Respiratory Minute Volumes and Breathing Rate: A Predictive Model

Biology 390

Background: An inspired or expired breath ($\boldsymbol{V_I}$ or $\boldsymbol{V_E}$) can be thought of as having two components, each of which is defined in terms of the place that air resides at respiratory midpoint (the peak of an inspiration). They are:

V_A -- the "alveolar" volume -- the volume of air that enters the exchange area of the respiratory system (perfused alveoli and perhaps terminal bronchi)
V_D -- the "dead space" volume -- the air that enters the body but never passes further than some part of the conducting airways (mouth, throat, bronchi). This is the air that does not undergo exchange with the blood. Sometimes the dead space is broken into two components:

- the anatomical dead space (the parts where there is, for anatomical reasons, no significant gas exchange with the blood) and
- the physiological dead space (areas where exchange is possible under some conditions but where it is not presently occurring -- example -- an under perfused alveolus or area where fluid has built up (sometimes also called the pathological dead space).

But lets not get carried away!

So, for an inspired or expired breath:

$V_E = V_A + V_D$

For the present we only have the ability to measure the expired (or inspired) tidal volumes and minute volumes. However, in

Note that volume can be turned into flow (volume rate) by multiplying through by the breathing rate, ***f***: For instance, expired tidal volume, $\boldsymbol{V_E}$ to expired minute volume **:**

$$\dot{V}_E = f * V_E$$

$$\dot{V}_E = \dot{V}_D + \dot{V}_A$$

In any case, during breathing, air always enters the dead space but it may or may not enter the alveolar space (if the breath is too shallow, only the dead space is ventilated).

If a subject remains in a constant metabolic state, he will breathe in a manner that causes arterial blood *p*H to remain constant at about 7.4. This corresponds to breathing to maintain the arterial P_{CO2} at 40 torr.

NAMES______________________________

The Question: What happens if someone changes breathing rates but keeps the same rate of metabolism (demand for respiratory gas exchange)? How does their $\dot{V}_E$ change? If one simply assumes that V_E remains the same, then $\dot{V}_E$ increases with ***f***. For this case, calculating change in $\dot{V}_E$ is trivial. Moreover, such a response does not make good physiological sense. So, let's do something harder and more meaningful.

Assume that a person:

- changes breathing rates but
- keeps the same rate of metabolism and
- attempts to breathe in a manner that will keep them in the same blood-gas steady state, regardless of breathing rate (thus -- a constant P_{aCO2} of 40 torr).

Below is a table that gives various respiratory parameters and asks you to predict the others for situations that meet the three bullets immediately above. To complete the table, do the following:

1. Find and fill in the remaining parameters for the person breathing at 12 breaths per min.
2. Now, think about what volumes or minute volumes will remain the same regardless of breathing rate (if the metabolism and blood gases are to remain at steady values). Hint -- one respiratory volume and one type of minute volume remains constant regardless of rate -- which are they and WHY?).

3. The table below is a model -- we will try to verify the predictions it makes for $\dot{V}_E$ as a function of ***f*** in lab. The procedure will be discussed during lab.

f	$\dot{V}_E$ (L/min)	V_D (L)	$\dot{V}_D$ (L/min)	$\dot{V}_A$ (L/min)	V_A (L)
12	6.00			4.20	
6					
15					
20					
30					

REAL DATA

Gender	Ht (m)	Mass (kg)	Breathing rate (b/m) 6	12	20	30	breathing as inclined f	VDE
M	1.8	73	8.1	7.4	7.6	9.7	--	7.4
F	1.6	57	5.9	8.8	16.8	15.8	16	8.6
M	1.78	70.5	8.8	7.3	7.9	12.4	9	6.6
			7.6	7.8	10.8	12.6	12.5	7.5