Is 4-8ml per kg still relevant

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

NIH NHLBI ARDS Clinical Network
Mechanical Ventilation Protocol Summary

INCLUSION CRITERIA: Acute onset of

1. $PaO_2/FiO_2 \leq 300$ (corrected for altitude)
2. Bilateral (patchy, diffuse, or homogeneous) infiltrates consistent with pulmonary edema
3. No clinical evidence of left atrial hypertension

PART I: VENTILATOR SETUP AND ADJUSTMENT

1. Calculate predicted body weight (PBW)
   Males = 50 + 2.3 [height (inches) - 60]
   Females = 45.5 + 2.3 [height (inches) -60]
2. Select any ventilator mode
3. Set ventilator settings to achieve initial V_T = 8 ml/kg PBW
4. Reduce V_T by 1 ml/kg at intervals ≤ 2 hours until V_T = 6ml/kg PBW.
5. Set initial rate to approximate baseline minute ventilation (not > 35 bpm).
6. Adjust V_T and RR to achieve pH and plateau pressure goals below.

OXYGENATION GOAL: PaO_2 55-80 mmHg or SpO_2 88-95%
Use a minimum PEEP of 5 cm H_2O. Consider use of incremental FiO_2/PEEP combinations such as shown below (not required) to achieve goal.

Lower PEEP/ higher FiO2

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

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

Higher PEEP/ lower FiO2

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

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

PLATEAU PRESSURE GOAL: ≤ 30 cm H_2O
Check Pplat (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or V_T.
If Pplat > 30 cm H_2O: decrease V_T by 1ml/kg steps (minimum = 4 ml/kg).
If Pplat < 25 cm H_2O and V_T< 6 ml/kg, increase V_T by 1 ml/kg until Pplat > 25 cm H_2O or V_T = 6 ml/kg.
If Pplat < 30 and breath stacking or dys-synchrony occurs: may increase V_T in 1ml/kg increments to 7 or 8 ml/kg if Pplat remains ≤ 30 cm H_2O.

1

Disclosures

No Disclosures to Report

2

Objectives

1. Understanding the role of Driving Pressure

2. How to measure driving pressure in spontaneously breathing patients

   Is Plateau Pressure – Total PEEP the only way?

3

Articles: Guiding Ventilation with Driving Pressure

https://link.springer.com/epdf/10.1007/s00134-024-07440-5?sharing_token=cAPQ6ESjTeycVDzwtCVZrPe4RwlQNchNByi7wbcMAY7L4weQ2pX8XapptiMRpK-NDKpLw4_qDt0XKDOFxMAHQauwvxg__RagvtkbK6kyVNRXqEQkcV3ghnUW-qbcnDR-EXeJmy7Oq2F3H_MkJdYUE_8S6aAp5LVYfUCx3AfkRZw%3D

https://ccforum.biomedcentral.com/articles/10.1186/s13054-023-04591-7

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6639048/

https://rc.rcjournal.com/content/64/8/1017

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7280884/

https://www.wjgnet.com/2220-3141/full/v13/i1/88385.htm

https://onlinelibrary.wiley.com/doi/10.1155/2022/6236438

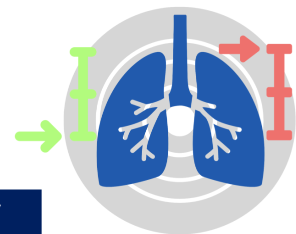
4

ARDSnet

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 to12ml/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.

5

What is ARDS?

ARDS – The Berlin Criteria

Symptom begin within 1 week of insult, or new/worsening symptoms in last 1 week
Bilateral opacities on chest imaging*
$PaO_2/FiO_2 \leq 300$ while on PEEP ≥ 5 cm H_2O
Not fully attributed to cardiac failure and/or volume overload

Basically ARDS is a bilateral inflammatory process that is associated with hypoxemia.

Is all hypoxemia ARDS? No

A right middle lobe infiltrate with a high shunt fraction

A mucus plug or atelectasis that is then causing hypoxemia.

Cardiac: Shunts in the heart that can make you hypoxemic that are not related to the lungs.

