mass screening,cardiovascular system,
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ANALYSIS OF THE AGREEMENT OF CAVASCREEN SYSTEM DIAGNOSTIC SUGGESTIONS WITH THE REAL CLINICAL STATE OF A PATIENT

The CAVASCREEN System is intended for mass screening of the cardiovascular system by physicians as general practitioners or family doctors. This system supports the decision on directions for further specialistic diagnostics of a patient based on analysis of objective measurement data obtained from the examination. The shortage of proper accessible literature evidence connected with the complex assessment of the cardiovascular system, offered by CAVASCREEN System, caused the necessity of clinical tests for the purpose of checking the agreement of obtained results with the real state of a patient.
This paper presents the idea of non-invasive multi-parameter measurements of the cardiovascular system and the rules of determination of the characteristic hemodynamic parameters of a patient, which are used by expert system to create the final examination results. This article also presents verification method of diagnostic suggestions of CAVASCREEN System and the statistical results analysis of the clinical tests passed.

1. INTRODUCTION

The wide preventive activity relies on accessibility of efficient, non-invasive and cheap diagnostic methods like mass screening.
The system CAVASCREEN is intended for diagnosis of the cardiovascular system based on impedance measurements of blood flow in chosen areas of the body.
Practical methods of the measurement:

- tetrapolar rheography;
- skin electrometry;
- blood pressure measurement.

The cardiovascular system is treated as anatomical-functional whole, and the inspection of disturbances of the blood flow in each circulatory region is accomplished in the context of

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the circulatory system entirety. The influence of body position (the gravitational factor) is taken into account in the analysis of autoregulation mechanisms of the circulatory system [1][2].

2. PERFORMING THE EXAMINATIONS WITH THE USE OF CAVASCREEN SYSTEM

2.1. DESCRIPTION OF THE SYSTEM AND METHODOLOGY OF EXAMINATION.

The developed measuring system presented in Fig.1 consists of multi-parameter measuring module collecting biomedical data, and the computer. The computer program presents and archives measurement results, processes data and generates examination reports.

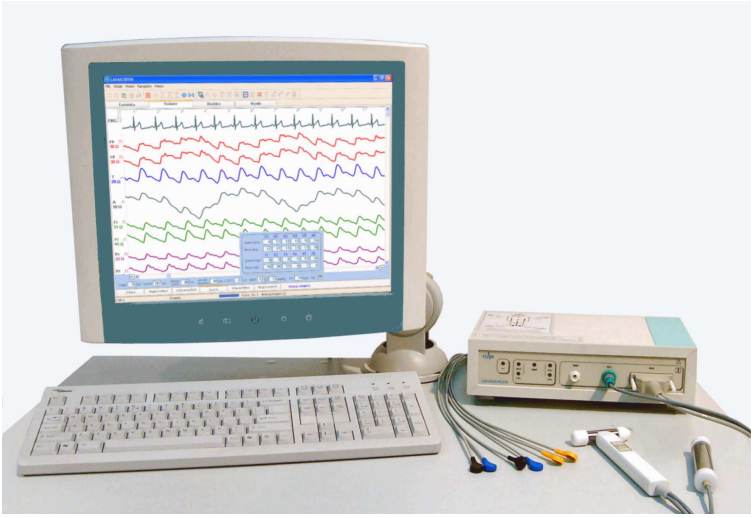

Fig. The measurement CAVASCREEN System

The examination consists in recording of the curves of impedance changes in eight body regions simultaneously with electrocardiogram, with skin tissues conductivity and with blood pressure measurement.
All measurements are performed twice: first in standing position, and then after several minutes of the rest recumbently. The rheograms are taken from: both sides of the head, pectoral region, abdominal region, pelvic and crural regions for the common measuring current which flows from forehead to feet. Along with rheograms recording, the base impedance is measured in every region analysed. The electrocardiogram is taken from rheografic electrodes in the pectoral region, and the measurement of the skin conductivity is performed in twenty four points on external and internal sides of the palm and feet. The blood pressure measurement is performed on the arm using oscylometric method.

2.2. DETERMINATION OF HEMODYNAMIC PARAMETERS AND CREATION OF FINAL EXAMINATION REPORTS

The main object of analysis is a cycle of the first derivative of rheografic signal from the chest (DRG), which is used to compute the stroke volume (SV) and the cardiac output (CO). For the

purpose of SV value calculations (Kubicek formula)[5], there are marked characteristic points of systolic wave of the cycle: the amplitude DRG (points 3 and 4) and the duration of systolic phase (points 3 and 6) [3][4]. The sequence of changes in electrocardiogram (ECG), phonocardiogram (FCG), the basic rheogram (PRG) and its first derivative (DRG), the changes in aorta and pulmonalis arteria pressures and volumes of the heart ventricles are presented in Figure 2.

