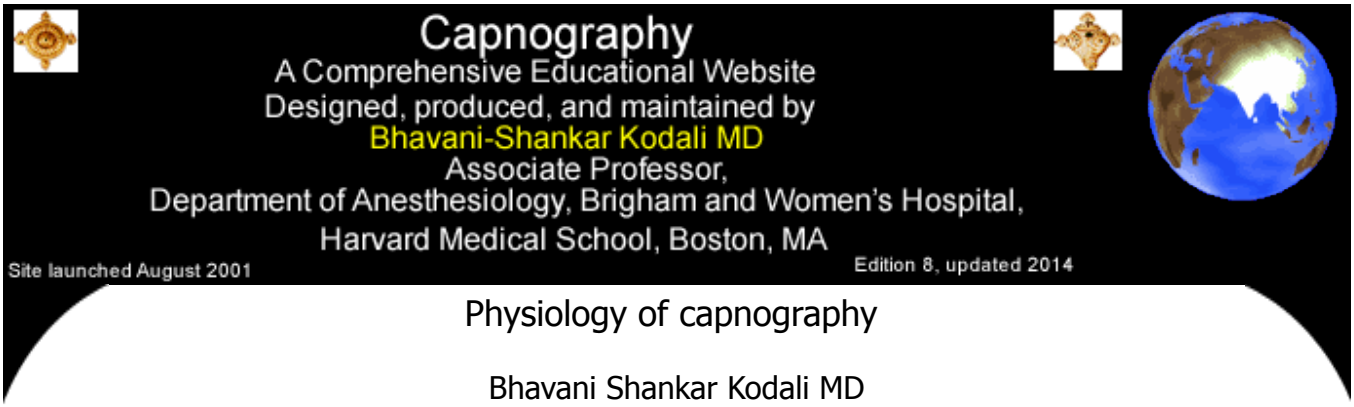

Physiology of capnography

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Can Negative (a-ET)CO_2 differences occur?

YES

Where can they occur?

Healthy subjects during low frequency high tidal volume ventilation
Pregnant subjects
Infants and Children
After coming off cardiac bypass
During and after exercise.

What are the reasons for negative values?

