ISSN print: 1224-5984
ISSN online: 2248-3942

Rom Biotechnol Lett. 2019; 24(3): 499-505
doi: 10.25083/rbl/24.3/499.505

Received for publication, September, 20, 2017
Accepted, December, 10, 2018

Original paper

Determining the electric potential of blood – a possible screening method at the population level

CONSTANTIN BĂLĂEȚ[1, 2], GHEORGHE MANOLE[3, 4], TRAIAN BĂLĂEȚ[5], BOGDAN-IOAN COCULESCU[1, 3, 6 *]

[1]BioterraUniversity, Faculty of General Nursing, Bucharest, Romania
[2]Lil Med Clinic, Bucharest, Romania
[3]Titu Maiorescu University, Faculty of Medicine, Preclinical Department, Bucharest, Romania
[4]ClinicalHospital Colentina, Bucharest, Romania
[5]University of Bucharest, Faculty of Physics, Romania
[6]Center for Military Medical Scientific Research, Department of Anti-infective Medical Protection and Epidemiological Emergencies, Bucharest, Romania

Abstract

This study addresses two objectives: first to innovate, through utilizing an analyzer designed by one of us to design the bioelectric potential of blood whose value can be used for screening patients and healthy subjects; and secondly, to develop a novel diagnosis method. To date, there is no known method of determining the electric potential of blood.

The method we propose is useful for determining the general functional state of the body, and it could indirectly indicate whether a specific organ is affected. This type of screening could be useful as an early diagnosis method. Future applications also include screening animals or plants.

If a certain threshold is met, further investigations could be employed and thus an early diagnosis established before a disease becomes chronic.

Keywords Blood bioelectric potentials, analysis of bio-potential, screening type diagnosis method

To cite this article: BĂLĂEȚ C, MANOLE G, BĂLĂEȚ B, COCULESCU BI. Determining the electric potential of blood – a possible screening method at the population level. *Rom Biotechnol Lett*. 2019; 24(3): 499-505. DOI: 10.25083/rbl/24.3/499.505

*Corresponding author: BOGDAN-IOAN COCULESCU, Titu Maiorescu University, Faculty of Medecine, Bucharest, Romania
E-mail: bogdancoculescu@yahoo.fr

Introduction

Since the human body functions as a whole, the malfunction of one organ can affect the health of other organs. Regardless of the physical location of the malfunction, diseases are the clinical expression of various cellular metabolic dysregulations, which also lead to changes in the blood physio-chemical and electrical properties (C. BĂLĂEȚ & al. [1,2], G. MANOLE [3]).

There are two mechanisms that lay at the core of the cellular metabolic dysregulation which affects the composition of blood: total water distribution and homeostasis. Maintaining homeostasis, meaning appropriate concentrations of nutrients, electrolytes, water and gases (O_2 and CO_2), is the result of the membranes which separate the extracellular (interstitium and intravascular) and the cellular compartments and it is necessary for life. Membranes have different properties, which are defined by their structure, and allow water, electrolytes and nutrient exchange between these compartments (G. MANOLE [4]). Transmembrane transfers occur until the Gibbs-Donnan equilibrium (ideal equilibrium) installs, which is equivalent to an equal ion distribution on both membrane sides (Table 1).

Table 1. Electrolyte distribution in the internal environment

Structural components (in mEq/L)		Medium	
		extracellular	intracellular
Cations	Na^+	138-142	10
	K^+	4.5-5	140
	Ca^{2+}	5	≤0,0001
	Mg^{2+}	1.5-2	58
Total: approximately		155	
Anions	Cl^-	103-108	4
	HCO_3^-	24-27	10
	SO_4^{2-}	0.5-1	2
	HPO_4^{2-}	2	11
	$H_2PO_4^-$	2	11
Total: approximately		155	
Proteins		16	40
Organic acids		6	

Ion transport through membranes, regardless of its type, is in fact a transport of electrolytes which generate and conduct electric current in an aqueous solution. Unequal distribution of ions on the two sides of the membranes leads to a difference in electric potential (a dynamic yet imperfect equilibrium), despite the two compartments being electrically neutral on their own (G. MANOLE [4], M. DOROFTEIU [5]).