Using the suitable algorithms to mark the characteristic points is very important in eliminating methodological errors related with a multiplicity of shapes of the first derivative (DRG).

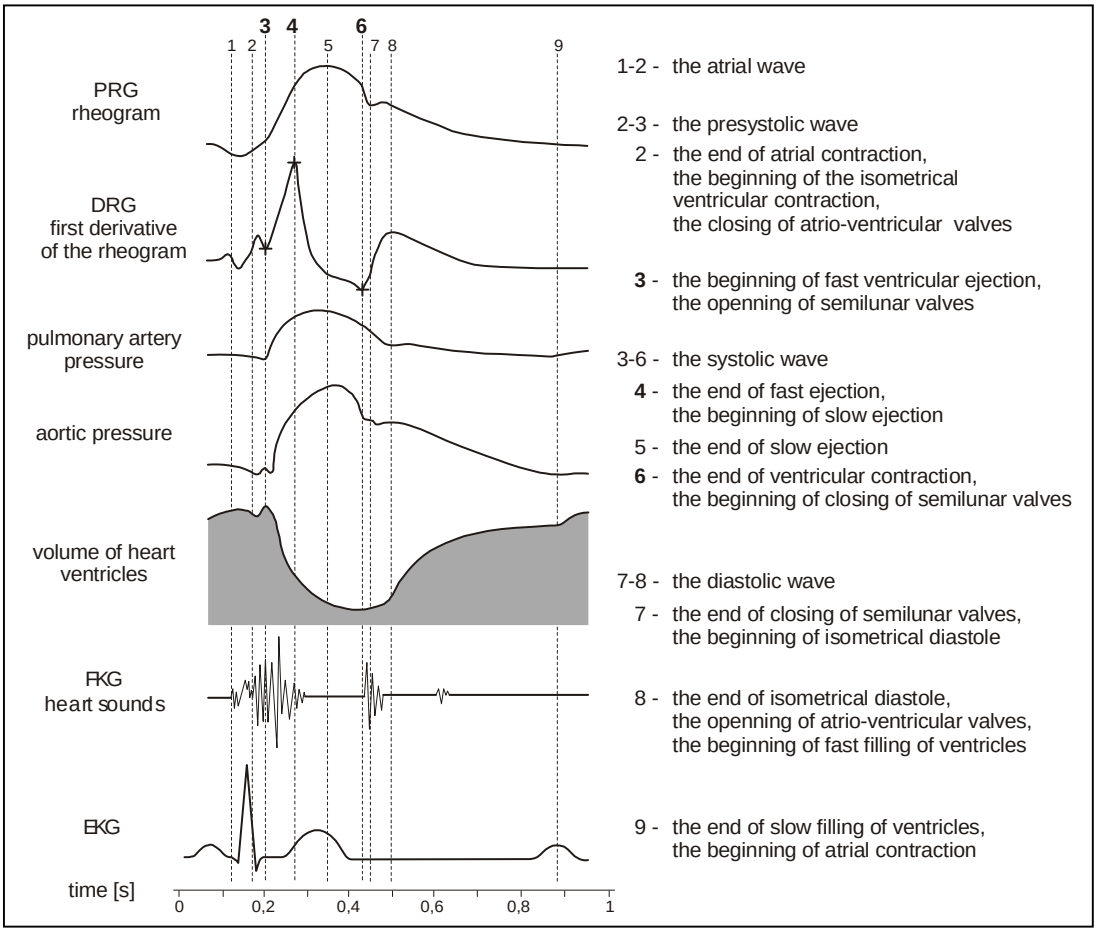

Fig.2 The schematic graph of the hemodynamic cycle [1]

The hemodynamic indicators used in the multiparameter analysis, characterize the activity of the cardiovascular system recumbently, standing and the percentage changes in patient's standing position with relation to the recumbence. These parameters and indicators are both generally used in circulation physiology and the cardiology as well as used in auxiliary way by expert system. The most essential indicators in circulatory system diagnostics are: stroke volume (SV), cardiac output (CO), mean arterial pressure (MAP), heart contractility index (DRG_{max}), cardiac index (CI), heart rate (HR), total peripheral resistance (TPR).

Results of the multiparameter analysis after classification by expert system with reference to database standards create final examination results [2]. Descriptive diagnostic suggestions and the graphic presentation create image of the patient circulatory system state supporting the doctor in diagnosing and in the decision on possible specialistic diagnostics and prophylaxis.

.In Figure 3 there is presented partial examination result describing the pathology detected in the left crus, which was appeared in standing position of the patient.

