


Sodium, potassium and calcium analysis by means of electrical bioimpedance in patients with ischemic heart disease and coronary artery bypass graft surgery

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Competing interests

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Acronyms

EBI: electrical bioimpedance

ABSTRACT

Introduction: Heart diseases lead Cuban health statistics as one of the main causes of death with predominance of ischemic heart disease. Traditionally, in Cuba the plasma electrolyte concentrations is determined by standardized ions and blood gases analysis. But there are other methods such as electric bioimpedance which measures the total amount of main ions of organic liquids, and provides more real information about the concentrations of these electrolytes in the human body.

Objective: To determine the values of total exchangeable body sodium and potassium electrolytes by bioelectrical impedance before and on the seventh day of surgery, and compare them with a reference population.

Method: A longitudinal and prospective study was carried out with 42 patients aged 40 and over with ischemic heart disease, from both sexes, treated with coronary artery bypass grafting without extracorporeal circulation at the "Centro Territorial de Cirugía Cardiovascular de Santiago de Cuba" in the first four months of 2015. Bioimpedance measurements were made at 50 kHz, using the right-sided tetrapolar method. The parameters were studied according to sex, age groups and electrolyte values.

Results: A decrease in interchangeable sodium (2984.98 ± 426.3 vs. 3349.7 ± 805.0 mmol) and potassium (3076.75 ± 265.06 vs. 3251.3 ± 593.85 mmol) was found before surgery. In the postoperative period, the values obtained for exchangeable sodium (3097.5 ± 447.29 mmol, $p < 0.05$) were statistically significant.

Conclusions: Before and after surgery, the electrolytes studied showed values below the standards, although this variation was not always significant.

Key words: Ischemic heart diseases, Sodium, Potassium, Calcium, Electrical bioimpedance

Análisis de sodio, potasio y calcio por bioimpedancia eléctrica en pacientes con cardiopatía isquémica y cirugía de revascularización miocárdica

RESUMEN

Introducción: Las enfermedades del corazón encabezan las estadísticas sanitarias cubanas como una de las principales causas de defunciones, con predominio de la cardiopatía isquémica. Tradicionalmente, en Cuba se determina la concentración

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plasmática de los electrolitos por métodos ionogasométricos estandarizados, pero existen otros métodos como la bioimpedancia eléctrica que mide la cantidad total de los principales iones de los líquidos orgánicos, y brinda una información más real sobre las concentraciones de estos electrolitos en el cuerpo humano.

Objetivo: Determinar por bioimpedancia eléctrica los valores de los electrolitos calcio corporal total, sodio y potasio intercambiables antes y al séptimo día de la intervención quirúrgica, y compararlos con una población de referencia.

Método: Se realizó un estudio longitudinal y prospectivo con 42 pacientes de 40 y más años de edad, con cardiopatía isquémica, de ambos sexos, tratados mediante cirugía de revascularización miocárdica sin circulación extracorpórea en el Centro Territorial de Cirugía Cardiovascular de Santiago de Cuba, en el primer cuatrimestre de 2015. Las mediciones por bioimpedancia se realizaron a 50 kHz, mediante el método tetrapolar ipsilateral derecho. Los parámetros fueron estudiados según sexo, grupos de edad y valores de los electrolitos.

Resultados: Se encontró una disminución del sodio ($2984,98 \pm 426,3$ vs. $3349,7 \pm 805,0$ mmol) y el potasio ($3076,75 \pm 265,06$ vs. $3251,3 \pm 593,85$ mmol) intercambiables antes del acto quirúrgico. En el período postoperatorio, los valores obtenidos de sodio intercambiable ($3097,5 \pm 447,29$ mmol; $p < 0,05$) resultaron estadísticamente significativos.

Conclusiones: Antes y después de la cirugía, los electrolitos estudiados mostraron valores por debajo de los estándares, aunque no siempre esta variación resultó significativa.

Palabras clave: Cardiopatía isquémica, Sodio, Potasio, Calcio, Bioimpedancia eléctrica

INTRODUCTION

For more than four decades, heart disease has led Cuban health statistics as one of the leading causes of death, with predominance of ischemic heart disease¹. Currently, Coronary artery bypass graft surgery is a cornerstone in the treatment of people affected by these conditions, as well as the most commonly performed procedure in almost the entire world².

Among the modifications that occur in those suffering from these diseases, it is well known that surgery causes a negative nutritional balance, due to the increase in energy and somatic requirements required by the surgical intervention. In addition to the deficient diet, characteristic of immediate preoperative and postoperative periods. As a general rule, the greater the magnitude of the surgery, the greater the duration and depth of the metabolic response as a normal manifestation of the intervention³. However, as a surgical technique after all, although not as "aggressive" as when cardiopulmonary bypass is used, it requires-according to its technical principles and the characteristics and importance of the organ involved- the patients to be thoroughly studied beforehand, including some components of body composition such as the determination of different electrolytes, among other essentials. Traditionally,

in Cuba the plasma concentration of electrolytes is determined by standardized ionogasometric methods, which cannot always be used, among other factors, due to the lack of proper equipment, reagents and techniques, trained personnel and high costs^{4,5}. In addition to the methods already mentioned, there are others to measure the total amount of the main ions of organic liquids since they allow to quantify the so-called interchangeable mass of a certain ion and, therefore, provide more accurate information about the concentrations of these electrolytes in the human body.

