Canada; [3]Division of Respirology, Department of Medicine, University Health Network and Sinai Health System, Toronto, Ontario, Canada; [4]Department of Medicine, Faculty of Medicine Ramathibodi Hospital and [5]Division of Respiratory Diseases and Tuberculosis, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand; [6]Adult Intensive Care and Burn Unit, University Hospital and University of Lausanne, Lausanne, Switzerland; and [8]Toronto General Hospital Research Institute, Toronto, Ontario, Canada

ORCID IDs: 0000-0001-6844-6314 (N.R.); 0000-0002-7512-1865 (L.C.); 0000-0002-0990-6701 (E.C.G.).

Strong effort during mechanical ventilation, even if synchronized, may cause injurious inflation, including pendelluft (i.e., the early inspiratory transfer of gas from nondependent to dependent lung). In this setting, strong effort may cause dependent overstretch and tidal recruitment, worsening lung injury in dependent lung despite a low V_T

Assessing the Drive to Breathe: Occlusion Pressure – Many Names P0.1/P100

> Intensive Care Med. 2018 Sep;44(9):1532-1535. doi: 10.1007/s00134-018-5045-8. Epub 2018 Jan 19.

The airway occlusion pressure ($P_{0.1}$) to monitor respiratory drive during mechanical ventilation: increasing awareness of a not-so-new problem

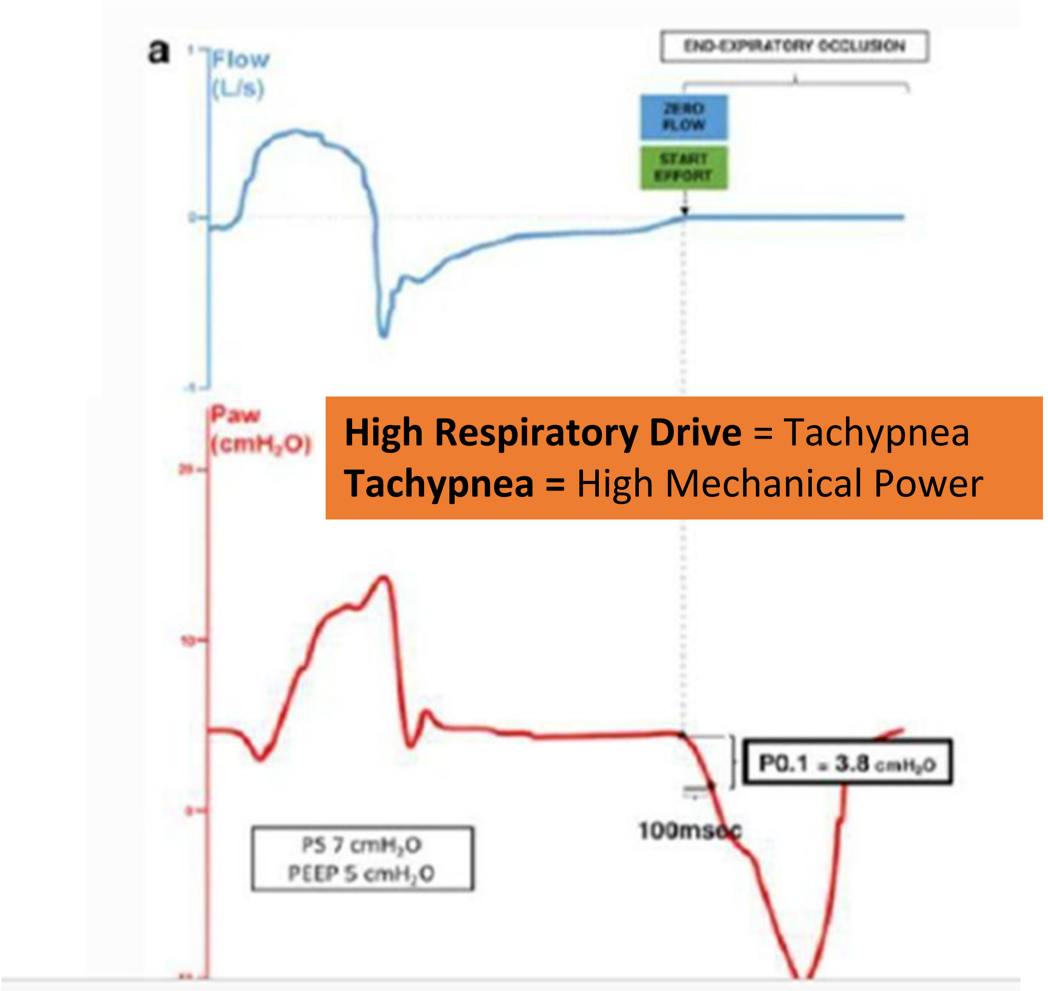
Irene Telias [1 2 3 4], Felipe Damiani [1 2 5], Laurent Brochard [6 7]