Normal CXR with hypoxemia? Maybe its Cardiac

6

ARDS Criteria

	Berlin criteria	Kigali modifications
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Oxygenation	$PaO_2/FiO_2 \leq 300$	$SpO_2/FiO_2 \leq 315$
PEEP requirement	Minimum 5 cm H_2O PEEP required by invasive mechanical ventilation (noninvasive acceptable for mild ARDS)	No PEEP requirement
Chest imaging	Bilateral opacities not fully explained by effusions, lobar/lung collapse, or nodules by chest radiograph or CT	Bilateral opacities not fully explained by effusions, lobar/lung collapse, or nodules by chest radiograph or ultrasound
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload [need objective assessment (e.g., echocardiography) to exclude hydrostatic edema if no risk factor present]	Respiratory failure not fully explained by cardiac failure or fluid overload [need objective assessment (e.g., echocardiography) to exclude hydrostatic edema if no risk factor present]

ARDS, acute respiratory distress syndrome; PEEP, positive end expiratory pressure.

ARDS New Global Definition 2023

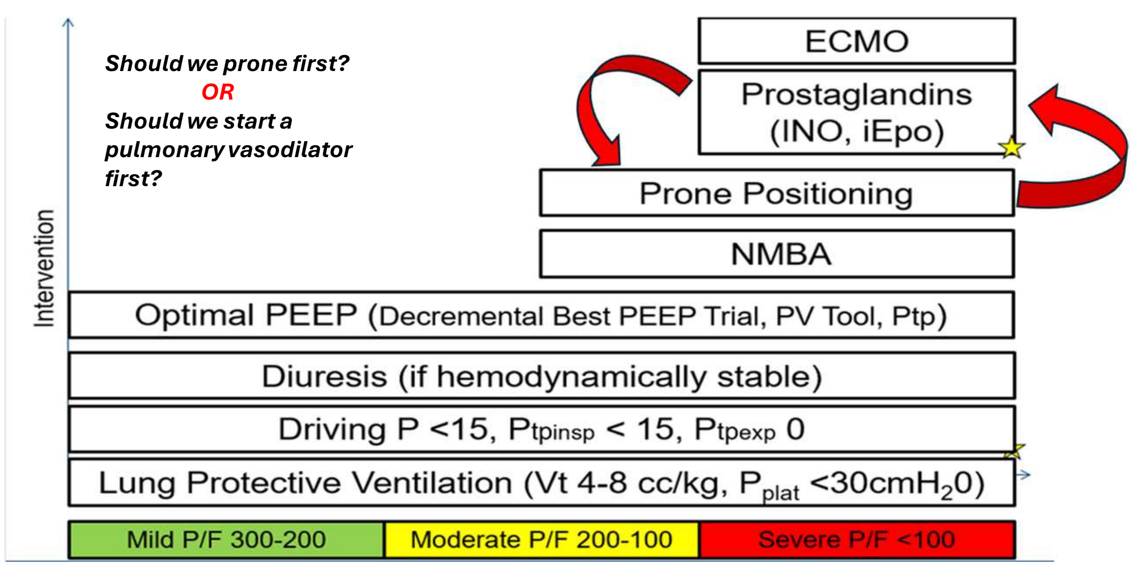
• new definition criteria	Classification		
	Mild	Moderate	Severe
Time to instalation	Up to seven days - known risk fator(s)		
Pulmonary edema	Not explained by cardiogenic edema or intravascular volume overload		
Radiologic features	Bilateral infiltrates on chest X-ray or CT or lung ultrasound (by a trained professional) (not explained by nodules, pleural effusion or atelectasis)		
Hypoxemia PaO_2/FIO_2**	201-300 with NIV/CPAP PEEP ≥ 5* or HFNO > 30l/min	101 - 200 com PEEP ≥ 5	≤ 100 com PEEP ≥ 5
Hypoxemia SpO_2/FIO_2	≤ 315 with SpO_2 ≤ 97%		

