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Developing the Structure of a Hardware and Software System for Quantitative Diagnosis of Microhemodynamics

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Abstract

Currently, vascular diseases are the leading cause of disability all over the world. Recent publications have pointed out microcirculation disorders as the main cause of vascular diseases. In this paper, we present an analysis of the existing diagnostic methods and identify the advantages, disadvantages and limitations of each method. The analysis showed that there are no accurate quantitative criteria for assessment and diagnosis of peripheral circulation in any of the methods. Our results can be used for the development of medical and technical requirements for hardware and software systems for quantitative diagnosis of microhemodynamic disorders. **(Int J Biomed. 2015;5(4):228-230.)**

Keywords: *microcirculation; vascular diseases; quantitative criteria of diagnosis.*

Introduction

Currently, vascular diseases (chronic venous insufficiency, chronic arteriosclerosis obliterans of the lower extremities, diabetic angiopathy, and others) are the leading cause of disability all over the world, including among people of productive age. Furthermore, there is a tendency to a growth in the number of patients with these types of diseases and a decrease in their average age. Recent publications have pointed out microcirculation disorders as the main cause of vascular pathology [1]. The main problems occurring in the research of such disorders are as follows [2]:

(1) a lack of quantitative criteria and accepted methods of diagnosis, which leads to the detection of the diseases at later stages and late treatment,

(2) the impossibility of developing new methods of treatment and the efficiency investigation without monitoring microcirculation condition.

For these reasons, the choice of a method for quantitative evaluation of microcirculation parameters is the main issue in the diagnosis and treatment of patients with vascular diseases.

Methods

The main problems in microcirculation research stem from the extremely small size of microvessels and their high branching. Nailfold capillaroscopy, reflecting microvascular function in all parts of the body, has been the main method of microcirculation research so far. There are several main advantages and disadvantages of this method (Table 1) [3,4].

Table 1.

Advantages and disadvantages of capillaroscopy

Advantages	Disadvantages
Simple and non-invasive Instant visualization The possibility of a detailed evaluation of all parts of the microvasculature The availability of biological objects A lack of significant anatomical features in the region of interest	Impossible to give a quantitative characteristics Results depend on the experience of the medical staff

Currently, the most routine methods for research of regional blood flow and microcirculation in clinical practice are the following [5-7]: transcutaneous oximetry, laser Doppler flowmetry (LDF), high-frequency Doppler ultrasound, tissue oximetry, radionuclide methods, impedance plethysmography, and photoplethysmography. We made a comparative analysis of these methods. We found that each method has its advantages and limitations, but none of them complies fully with clinicians' requirements. Due to this deficiency, it is recommended to use combined methods for microvasculature assessment [8].

Results

Our analysis of the existing diagnostic methods showed that when used together they give superfluous information about microcirculation parameters (Table 2). Unfortunately, there are no accurate quantitative criteria for assessment and diagnosis of peripheral circulation in any of the methods. Moreover, each technique has its significant disadvantages and limitations. Therefore, the problem of quantitative assessment of peripheral circulation is urgent and promising.

The purposes of the subsequent stages of the study are to:

- develop a structure of a hardware and software system for quantitative diagnosis of microhemodynamics (solution of diagnostic issues), and
- develop software and algorithmic tools for biorelevant therapy based on the received diagnostic data (solution of therapeutic issues).

A simplified scheme of a developed bioengineering system is shown in Fig.1. It reflects therapeutic and diagnostic circuits. Thus, this system corresponds to the purposes of the subsequent stages of study.

Table 2.

Comparative analysis of different methods for diagnosis of peripheral circulation