Affiliations + expand

PMID: 29350241 DOI: 10.1007/s00134-018-5045-8

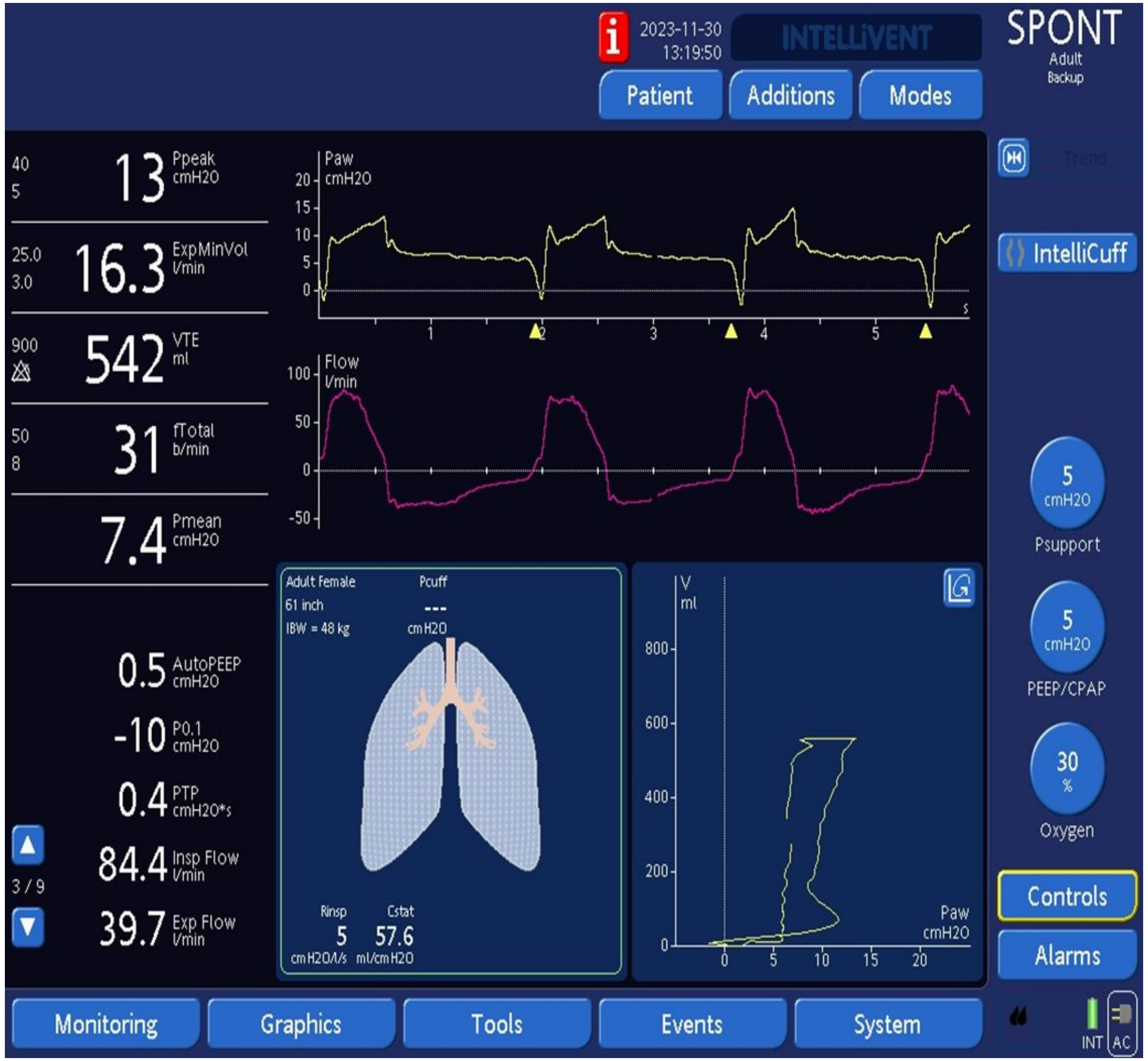
P0.1

> 3.5 cm H2O	2 - 3.5 cm H2O	< 2 cm H2O
High respiratory drive	Appropriate sedation	Low respiratory drive
Insufficient level of support	Appropriate level of support	High level of support
Under-assistance		**Over-assistance**
High rate of weaning failure	High rate of weaning success	High rate of weaning failure



High Respiratory Drive = Tachypnea
Tachypnea = High Mechanical Power

P0.1


2023-11-30
13:19:50
INTELLiVENT
SPONT
Adult
Backup
Patient
Additions
Modes
13 Ppeak cmH20
16.3 ExpMinVol l/min
542 VTE ml
31 fTotal b/min
7.4 Pmean cmH20
Paw cmH20
Flow l/min
IntelliCuff
5 cmH20 Psupport
5 cmH20 PEEP/CPAP
30 % Oxygen
Adult Female
61 inch
IBW = 48 kg
Pcuff
---
cmH20
0.5 AutoPEEP cmH20
-10 P0.1 cmH20
0.4 PTP cmH20*s
84.4 Insp Flow l/min
39.7 Exp Flow l/min
3 / 9
Rinsp 5 cmH20/l/s
Cstat 57.6 ml/cmH20
V ml
Paw cmH20
Controls
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC


2023-11-30
13:19:42
INTELLiVENT
SPONT
Adult
Backup
Patient
Additions
Modes
13 Ppeak cmH20
16.3 ExpMinVol l/min
520 VTE ml
30 fTotal b/min
7.4 Pmean cmH20
IntelliCuff
Backup
15 b/min Rate
15 cmH20 Pcontrol
0.9 s TI
Backup mode:
P-CMV
25 ms P-ramp
30 % ETS
2.0 -cmH20 P-trigger
5 cmH20 Psupport
5 cmH20 PEEP/CPAP
30 % Oxygen
Controls
0.4 AutoPEEP cmH20
-10 P0.1 cmH20
0.5 PTP cmH20*s
82.3 Insp Flow l/min
36.2 Exp Flow l/min
3 / 9
Adult Female
61 inch
IBW = 48 kg
Rinsp 5 cmH20/l/s
Cstat 57.6 ml/cmH20
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

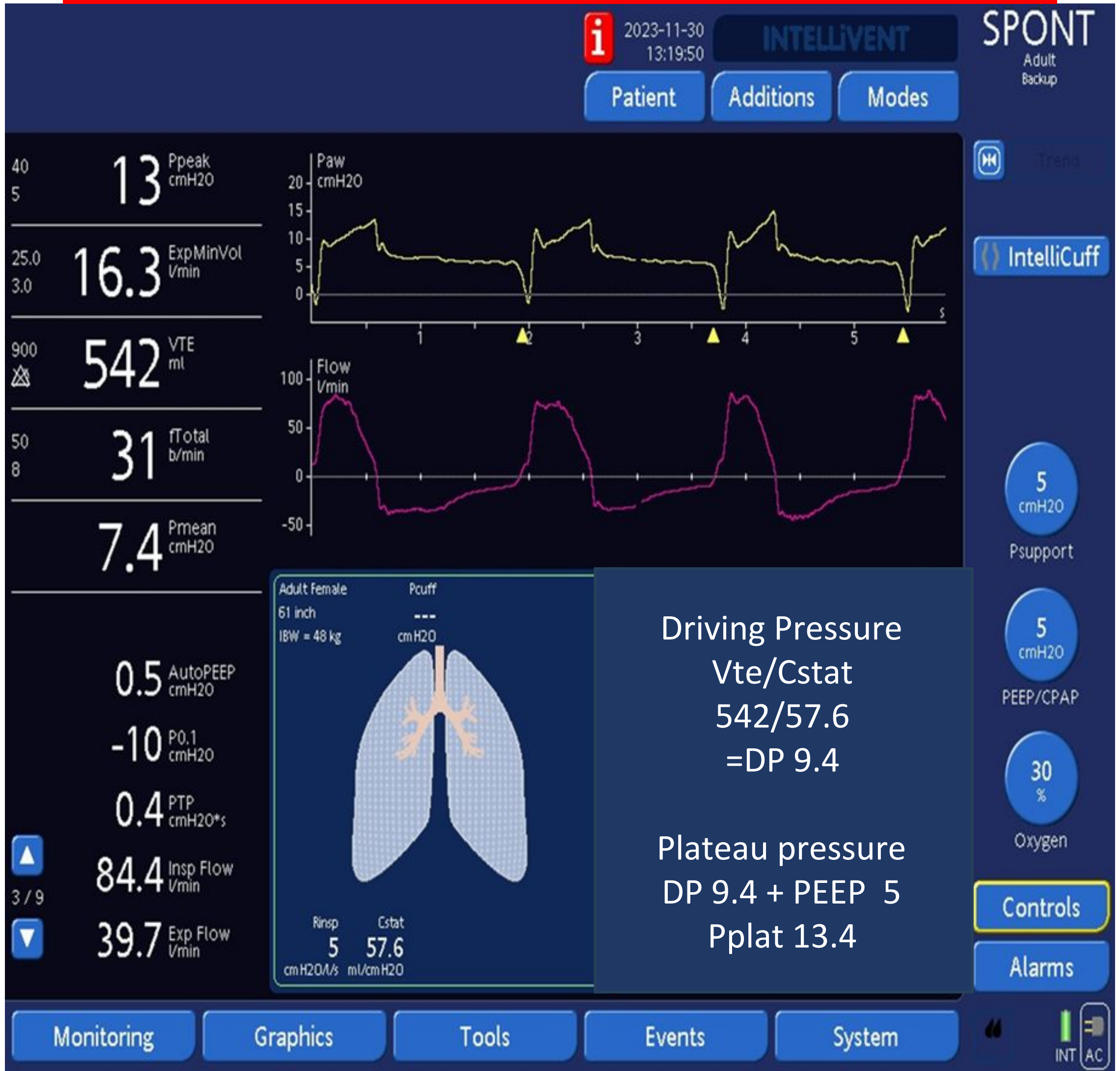
P0.1


2023-11-30
13:21:58
INTELLiVENT
SPONT
Adult
Backup
Patient
Additions
Modes
12 Ppeak cmH2O
14.3 ExpMinVol l/min
467 VTE ml
30 fTotal b/min
6.9 Pmean cmH2O
1.3 AutoPEEP cmH2O
-6.9 P0.1 cmH2O
0.3 PTP cmH2O*s
71.2 Insp Flow l/min
23.2 Exp Flow l/min
3 / 9
Paw cmH2O
Flow l/min
IntelliCuff
Backup
15 b/min Rate
0 ms P-ramp
5 cmH2O Psupport
15 cmH2O Pcontrol
60 % ETS
2.0 -cmH2O P-trigger
5 cmH2O PEEP/CPAP
0.9 s TI
30 % Oxygen
Backup mode:
P-CMV
Controls
Adult Female
61 inch
IBW = 48 kg
Rinsp 6 cmH2O/l/s
Cstat 79.5 ml/cmH2O
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

