Are We Picking the Most Appropriate Ventilator Settings?

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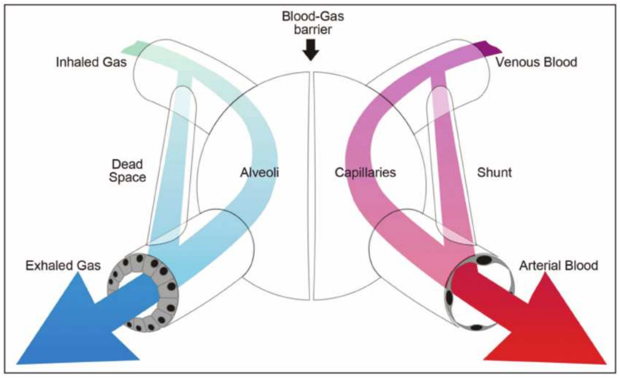

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Disclosures

None to Report

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Objectives

1. Targeting Alveolar Minute Ventilation and not Minute Ventilation
2. Masking the Intrinsic Drive to Breathe

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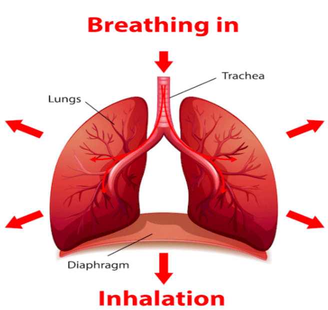
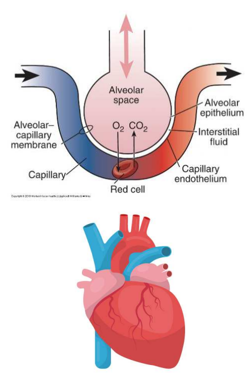
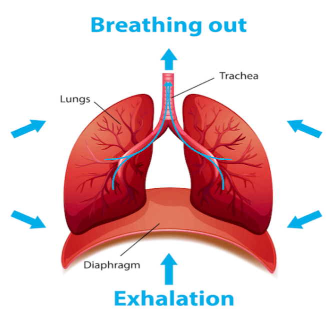
What is Ventilation? Two Part Process

The beginning and end of oxygenation, circulation and perfusion

Without these you will not have effective gas change







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Choosing Tidal Volume is Patient Dependent

We All Know This

Tidal Volume

on the Ventilator is Based on

IDEAL BODY WEIGHT

not Actual Body Weight

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Setting the VT and RR

How do you set the Respiratory Rate?

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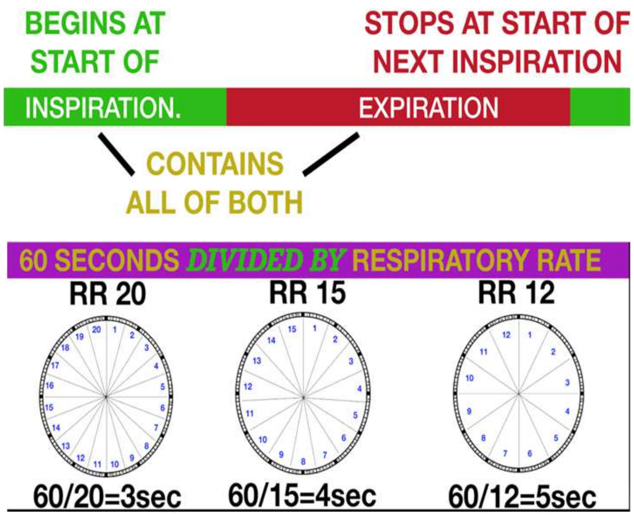
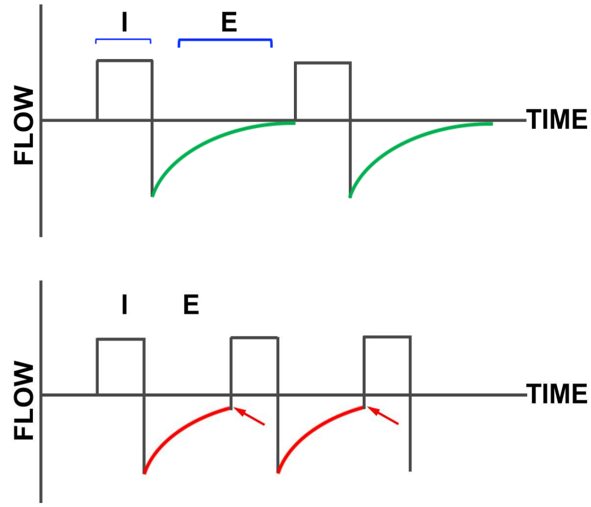
Setting the RR based on the Total Cycle Time and the I:E Ratio