All of the above justifies the efforts being made throughout the world, mainly in the underdeveloped countries to find precise and affordable methods allowing these determinations to be accurately performed. The electrical bioimpedance (EBI) is a feasible procedure since it is accurate, cheap, bloodless and accepted among patients⁶.

Ischemic heart disease, as a noncommunicable chronic disease, is a priority for the Cuban Ministry of Public Health. This condition has its genesis in the functioning of the heart where the ionic composition, especially the electrolytes and their concentrations is extremely important. For these reasons there was an urgent need to establish a diagnostic method like EBI, more advantageous than those used for these purposes so far, which led to conduct this

research.

METHOD

A longitudinal and prospective study was carried out to determine the total body electrolyte values by means of the EBI method in patients aged 40 and over, from both sexes, with ischemic heart disease, who underwent coronary artery bypass grafting without cardiopulmonary bypass in the "Centro Territorial de Cirugía Cardiovascular de Santiago de Cuba" from January to April 2015.

Experimental procedure

The patients underwent a first measurement before surgery, on the day of surgery. The records were made between 06:30 - 07:00 hours in a room heated to 23 degrees Celsius and with an environmental humidity of 60-65%, fasting from 21:00 the night before, with bladder emptied. Interrogation and physical examination were carried out by medical personnel, who measured height and body weight with a margin of error of 0.5 centimeters and 0.5 kilograms, respectively, using a SECA SC scale (Germany), calibrated, with coupled stadiometer. Body mass index ($BMI = kg/height^2$ in meters) was calculated with the weight and height results.

To measure the bioelectrical parameters, a BioScan 98 (BioLógica Tecnología Médica SL, Barcelona, España [<http://www.bl-biologica.es>]), was used, which was calibrated every day before the beginning and end of measurements with a device of known electrical values (phantom) for a reading error of $\pm 1\%$. The BioScan emits a current of 800 μA (microamperes), at a frequency of 50 KHz, through the distal electrodes; while the voltage drop (V) was detected by the proximal sensor electrodes according to Ohm's law.

The records were made in the supine position, without a pillow under the head, on a non-conductive surface, with arms separated from the thorax and legs slightly spread apart. Obese patients were placed a non-conductive cloth between their thighs. The electrodes were placed after cleaning the skin with alcohol and were placed, according to the right ipsilateral tetrapolar method, in the following positions:

- Stimulators, in the medial area of the dorsal surfaces of the hand and foot near the metacarpal and metatarsophalangeal joints.
- Sensors, between the distal epiphysis of the ulna

and the radius, at the level of the pisiform bone, as well as at the midpoint between both malleoli.

The distance between the stimulating electrodes and sensors was fixed, and not less than 5 cm. The record technique described corresponds to that recommended by the National Institutes of Health Technology Assessment Conference Statement (1994)⁷.

The second measurement was made in the post-operative period, on the seventh day after surgery, following the same steps explained above.

Statistical analysis

For the analysis of the information the statistical system SPSS v. 12.0 was used. The same statistical system was used to create the database, with the help of a third-generation Pentium 5 computer.

As a summary measure, the arithmetic mean (\bar{x}) and the standard deviation (SD) were used. The results obtained were reflected in tables to facilitate their compression and analysis.

The statistical data processing is detailed below:

The hypothesis test for the mean were carried out with a level of significance $\alpha=0.05$, and significant differences were considered when $p<0.05$.

To compare the average values of the biochemical variables of interest determined in the study, the averages of normal for both sexes of the apparently healthy (reference) population were taken as reference⁸.

To determine whether the estimated random variables (electrolyte levels) in the studied patients corresponded or not with a normal or Gauss probability distribution, the Kolmogorov-Smirnov test was applied for the goodness of fit.

The hypothesis that the mean level of the biochemical variables of the patients with heart disease studied, before and after the surgical intervention, was the same as that of the supposedly healthy (reference) population, was verified by the t-test⁸.

To verify if there were changes in the levels of the electrolytes studied, the paired differences test was used between the measurements before (pre-operatively) and the seventh (postoperative) day of the surgical intervention.

The intervals of the electrolyte values outside the expected in a population with ischemic heart disease were obtained by calculating the 95% confidence interval, calculated by $\pm ts/\sqrt{n}$, where t was taken in the table of the distribution t of Student with: $GL=n-1$ and $nc=95\%$, in which GL are the de

degrees of freedom and nc the level of confidence.

RESULTS

The male sex prevailed in the patients with ischemic heart disease studied. **Table 1** shows that in both sexes, those in the age groups 50 to 59, and 60 and over are predominant.

When evaluating the electrolytes analyzed in the preoperative period and comparing them with the values corresponding to supposedly healthy individuals (**Table 2**), significant differences were found

between sodium (2984.98 ± 426.3 vs. 3349.7 ± 805.0 mmol) and potassium (3076.75 ± 265.06 vs. 3251.3 ± 593.85 mmol) interchangeable, given by values diminished with respect to those previously established for a normal population at these ages.

