

## The Biophysical Modelling of the Global Role of the Cardiovascular System at Stress

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### Abstract

At normal state the electrocardiogram presents for each cycle a sequence of five waves denoted with the letters P, Q, R, S T. Each of these waves represents the electric activity in the various phases of the cardiac cycle. Further on, we present the modelling of the blood volume, if we administer a certain substance amount, then its passing speed will depend on its concentration, hence the volume at which it spreads in the deposit. The isotopic methods present the advantages of a more direct expression of the factors mentioned and the increased objectivity of the results compared to other functional exploration methods. A direction of priority interest is represented by the biocybernetic concept, biomathematics and system theory for the explanation of the cardiovascular control in the physical effort. Stress cardiomyopathy is a disease caused by an intense emotional or physical stress leading to reversible, rapid or severe cardiac dysfunction. Heart disease causes the greatest worries. The idea of the disease transforms the person with his own mentality in a danger state: myocardial infarction, heart insufficiency, coronaric diseased people, blood hyperpressure, paroxymal tachycardia.

### Keywords

Electrograms; Compartment method; Psychology; Biophysics.

## Introduction

The first electrograms were made by Eindhoven in 1903 at Leyden, using electrodes applied in the bipolar deviation in three points on the body. The potentials collected with these electrodes represent the projections of the cardiac vectors on the exploration axes. The amplitudes of the vector at its turn is proportional with the electromotor force of the heart, whose size is a very important diagnostic mean in the medical clinic for the assessment of the heart's functioning state. At normal state the electrocardiogram presents for each cycle a sequence of five waves denoted with the letters P, Q, R, S T. Each of these waves represents the electric activity in the various phases of the cardiac cycle [1].

Further on, we present the modelling of the blood volume, if we administer a certain substance amount, then its passing speed will depend on its concentration, hence the volume at which it spreads in the deposit. This size is hard to determine. This is why Dost defined the amount of substance which would realise an initial concentration exactly defined in blood after the complete resorbtion and after the installation of a supposed equilibrium as dose. [2] This initial fictional concentration in blood is denoted with  $c$ . It would be achieved at time  $t = 0$ , and at the time  $t$  the concentration would be  $c^*$ . Then results the analogy with the formula of  $c^*$  increase in relation of the reaction speed:

$$c^* = \frac{dc^*}{dt} = k \cdot (c - c^*)$$

and integrating:

$$c^* = c \cdot (1 - e^{-kt});$$

for the concentration decrease speed:

$$-\frac{dc^*}{dt} = k_2 \cdot c^*$$

integrate

$$c^* = c \cdot e^{-k_2 \cdot t}$$

If the two processes combine, it is mandatory that the concentration increase speed be proportional with the invasion constant  $k_1$ , hence with the amount of substance still present in the storage:

$$c \cdot e^{-k_1 \cdot t}$$

from here:

$$\frac{dc^*}{dt} = k_1 \cdot c \cdot e^{-k_1 \cdot t}$$

The concentration decrease speed will be on its turn proportional with the elimination speed  $k_2$ , hence with

the present blood level:

$$\frac{dc_2^*}{dt} = -k_2 \cdot c_2^*$$

The amount of the two speeds gives the modification which is produced when the two processes take place simultaneously. For this case the relations are valid:

$$dc^* = dc_1^* + dc_2^*$$

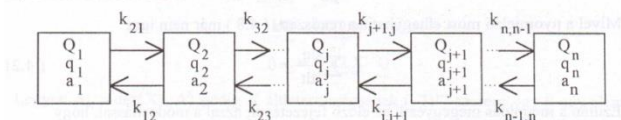
$$\frac{dc^*}{dt} = c \cdot k_1 \cdot e^{-k_1 \cdot t} - k_2 \cdot c_2^*$$