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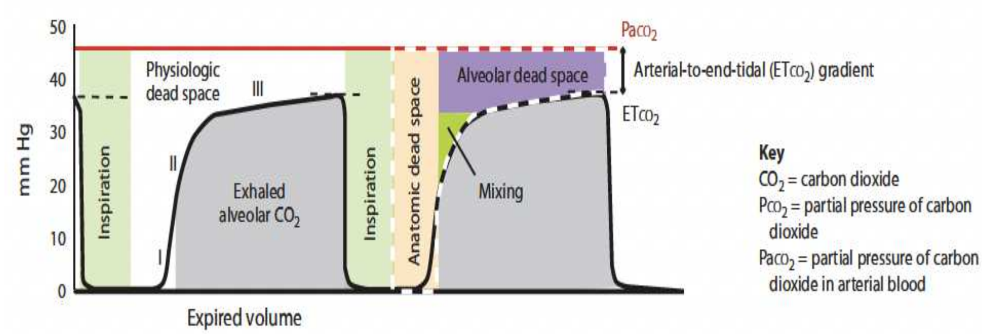
Setting the RR based on ETCO2



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ARMA Trial

Tidal volume settings

Before the ARMA Trial (2000) tidal volume settings had been 12-15ml/kg

ARMA found that 6ml/kg of ideal body weight was safer in patients with ARDS

Most Sources recommend 6-8 ml/kg IBW since the ARMA Trial (For Everybody)

Respiratory rate settings

For a normal adult it is 70-110ml/kg/min

To achieve this, a Respiratory Rate of 12-16 bpm using Vt 6-8ml/kg is used

For ARDS, poorly compliant lungs and other patients with necessarily small tidal volumes, the respiratory rate should be higher

For patients with severe bronchospasm and gas trapping, the respiratory rate should be lower.

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Targeting Dead Space

The progressive reduction of V_T has led to an increase of the respiratory rate (RR), with no clear recommendation on how to set it, leading to the impact of dead space becoming highly relevant. ***More than 50 years ago,*** a minute ventilation of 100 mL/kg $_{IBW}$/min was recommended for surgical populations, which was increased by 10% for each degree Celsius above 37°C and decreased by 10% for each degree Celsius below 37°C to target patients with different dead space and CO_2 production (because of metabolism, temperature, presence of sepsis, vasopressors, etc).

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Is a Normal Minute Ventilation 4-8lpm?

Minute Ventilation

A measurement of the amount of air that enters the lungs per minute. It is the product of respiratory rate and tidal volume.

Minute Ventilation = RR x Vt

Perfect World
Minute Ventilation = 4lpm
Cardiac Output 4lpm
paCO2 40 mmHg

VQ Mismatching Can Prevent This

Alveolar Minute Ventilation

The same concept as minute ventilation, however Alveolar Ventilation, takes physiological dead space into account.

Alveolar Ventilation = RR x (Vt- Vd)

Physiology, Tidal Volume

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Last Update: May 1, 2023.