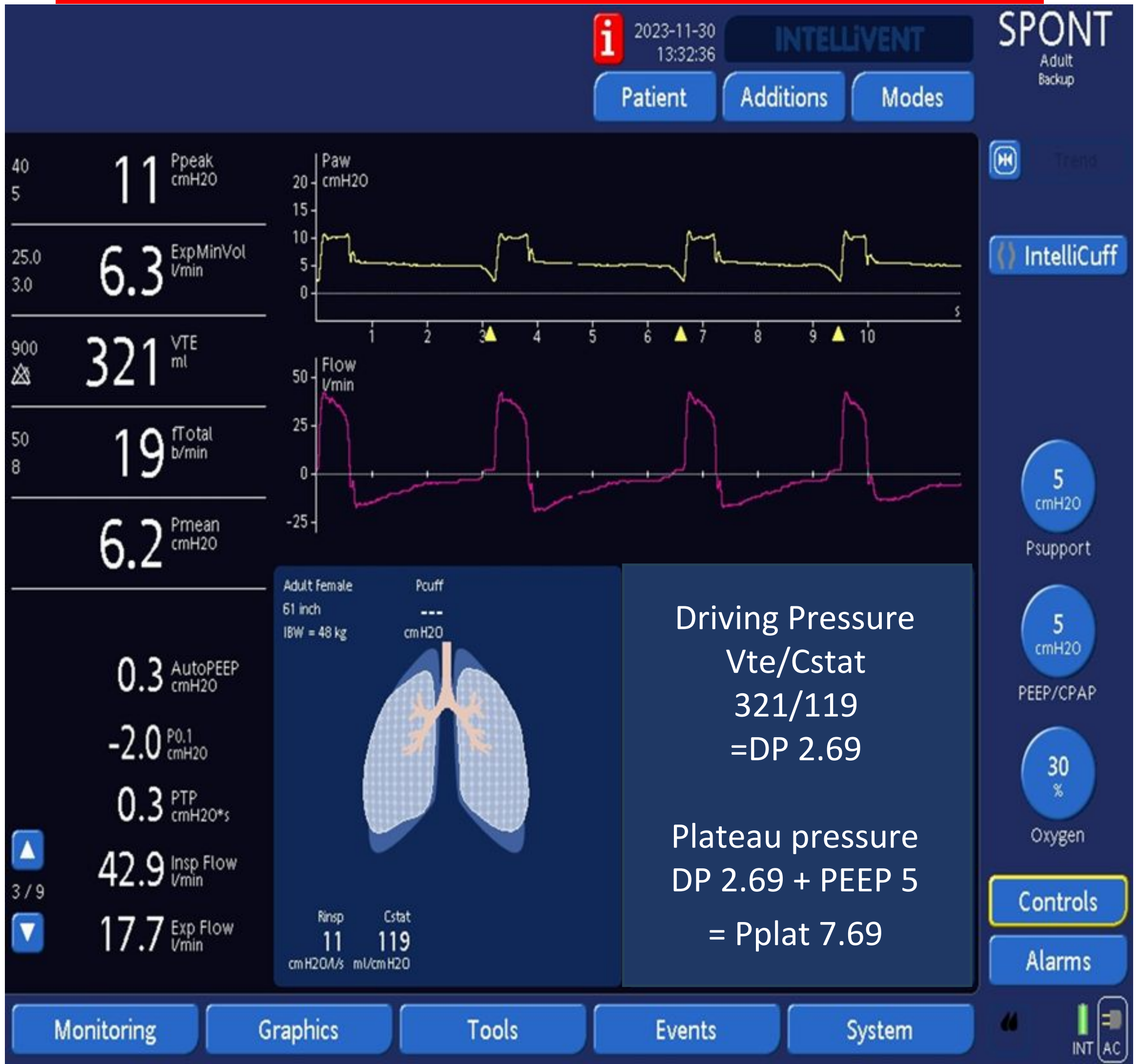

2023-11-30
13:34:16
INTELLiVENT
SPONT
Adult
Backup
Patient
Additions
Modes
11 Ppeak cmH2O
7.5 ExpMinVol l/min
366 VTE ml
19 fTotal b/min
6.5 Pmean cmH2O
0.4 AutoPEEP cmH2O
-2.0 P0.1 cmH2O
0.4 PTP cmH2O*s
45.3 Insp Flow l/min
18.4 Exp Flow l/min
3 / 9
Paw cmH2O
Flow l/min
IntelliCuff
Backup
15 b/min Rate
0 ms P-ramp
5 cmH2O Psupport
15 cmH2O Pcontrol
60 % ETS
2.0 -cmH2O P-trigger
5 cmH2O PEEP/CPAP
0.9 s TI
30 % Oxygen
Backup mode:
P-CMV
Controls
Adult Female
61 inch
IBW = 48 kg
Rinsp 12 cmH2O/l/s
Cstat 154 ml/cmH2O
Alarms
Monitoring
Graphics
Tools
Events
System
INT
AC

