Manifestation of internal organs malfunction
by laser Doppler study on microcirculation

ROMAN MANIEWSKI and ADAM LIEBERT

Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, 4 Trojdena St.,
02-109 Warsaw, Poland

Received 9 October 1998; accepted 30 March 1999

Abstract—Monitoring of microvascular blood perfusion provides very specific information on the
proper function or malfunction of some internal organs, e.g. the pancreas and kidney. The laser
Doppler method was used to measure microperfusion in the skin of the lower limb of diabetic patients
and patients undergoing hemodialysis. This method offers non-invasive, real-time monitoring and is
already accepted in many clinical experiments. The method and the laser Doppler instruments used
are described. Special attention is paid to the investigation of microvascular abnormality in diabetes
by using a multichannel laser Doppler system during postocclusive reactive hyperemia. The study
group consisted of 41 diabetes and 24 healthy subjects with no history of family diabetes. The most
valuable data were obtained from the probe located on the most distal part of the foot. Some hyperemic
parameters (maximum of hyperemic response, time to peak flow) were significantly different for the
diabetic group as comparing to the norm. In the microcirculation study during hemodialysis, three
patients with kidney dysfunction were investigated. Increase in red blood cell velocity was observed,
probably caused by better distribution of blood to the peripheral circulation.

Key words: Microcirculation; blood perfusion; laser Doppler method; diabetes mellitus; hemodialysis.

1. INTRODUCTION

Microcirculation performs an essential role in the regulation of the metabolic,
hemodynamic and thermal state of the organism. The physiological condition of
the microcirculation indirectly provides very specific information on the proper
function or malfunction of some internal organs (e.g. the heart, pancreas and
kidney) and artificial systems for organ support. Microvascular perfusion in the
diabetic foot is, for example, good marker of pancreas dysfunction. Changes in
microperfusion during dialysis may also provide information about the degree of
kidney malfunction useful for dialysis process optimization.

A variety of techniques have been devised for the measurement of blood flow in
microcirculation [1]. However, some of these methods are invasive (radioisotope
washout) and they generally define total blood perfusion in large amounts of tissue including large vessels and subcutaneous tissue. In recent years a new laser Doppler technique has been proposed [2, 3]. This method has emerged in the absence of any other method to fill the clinical requirements of a non-invasive, continuous and real-time measurement of undisturbed microcirculation. In spite of some instrumental problems, e.g. relative calibration and unknown measurement depth, the method is already used in clinical experiments [3, 4].

2. METHODS AND MATERIALS

The laser Doppler method was used for monitoring microvascular blood perfusion. As shown in Fig. 1, this method is based on differences in scattering of the coherent laser light by moving and non-moving structures within the tissue. Light backscattered from moving particles such as blood cells (mainly red blood cells) is shifted in frequency according to the Doppler principle, while the radiation backscattered from the static (non-moving) structural components of the tissue remains at the same frequency. This Doppler shift of laser light frequency is the information carrier about the velocity and concentration of red blood cells in a measured volume of the tissue [5].

In the presented study a 12-channel laser Doppler system (Oxford Optronics, UK) was used. This system allows for continuous, simultaneous perfusion monitoring in 12 locations on the body. The instrument operates with two laser diodes emitting light with a wavelength of 780 nm. The laser power output at the probe tip is about 1 mW. Simultaneously with perfusion, temperature was also measured by temperature sensors located in the mentioned laser Doppler probes [6].

In microperfusion measurement of diabetic patients the laser Doppler probes were placed on the foot and occlusion of lower limb was applied as a stimulation test [7, 8].

![Figure 1. General idea of laser Doppler perfusion measurement.](image-url)