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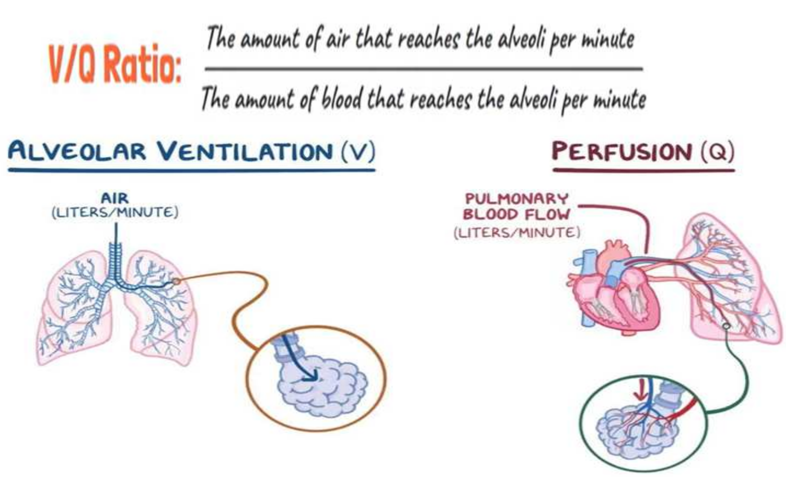
VQ Matching



VQ mismatching alters what we think our patient's Minute Ventilation

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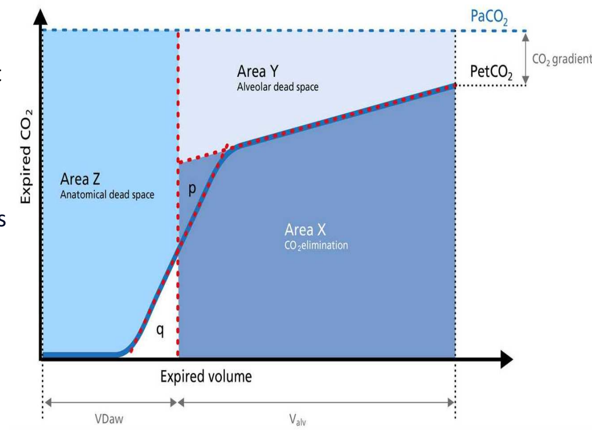
What is Vd (Dead space)

The amount of volume inhaled that does not take part in gas exchange

Anatomical
Volume in the conducting airways that does not take part
In gas exchange

Alveolar
Ventilated lung with decreased perfusion from atelectasis
And/or decrease supply of pulmonary blood flow

Physiological
Combination of Anatomical and Alveolar dead space



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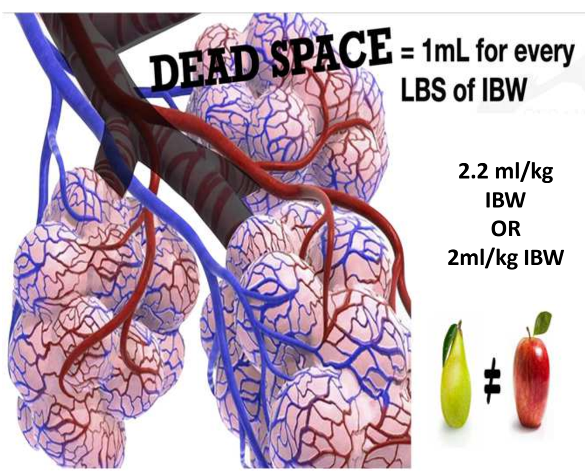
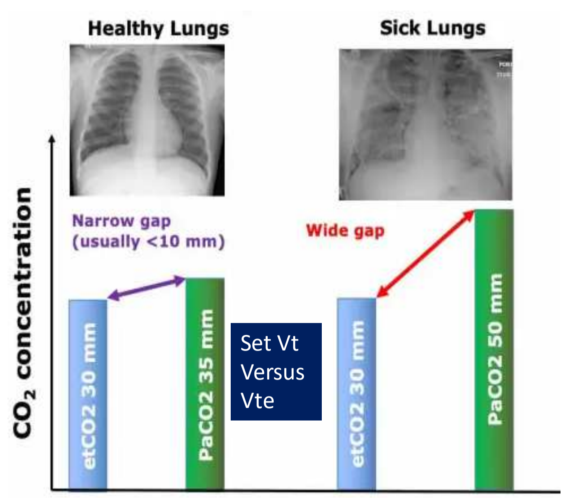
Is Dead Space 150ml for everyone?