The solution of this equation has the following expression:

$$c^* = \frac{c \cdot k_1}{k_2 - k_1} (e^{-k_1 \cdot t} - e^{-k_2 \cdot t})$$

## The Compartment Method

The explorations with radioisotopes provide data on the main factors that the functional state of the blood flow depends on: absolute blood flow, relative blood flow, circulation speed, blood mass, capillary permeability. These factors can be separated or global. The isotopic methods present the advantages of a more direct expression of the factors mentioned and the increased objectivity of the results compared to other functional exploration methods. [3] One of the most often used methods for the evaluation of the use of radioisotopes in the cardio-vascular system is the compartment method. Below we present this method very briefly. We suppose that the compartments form a chain (see Figure) and the characteristic matrix of this chain will have the following form:



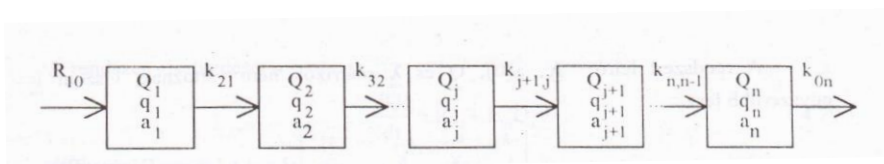
$$k = \begin{vmatrix} -k_{21} & k_{12} & 0 & \dots & 0 \\ -k_{21} & -(k_{12} + k_{32}) & k_{23} & \dots & 0 \\ 0 & k_{32} & -(k_{23} + k_{43}) & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & -(k_{n-1,n} + k_{0n}) \end{vmatrix}$$

According to Laplace's transformation, we obtain the solutions:

$$k_{21} X_{1i} - \frac{Q_2}{Q_1} k_{12} X_{2i} = \lambda_i X_{1i}$$

$$- \frac{Q_1}{Q_2} k_{21} X_{1i} + (k_{12} + k_{32}) X_{2i} - \frac{Q_3}{Q_2} k_{23} X_{3i} = \lambda_i X_{2i}$$

If we introduce another simplification that each compartment has a flow only towards the neighbouring compartment ( $k_{11}=k_{21}$ ,  $k_{22}=k_{32}$ , ...,  $k_{nn}=k_{0n}$  then the chain's scheme will be given in figure.



In this case the radioisotope is injected only in the first compartment:

$$a_1(0) \neq 0, a_2(0) = a_3(0) = \dots = 0$$

for the matrix we obtain a simpler case

$$sI - k = \begin{vmatrix} s+k_{21} & 0 & 0 & \dots & 0 \\ -k_{21} & s+k_{32} & 0 & \dots & 0 \\ 0 & -k_{32} & s+k_{43} & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & s+k_{0n} \end{vmatrix}$$

We introduce the following supplementary relations:

$$\Delta = (s+k_{21})(s+k_{32})(s+k_{43})\dots(s+k_{0n})$$

$$\Delta_{11} = (s+k_{32})(s+k_{43})\dots(s+k_{0n})$$

$$\Delta_{12} = -[-k_{21}(s+k_{43})\dots(s+k_{0n})]$$

$$\vdots$$

$$\Delta_{1n} = (-1)^{1+n}(-k_{21})(-k_{32})(-k_{43})\dots(-k_{0n})$$

And hence closer, determining the characteristic parameters for the first compartment it is possible to determine the characteristic parameters for the other compartments. A direction of priority interest is represented by the biocybernetic concept, biomathematics and system theory for the explanation of the cardiovascular control in the physical effort. [4] The system is considered as an ensemble of interacting components subject to perturbations and manifesting a certain behaviour. Under a strictly practical

report, the elaboration of the algorithms of the regulating parameters of the cardiovascular system would serve at the construction of the heart prosthesis or the directing of the artificial circulation.

The cybernetic elements of the system are the following:

- 1) the controlled system – heart and vascular system with the adjusted parameters (cardiac flow, flow resistance, venous tonus) and the likely disturbing factors;
- 2) the sensory, transformation and comparison elements – baroreceptors and vascular chemoceptors, muscular proprioceptors with their entry commands;
- 3) the mechanism of the effect which in the case of the heart is especially the sinoatrial node;
- 4) regulating centre (command elements) – nervous centres, subcortical vegetative neuron, endocrine subsystems (sympatho-adrenal, hypophysary - corticoadrenal, hypophysary – thyroidal etc.).

