CRITICAL CARE

LETTER

Do fluctuations of $PaCO_2$ impact on the venous–arterial carbon dioxide gradient?

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The mixed venous–arterial difference in carbon dioxide tension (ΔCO_2) has been proposed as an index of the adequacy of tissue perfusion in septic shock. Indeed, ΔCO_2 increases with low cardiac output or inadequate microcirculatory perfusion [1,2]. Because carbon dioxide by itself can influence vascular tone [3] we hypothesized that, in the same patient, changes in the arterial partial pressure of carbon dioxide ($PaCO_2$) can influence ΔCO_2 values.

The study protocol was approved by the local ethics committee (comité de protection des personnes Sud Est I protocol number 2010-36) and stated that informed consent was not required. We studied 10 patients (age = 66 ± 11 years, Simplified Acute Physiology Score II = 35 ± 6) admitted to the ICU after elective cardiac surgery. The patients were all monitored with a pulmonary artery (Swan–Ganz) catheter. The tidal volume was set at 8 ml/kg, and the respiratory rate (RR) was set at 10, 13 or 16 breaths/minute, successively, in a randomized order. After 30 minutes of stabilization in each ventilatory condition, arterial and venous blood gases were measured together with the cardiac index and mean arterial pressure. Venous samples were withdrawn from the central venous catheter. The three series of measurements for one patient were performed within 2 hours. ΔCO_2 ≤6 mmHg was considered normal [1]. Results are presented as mean ± standard deviation. Data were analyzed by repeated-measures analysis of variance and Scheffé's *post-hoc* test or chi-squared test and Bonferroni correction when suitable.

$PaCO_2$ varied consistently with the changes in RR, and we observed a significant increase in ΔCO_2 between RRs of 10 and 16 breaths/minute; this was associated with a significant decrease in the number of patients with a normal ΔCO_2 value (Table 1). Interestingly, central venous saturation also decreased significantly when the RR was increased.

In ventilated hemodynamically stable postoperative patients, changes in $PaCO_2$ variations can influence ΔCO_2. Similarly, in healthy volunteers hyperventilation is associated with an increase of the difference between arterial and venous peripheral carbon dioxide [4]. A possible explanation is that hypocapnia induces microvascular constriction, thus increasing stagnation flow, and therefore increases the gap. This hypothesis could be an explanation for the increment of gut mucosal–arterial PCO_2 gradient observed with acute moderate hypocapnia [5]. In this situation, the decrease in central venous saturation could be interpreted as an increase of tissular oxygen extraction induced by a low oxygen delivery with vasoconstriction [3].

Although the carbon dioxide gap is a valuable index to evaluate perfusion in a shock state, one must be warned of the effect of moderate hyperventilation on this gradient. The direct effect of carbon dioxide on microcirculation needs to be confirmed by further experiments.

Table 1. Blood gas values and hemodynamic data at different respiratory rates

	Respiratory rate		
	10 breaths/minute	13 breaths/minute	16 breaths/minute
$PaCO_2$ (mmHg)	45.5 ± 9.9	39.7 ± 7.9*	35.9 ± 7.9†‡
ΔCO_2 (mmHg)	4.2 ± 1.8	6.6 ± 2.8	7.6 ± 1.7†
pH	7.29 ± 0.06	7.32 ± 0.06*	7.35 ± 0.07†‡
Bicarbonate (mmol/l)	21.2 ± 2.5	20.7 ± 2.5	20 ± 2.5
ΔCO_2 ≤6 mmHg, ***n*** (%)	10 (100)	4 (40)*	2 (20)†
$ScvO_2$ (%)	77.9 ± 4.1	74.7 ± 7.4	72.6 ± 7.1†
Cardiac index (l/m²)	2.37 ± 0.5	2.36 ± 0.6	2.36 ± 0.6
Mean arterial pressure (mmHg)	71.7 ± 13.3	68 ± 14.5	71.4 ± 13.2
Temperature (°C)	36.9 ± 0.9	36.9 ± 0.9	36.8 ± 0.9

ΔCO_2, venous–arterial difference in carbon dioxide tension; $PaCO_2$, arterial partial pressure of carbon dioxide; $ScvO_2$, central venous oxygen saturation. *P <0.05 (respiratory rate 10 vs. 13 breaths/minute), †P <0.05 (respiratory rate 10 vs. 16 breaths/minute), ‡P <0.05 (respiratory rate 13 vs. 16 breaths/minute).

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Abbreviations
ΔCO_2, venous–arterial difference in carbon dioxide tension; $PaCO_2$, arterial partial pressure of carbon dioxide; RR, respiratory rate.

Competing interests
The authors declare that they have no competing interests.

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