2.2 ml/kg
IBW
OR
2ml/kg IBW



Set Vt
Versus
Vte

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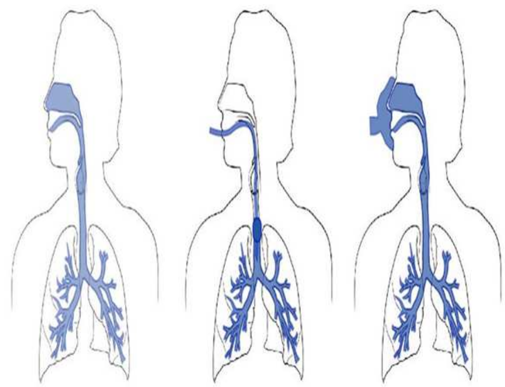
Dead Space is Different for Everyone and it Matters!

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



Normal anatomical dead space: 150ml
Intubated anatomical dead space: 70ml
NIV anatomical dead space: 200ml

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Questions to always ask and answer

1.How much support does the patient need from the ventilator?

Initially we often do not know the patient's current ventilation/Oxygenation status! We assume….

2.What are other factors to consider to deliver those settings?

Airway Resistance, Lung Compliance, Body Habitus, etc

3.Why do we not always consider dead space?

Because we do not talk about it enough

PIP	I:E	RR	V_{TE}	V_{Tot}	
V_T IBW	RR ?	T_i	FiO_2	PEEP	Additional settings

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Picking an Appropriate Tidal Volume and Respiratory Rate

Minute Ventilation (Ve) = Amount of air moved in and out of the lungs in one minute
Does not account for physiological dead space

Example: Patient IBW 50kg x Vt 6ml = Vt 300ml but what is the RR going to be….Where do you start?
RR 15 x Vt 300ml = ***Mv 4.5Lpm***

Alveolar Minute Ventilation (Va) = Amount of air moved in and out of the lungs in one minute
Does account for physiological dead space

Example: Patient IBW 50kg x Vt 6ml = 300ml
VD: IBW 50kg x 2ml VD = 100ml
Vt 300ml – VD 100ml = 200ml reaching the alveoli for gas exchange
RR 15 x Vt 200ml = ***Mv 3Lpm***

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How can we Pick a Respiratory Rate based on Alveolar MV

The Tidal Volume (Vt) is still based on IBW
Respiratory Rate (RR) becomes based on a Va

100 ml/kg/min
OR
120ml/kg/min

Ventilatory ratio: a simple bedside measure of ventilation

P. Sinha · N.J. Fauvel · S. Singh · N. Soni

Affiliations & Notes   Article Info

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If you use the 100 or 120ml/kg, choosing a low VT will always give you a higher rate
If you use the 100 or 120ml/kg, choosing a Higher VT will always give you a lower rate

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Alveolar and Dead Space ventilation

Target: 100 mL/kg/min

IBW: 50 kg

Tidal Volume: 300 mL

MV: 100ml x 50kg = 5000 mL (or 5LPM)