xlung www.xlung.net

Am J Respir Crit Care Med 2023;207:A6229

7

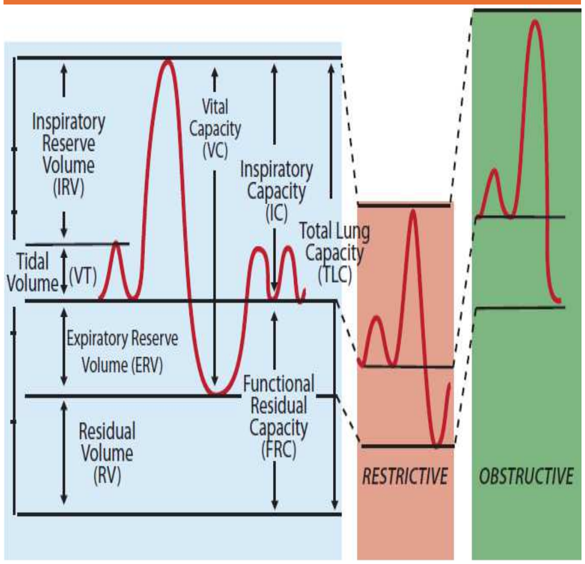
Managing ARDS



8

Blankets are for Naps NOT Mechanical Ventilation

Mechanical Ventilation is an Individualized Approach



Approximations For the 70kg (IBW) Male

mL / Kg IBW	f	Vt	MV	Dead Space	DS% of Vt	MVa
4	~25	280	7000	100	36%	4500
5	~20	350	7000	100	29%	5000
6	~16	420	6720	100	24%	5400
7	~14	490	6860	100	20%	5600
8	~12	560	6720	100	18%	5800
9	~11	630	6930	100	16%	5900
10	~10	700	7000	100	14%	6000

9

PReVent Trial

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

Current international guidelines recommend using low tidal volumes (<6-8 ml/kg) during mechanical ventilation of patients with ARDS to reduce the number of ventilator-free and alive days at day 28

It is less certain whether tidal volume restriction benefits patients without ARDS as the population of ventilated non ARDS patients are many times larger than ARDS patients which were excluded from ARDS trials

Lower tidal volumes could also lead to greater patient- ventilator asynchrony, higher sedation requirements, and prolonged duration of mechanical ventilation

10

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

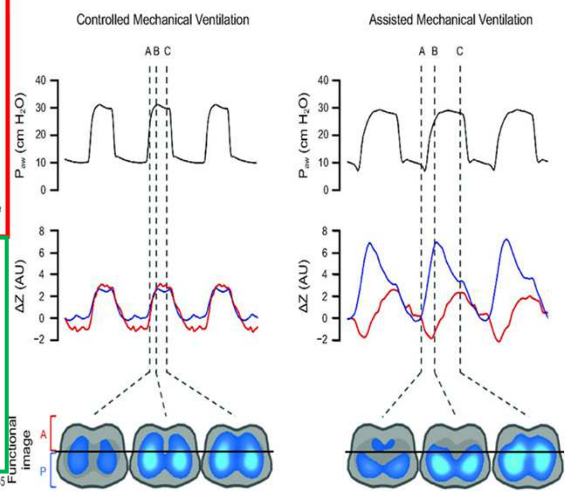
Yahya Shehabi[1,2], Rinaldo Bellomo[3,4,5,6], Michael C. Reade[7,8], Michael Bailey[5], Frances Bass[2], Belinda Howe[5], Colin McArthur[9], Ian M. Seppelt[10], Steve Webb[11,12], and Leonie Weisbrodt[13]; Sedation Practice in Intensive Care Evaluation (SPICE) Study Investigators and the ANZICS Clinical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



11

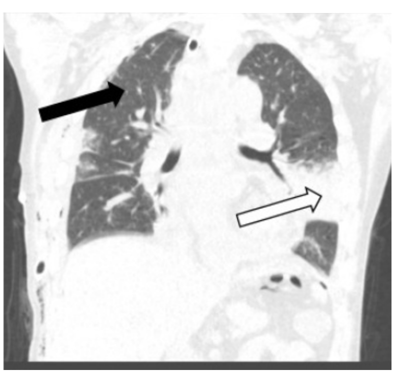
Preventing Trauma of the Functioning Lung

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

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



Driving pressure would be lowest when the PEEP maintains alveoli at the functional residual capacity at the end of expiration and V_T expands the lungs within the 'functional lung size'

This warrants an important question!