	High-frequency Doppler ultrasound	LDF	Transcutaneous oximetry	Tissue oximetry	Radionuclide methods	
					Perfusion scintigraphy	Clearance method
Functional principle	Doppler effect		local heating of tissue	the interaction of photons with biological tissue	RFP loading with registration of relevant parameters	
Probing depth	3.5…8 mm	~ 1 mm	surface layer of the skin	~ 2 cm	skin, muscles	
Registered parameters	- linear and volumetric blood flow velocity; - rheographic index	- microcirculation index; - mean perfusion in the microvasculature; - average blood flow modulation; - coefficient of variation; - bypass index; - spectral characteristic	- partial pressure of oxygen in the surface layers of the skin ($TcpO_2$)	-absorption coefficient (μ_a); - transport scattering coefficient (μ_s'); - concentrations of oxy- deoxy- and total hemoglobin ([HbO_2], [HHb] and [THb]); - tissue oxygen saturation (StO_2)	radiation intensity of accumulated radiopharma-ceutical	radiopharmaceutical washout period
Using the functional tests	is required for increase the information content of research	is required as one of the stages of research	is required for increase the information content of research	is required for increase the information content of research	not required	is required for increase the information content of research
Availability of quantitative criteria for diagnosis	-	±	±	-	-	-
Features of the method	- integrated of estimated parameters; - a limited number of technical implementations; - a limited number of measurement techniques				- possibility of investigating micro-circulation in the skin and in muscle; - possibility of differentiating nutritional and bypass blood flow.	
	- audible and visual control of sensor installation; - determine the type of vessel in the form of the curve; - evaluation of the direction of blood flow	- understanding of the results is more difficult than the study itself; - data obtained in the foreign literature can't be used in Russia	- some algorithms successfully used in clinical practice	- insufficient information about the application in Russia; - absence of correct algorithms for calculating parameters		
Examples of devices	Minimax-Doppler-K (Minimax, St. Petersburg)	LAKK-02 (LAZMA, Moscow)	TCM400 (Radiometer, Denmark)	OxiplexTS (ISS Inc., USA)	Sigma–410S (USA, Germany)	DIACAM (Siemens, Erlangen, Germany)

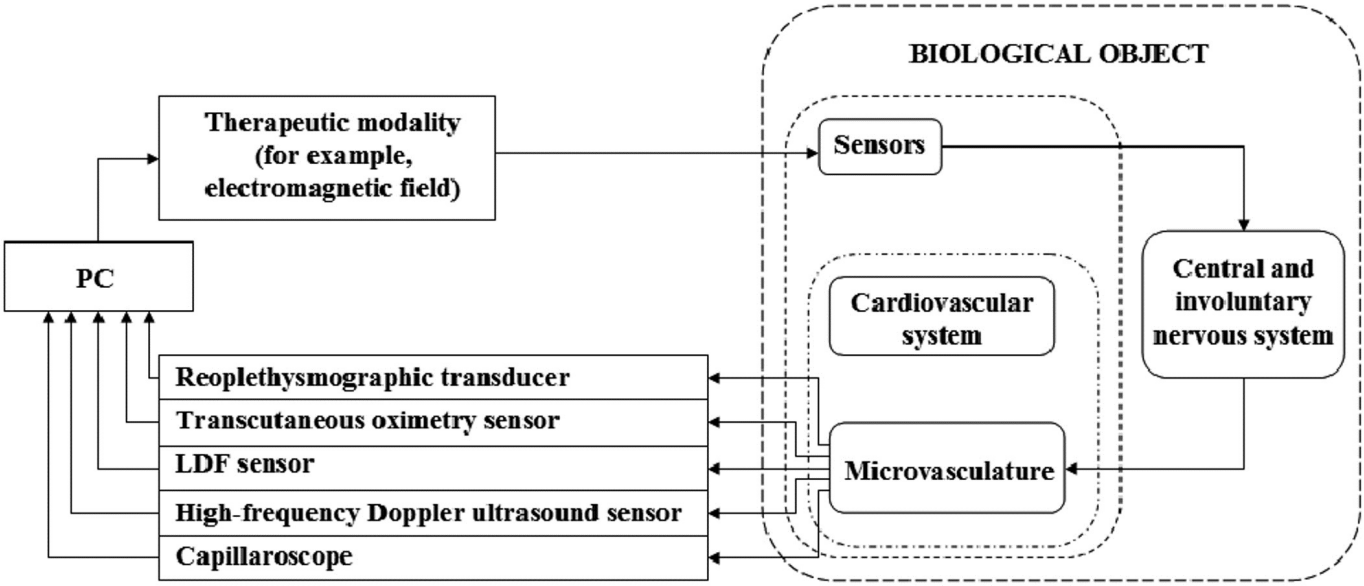

Fig. 1. *A simplified scheme of a developed bioengineering system*

Our results can be used for the development of medical and technical requirements for hardware and software systems for quantitative diagnosis of microhemodynamic disorders.

Competing interests

The authors declare that they have no competing interests.

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