RR: 5000ml / 300vt = 16 for a Respiratory Rate

Example: 50kg patient with 100ml of deadspace

50kg patient with 2ml/kg VD = 100ml VD
100ml x 50kg = 5000ml minute ventilation
4 mL / kg = frequency of 25 (5000ml/200ml = RR25)
5 mL / kg = frequency of 20 (5000ml/250ml = RR20)
6 mL / kg = frequency of 16 (5000ml/300ml = RR16)
7 mL / kg = frequency of 14 (5000ml/350ml = RR14)
8 mL / kg = frequency of 12 (5000ml/400ml = RR12)
9 mL / kg = frequency of 11 (5000ml/450ml = RR11)
10 mL / kg = frequency of 10 (5000ml/500ml = RR10)

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Examples 100 ml/kg/min for IBW 50kg

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt200 (4ml/kg)
= 25 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt250 (5ml/kg)
= 20 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt300 (6ml/kg)
= 16 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt350 (7ml/kg)
= 14 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt400 (8ml/kg)
= 12 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt500 (10ml/kg)
= 10 bpm

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Examples 120 ml/kg/min for IBW 50kg

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/200 (4ml/kg)
= 30 bpm

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/250 (5ml/kg)
= 24 bpm

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/300 (6ml/kg)
= 20 bpm

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/350 (7ml/kg)
= 17 bpm

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/400 (8ml/kg)
= 15 bpm

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/500 (10ml/kg)
= 12 bpm

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Comparing 100 ml/kg/min and 120ml/kg/min for IBW 50kg for 6-8ml/kg

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt300 (6ml/kg)
= 16 bpm

↔

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/300 (6ml/kg)
= 20 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt350 (7ml/kg)
= 14 bpm

↔

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/350 (7ml/kg)
= 17 bpm

100 ml/kg/min
100ml x 50kg IBW = Mv 5000ml
Mv 5000ml/Vt400 (8ml/kg)
= 12 bpm

↔

120 ml/kg/min
120ml x 50kg IBW = Mv 6000ml
Mv 6000ml/400 (8ml/kg)
= 15 bpm

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Making it Simple

- Should we pick 100ml/kg/min if we know our patient has not been adequately ventilating?
- What about 120 ml/kg/min?
  - If you think your patient is sicker with more dead space, then yes!
- The math is the same for the RR regardless of Vt based on IBW
  - 4,5,6,7,8,9, or 10ml/kg = RR will calculate the same regardless of the Vt based on IBW

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Comparing 100 ml/kg/min and 120ml/kg/min for IBW 50-60-70kg @ 6ml/kg

100 ml/kg/min		120 ml/kg/min
100ml x 50kg IBW = Mv 5000ml Mv 5000ml/Vt300 (6ml/kg) = **16 bpm**	⟺	120ml x 50kg IBW = Mv 6000ml Mv 6000ml/300 (6ml/kg) = **20 bpm**
100 ml/kg/min 100ml x 60kg IBW = Mv 6000ml Mv 6000ml/Vt360 (6ml/kg) = **16 bpm**	⟺	**120 ml/kg/min** 120ml x 60kg IBW = Mv 7200ml Mv 7200ml/360 (6ml/kg) = **20 bpm**
100 ml/kg/min 100ml x 70kg IBW = Mv 7000ml Mv 7000ml/Vt420 (6ml/kg) = **16 bpm**	⟺	**120 ml/kg/min** 120ml x 70kg IBW = Mv 8400ml Mv 8400ml/420 (6ml/kg) = **20 bpm**

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Regardless of the Ideal Body Weight

100ml/kg/min	***120ml/kg/min***
4 mL / kg = RR25	4 mL / kg = RR25
5 mL / kg = RR20	5 mL / kg = RR24
6 mL / kg = RR16	6 mL / kg = RR20
7 mL / kg = RR14	7 mL / kg = RR17
8 mL / kg = RR12	8 mL / kg = RR15
9 mL / kg = RR11	9 mL / kg = RR11
10mL/ kg = RR10	10mL/ kg = RR10

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Scenario 1: 100ml/kg/min

28-year-old female with an IBW of 50kg who was intubated for airway protection.

What will the Respiratory Rate be?