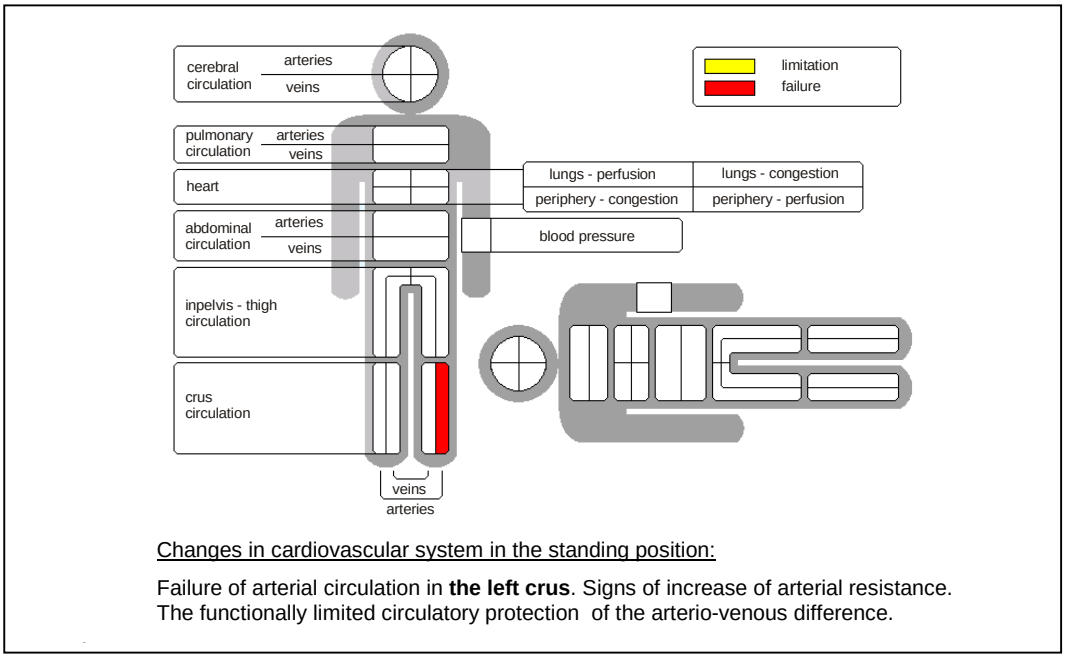

Fig.3 The example of partial examination result

3. VERIFICATION OF DIAGNOSTIC REPORTS IN CLINICAL TESTS

3.1. THE POPULATION EXAMINED AND THE REFERENCE METHODS USED

The results of clinical tests realized in the project had to show, how much faithfully the diagnostic reports of the CAVASCREEN System describe dysfunctions of the circulatory system in examined regions of the body with relation to clinical reference methods.

The examined population was limited to patients directed to the clinical treatment, for whom the diagnosing reference methods were an integral components of medical proceeding. In clinical tests participated 222 patients, therein 169 patients diagnosed completely and 53 patients with diagnosed lower limbs only. Except hospitalized patients, 1082 volunteers without any pathological symptoms were examined.

Reference examinations contained physical (subjective and objective) tests complemented additionally by: USG with double imaging in the colour (duplex Doppler), angio-TK, angio-MR and measurement of segmental pressures with assessment of indicators (for lower limbs). Generally, dysfunctions of the circulatory system were determined in the following regions (rys.4) :

Area of vascularization	Number of examinations
Cerebral circulation	169
Coronary circulation and the area of the heart	99
Lower limbs	221
The number of all reference examinations performed	489

Fig.4 Regions and the number of examinations with reference methods used

3.2. MEDICAL DOCUMENTATION

Data from the case history of patient were contained in the Clinical Protocol, representing in parametric form the kind of disease and its severity – documented with the use of reference diagnostic methods. The examination results obtained from the CAVASCREEN System were contained in similar parametric protocol, created by expert system. Such form of protocols made possible the representation of examination results globally and in the groups according to the sex and diagnosed regions with reference methods used.

4. THE RESULTS OF CLINICAL TESTS

Statistical analysis of the results consisted in the percentage agreement estimation of typical clinical and CAVASCREEN System diagnoses. Summary results of agreement of diagnostic decisions for all dysfunctions in analysed circulation regions at the hospitalized patients represents the following table (Fig. 5).

	Cerebral circulation	Coronary circulation and the area of the heart	Lower limbs
The total agreement of the pathology estimations	75 % (30 / 40)	89,9 % (89 / 99)	99,2 % (131 / 132)
The total agreement of the pathology estimations		92,3 % (250 / 271)	
The total agreement of cases estimations		80,4 % (393 / 489)	

Fig.5 The agreement of estimations of patient's states

These results show the large diagnostic agreement in the lower limbs and in the coronary circulation. The reason of smaller agreement in the cerebral circulation is a small number of detected circulatory dysfunctions in this region in examined group of patients, and because many reference diagnoses were based only on physical examining.