End Result P0.1 and Airway Pressures

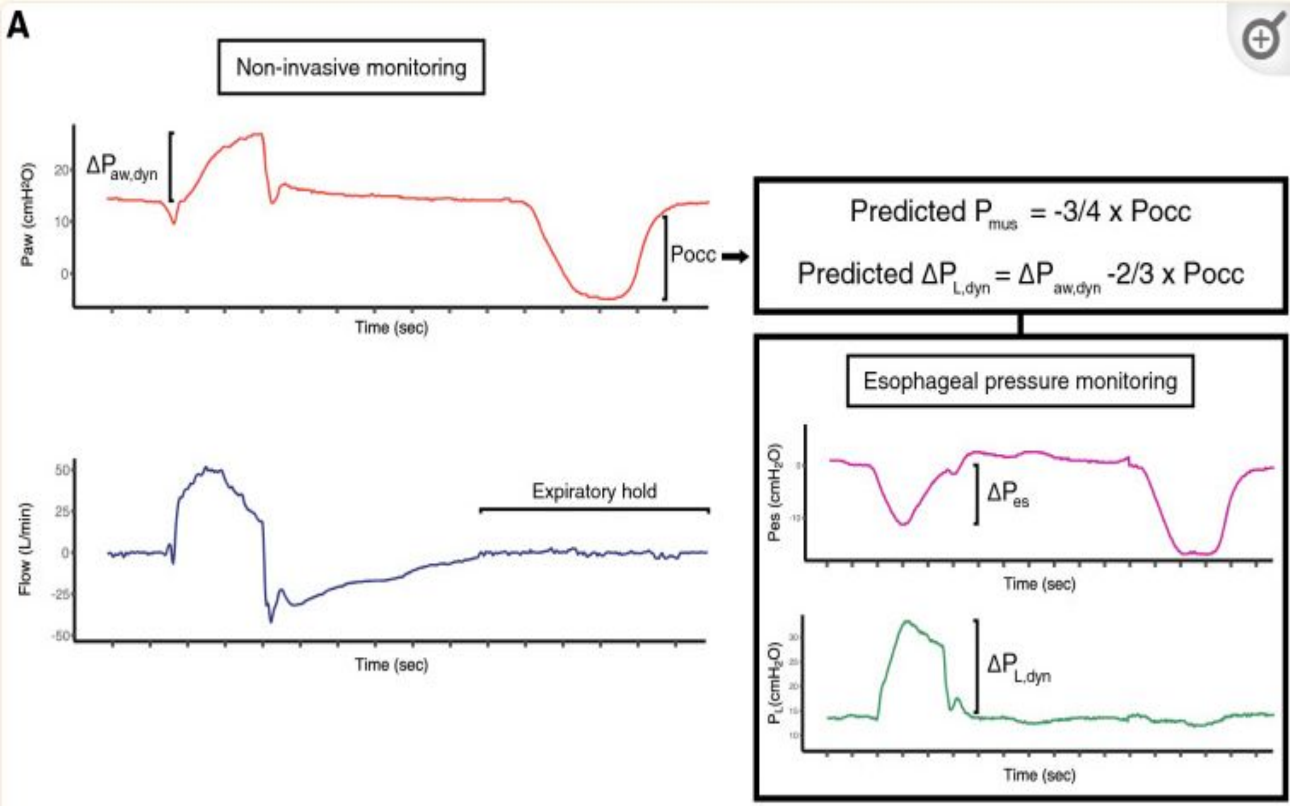
Asynchronous Airway Pressures



Synchronous Airway Pressures



Pocc: End Expiratory Occlusion Pressure



Normal Range -5 to -20 cmH2O

Pocc can be used to estimate both P_{mus} and $\Delta P_{L,dyn}$, a measure of the dynamic mechanical stress applied to the lung during inspiration estimated from Pocc by validated correction factors that adjust for chest wall elastance and the difference in chest wall kinematics between occluded and non-occluded conditions.

PMCID: PMC7334114
PMID: 32623476
Published online 2020 Jul 4. doi: 10.1007/s00134-020-06167-3

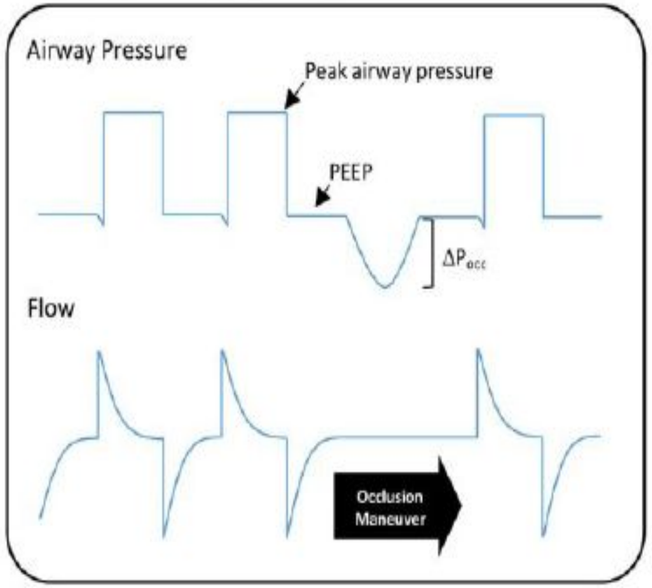
Monitoring patient–ventilator interaction by an end-expiratory occlusion maneuver