6ml/kg = 300ml
RR = 16
MV = 4.8L

100ml x 50kg = 5000ml MV
5000ml/300ml = 16 RR
Settings
Vt 300ml x 16RR =
Va 4800ml (4.8L)

7ml/kg = 350ml
RR = 14
MV = 4.9L

100ml x 50kg = 5000ml MV
5000ml/350ml = 14 RR
Settings
Vt 350ml x 14RR =
Va 4900ml (4.9L)

8ml/kg = 400ml
RR = 12
MV = 4.8L

100ml x 50kg = 5000ml MV
5000ml/400ml = 12 RR
Settings
Vt 400ml x 12RR =
Va 4800ml (4.8L)

100ml/kg/min
4 mL / kg = RR25
5 mL / kg = RR20
6 mL / kg = RR16
7 mL / kg = RR14
8 mL / kg = RR12
9 mL / kg = RR11
10mL/ kg = RR10

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Scenario 2: 100ml/kg/min

28-year-old female with an IBW of 70kg who was intubated for airway protection.

What will the Respiratory Rate be?

6ml/kg = 420ml
RR = 16
MV = 6.7L

100ml x 70kg = 7000ml MV
7000ml/420ml = 16 RR
Settings
Vt 420ml x 16RR =
Va 6700ml (6.7L)

7ml/kg = 490ml
RR = 14
MV = 6.8L

100ml x 70kg = 7000ml MV
7000ml /490ml = 14 RR
Settings
Vt 490ml x 14RR =
Va 6800ml (6.8L)

8ml/kg = 560ml
RR = 12
MV = 6.7L

100ml x 70kg = 7000ml MV
7000ml/560ml = 12 RR
Settings
Vt 560ml x 12RR =
Va 6700ml (6.7L)

100ml/kg/min

4 mL / kg = RR25
5 mL / kg = RR20
6 mL / kg = RR16
7 mL / kg = RR14
8 mL / kg = RR12
9 mL / kg = RR11
10mL/ kg = RR10

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Scenario 3: 120ml/kg/min

28-year-old female with an IBW of 50kg who was intubated for airway protection.

What will the Respiratory Rate be?

6ml/kg = 300ml
RR = 20
MV = 6L

120ml x 50kg = 6000ml MV
6000ml/300ml = 20 RR
Settings
Vt 300ml x 20RR =
Va 6000ml (6L)

7ml/kg = 350ml
RR = 17
MV = 5.9L

120ml x 50kg = 6000ml MV
6000ml/350ml = 17 RR
Settings
Vt 350ml x 17RR =
Va 5900ml (5.9L)

8ml/kg = 400ml
RR = 15
MV = 6L

120ml x 50kg = 6000ml MV
6000ml/400ml = 15 RR
Settings
Vt 400ml x 15RR =
Va 6000ml (6L)

120ml/kg/min

4 mL / kg = RR25
5 mL / kg = RR24
6 mL / kg = RR20
7 mL / kg = RR17
8 mL / kg = RR15
9 mL / kg = RR11
10mL/ kg = RR10

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Scenario 3: 120ml/kg/min

28-year-old female with an IBW of 70kg who was intubated for airway protection.

What will the Respiratory Rate be?

6ml/kg = 420ml	7ml/kg = 490ml	8ml/kg = 560ml
RR = 20	RR = 17	RR = 15
MV = 8.4L	MV = 8.3L	MV = 8.4L
120ml x 70kg = 8400ml MV 8400ml/420ml = 20 RR Settings Vt 420ml x 20RR = Va 8400ml (8.4L)	120ml x 70kg = 8400ml MV 8400ml/490ml = 17 RR Settings Vt 490ml x 17RR = Va 8300ml (8.3L)	120ml x 70kg = 8400ml MV 8400ml/560ml = 15 RR Settings Vt 560ml x 15RR = Va 8400ml (8.4L)