Experimental errors

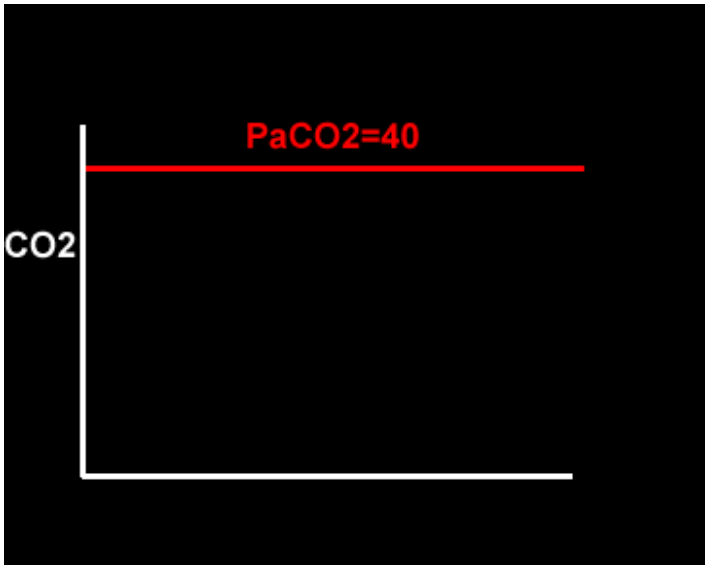
Rebreathing

Inadvertent addition of CO_2 to the inspired gases

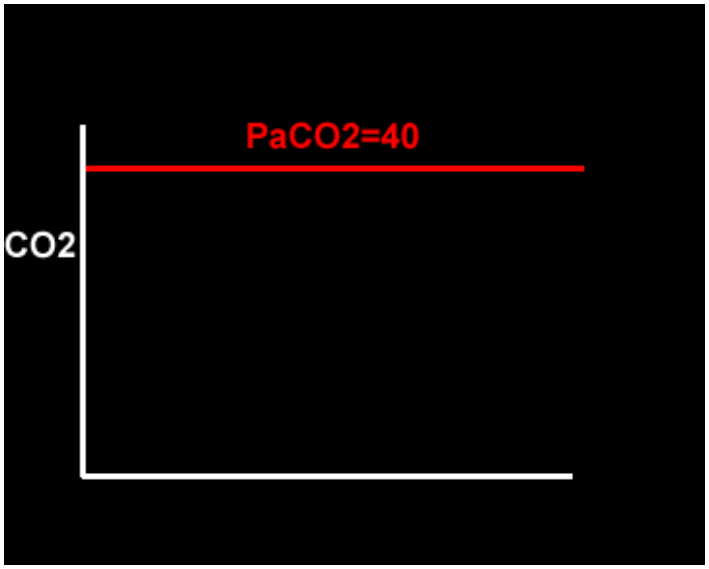
Physiological reasons

Four physiological reasons

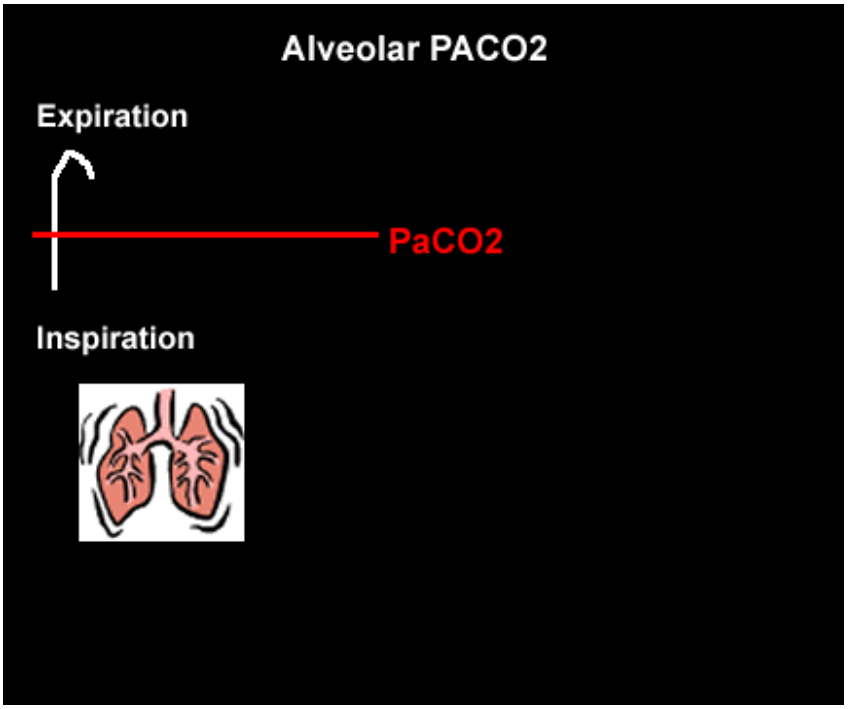
Smaller alveolar dead space and inherent upward slope of phase III



