Splanchnic Vasoregulation and Metabolism: New Insights into Physiology

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University of Kuopio, May 18, 2001
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Introduction: The purpose of this study was to evaluate changes in hepato-splanchnic perfusion and organ function in cardiac surgery patients and to further re-assess the findings in animals. Cardiac surgery patients served as a model of the adaptation of tissue perfusion to increasing demand due to postoperative rewarming. The monitoring tools for splanchnic perfusion are likely to be affected by several sources of error, and it was hypothesized that in addition to previously known sources of error, the Haldane effect potentially also alters the results of tonometry. The Haldane effect alters the relationship between venous-arterial CO_2 content difference and pCO_2 gradients.

Methods: The effects of rewarming and extubation on regional (dye-dilution method) and mucosal (tonometry) blood flow distribution; metabolism (lactate exchange) and cellular integrity (Glutathione-S Transferase A) were studied prospectively in 17 uncomplicated cardiac surgery patients. The Haldane effect's influence on regional and mucosal pCO_2 gradients was tested in a different group of 28 patients after cardiac surgery. In 52 pigs, the effects of low systemic blood flow, isolated mesenteric ischemia and reperfusion were used to study regional blood flow changes (ultrasound transit time), the hepatic arterial buffer response, and associated changes in regional lactate metabolism and cellular integrity.

Results: Rewarming in patients after cardiac surgery was associated with blood flow redistribution to peripheral tissues despite high splanchnic oxygen extraction. Liver function was not impaired and cellular integrity was not disturbed. In more than half of patients after cardiac surgery, increases in gastric mucosal-arterial pCO_2 gradients despite increases in total hepato-splanchnic blood flow could be explained by decreased oxygen extraction (the Haldane effect) and metabolic changes. Moderate cardiac tamponade was associated with increased hepatic arterial blood flow, whereas hepatic arterial blood flow decreased during prolonged tamponade. During mesenteric ischemia, both celiac trunk and hepatic arterial blood flow increased. The hepatic arterial buffer response was exhausted during tamponade and mesenteric ischemia, and recovered only partially during reperfusion. The hepatic lactate uptake decreased during tamponade but increased during mesenteric ischemia, thus preventing systemic hyperlactatemia.

Conclusions: Signs of tissue perfusion after cardiac surgery and extracorporeal bypass are not associated with functional consequences in hemodynamically stable patients. In these patients, the Haldane effect may explain increasing mucosal-arterial pCO_2 gradients despite preserved or increased mucosal perfusion. Mesenteric ischemia and low systemic perfusion in pigs abolishes the hepatic arterial buffer response. The capability of the liver to increase lactate uptake is preserved during mesenteric ischemia and exceeded during low systemic blood flow. The unchanged hepatic but increasing prehepatic Glutathione-S Transferase A exchange during tamponade suggests cellular damage in splanchnic organs other than the liver.

List of original publications

I. Jakob SM, Ruokonen E, Takala J. Assessment of the adequacy of systemic and regional perfusion after cardiac surgery. Br J Anaesth 2000; 84: 571-577.

II. Jakob SM, Kosonen P, Ruokonen E et al. The Haldane effect – an alternative explanation for increasing gastric mucosal pCO_2 gradients? Br J Anaesth 1999; 83: 740-746.

III. Jakob SM, Tenhunen JJ, Heino A et al. Effects of systemic arterial hypoperfusion on splanchnic hemodynamics and hepatic arterial buffer response in pigs. Am J Physiol Gastrointest Liver Physiol 2001; 280: G819-G827.

IV. Jakob SM, Merasto-Minkkinen M, Tenhunen JJ et al. Prevention of systemic hyperlactatemia during splanchnic ischemia. Shock 2000; 14: 123-127.

V. Jakob SM, Tenhunen JJ, Heino A et al. Splanchnic vasoregulation during mesenteric ischemia and reperfusion. Submitted (Shock)

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