In medical practice, homeostasis allows us to determine the variations in blood composition and thus the modifications to its chemical and physical properties (C. BĂLĂEȚ & O. SEVASTRE [6]). This could be used to further assess the health status and aid early diagnosis. In support to this statement, medical practice is already using paraclinical investigations which target electrical potentials of organs of cells, such as the electrocardiogram or the electroencephalogram) for assessing the health status (G. MANOLE [3], F.F. BECKER & al. [7], S. GRIMNES & O.G. MARTINSEN [8]). However, the electric potential of blood has never been determined in either medical practice or research.

Material and methods

The study had two objectives:

– to investigate the possibility of measuring the electrical/electromagnetic field of blood (innovation);

– to propose this method as an early diagnosis tool.

This study was conducted in accordance with the ethical standards of Declaration of Helsinki. All persons gave their informed consent prior to their inclusion in the study.

The innovative part of the study consists of utilising a device/analyser for highlighting the bioelectric potential of blood. The device has a vacutainer, where 1.6 ml blood and 0.4 ml anticoagulation solution (isotonic solution of trisodium citrate) are added (see Fig. 1).

We introduced an aluminium tube (whose wall thickness was 1 mm) inside the vacutainer. This procedure needs to be slightly forceful. This tube acted as an electrode. At one end it had a copper wire (0.5 mm thickness). In the centre of the lumen of the tube, at the other end, we introduced the other copper wire electrode (same thickness). The two wires connected with the two electrodes were coupled to an amplifier of the power 10^4. However, we consider an optimal power to be 10^6. We measured the electrical signals for maximum 20 seconds, every 5 seconds, which corresponds to 4 determinations. This data was registered in a computer and on physical support.

To address the second objective of the study we recruited 35 subjects, including 30 healthy controls, and 5 patients with sigmoid neoplasm. The number of subjects was small, since this was a pilot study aimed at determining the standard bioelectric normal values in health and to compare them with the abnormal ones in disease. The patients underwent a complex screening procedure beforehand, including haematological and biochemical laboratory tests. The 5 patients also underwent a colonoscopy and a biopsy, and they were confirmed $T_1N_oM_o$ (R. LABIANCA & al. [9]). The 5 patients all had anaemia, with the circulating haemoglobin levels around 8-10 g% mL in blood, meaning medium severity.

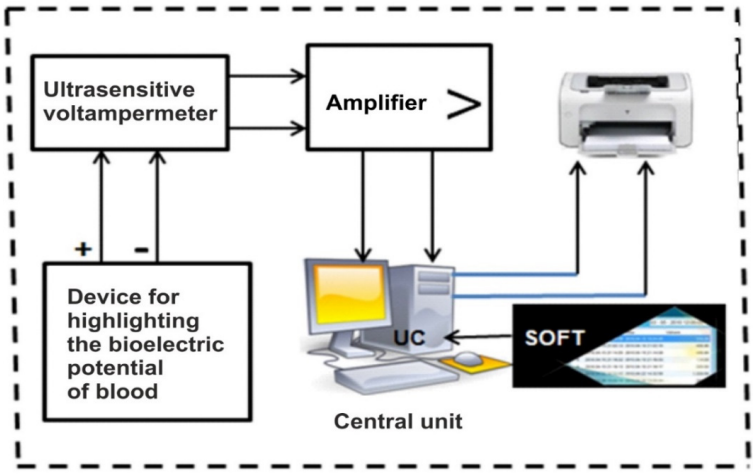


Figure 1. Schematic representation of how to determine the electrical potential of a blood sample

Results and Discussions

1.1. From an electrical point of view, the anti-coagulant + blood mixture behaves as a standard electrolyte, which develops an electric field whose characteristics are given by voltage (V) and amperage (A). Because there are two sources which generate electric potential (the blood and the anticoagulant), we must note that the results will be influenced by this factor. The contribution of the anticoagulant is constant, and it contributes to amplifying the intensity of the bioelectrical field. Thus the electrical potential value of blood is given by:

$$\Sigma_{\text{volts- anticoagulant}} + \Sigma_{\text{volts-figurant elements}} + \Sigma_{\text{volts-biochemical substances in the blood}} = \Sigma_{\text{volts}(n +/- 1)};$$

$$\Sigma_{\text{ampers-anticoagulant}} + \Sigma_{\text{amperi-figurant elements}} + \Sigma_{\text{ampers-biochemical substances in the blood}} = \Sigma_{\text{ampers}(n +/- 1)};$$

The voltage and amperage values were measured by four readings, spaced at 5 seconds. For both the control subjects and the patients the voltage and amperage values were averaged. Therefore, there were 4 average voltage and amperage values for each subject. This is illustrated in Fig. 2 (a, b).