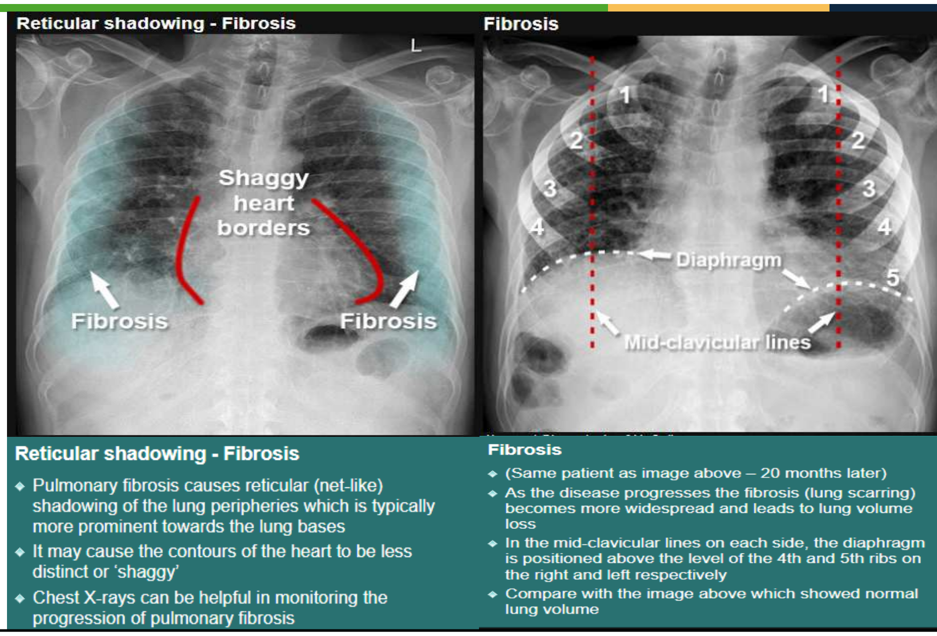
Is 4-8ml/kg IBW appropriate for the Functional Lung?

Release of inflammatory mediators lead to lung inflammation and cause injury to other organs.

Functional lung size is different than anatomical lung size: Aerated alveoli contribute to ventilation

12

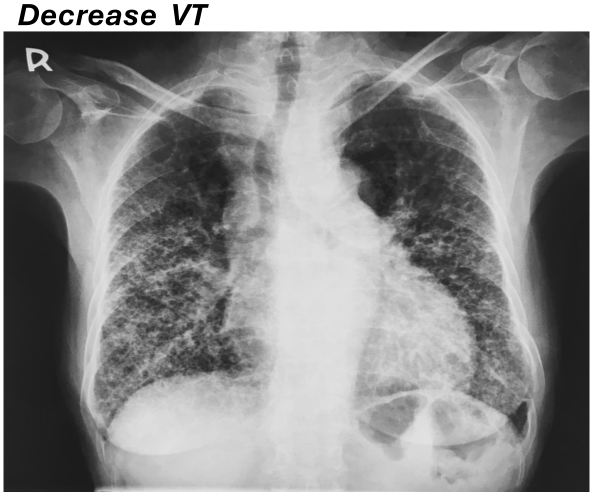
Functional lung size is different than Anatomical lung size