Jose Dianti,[1,2] Michele Bertoni,[3] and Ewan C. Goligher[1,2,4]

▸ Author information ▸ Article notes ▸ Copyright and License information PMC Disclaimer

Pocc: Pmus and Dynamic Transpulmonary Driving Pressure

Ventilator Waveforms



Computations

Predicted Pmus = -3/4 x ΔP_{occ}

Predicted ΔP_L = (Peak airway pressure - PEEP) - 2/3 x ΔP_{occ}

Note: ΔP_{occ} is always ≤ 0 cm H_2O (the magnitude of decrease in airway pressure from inspiratory effort during the occlusion)

Measure ΔP_{occ} every 4-8 hours (3 single-breath end-expiratory occlusions)

↓

Estimate P_{mus}
If ΔP_{occ} < 0 cm H_2O, estimate ΔP_L

↓

Predicted P_{mus} > 13-15 cm H_2O
OR
Predicted ΔP_L ≥ 16-17 cm H_2O

Yes →

Consider P_{es} monitoring to guide clinical management

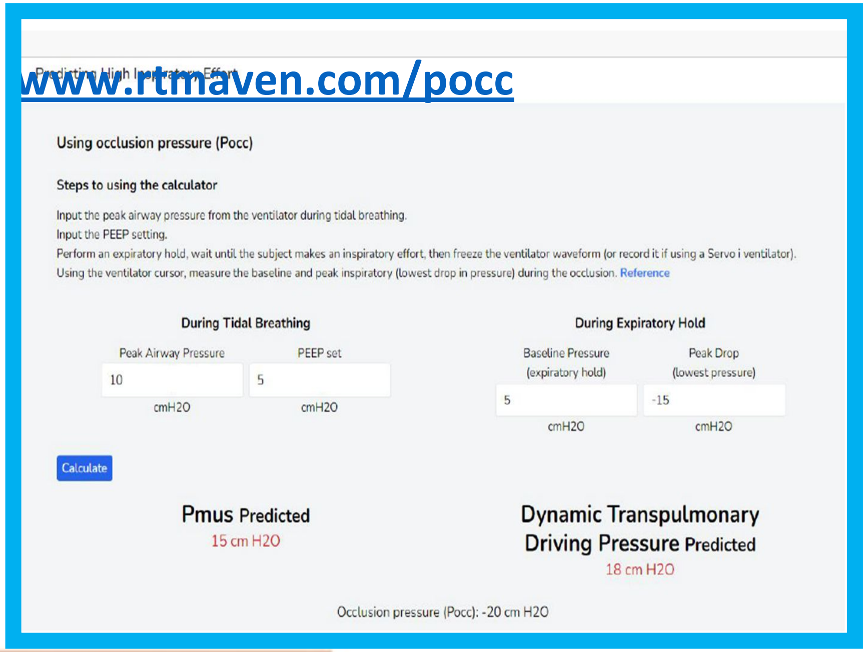
OR

Consider modifying sedation and ventilation to achieve predicted Pmus and ΔP_L within acceptable limits