Water accounts for approximately 60% of the body weight. From an electrochemical perspective, it has ion solvent properties, allowing the ions to exteriorize their charge, thus transforming them into electrolytes. The blood plasma consists of 90% water (G. MANOLE [4]). The ions and molecules that are present in the plasma form ion-dipole bonds with the water molecules (G. MANOLE [4], V. VASILESCU [10]). The quantitative distribution of these electricity carriers is described, comparing the intra-cellular and the extracellular space in Table 1. The unequal distribution and the electrical fields of the ions and molecules (such as proteins) are due to the presence of the separating membranes.

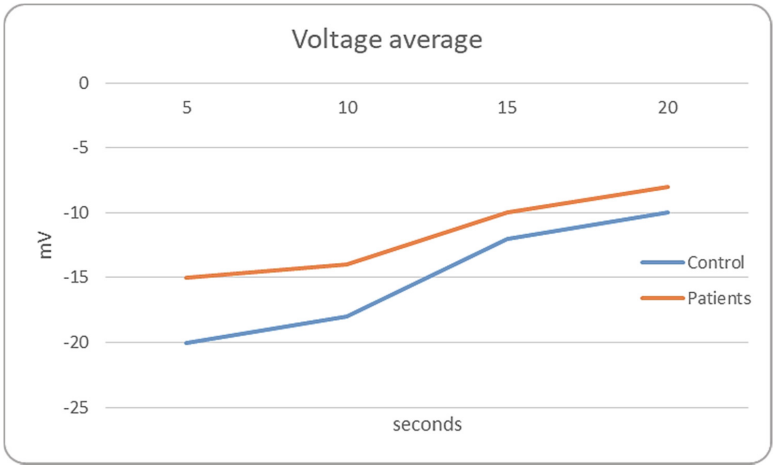
In the healthy organism, proteins are found both extracellularly (in the interstitium, but also intravascularly) and intracellularly, where their presence is significantly higher (2.8 times). Their electrical charge is influenced by their quantity and by their pH. Therefore, we also included the plasma pH in our laboratory tests.

In an aqueous solution, such as plasma, the serum proteins work as electrolyte ampholytes. The $^{-}$COOH group provides them with buffer properties as follows:

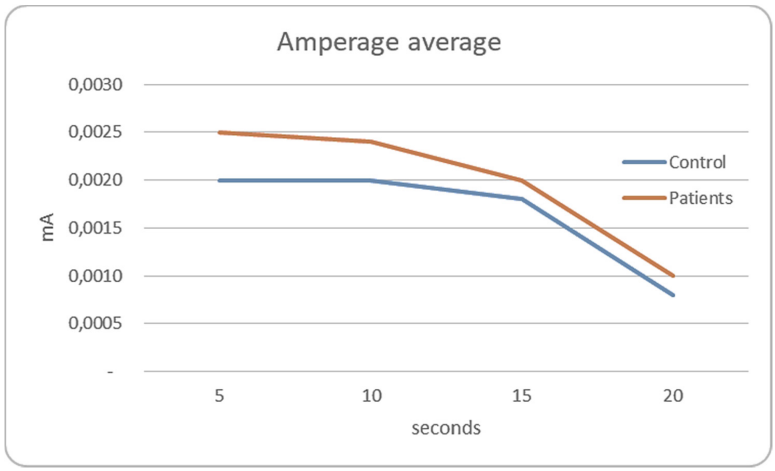
a. Aminoacid + H_2O → HO^-

b. Aminoacid -dissociation → H^+ (V. VASILESCU [10]).

In current medical practice, a disease is diagnosed based on the values of blood constituents, which are a result of the membranar exchanges between the intracellular



a. The 4 determinations of the average voltage obtained at 5 seconds interval for the two patient sublots – control (blue) and patients (red).



b. The average amperage obtained at 5 seconds interval for the two patient sublots – control (blue) and patients (red).

