Jerónimo Graf

Comment on Tusman et al.: Validation of Bohr dead space measured by volumetric capnography

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Dear Editor,

I read with great interest the paper by Tusman et al. on Bohr dead space (VD_{Bohr}) measurement from volumetric capnography. Their analysis based on an equation fitting the CO_2 expirogram provides a substantial improvement for the objective assessment of its components [1].

Even though it is clear that the use of $PaCO_2$ as a surrogate for ideal alveolar PCO_2 in the Bohr equation—as suggested by Enghoff—may lead to overestimation of physiological dead space [2, 3], replacing it for mean alveolar PCO_2 ($PACO_2$)—as originally devised by Bohr and recently accomplished by Tusman et al. [1]—will solely account for airway dead space (VD_{aw}) and not for alveolar dead space (VD_{alv}). This is shown by the following set of equations.

According to Fowler's approach, tidal volume (VT) divides into VD_{aw} and alveolar VT (VT_{alv});

$VT = VD_{aw} + VT_{alv}$. The mixed expired CO_2 fraction ($FeCO_2$) over one breath is the ratio between the expired CO_2 volume (VCO_{2br}) and VT; $FeCO_2 = VCO_{2br}/VT$. According to the alveolar gas equation, the mean alveolar CO_2 fraction ($FACO_2$) is the ratio between VCO_{2br} and VT_{alv} , or $FACO_2 = VCO_{2br}/(VT - VD_{aw})$. Replacing the terms above in the Bohr equation as suggested by Tusman et al. [1] gives:

$$VD_{Bohr} = \frac{[VCO_{2br}/(VT - VD_{aw}) - VCO_{2br}/VT]}{[VCO_{2br}/(VT - VD_{aw})]} \times VT.$$

Solving the equation leads to $VD_{Bohr} = VD_{aw}$. The inability of VD_{Bohr} to include VD_{alv} is most clearly depicted by pulmonary embolism under controlled mechanical ventilation. As experimentally shown by Breen et al. [4], alveolar CO_2 plateau depression in this setting is not recognized as the expected increase in VD_{alv} from volumetric capnography alone if $PaCO_2$, proving CO_2 retention, is not taken into account. Bohr dead space will include some VD_{alv} if the point selected from the up-slope alveolar plateau to represent ideal alveolar PCO_2 approaches end-tidal PCO_2 , and thus $PaCO_2$ [5].

In the introduction of Tusman's paper [1], VD_{Bohr} , instead of VD_{Bohr}/VT , is presented as equal to $(PACO_2 - PeCO_2)/PACO_2$. The same is true in Fig. 1, and in the results section where VD_{Bohr} is said to be expressed in milliliters although it really corresponds to a ratio [1]. These small oversights may confuse the reader.

Summing up, using CO_2 as a tracer of overall ventilatory efficiency still requires the measurement of VCO_2 , expired minute ventilation and $PaCO_2$ [5], while keeping in mind that the later may also be increased by shunt and/or V/Q inequalities leading to physiological dead space overestimation [6].

References

1. Tusman G, Sipmann FS, Borges JB, Hedenstierna G, Bohm SH (2011) Validation of Bohr dead space measured by volumetric capnography. *Intensive Care Med* 37:870–874. doi: [10.1007/s00134-011-2164-x](https://doi.org/10.1007/s00134-011-2164-x)
2. Kuwabara S, Duncalf D (1969) Effect of anatomic shunt on physiologic dead space-to-tidal volume ratio—a new equation. *Anesthesiology* 31:575–577
3. Coffey RL, Albert RK, Robertson HT (1983) Mechanisms of physiological dead space response to PEEP after acute oleic acid lung injury. *J Appl Physiol* 55:1550–1557
4. Breen PH, Mazumdar B, Skinner SC (1996) How does experimental pulmonary embolism decrease CO_2 elimination? *Respir Physiol* 105:217–224
5. Drummond GB, Fletcher R (2006) Deadspace: invasive or not? *Br J Anaesth* 96:4–7. doi: [10.1093/bja/aei289](https://doi.org/10.1093/bja/aei289)
6. Wagner PD (2008) Causes of a high physiological dead space in critically ill patients. *Crit Care* 12:148. doi: [10.1186/cc6888](https://doi.org/10.1186/cc6888)

J. Graf (✉)

Departamento de Paciente Crítico,
Clínica Alemana de Santiago,
Facultad de Medicina Clínica
Alemana - Universidad del Desarrollo,
Av. Vitacura 5951, Vitacura,
Santiago, Chile
e-mail: jeronimograf@yahoo.com
Tel.: +56-2-2101414
Fax: +56-2-2101411