### **Stress Manifestation in the Circulatory Apparatus**

The cardiovascular system has a major role in the biopsyo-social reaction of the human organism. This problem is important considering the concerning incidence of cardiovascular disease at global level, mainly due to stress. [5] This problem is of main interest. Stress, especially the one with negative influences (distress) became a component of the contemporary life. The integrated and correlated interests involved in the cardiovascular adaptation imply central cortical commands (cerebral cardiorespiratory neurons), hypothalamic, the sympathetic and parasympathetic nervous system exerted on the heart (cardiac frequency, systolic flow, cardiac flow) and the vascular system (arteries, capillaries, veins). There are particularities as well: hence, local factors of autoadjustments of the blood flow, of the cerebellum and brain stem interfere in the physical effort, elements which influence the motor system. [6]

Stress cardiomyopathy is a disease caused by an intense emotional or physical stress leading to reversible, rapid or severe cardiac dysfunction. They mimic a myocardic heart attack. Some authors sustain that watching a stressing football game doubles the risk of an acute cardiovascular event. Various papers intend to relate the individual personality and behaviour characteristics with the stress susceptibility and the cardiovascular diseases. Most of these papers follow the A and B typology, some studies prove the increase vulnerability to the coronary disease of the subjects belonging to type A. Currently the type A personality is considered as being prone to psychosomatic disease and not exclusively for the coronary disease. Stress affects the peripheral hemodynamic through effects depending on its intensity: light stress reduces the peripheral resistance through the activation of the vascular receptors  $\beta$ , and the intense stress increases the peripheral resistance and the diastolic arterial pressure through the receptors  $\alpha$ .

The stress system included several neuroendocrine subsystems. [7] A key role comes to the hypothalamic pituitary adrenal axis which assures the secretion of the stress hormone – cortisol and on the other side the adrenal medullar system with the secretion of the catecholamines (adrenalin and noradrenalin). Both systems assure the mobility related reflexes, mobilize cognition and attention and stimulate the cardiovascular and metabolic functions under stress conditions. We showed that the psychophysiological assessment of cardiovascular risk factors must include stress and the coronary prone behaviour. The mentioned studies are included briefly in the volume 30 Biophysics (Vincze, 2007). In the same volume, there is also the summary of the article „Block diagrams of the circulation in physical effort” (Derevenco,

Vincze, 1979). In conclusion the intense effort and the psychoemotional distress represent risk factors for the coronary disease and other cardiovascular affections.

## Psychological Aspects of the Cardiovascular Apparatus

Psychological disturbances of variable intensity appear secondary to the installation of a disease of the cardio-vascular apparatus. The psychic disturbances have an evolution parallel with the one of the generating cardiovascular affections, the episodes of acute insufficiency aggravating the intensity of the psychiatric symptomatology. [8-9] They also described a maniacal agitation state which appears in the acute period of the myocardic heart attack. The etiopathogeny of the apparition of the psychic disturbances secondary to certain cardio-vascular affections come from the life regimen that the diseased person must follow, invoke the helplessness sensation. These restrictions determine modifications in the social and family relations. The role of the personality structure seems more important than the seriousness of the cardiopathy. [10-12]

Initially all the sick people enter a state of anxiety, having the permanent tendency to protect themselves. The psychic disturbances evolve in parallel with the cardiovascular affection which caused them. They improve together with it but the fact that most of these diseases have a long duration, offers the chronic characters and psychic symptoms. Heart disease causes the greatest worries. The idea of the disease transforms the person with his own mentality in a danger state. Myocardial infarction. A part of the heart is destroyed due to the occlusion of the coronary artery. This accident is caused by a blood clot which partially blocks the artery, hindering the blood circulation. In the acute phase there is the intense anxiety, the feeling of imminent death, panic, psychomotor excitation or inhibitions, sometimes coma. After an infarction the presence of anxiety, depression, hysterical reaction, obsessive forms, medicine abuse, state of dependence towards the environment – are compulsory.