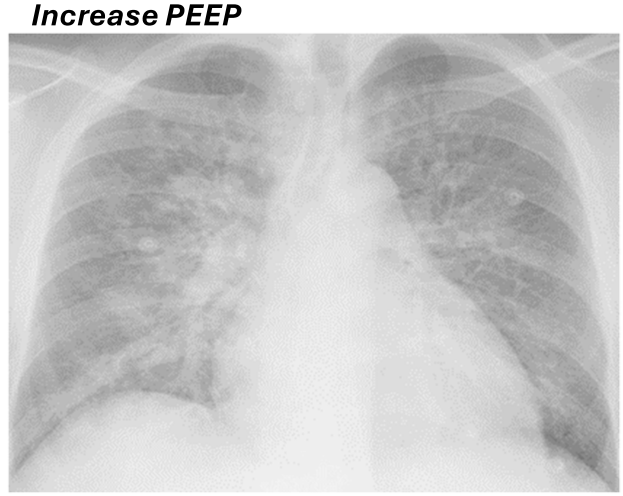
13

The Importance of the CXR

Driving Pressure >15cmH20
Plateau Pressure >30cmH20
Decrease VT



Driving Pressure >15cmH20
Plateau Pressure >30cmH20
Increase PEEP



14

Keeping Airway pressures Safe

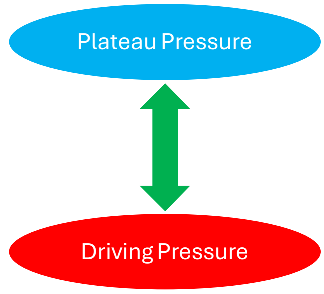

The NEW ENGLAND JOURNAL *of* MEDICINE

SPECIAL ARTICLE

N ENGL J MED 372;8 NEJM.ORG FEBRUARY 19, 2015

Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

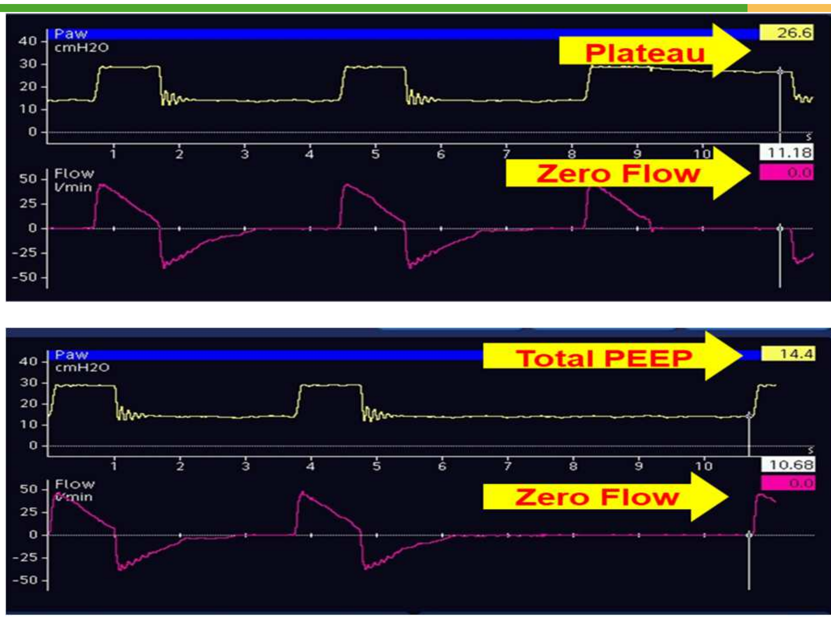
Marcelo B.P. Amato, M.D., Maureen O. Meade, M.D., Arthur S. Slutsky, M.D., Laurent Brochard, M.D., Eduardo L.V. Costa, M.D., David A. Schoenfeld, Ph.D., Thomas E. Stewart, M.D., Matthias Briel, M.D., Daniel Talmor, M.D., M.P.H., Alain Mercat, M.D., Jean-Christophe M. Richard, M.D., Carlos R.R. Carvalho, M.D., and Roy G. Brower, M.D.



To minimize ventilator-induced lung injury in patients with ARDS, the proportion of lung available for ventilation is markedly decreased, which is reflected by lower respiratory-system compliance (CRS). Therefore normalizing VT to CRS indicating the “functional” size of the lung would provide a better predictor of outcomes in patients with ARDS utilizing driving pressure (ΔP=VT /CRS) than VT alone. **The aerated lung in a patient with ARDS is not “stiff” but is small**. we hypothesized that the functional lung size during disease is better quantified by CRS than by predicted body weight.

15

Driving Pressure: Titrate PEEP or VT?



Plateau 26.6

Minus

Total PEEP 14.4

Equals

Driving Pressure 12.2

16

What is Driving Pressure?

Passive → Driving Pressure = P_{plat} - PEEP

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

High driving pressure was also associated with increased mortality in patients receiving pressure support mode ventilation in a recent retrospective cohort study [24].

Passive/Active → Driving Pressure = $\frac{V_T}{C_{ST}}$

Can we estimate a Safe VT?