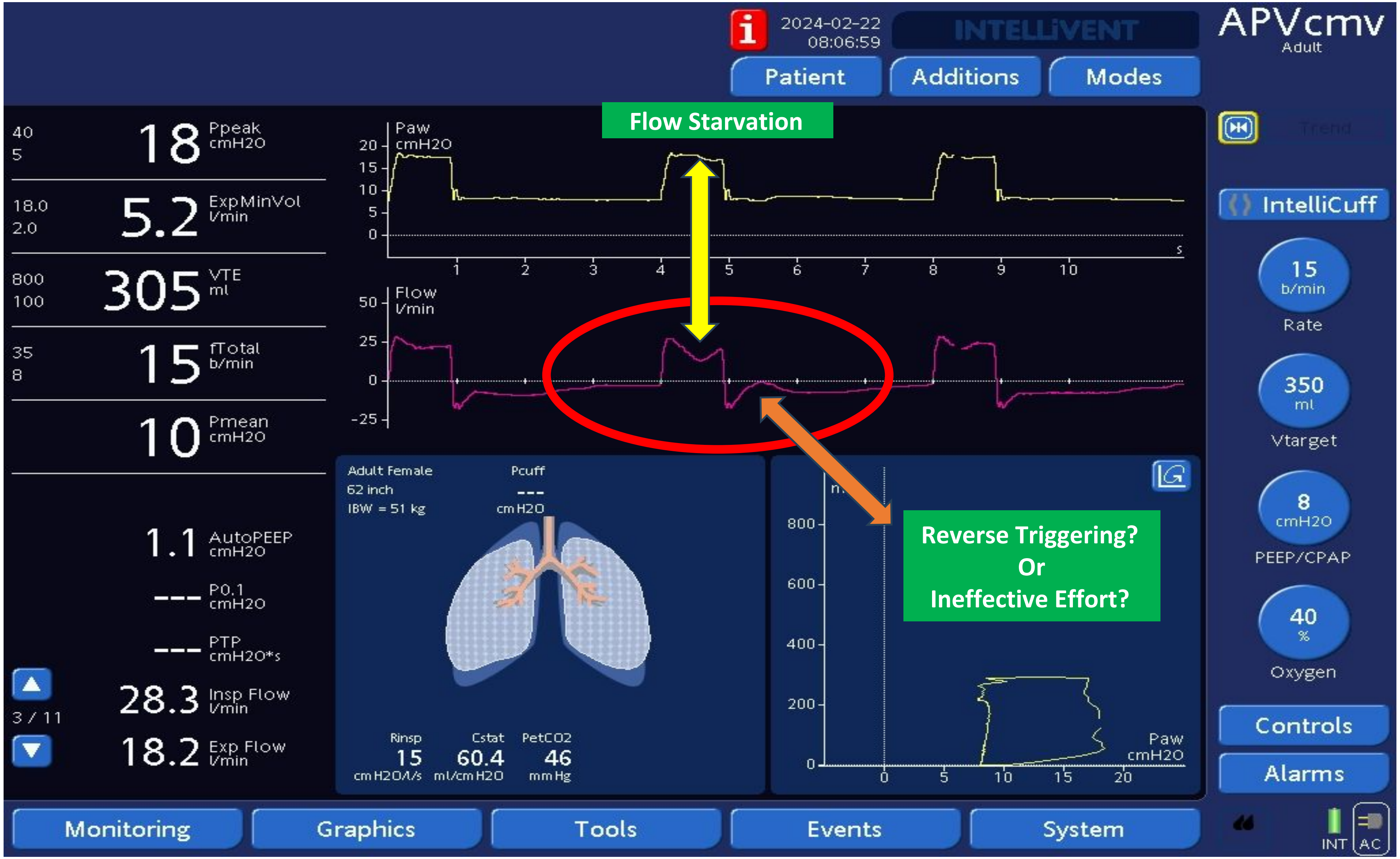
No ↓

Target achieved

www.rtmaven.com/pocc



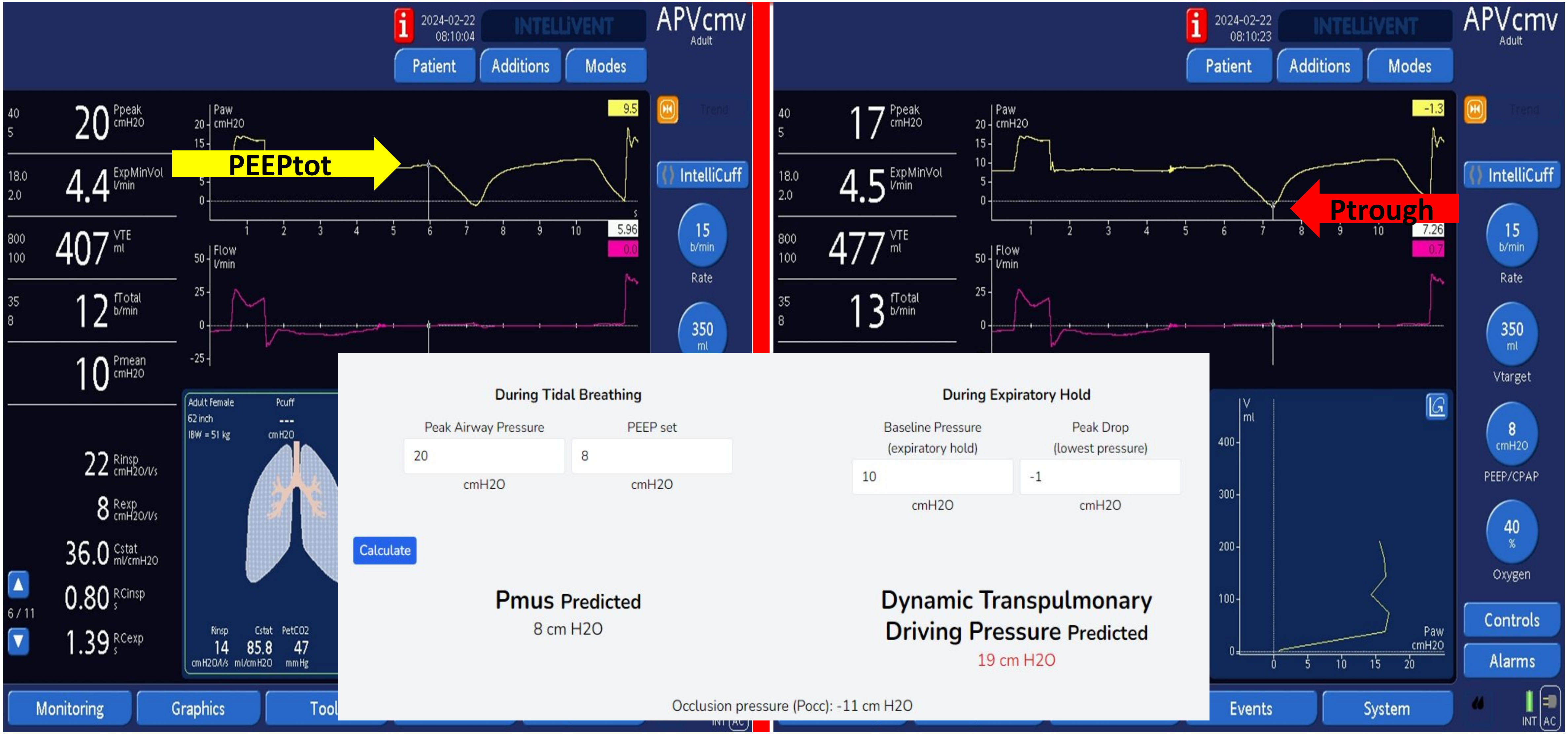
Sedated Intubated Patient



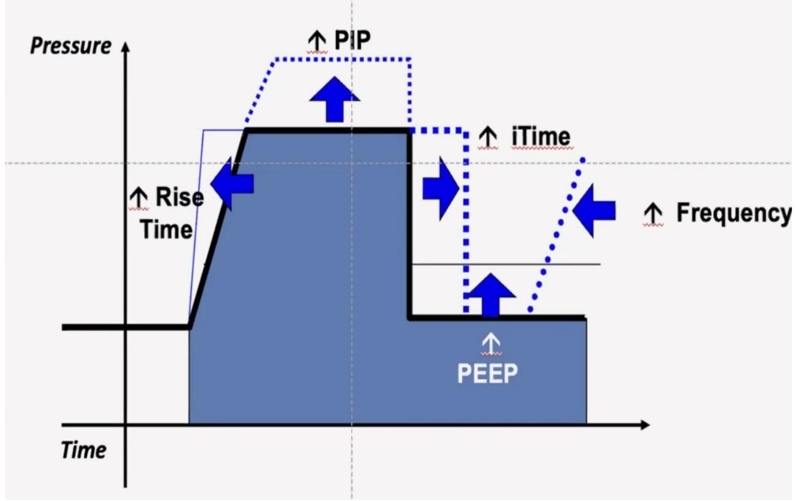
Why is the Plateau Rising?

Why is there no P0.1?

Pocc: Pmus and Dynamic Transpulmonary Driving Pressure

