Commentary

Influence of flow on mucosal-to-arterial carbon dioxide difference

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Published online: 1 November 2002 *Critical Care* 2002, **6**:463-464 (DOI 10.1186/cc1845)
This article is online at http://ccforum.com/content/6/6/463
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Abstract

Intramucosal-to-arterial carbon dioxide difference (the so-called P_{CO_2} [partial carbon dioxide tension] gap) remains largely unaltered during decreased oxygen delivery, if the latter is reduced as flow is maintained. In this condition (hypoxic hypoxia or anaemic hypoxia), the P_{CO_2} gap fails to mirror intestinal tissue dysoxia. Results from several experiments have demonstrated that blood flow is the main determinant of P_{CO_2} gap. Gastrointestinal tonometry is clearly a useful indirect method for monitoring perfusion, but it has rather limited value in detecting anaerobic metabolism when blood flow is preserved. These considerations render it very unlikely that P_{CO_2} may dramatically increase (or that intramucosal pH may decrease) in any hypoxic state with preserved flow.

Keywords: hypoxia, intestine, monitoring, oxygen delivery, tonometry

In the present issue of *Critical Care*, Dubin and collaborators [1] report the results of a study in which they tested the hypothesis that intramucosal-to-arterial carbon dioxide difference (the so-called P_{CO_2} [partial carbon dioxide tension] gap) may remain unaltered during dysoxia (a state in which oxygen delivery [D_{O_2}] is insufficient to sustain oxygen demand) because D_{O_2} is reduced when flow is maintained. In order to achieve this and to avoid the confounding effects of low flow, they produced hypoxaemia with preserved intestinal flow. The P_{CO_2} gap obtained in this condition (hypoxic hypoxia [HH]) was compared with that obtained in ischaemic hypoxia (IH).

This work conducted in sheep is an important confirmatory study of our previous studies that dealt with differential effects of IH and HH on P_{CO_2} gap [2,3]. In those earlier reports, we clearly demonstrated that dog limb venous-to-arterial carbon dioxide gap [2] increased greatly in IH (approximately 17 mmHg at critical D_{O_2} and approximately 27 mmHg at maximal D_{O_2}) and remained almost unaltered in HH (10 mmHg) [2]; and that pig gastrointestinal mucosal-to-arterial carbon dioxide gap increased to a greater extent in IH (maximal value approximately 50 mmHg) than in HH (maximal value approximately 30 mmHg) [3]. In the range of D_{O_2} values below the critical level, increases in P_{CO_2} gap were smaller in HH than in IH, although similar decreases in D_{O_2} were achieved. Dependency on oxygen supply may therefore develop in the absence of large increases in tissue P_{CO_2} during hypoxia. We concluded that these experimental findings were important in interpreting moderate increases in intestinal mucosal P_{CO_2}, because mucosal-to-arterial carbon dixoide difference (ΔP_{CO_2}) may underestimate the extent of oxygen supply limitation [3].

It is important to emphasize that, if studies are to be valid, those investigating oxygen supply dependency must consider important experimental conditions, which were clearly present in our previous studies [2,3]. The first condition is that the lowest D_{O_2} value reached by the end of the decreased D_{O_2} period must clearly go beyond the critical D_{O_2}. The second is that the magnitude of decreased D_{O_2} must be similar in both IH and HH. Although the first condition appeared to be met in the report from Dubin and coworkers [1], the second one did not because the lowest D_{O_2} reached at the intestinal level was clearly different between the groups (about 20 ml/kg per min in IH and about

D_{O_2} = oxygen delivery; HH = hypoxic hypoxia; IH = ischaemic hypoxia; P_{CO_2} = partial carbon dioxide tension.

40 ml/kg per min in HH). ΔP_{CO_2} in IH increased to a maximum of about 40 mmHg, which is lower than the approximately 50 mmHg achieved in our work [3]. This suggests that the D_{O_2} challenge in the experiments reported by Dubin and coworkers was less severe than that in ours. Although this is unfortunate, it does not prevent that study from confirming that ΔP_{CO_2} fails to mirror intestinal tissue dysoxia and that blood flow is the main determinant of ΔP_{CO_2}. Tonometry is clearly a useful method for monitoring perfusion, but it has rather limited value in detecting anaerobic metabolism when blood flow is preserved.

The latter point was further confirmed by Dubin and collaborators during anaemic hypoxia, and results were presented recently at the 15th Annual Congress of the European Society of Intensive Care Medicine, in Barcelona [4]. In that new set of experiments conducted in sheep, ΔP_{CO_2} did not increase when D_{O_2} was lowered below its critical value during progressive severe anaemia.

All together, the four studies [1–4] demonstrate the following: that ΔP_{CO_2} cannot be taken as a surrogate marker of dysoxia; and that increased ΔP_{CO_2} cannot occur when flow is constant. These considerations render it very unlikely that ΔP_{CO_2} may dramatically increase (or that intramucosal pH may decrease) during normal flow [5]; incomplete experimental information needs to be considered in that particular case to explain apparent contradictory results. For example, flow heterogeneity may clearly complicate interpretation of results; high flow coexisting with islands of low flow may mimic the coexistence of a high carbon dioxide gap with normal or even high-flow oxygenation [6]. As mentioned by Dubin and coworkers [1], impaired villous microcirculation has been suggested [6] to be the causal phenomenon in cytopathic hypoxia [5], a situation in which intramucosal acidosis should theoretically arise with preserved tissue perfusion.

Competing interests

None declared.

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