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Orthogonal Polarization Spectral (OPS)/Sidestream dark field (SDF) imaging: a new method for the observation of the microcirculation in pediatrics

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Abstract

Microcirculation plays an important role both in physiological and pathophysiological states. Early recognition of changes in microcirculation is crucial for starting early therapeutic intervention and reversing the organ failure. Orthogonal polarization spectral (OPS) and Sidestream dark field imaging (SDF) are relatively new noninvasive methods that allow direct visualisation of the microcirculation at the bedside and analysis using semi-quantitative scores. In human medicine, these optical devices have been so far carried out in critically ill adult patients (sepsis, shock, cardiac arrest etc.). To date, only a few medical papers have been published on the use of the technique in children, in particular in preterm neonates. Although it has been the sublingual region commonly used for the observation in adults, the most frequently used site for assessment in newborns is the skin or buccal mucosa. The studies published on the use of OPS/SDF imaging in the newborns show them as a potentially important addition to hemodynamic monitoring in neonatal intensive care.

Key words: microcirculation, neonates, Orthogonal polarization spectral imaging, Sidestream dark field imaging, functional capillary density

Abbreviations

OPS	Orthogonal polarization spectral
SDF	Sidestream dark field
FCD	Functional capillary density
ECMO	Extracorporeal membrane oxygenation
PDA	patent ductus arteriosus

Introduction

Microcirculation is an important part of the cardiovascular system. It ensures the tissue oxygen supply and has a crucial role in the interaction between blood and tissue, both in physiological and pathophysiological states. [1-3] The microvascular perfusion is controlled locally in health and is maintained despite changes in arterial blood pressure. The local autoregulation mechanisms are very individual, vary depending on organs, diseases, metabolic activity or even each patient.

Arterial blood pressure is considered as a main marker of tissue perfusion. However there is no absolute threshold blood pressure that would define adequate perfusion. Microvascular blood flow measurement as a direct oxygen supply indicator would be an important additional tool to hemodynamic assessment in intensive care. Early detection

of abnormalities in the tissue perfusion allows early intervention and better clinical outcome in critically ill patients. [4] Orthogonal polarization spectral (OPS) [2] and its improved successor Sidestream dark field (SDF) imaging are relatively new noninvasive handheld devices for bedside observation of the microcirculation. [5]

OPS/SDF imaging

The development of new technologies for microvascular observation enabled studying various pathophysiological states at the capillary level. The techniques were validated in animal studies with great effort to implement them to clinical research. For many years, capillary microscopy had been the only method for observation of the microcirculation in humans. Capillary microscopes can be used only on easily accessible surfaces (skin, nailfold, lip or bulbar conjunctiva) and therefore have significant limitations in clinical applications. OPS imaging technology and its validation against conventional capillary microscope provide new possibilities for further clinical research in microcirculation. [5]

The most frequently used place for direct visualisation of the microcirculation in adults is the sublingual area. Clinical studies are focused mainly on critically ill patients (in sepsis, shock, cardiac arrest). [3, 5] The device is based on the principle that green polarized light (548 nm) illuminates the tissue surrounding the capillaries and is absorbed by hemoglobin within the erythrocytes. The backscattered light passes through the analyzer that filters out surface reflections creating a high-contrast image of flowing erythrocytes in capillaries.

Despite visualizing the blood flow alterations in critically ill patients, several limitations in OPS imaging still remain, in particular movement and pressure artefacts. [4, 5] SDF imaging, a new improved device based on OPS technology, provides a better image quality. In this technique a light guide is surrounded by light emitting diodes (LED) of wavelenght 530 nm to provide sidestream dark field illumination. The lens system of the light guide is optically isolated from the ring of LEDs to prevent images from contamination by tissue surface reflections. In the videosequence red blood cells are imaged as dark flowing structures against white/grayish background. To provide a high quality image diodes are emitting the light in sychrony with the frame rate of the CCD camera. This stroboscopic imaging prevents from artefacts while capturing flowing structures (erythrocytes). For the purpose of SDF imaging the Microscan videomicroscope was developed (Microvision Medical, Amsterdam, Netherlands). The probe with a sterile disposable cap is placed on the organ/tissue surface and allows the observation of the microcirculation morphology and perfusion in various clinical states. The videosequence is visualised on a monitor. Digitally recorded images are stored on a hard-drive and the analysis is performed off-line. [5] However, the analysis of videosequences is time-consuming and requires certain training period. There are several software systems and scoring scales available for the analysis. A round table conference in 2006 focused on key points for optimal visualisation of the microcirculation as well as on various scoring systems. The participants proposed recommendations for the image acquisition and further analysis which include investigating minimum 3-5 sites per organ, each videosequence at least of 20 s. The scores consist of functional capillary density (FCD) – a parameter of perfusion and an indirect index of tissue oxygen supply measured in cm/cm², proportion of perfused vessels (PPV) and semi-quantitative microcirculatory flow index (MFI) based on predominant type of flow in four quadrants (0 = no flow, 1 = intermittent, 2 = sluggish, 3 = normal). [6]