Seven days after surgery, the exchangeable sodium values continued to decrease significantly in the patients with respect to the reference levels (3097.5 ± 447.29 mmol, $p=0.04$), but not those of the interchangeable potassium (3192.5 ± 250.8 vs. 3251.3 ± 593.85 , $p=0.17$) and total body calcium (9.2 ± 1.70 vs. 9.25 ± 1.31 , $p=0.8$), which did not show significant differences (**Table 3**).

Table 1. Patients according to age and sex.

Age (years)	Sex				Total	
	Male		Female		Nº	%*
	Nº	%*	Nº	%*		
40 – 49	3	8.4	1	16.7	4	9.5
50 – 59	20	55.5	3	50.0	23	54.8
60 y más	13	36.1	2	33.3	15	35.7
Total	36	100.0	6	100.0	42	100.0

* Percentages calculated by columns

Source: Data collection chart

Table 2. Descriptive values according to electrolytes in the preoperative period and significance of changes with respect to reference patterns.

Electrolytes (mmol)	Preoperative period (N=42; $\bar{x} \pm SD$)	Reference (N=1080; $\bar{x} \pm SD$)	t	p
Exchangeable sodium	2984.98 ± 426.3	3349.7 ± 805.0	2.9	0.0036
Exchangeable potassium	3076.75 ± 265.06	3251.3 ± 593.85	3.9	0.0002
Total body calcium	9.01 ± 1.48	9.25 ± 1.31	1.03	0.3

SD, standard deviation

Table 3. Descriptive values according to electrolytes in the postoperative period and significance of changes with respect to reference patterns.

Electrolytes (mmol)	Postoperative period (N=42; $\bar{x} \pm DE$)	Reference (N=1080; $\bar{x} \pm DE$)	t	p
Exchangeable sodium	3097.5 ± 447.29	3349.7 ± 805.0	2.02	0.04
Exchangeable potassium	3192.5 ± 250.8	3251.3 ± 593.85	1.37	0.17
Total body calcium	9.2 ± 1.70	9.25 ± 1.31	0.23	0.8

SD, standard deviation

Table 4. Significance of electrolyte changes in the pre and postoperative periods.

Electrolytes (mmol)	Preoperative N=42; $\bar{x} \pm SD$	Postoperative N=42; $\bar{x} \pm SD$	t	p
Exchangeable sodium	2984.98 \pm 426.3	3097.5 \pm 447.29	-5.804	<0.001
Exchangeable potassium	3076.75 \pm 265.0	3192.5 \pm 250.80	-6.5	0.01
Total body calcium	9.01 \pm 1.48	9.2 \pm 1.70	-0.5	0.58

SD, standard deviation

When analyzing the electrolyte values before and after the surgery in the selected patients (**Table 4**), the levels of all electrolytes increased, although only significant differences were exchangeable sodium ($p < 0.001$) and potassium ($p = 0.01$)

DISCUSSION

Age and sex are demographic variables that influence the onset of conditions suffered by the members of this casuistry^{2,10,11}. Our results coincide with the literature, where the predominance of patients aged 50-59 years with ischemic heart disease is considered, followed by those aged 60 and over which corresponds to that described in other investigations¹⁻¹⁴, where it is stated that ischemic heart disease usually appear at these ages.

The prevalence of men can also be appreciated, a finding that agrees with the universally accepted. Males are the most affected by ischemic heart disease, which is attributable to a greater tendency to be exposed to risk factors, such as smoking and alcohol consumption¹³⁻¹⁵.

The findings regarding reduced values of interchangeable sodium in the preoperative period could be explained by the fact that hyponatremia is the most frequent electrolyte disorder in about 30% of patients hospitalized in critical areas, with a high rate of deaths, as well as up to 40% of those admitted to intensive care units, which makes it an independent variable associated with morbidity and mortality¹⁶. The cause of hyponatremia could perhaps be attributed to the sustained use of diuretics to prevent oedemas, which reduces the reabsorption of sodium in the renal tubules, and causes natriuresis^{17,18}.

A possible explanation of the results regarding the reduction of interchangeable potassium in these patients during the preoperative period could be a consequence of renal disorders, diarrhea, consumption of antibiotics or diuretics¹⁸. The latter is consid-

ered the probable cause of our investigation results.

The values of interchangeable potassium in the pre-and postoperative states could be due to the period of catabolism that begins with the operation and to the change due to anabolism, described as the phase of extraction of corticosteroids to be identified through a free-water spontaneous sodium diuresis, a positive potassium balance and a decrease in nitrogen excretion; a transitional interval that will last from one to two days. In this context, according to Marín *et al.*¹⁵ and other authors¹⁹, the patient enters a prolonged period of early anabolism and weight gain.

CONCLUSIONS

Before and after surgery, interchangeable sodium and potassium showed values below the standards, although this variation was not always significant, especially in the postoperative period, when a tendency towards normality was observed. Calcium did not have a significant difference with the reference population, nor between pre and postoperative in patients with ischemic heart disease in this study.

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