17

Cstat x Desired Driving Pressure

Current Driving Pressure		Cstat x Desired Driving Pressure
Vte 500ml Cstat 50ml 500/50 = DP 10	→	50ml x 15cmH20 = Vt 750ml
Vte 800ml Cstat 32ml 800/32 = DP 25	→	32ml x 15cmH20 = Vt 480ml
Vte 300ml Cstat 15ml 300/15 = DP 20	→	15ml x 15cmH20 = Vt 225ml

18

Cstat = 1 Driving Pressure (A Very Important Number to Assess/Trend)

VT 500ml and Cstat 50ml

500/50 = Driving Pressure 10

Cstat 50 x DP 10 = VT 500ml

Driving Pressure 1 = 50ml

Driving Pressure 2 = 100ml

Driving Pressure 3 = 150ml

Driving Pressure 4 = 200ml

Driving Pressure 5 = 250ml

Driving Pressure 6 = 300ml

Driving Pressure 7 = 350ml

Driving Pressure 8 = 400ml

Driving Pressure 9 = 450ml

Driving Pressure 10 = 500ml

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.

$$\text{Driving Pressure} = \frac{V_T}{C_{ST}}$$

19

Are We Delivering the Safest VT?

Randomized Controlled Trial > Am J Respir Crit Care Med. 2021 Jun 1;203(11):1378-1385.
doi: 10.1164/rccm.202009-3536OC.

Effect of Lowering Vt on Mortality in Acute Respiratory Distress Syndrome Varies with Respiratory System Elastance

Ewan C Goligher [1 2 3], Eduardo L V Costa [4 5], Christopher J Yarnell [1 6 2], Laurent J Brochard [1 7], Thomas E Stewart [8], George Tomlinson [2], Roy G Brower [9], Arthur S Slutsky [1 7], Marcelo P B Amato [4]

Affiliations + expand

PMID: 33439781 DOI: 10.1164/rccm.202009-3536OC

Clinicians should not regard ventilation with a VT of 6 ml/kg of IBW as adequately lung protective when driving pressure remains elevated.
It is important to note that many patients with high Ers randomized to a lower-VT strategy were ventilated with a VT of 4–5 ml/kg in the clinical trials included in this analysis.
Lowering VT below 6 ml/kg when driving pressure remains higher than 15 cm H_2O, appreciating that a very low VT might be achieved by increases in the respiratory rate .
The mortality benefit of ventilation with lower Vt in ARDS varies according to elastance, suggesting that lung-protective ventilation strategies should primarily target driving pressure rather than Vt.

20

Calculating Airway Pressures

Driving Pressure

Vte/Cstat

199/6.5

= DP 30.6

Estimated Plateau Pressure

DP + PEEP

30.6 + 5

= Plateau 35.6

Safe VT (related to CXR)

Cstat x Desired Driving Pressure

6.5 x 15

= VT 97.5ml

21

Calculating Airway Pressures

Driving Pressure

Vte/Cstat

360/18.5

= DP 19.45

Estimated Plateau Pressure

DP + PEEP

19.45 + 22

= Plateau 41.45

Safe VT (related to CXR)