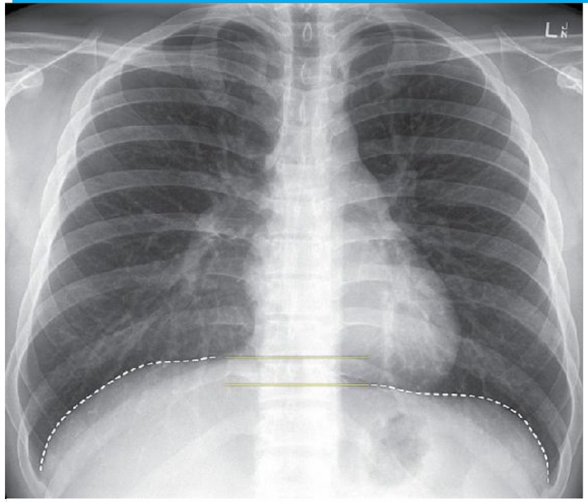


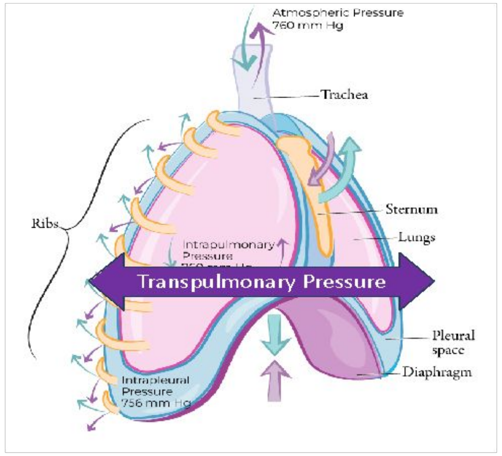
Summary: Prevent Trauma of the Functioning Lung

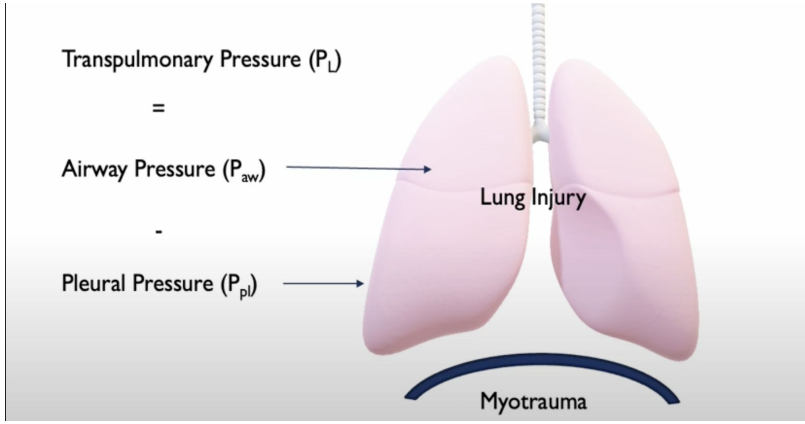


Pmus + Pvent = Resistance x Flow + Elastance x Volume

Breath Delivery = Airway Resistance + Lung Compliance







V_T	RR	T_i	PEEP
IBW	*TC*	*Lung Inflation*	*FRC*