Microcirculation in clinical research

In clinical research methods for visualisation of the microcirculation have been widely applied in critically ill adult patients (in sepsis or other forms of distributive shock). The key point is to undestand the changes of the microcirculation at the molecular level. The most frequently used site for assessment in clinical research is the sublingual mucosal surface. Recent studies have shown pathophysiological changes at the sublingual level in the development of organ failure in septic patients that can be observed already at early stages of the disease. There are dearrangements in the blood flow at the capillary level, de Backer et al. [7] described reduced vessel density and reduced proportion of the perfused small (<20 μm) vessels in patients with sepsis. These alterations are more remarkable in patients with a worse outcome. In survivors, the perfusion improves with adequate therapy but just if treated at early stages of the sepsis. Microvascular impairment can be observed also in patients with severe heart failure and cardiogenic shock. In comparison with a control group, there was a lower proportion of small vessels perfused in cardiac failure. [8]

Microcirculation in pediatrics/neonatology

Microcirculatory changes in various pathophysiological states can be observed also in neonates.

Recently there have been several medical papers focused on the investigation of the microcirculation in newborns, especially in preterm infants. [4, 9-15] With regard to the fact that there are significant differences in children (different body proportions, higher metabolic rate, lack of compensatory respiratory and cardiovascular reserve) as well as different pathophysiological response to illness, children cannot be regarded as small adults and deserve own clinical research to provide age related parameters. Before OPS/SDF imaging the assessment of the microcirculation was performed by videophotometric microscopy or laser Doppler. In the last 10 years, the field of interest has been focused on OPS/SDF imaging, the studies have shown alterations at microcirculatory level in various pathophysiological states in neonates. Although it is the sublingual region commonly used for observing of the microcirculation in adults, the most frequently used site for assessment in pediatric patients is the skin [9, 10, 15] or buccal mucosa. [4, 11-14] Genzel-Boroviczeny et al. focused on observing the microcirculation transcutaneously, provided first quantitative microvascular parameters in neonates using OPS imaging and proved its use as a safe noninvasive tool in children. The study group has also published data on changes in erythrocyte blood flow according to hemoglobin levels in the first days after birth [9], further research showed changes in microcirculation after therapeutic transfusion. [10] The observation of the sublingual area that is the most frequently used for the assessment of the microcirculation in adult patients is however not easy to do in children. The sublingual region is difficult to access due to the size of the probe, the examination itself is not very well tolerated and there are also sequence artefacts because of the great amount of saliva in the mouth. Transcutaneous observation of the microcirculation using OPS/SDF imaging is only possible to be performed in newborns and infants, in older children the measurement is limited because the skin is thicker and the microcirculation has a more adult pattern. [11] Top et al. have published studies on the use of the technique in critically ill neonates as well as in infants and older children. They have observed the buccal mucosa which shares the common embryogenic origin with the splanchnic mucosa, the group focused on children up to 15 years and reported that there are similar alterations on buccal mucosa in septic pediatric patients. [11] The microvascular response to extracorporeal membrane oxy-

genation (ECMO) of critically ill infants with respiratory distress was investigated in further studies and proved microcirculatory alterations (reduced FCD) in ill infants in comparison with a control group. [12] In a more recent paper Top et al. showed the effect of inhaled NO in infants with persistent pulmonary hypertension and proved that inhaled NO positively affects the microcirculation. [13] Hiedl et al. investigated the differences in microcirculatory parameters in preterm infants with hemodynamically significant persistent ductus arteriosus (PDA) in comparison with preterm infants without PDA and found that these changes disappeared after therapeutic intervention. [14]

Conclusion

Tissue oxygenation and homeostasis are essential for every living cell and depend on microvascular perfusion. OPS/SDF imaging allow direct visualisation of the microcirculation and even though the studies have so far focused mainly on adult patients, there have been several medical papers lately that showed its use in pediatric intensive care, in particular in neonatology. The main difference for the observation in pediatrics is the area for the investigation. Most study groups observed the microcirculation of the skin, only Top et al. used the buccal mucosa. There have been published data mainly on microcirculatory parameters of preterm infants with pre-existing disease but physiological microvascular parameters have not been widely reported yet. The physiology of the microcirculation in neonates might have an importance for further studies. The field of the clinical research in microcirculation is open and suggests several new directions. The methods have some limitations but if the development of technology enables online analysis, OPS/SDF imaging might help the clinicians to start early and effectively targeted therapy.

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