120ml/kg/min

4 mL / kg = RR25
5 mL / kg = RR24
6 mL / kg = RR20
7 mL / kg = RR17
8 mL / kg = RR15
9 mL / kg = RR11
10mL/ kg = RR10

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Masking the Intrinsic Drive to Breathe with Lung Protective Ventilation

Review | Open access | Published: 24 March 2020

Physiology of the Respiratory Drive in ICU Patients: Implications for Diagnosis and Treatment

Annemijn H. Jonkman, Heder J. de Vries & Leo M. A. Heunks

Critical Care **24**, Article number: 104 (2020) | Cite this article

55k Accesses | **52** Citations | **79** Altmetric | Metrics

The respiratory drive directly determines breathing effort when neuromuscular transmission and respiratory muscle function are intact. We define breathing effort as the mechanical output of the respiratory muscles, including both the magnitude and the frequency of respiratory muscle contraction.

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Masking the Intrinsic Drive to Breathe with Lung Protective Ventilation

Setting a High Respiratory Rate = Potential Risk of masking the patients drive to breathe!

If the rate is too high we need to be cautious of the higher rate masking the patients intrinsic drive to breathe

nature > nature medicine > on the market > article

On the Market | Published: December 1999

Neural control of mechanical ventilation in respiratory failure

Christer Sinderby, Paolo Navalesi, Jennifer Beck, Yoanna Skrobik, Norman Comtois, Sven Friberg, Stewart B. Gottfried & Lars Lindström

Nature Medicine 5, 1433–1436 (1999) | Cite this article

6405 Accesses | 455 Citations | 11 Altmetric | Metrics

The ideal approach to coordinate mechanical assistance with patient demand would be to use the neural output of the respiratory center to control the timing and the magnitude of positive pressure applied by the ventilator. The ability of the patient to interact with the ventilator in these circumstances is substantially impaired

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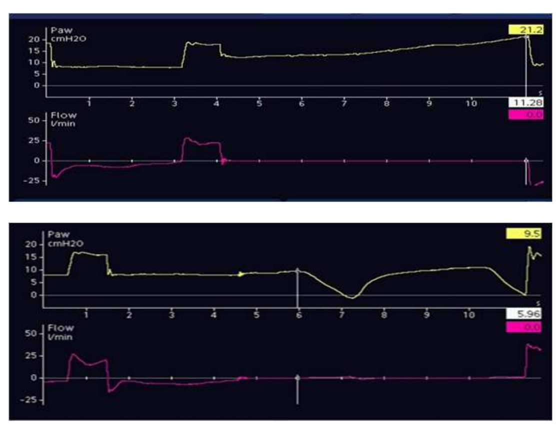
Assessing the Intrinsic Drive to Breathe



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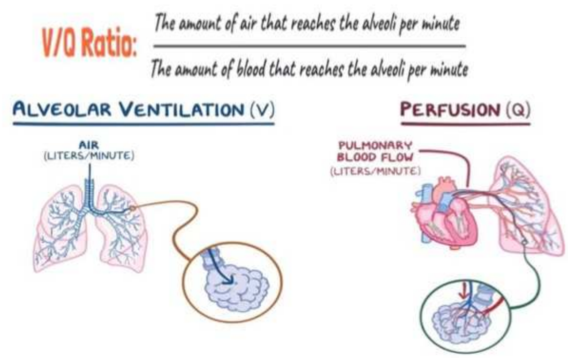
Minute Ventilation and Alveolar Ventilation are not the same

100ml/kg/min	***120ml/kg/min***
4 mL / kg = RR25	4 mL / kg = RR25
5 mL / kg = RR20	5 mL / kg = RR24
6 mL / kg = RR16	6 mL / kg = RR20
7 mL / kg = RR14	7 mL / kg = RR17
8 mL / kg = RR12	8 mL / kg = RR15
9 mL / kg = RR11	9 mL / kg = RR11
10mL/ kg = RR10	10mL/ kg = RR10



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