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CORRESPONDENCE

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Validation of Bohr dead space measured by volumetric capnography: reply to Graf

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Dear Editor,
We are grateful for the opportunity to respond to the comments of Dr. Graf [1] about our validation of Bohr's dead space [2]. He expressed his concerns about using Bohr's formula [3] for measuring physiological dead space as this would only account for its airway (VD_{aw}), but not for its alveolar (VD_{alv}) fraction. Using and re-arranging standard equations, he comes to the conclusion that $VD_{Bohr} = VD_{aw}$. Now, the original dead space equation can be arranged as $VD/VT = (FA_x - F\bar{E}_x)/(FA_x - FI_x)$, where X can be any tracer gas. If FI_x equals zero, as is the case with CO_2, then the equation becomes $(FA_x - F\bar{E}_x)/FA_x$. The difference between FA_x and $F\bar{E}_x$ will thus be related to a lung compartment that during expiration does not deliver the tracer gas X. This is per definition a dead space, and it does not matter whether the expired tracer-free gas comes from the airway or from the alveolar space. Although the theoretical relationship may be simple and straight forward, practical problems arise when trying to distinguish airway from alveolar dead spaces. Fowler's analysis of volumetric capnography provides a method to determine airway dead space [4]. However, such a graphical analysis cannot be precise and is fraught with the risks inherent in the subjective fitting of a straight line to a plot of individual measurement points in an attempt to define airway dead space. As a consequence such an approach will also cause uncertainties in the estimation of the magnitude of alveolar dead space. Therefore, by using mean alveolar CO_2 estimated from the mid-portion of phase III, as suggested in our paper, VD_{Bohr} will—by the nature of the measurement—also include any kind of alveolar dead space.

Support for this notion, if needed, comes from the following figure: Fig. 1.

The figure was created from data obtained from a cardiac surgery patient during weaning from cardiopulmonary by-pass. Pulmonary blood flow (PBF) was increased stepwise to study the effects on dead space of systematic changes in pulmonary blood flow (PBF) [5]. With ventilator settings remaining constant throughout the study period, VD_{Bohr}, comprising both physiological and alveolar dead spaces, gradually decreased from high values at low PBF to low values at high PBF, whereas VD_{aw} remained unchanged. From these findings it can be seen that Bohr's original formula is well capable of detecting conditions of low PBF similar to the ones commonly found during pulmonary embolism, findings that clearly contradict Dr. Graf's arguments. The data of our published study confirm the reasoning that VD_{Bohr} encompasses a true alveolar component that should not be mixed up with VD_{aw}.

Finally, we agree with Dr. Graf in that VD_{Bohr} is a ratio relating dead space to the tidal breath (VD/VT) and that it is a dimensionless value. However, in our paper we intended to remain with the original nomenclature of Fletcher, who used the term "Bohr dead space" to refer to the dead space obtained from Bohr's formula [6].

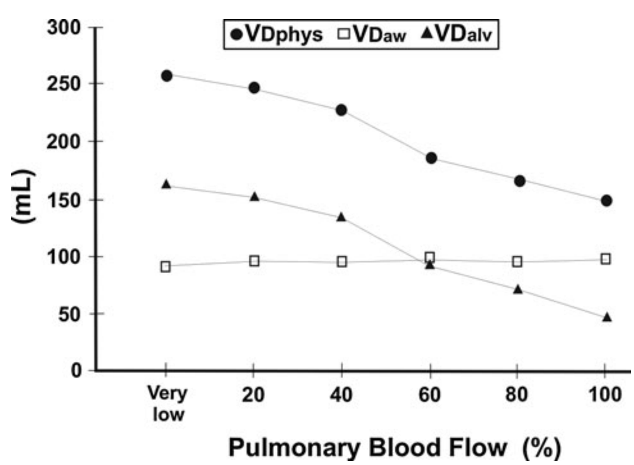

Fig. 1 Physiological, airway and alveolar dead space fractions at increasing levels of pulmonary blood flow (PBF) in a cardiac surgery patient during weaning from cardiopulmonary by-pass while ventilator settings were kept constant

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