**Heart insufficiency.** This disease consists of the hearts incapacity to assume its function as pump and to maintain the blood flow and to irrigate the body. For various reasons, the heart does not contract enough. Anxiety, night turmoil, terrifying dreams appear. In the serious states, delirious ideas may appear, narrowing of the consciousness field at different levels, sleepiness or excitation, light confusion episodes, because the anxiety-depressive fund is favourable for the apparition of interpretative ideas. Their main characteristic is the feeling of imminent death.

In **mitral insufficiency**, usually apparent sadness appears, seriousness, depression, usually is associated with hypersensitivity at psychological traumas, psycho-astemic features appear. They have docile character, they are understanding with a lot of affection manifested to others, receptive to the sufferance of the others, drawn to help those in need, altruist.

**Coronaric diseased people** – they have an exaggerate ambition beyond their real strengths, they work without pause, hyperexigence and they tend towards a limitless perfection. But the internal force is fragile and apparent, which is compensated by a compulsive-autoritary character.

**Arterial hyperpressure** – is an abnormal increase of the arterial tension; if untreated, it may favour the stroke. The causes are unknown. Headache appears in all the cases, as well as physical and psychological

asthenia, intolerance to noises. The emotiveness is superficial joined by accesses of irritability, affective weakness, depression, anxiety, insomnias, transitory confusion episodes, especially the night ones with delirium. The patients, regardless of their personality are incapable to express aggressiveness. Fearing the consequences of the expression of these impulsions, they hide their need of competitiveness. Generally we find a refrained ambition simultaneously with the fear of aggressiveness, hence they are always tense, with an attitude of repressed anger. They have personalities with anxiety caught in any type of aggression (political, economical), interiorize, they crank the purely aggressive tendencies aimed at the partners, but the defence process appears converting through cardiac and vasomotor reactions, they maintain one another.

**Blood hyperpressure** – is a decrease of blood pressure, which can be permanent or it appears in crisis times. The characteristics of the sick people are tiredness, exaggerated emotiveness, collapse (sudden loss of consciousness) joined by the abolition of the motor functions, but maintaining the circulatory and respiratory functions. This faint state contributes to the apparition of the neuroastenic and mental character, anxiety state.

**Arteriosclerosis**– installs progressive deposits on the arteries walls narrowing their dimension and restraining the blood to circulate normally. In this disease, the intellectual functions become gradually weak. The sick people become aware of their health state. The fear of worsening of the disease determines characteristic modifications with aspects of irritability, megalomania and selfishness.

**Variable blood pressure** – refers to those with hyper or hypopressure. The unevenness of arterial pressure reflects through oscillations of the various parameters of the mental life. We observe the alternation between activity phases: activity, debordation and inspiration and phases of discouragement: passivity, inertial, despair. The base of the personality becomes captured by an excessive emotiveness, exaggerate impressionability, exteriorized with a bipolar character between the choleric-melancholic attitude. Those around are used with the affective – conative values, which are not disturbing for the others, because it manifests especially in the creative activities.

**Paroxymal tachycardia** is found in the hysteroid type, demonstrative, with emotional immaturity and intolerant to frustrations. They have exaggerate affective exigencies, the weakness of self-control results from liveliness and verbal aggressiveness, stubborn in the centre of attention, claims to direct and order a group until total submission with their illogical, irrational ideas born under the influence of pulsing, intensified by the imaginary life. This extraversion is used for dramatization and used to influence and manoeuvre the entourage. The type „dying grandma”, if their wishes are not executed immediately, they become theatrical, as form of affective blackmail. Hyperexcitation and hyperemotiveness with tachycardia maintain one another.

The recent research confirmed the harmfulness of stress on the coronaries, the mortality is on the first event. The life of the heart sick people through the numerous restrictions imposed to them deviate their life from the normal person. In the daily life they have restrictions to movement, food, sexuality, which generate the apparition of the devalueing feeling.

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