Figure 2. The graphical aspect of the average voltage values and the potential of the electrical potentials at the level of the blood samples collected from the all subjects co-opted in this study.

space and the interstitium, which lead to indirect data about the functional state of organs (G. MANOLE [4], B.I. COCULESCU & al. [11, 12]). The device that measures the electrical potential of blood is based on the fact that the polarisation of the cellular membrane has a tight relation with the cellular functions, which applies to all living organisms. During resting state, membranes have positive charges on the outside and negative charges on the inside (cytoplasm), and when the cell is excited, the activity changes. These resting state and action electrical transmembranar potentials are generated due to the diffusion of ions from the interstitium through the cellular membrane into the intracellular space depending on the information received by the cell (G. MANOLE [3,4]).

Both physico-chemical and biological factors contribute to the polarisation of membranes. These factors are

dependent on the composition, concentration, and the electrical charge of the substances in the interstitium and in the cytoplasm, where the metabolic activity takes place. The control over water and electrolytes depends on the biochemistry of the membranes, which have a trilaminate structure that features permeable lipo-proteic complexes (G. MANOLE [3], C. BĂLĂEȚ & al. [6], J.P. MORUCCI et al. [13]), as show in Fig. 3.

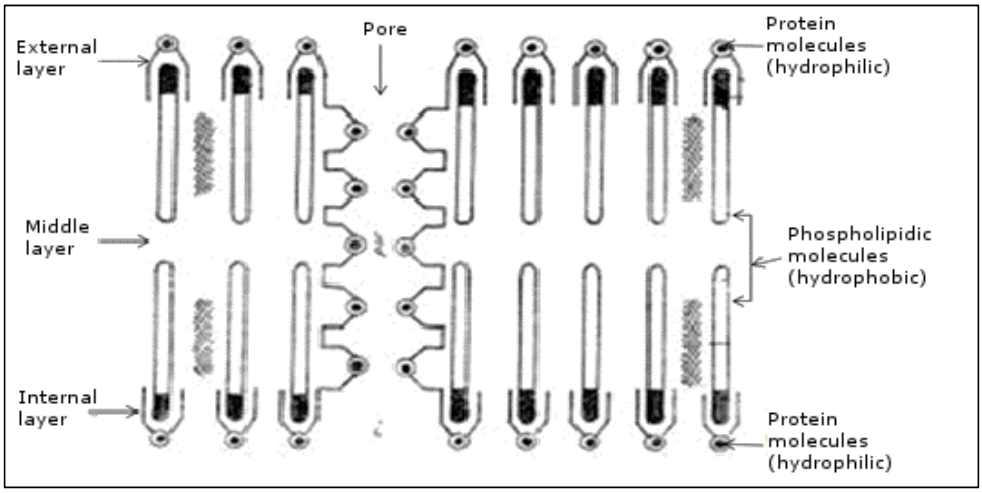


Figure 3. Schematic structure of the cellular membrane (I.C. VOICULESCU & I.C. PETRICU [14]).

The exchange between the interstitium and the cellular environment is possible due to membrane proteins which act as:

– permissive channels for ions, which allow the transport of small ions and molecules;

– carrier proteins which allow the transport of proteins through ligation and spatial conformation modifications, thus leading to facilitated diffusion (G. MANOLE [5], M.E. PĂTRUȚ & al. [15]).

These exchanges which come as a result of cellular metabolism, directly influence the electrical field (M.E. PĂTRUȚ & al. [16]). This is an adaptive process, with the final goal of ensuring the viability of the organism, which functions due to the cumulative activity of each individual cell. Although the cellular metabolic activity varies, the potential electric is constant between the interior and the exterior. The exchange flux contributes to maintaining an equilibrium between the two mediums (Gibss-Donan equilibrium). At organ level, the biocurrents generate bioelectricity, which is the principal modulator of cellular metabolism, and it is dependent on the intensity of the information this receives (G. MANOLE [3, 4], C. BĂLĂEȚ & al. [6], M.E. PĂTRUȚ & al. [16]).

Blood contains circulating elements (erythrocytes, leucocytes, thrombocyte fragments) and plasma. The presence of molecules and atoms, which generate electric current by undergoing H movement, is common to all components. Thus, for each cellular and plasmatic component there is an electrical charge, which could be described as a vector. Therefore, the blood components will express as a set of vectors illustrating the electrical potential, where each vector corresponds to a different component. The electrical potential is, in other words, a system of charges. The charges are spatially overlapping, leading to the summation of the potentials, and eventually to a local electrical field. This is possible because blood has a laminar flow, which translates as the uniformity of physico-chemical properties and electrical potential, for the reason that at the level of each branch of the vessels, the outer layer becomes internally and inversely (G. MANOLE [3],C. BĂLĂEȚ & al. [6],V. VASILESCU [10],M.E. PĂTRUȚ& al. [16]).

