Splanchnic Perfusion and Oxygenation in Critical Illness

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Introduction

A central task in critical care medicine is the continuous maintenance of adequate tissue oxygenation. However, impairment of tissue perfusion and, thus, oxygenation is a common issue in critical care medicine, e.g., caused by anemia, cardiac failure or sepsis. If systemic oxygen delivery is reduced or maldistributed, certain organs may be impaired in oxygenation even before systemic markers of tissue dysxia occur. Herein, the splanchnic region is particularly vulnerable in critical illness. Impaired splanchnic tissue perfusion and oxygenation play a crucial role in the development and maintenance of critical illnesses, e.g., the gastrointestinal tract may become the motor of sepsis and the multiple organ dysfunction syndrome. Thereby, the splanchnic region plays a role both as a target (e.g., through ischemia/reperfusion phenomena), but also as a source of the disease process (e.g., translocation of gastrointestinal endoluminal bacteria and toxins). Regarding the latter, continuous adequate microcirculatory oxygenation appears important to maintain the integrity of the gastrointestinal barrier function. The splanchnic region is not only affected by the disease process, but also by numerous therapeutic interventions, e.g., ventilation or drugs.

Monitoring of splanchnic perfusion and oxygenation may identify patients at risk of developing critical hypoperfusion or hypoxia early, and guide therapy targeted at restoring splanchnic perfusion and oxygenation [1]. Therefore, the splanchnic region has been regarded as the “canary of the body” [2]. However, this concept is hampered by the fact that direct, regional measurement of splanchnic perfusion and oxygenation is not routinely possible, and available systemic markers of splanchnic impairment (e.g., increased blood levels of liver enzymes) are regarded as only late and less sensitive signs.

Furthermore, the splanchnic region cannot be regarded as a homogeneous region, as it shows marked differences in the distribution of perfusion and oxygenation from organ to organ (e.g., higher perfusion of small intestines vs. stomach), but also within organs (e.g., higher PO$_2$ of serosa vs. mucosa). Thus, findings at one site cannot be extrapolated to other parts within the splanchnic region. The pathophysiology of splanchnic perfusion is further complicated by the unique features of blood supply, both at the macroscopic level (e.g., serial arrangement of the gastrointestinal tract and the liver via the portal vein; dual blood supply of the liver and its buffering capacity), but also at the microscopic level, e.g. countercurrent architecture of intestinal villi arteries and veins.
This chapter highlights aspects of the impairment of splanchnic perfusion and oxygenation in critical care settings. The first section introduces methods allowing direct or indirect measurement of splanchnic perfusion and oxygenation, followed by a second section on the impact on the splanchnic region of commonly used interventions in critical care medicine, especially on splanchnic tissue perfusion and oxygenation. We focus on respiratory therapy, renal replacement therapy, nutrition, volume resuscitation, vasoactive drugs and epidural anesthesia, because these therapies are most commonly used in the critically ill and may alter splanchnic perfusion.

I Methods to Measure Splanchnic Oxygenation and Perfusion

Assessment of the efficacy of perfusion and oxygenation requires adequate monitoring tools. Microcirculation and tissue oxygenation can be determined by various techniques. Each technique has its limitations in terms of specificity and sensitivity and it is important to be aware of the aspects of various techniques when interpreting and comparing results of different studies.

Tonometry

Hollow organ tonometry primarily measures intraluminal CO\textsubscript{2} [3], using a CO\textsubscript{2} permeable balloon probe introduced into the organ of interest, mainly the stomach. The sample within the balloon is aspirated after a sufficient equilibration time and analyzed for PCO\textsubscript{2}. Under the assumption that intraluminal PCO\textsubscript{2} reflects the balance between tissue CO\textsubscript{2} production and tissue CO\textsubscript{2} removal, the tonometrically determined PiCO\textsubscript{2} is regarded as an estimate of the adequacy of tissue perfusion and oxygenation. The measured PiCO\textsubscript{2} may be used to calculate the intramucosal pH (pHi), or more commonly the PCO\textsubscript{2}-gap (PCO\textsubscript{2}-gap = PiCO\textsubscript{2}-PaCO\textsubscript{2}). Of all measures to assess splanchnic perfusion/oxygenation clinically, tonometry remains the most widely distributed, although a number of problems in the interpretation of the findings still need to be resolved. The main problems are that it has a rather long equilibrium time, preventing the detection of rapid changes of gastrointestinal perfusion and that it cannot distinguish between tissue dysoxygenation and hypoperfusion, since both lead to an increased regional PCO\textsubscript{2}.

Perfusion Measurements

Blood flow and its distribution have been estimated by laser-Doppler and electromagnetic flow probes, indicator dye techniques, and administration of labeled microspheres. Although once regarded the gold-standard, microsphere techniques determine the distribution of labeled microspheres in different tissues only post-mortem at a single point in time. Furthermore, microspheres occlude at least a part of the capillary bed and can thereby acutely increase vascular resistances and lead to tissue hypoxia [4]. A more advanced method to measure perfusion is orthogonal polarization spectral imaging (OPS): The OPS technique is a further development of intravital microscopy [5], particularly developed for the measurement of surface-near microvascular anatomy and perfusion. Here polarized green light illuminates the tissue surface. Filtering of surface reflection by cross polarization allows intravital flow of blood cells to be observed in the microcirculation with great detail on