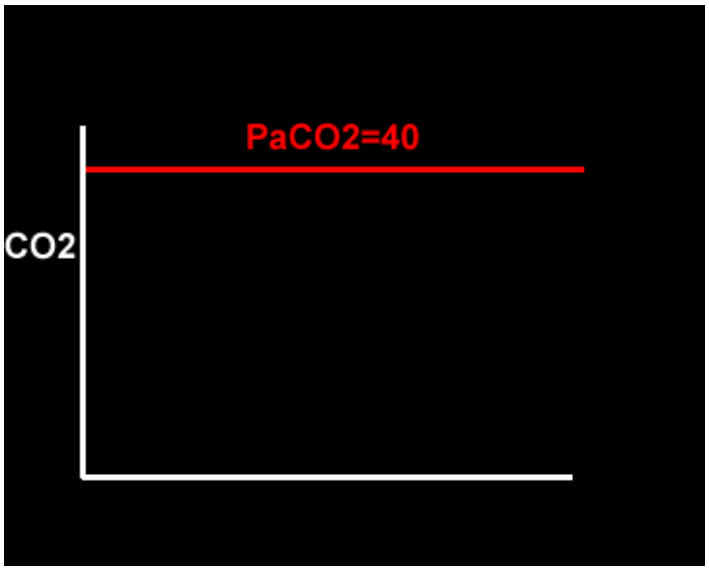
Increase in the slope of phase III



Exaggerated alveolar PCO_2 fluctuations during respiratory cycle due to increased CO_2 production and decreased FRC which make it more likely to sample higher alveolar PCO_2 (sampled as $PETCO_2$) during expiration greater than mean $PaCO_2$



Occurrence of phase IV



Negative (a-ET)PCO_2 gradients:

Negative (a-ET)$PC0_2$ values were observed more than 30 yr ago by Nunn et al. during anesthesia although no explanation was offered.[1] Fletcher et al. observed negative or zero (a-ET)PCO_2 values in 12% of normal subjects during anesthesia and IPPV with large tidal volumes and low frequencies.[2] Negative values were also observed during anesthesia in 50% of pregnant subjects,[3] in 8.1% of patients after post-cardiac bypass (PCB)[4] and in 50% of infants.[5]

Piper reviewed several studies with negative arterial to end-tidal CO_2 differences in 1986 and

concluded that the reasons for the remarkably pronounced disagreement between the experimental data of different studies cannot be definitely identified and suggested that it is desirable that more observational and experimental data become available in future to review this subject.[6] Since then several studies have reported negative differences as stated above. The following possible mechanism have been postulated to explain observed (a-ET)PCO_2 differences under various circumstances.

Large tidal volume and low frequency ventilation result in (i) better ventilation of dependent well-perfused alveoli which improves V/Q matching (small area of alveolar dead space as above in figure I). (ii) Gas emptying from slow alveoli to reach the mouth, whereas it would have remained in the airways with small frequent breaths. Under these circumstances the low V/Q areas (alveoli with higher $PC0_2$) make a more substantial contribution to the gas exchange. The net effect of these factors is to enable the terminal part of phase III to exceed mean $PaC0_2$, resulting in negative (a-ET)$PC0_2$.[2]

Alveolar PCO_2 varies cyclically, being lowest at end-inspiration and highest at end-expiration. However, because of mixing in the heart and syringe, $PaCO_2$ sampled at the radial artery is the spatial and temporal mean of alveolar PCO_2 (Riley's physiological integrator) and therefore it is quite possible for $PETCO_2$ to exceed the sampled $PaCO_2$. The increased cardiac output and increased $C0_2$ production, reduced FRC and low compliance associated with pregnancy may result in greater cyclical variations in alveolar $PC0_2$ during a respiratory cycle and also in more alveoli with long time constants. During expiration, $PAC0_2$ increases towards $PVC0_2$ (partial pressure of mixed venous $C0_2$) more rapidly in pregnant subjects because a larger amount of $C0_2$ is evolved into a lung which becomes smaller as expiration continues. Further, pregnant subjects resemble the obese in some features namely reduced FRC and low total compliance and hence may exhibit a biphasic slope reminiscent of phase IV of the nitrogen closing volume test. The $PC0_2$ of most alveolar gas is less than $PaC0_2$ but, in the terminal part of the expirate, $PC0_2$ rises rapidly and may exceed $PaC0_2$. The combined effect of these two mechanisms increases the slope of phase III (Figure 4) and the likelihood of sampling a $PETCO_2$ greater than $PaC0_2$.[3,7-12] The presence of a wide range of V/Q mismatching and reduced FRC may result in negative (a-ET)$PC0_2$ values in patients after cardiopulmonary bypass.[4,7] Increased $C0_2$ production and reduced FRC may be responsible for the negative (a-ET)$PC0_2$ values observed in infants.[5]

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