Based on these facts we could infer that the diseases which lead to structural modifications (quantitative or qualitative) of the blood components, also lead to modifications in the electrical potential of blood.

In our study, we illustrate that depending on the health status:

a) healthy subjects had an electric potential that fits within a delimited time frame;

b) patients had an electric potential whose values could indicate the presence of a disease (see Figure 3). We explain these values by correlating the electrical potential values with those of the haematocrit, blood cells counts, electrophoresis of serum proteins and tumour markers (ACE, CA242 and CA50).

1.2. The importance of correlating the electrical values of blood with the haemoleucogram

The blood has a laminar flow due to the electrostatic rejection forces that are present between its cellular components, especially those between erythrocytes.

The suspension of elements in the plasma is dependent on the blood viscosity, and this directly influences the electrical potential of blood. Normal blood viscosity is present in normocytic, normovolemic blood. For example, the 5 patients, anaemia, although normoblemic, generated oligocytemia, which then influenced the velocity of the blood flow via influencing the blood viscosity.

Differences in viscosity are created by differences in the amount of cellular components present in the blood, which also lead to electrostatic changes which could explain our results.

1.3. The importance of correlating blood bioelectricity characteristics with the characteristics that change the plasma composition

The modification of the plasma chemical composition can influence the electrical field of blood, both quantitatively and qualitatively.

Circulating proteins, an oncotic-osmolic component and amphothere substance, are involved in generating the values of the electrical potential of blood, through their concentration and through the rapport they have with its different fractions. Therefore, the euproteinemia, hipo or hyperproteinemia, as well as disproteinemia, could induce the modification of blood bioelectricity. These values have to be correlated with the voltage and amperage. One example of events that could lead to such outcomes is inflammation, where disproteinemia, hyperfibrinogenmia and circulating inflammatory markers are circulating (C. BĂLĂEȚ & al. [2]).

Moreover, neoplasm like modifications, which feature changes in proteins (C. BĂLĂEȚ & al. [2]), lead to the apparition of novel electrical charges which interfere with the normal blood components.

In conclusion, the disease states that are characterised by quantitative modifications of circulating proteins, modify the electrical field of the blood in comparison with the one in the healthy state. This could be due to plasmatic coloids, proteins, which decrease the electrostatic rejection forces between the circulating elements, especially those between erythrocytes, despite the presence of an anticoagulant. This happens because the circulating elements are present in a hyperviscous environment, which slows down the movement of electric charge carriers.

1.4. Other possible utilities of the blood bioelectricity for the medical practice

The results of determining the characteristics of the blood bioelectric field allow us to infer that it is possible to establish a standard healthy interval of voltage and amperage of blood. Determining this interval in health and disease, we believe we could offer medical practice a parameter that could be use for population screening that is affordable and easily determined. It is necessary to support the continuation of this study, so further subjects could be employed in our statistical analysis and predictive values obtained. Obtaining standard intervals for fresh blood, but also for blood that has been provided hours or days before the test could offer us important data that could aid the development of therapies. At the same time, we could obtain valuable data about individual blood components, and about how blood changes with time after it has been provided by the patient, which could be crucial for transfusions. Moreover, blood bioelectricity could be used in the study of haemorheology, and corroborated with the study of how medications impact the quality of blood (I.M. APETREI & al. [17], H. ZARE & al.[18]).

Medical literature confirms that neoplasms lead to haemological changes that impact the chemistry of plasma. We could speculate that this disease could be identified early with the blood bioelectricity method.

Conclusions

There are no other studies that have ever recorded the bioelectric potential of blood, or have speculated about such a process being used in the routine medical practice. The present study pioneers such research. Our method could be extremely useful in medical practice, since it is very reproducible even at industrial scale, and financially affordable from the construction to the usage phase. The investigation allows population screening, and could provide very valuable information about the health status

of a patient. Not only it would greatly aid diagnosis, but it could also be applied in zoology and plant biology.

Although we only measured the blood bioelectricity for 5 patients and 30 healthy controls, we can confirm that we saw a significant change in the bioelectric potential in the disease state. We can hypothetically infer that each disease could have its own bioelectric value ranges, and those could differ with its evolution stages.

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