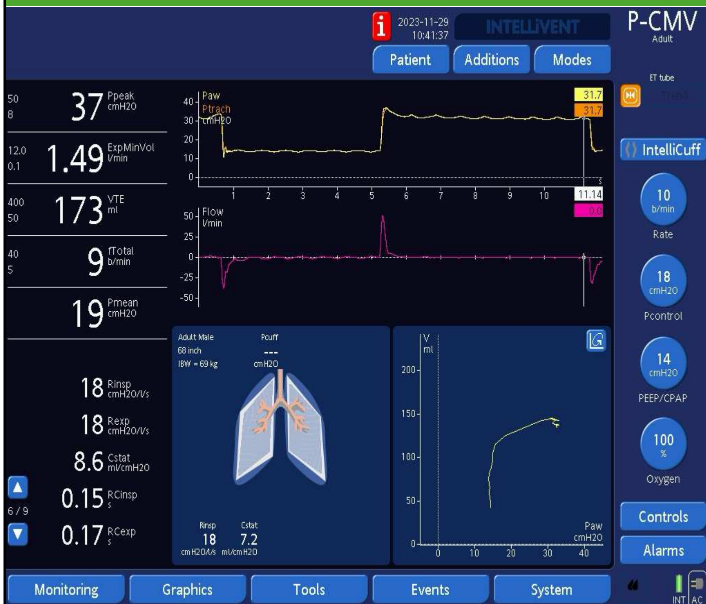
Cstat x Desired Driving Pressure

18.5 x 15

= VT 277ml

22

Calculating Airway Pressures



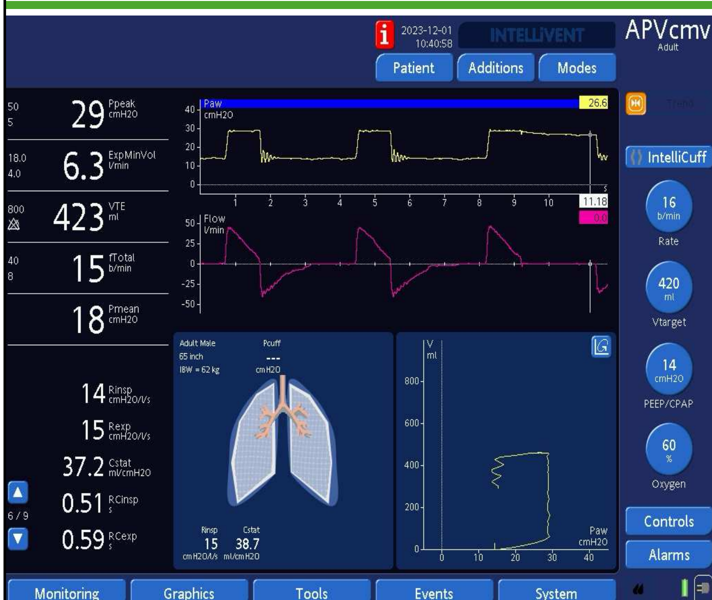
Driving Pressure
Vte/Cstat
173/7.2
= DP 24

Estimated Plateau Pressure
DP + PEEP
24 + 14
= Plateau 38

Safe VT (related to CXR)
Cstat x Desired Driving Pressure
7.2 x 15
= VT 108ml

23

Calculating Airway Pressures



Driving Pressure
Vte/Cstat
423/38.7
= DP 10.9

Estimated Plateau Pressure
DP + PEEP
10.9 + 14
= Plateau 24.9

Safe VT (related to CXR)
Cstat x Desired Driving Pressure
38.7 x 15
= VT 580ml

24

Calculating Airway Pressures

Driving Pressure

Vte/Cstat

411/21.8

= DP 18.8

Estimated Plateau Pressure

DP + PEEP

18.8 + 17

= Plateau 35.8

Safe VT (related to CXR)

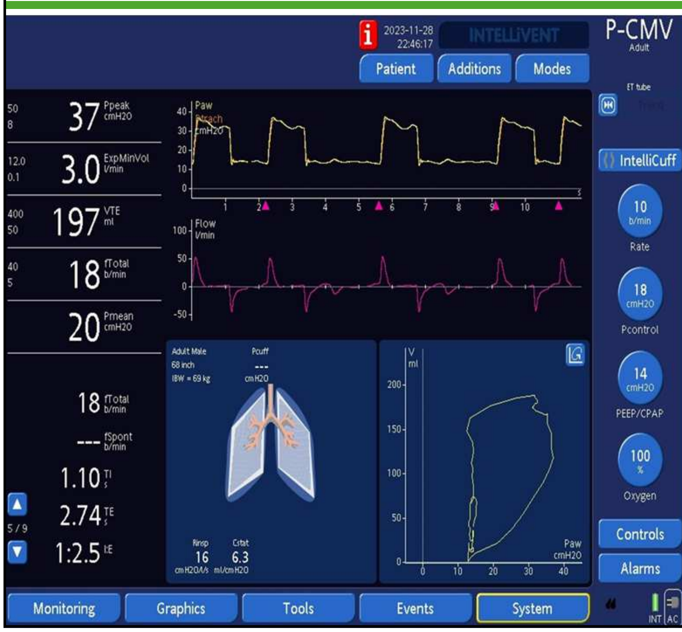
Cstat x Desired Driving Pressure

21.8 x 15

= VT 327ml

25

Calculating Airway Pressures



Driving Pressure

Vte/Cstat

197/6.3

= DP 31.2

Estimated Plateau Pressure

DP + PEEP

31.2 + 14

= Plateau 45.2

Safe VT (related to CXR)