To the evaluation of archived data were also used both multidimentional variance analysis and statistical discriminant analysis. The multidimentional variance analysis makes possible objective estimation of the inherent information in measurement data sets, so at the same time the estimation of existing differences between groups of patients. Basing on statistical discriminant analysis there are qualified discriminatory variables, which allows decreasing dimension of the variables space while keeping differences between groups. The classification, which assigned every patient to the specific group is possible using these variables.

The analysis was performed only with data obtained from CAVASCREEN System from 1082 examined healthy volunteers without any pathological symptoms, and 222 patients determined as diseased group.

For two groups of patients (healthy and diseased) it is possible to define the following parameters used to estimate the classification:

- SE **(**Sensitivity**)** – the probability that the pathological patient is classified as pathological,
- SP (Specifity) – the probability that the healthy patient is classified as healthy,
- PPV (Positive Predictive Value) – the probability that the patient, who was classified as pathological is really pathological,
- TA (Total Accuracy) – the probability of the correct classification.

As a result of analysis there were received the following values of classification parameters (Fig. 6) and the normal distribution of the probability density function PDF of the classification to the group diseased and healthy persons (Fig. 7) :

The number of patients	1304
SE (Sensitivity)	95,2 %
SP (Specifity)	73,7 %
PPV (Positive Predictive Value)	91,4 %
TA (Total Accuracy)	94,4 %

Fig.6 Values of classificatory parameters

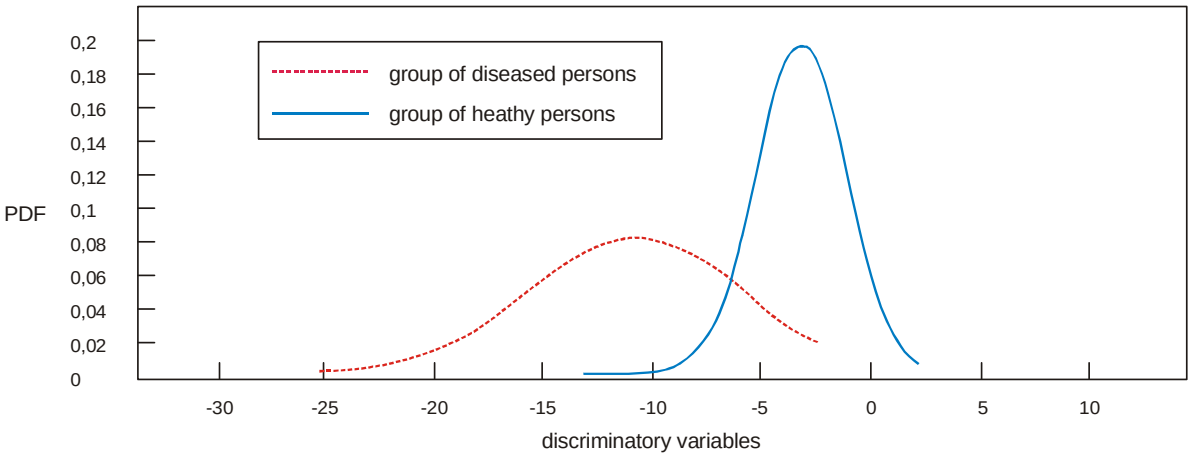

Fig.7 The normal distribution of the probability density function for the group diseased and healthy persons

Performed analysis demonstrate that in examined regions the diagnostic suggestions proposed by the CAVASCREEN System show a large agreement with the clinical estimations. Also statistical parameters of patients classifications to two groups healthy and diseased, particularly Sensitivity (SE) (the classification diseased persons to the diseased group) and probability (PPV) that the patient, who was classified as pathological is really pathological, are sufficiently good. Received results confirm diagnostic possibilities of evaluated CAVASCREEN System.

BIBLIOGRAPHY

[1] C.H. Best, Physiological bases of the physician proceedings, PZWL, Warszawa ,1971.
[2] G. Biełkania, The computer curative diagnostic expert system, ANTROPOS, Winnica, 2000.
[3] M. Nałęcz, The biocybernetics and the biomedical engineering part 2, EXIT, Warszawa ,2001.
[4] G. Pawlicki, Bases of the medical engineering, OWPW, Warszawa, 1997.
[5] W.G. Kubicek, Development and evaluation of an impedance cardiac output system, Aerosp Med, vol. 37, 1966