Cstat x Desired Driving Pressure

6.3 x 15

= VT 94.5ml

26

Calculating Airway Pressures

Driving Pressure

Vte/Cstat

163/7.3

= DP 22.3

Estimated Plateau Pressure

DP + PEEP

22.3 + 14

= Plateau 36.3

Safe VT (related to CXR)

Cstat x Desired Driving Pressure

7.3 x 15

= VT 109.5ml

27

Calculating Airway Pressures

Driving Pressure

Vte/Cstat

392/60.7

= DP 6.45

Estimated Plateau Pressure

DP + PEEP

6.45 + 5

= Plateau 11.45

Safe VT (related to CXR)

Cstat x Desired Driving Pressure

60.7 x 15

= VT 910ml

28

Calculating Airway Pressures

Driving Pressure
Vte/Cstat
298/21.7
= DP 13.7

Estimated Plateau Pressure
DP + PEEP
13.7 + 15
= Plateau 28.7

Safe VT (related to CXR)
Cstat x Desired Driving Pressure
21.7 x 15
= VT 325.5ml

29

Spontaneous Breathing Driving Pressure

Indian J Crit Care Med. 2016 Dec; 20(12): 689–694.
doi: 10.4103/0972-5229.195701
PMCID: PMC5225768
PMID: 28149025

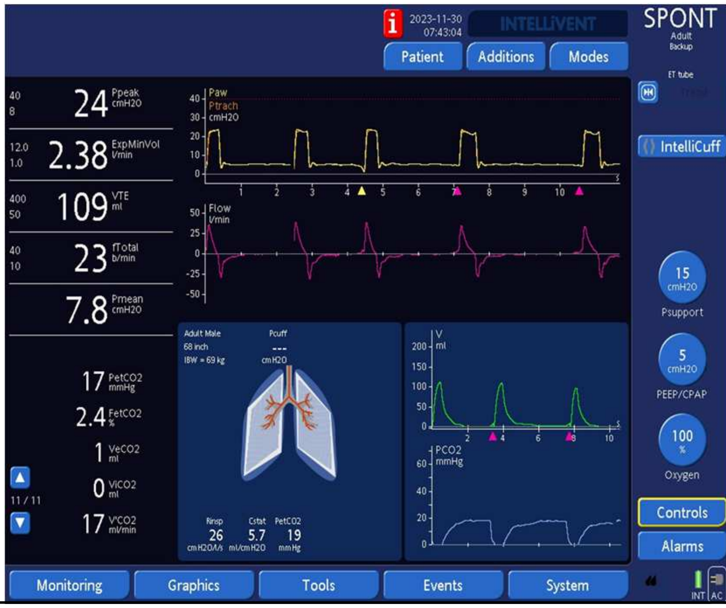
Comparison of patient-ventilator asynchrony during pressure support ventilation and proportional assist ventilation modes in surgical Intensive Care Unit: A randomized crossover study

Parshotam Lal Gautam, Gaganjot Kaur,[1] Sunil Katyal, Ruchi Gupta,[1] Preetveen Sandhu,[1] and Nikhil Gautam

Patient-ventilator asynchrony has been a concern and is observed in almost all spontaneous modes of ventilation. Patients with high level of asynchrony require a longer duration of mechanical ventilation (MV), higher incidence of tracheostomy, weaning failure, longer ICU, and hospital stay.

30

Calculating Airway Pressures



Driving Pressure
Vte/Cstat
109/5.7
= DP 19.1

Estimated Plateau Pressure
DP + PEEP
19.1 + 5
= Plateau 24.1

Safe VT (related to CXR)
Cstat x Desired Driving Pressure
5.7 x 15
= VT 85.5ml

31

Summary

Should we use the ml/kg IBW or should we set the Vt based on Driving Pressure ?

We need to start somewhere and then set Vt/PEEP based on the CXR and Driving pressure?

32