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Resistance and reactance in patients undergoing coronary artery bypass

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Abstract

Purpose: **The purpose of this study was to evaluate the effect of different surgical variables, such as perfusion duration and number of grafts, on resistance and reactance, in heart surgery patients.**

Methods: **77 patients submitted to coronary artery bypass were studied. The variable concerning time of extracorporeal circulation was classified in four progressive degrees. Resistance and reactance measurements were performed and compared to time of extracorporeal circulation and to number of grafts. Ten measurements were performed by bioelectrical impedance equipment.**

Results: **The comparison of reactance before surgery to the first measurement at the first postoperative day, for the different times of extracorporeal circulation, showed decrease (p = 0.01). Regarding gender, resistance and reactance showed significant differences (p < 0.001). There was also significant difference (p = 0.001) for the number of grafts.**

Conclusion: **The decrease of resistance and reactance is related not only with surgery procedure, but also with the number of grafts and time of extracorporeal circulation.**

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Keywords: *Coronary artery bypass. Extracorporeal circulation. Reactance. Resistance. Surgery.*

RESISTENCIA Y REACTANCIA DE LOS PACIENTES SOMETIDOS A CIRUGÍA DE REVASCULARIZACIÓN CORONARIA

Resumen

Objetivo: **El objetivo de este estudio fue evaluar el efecto de diferentes técnicas quirúrgicas, tales como la duración de perfusión y el número de injertos, sobre la resistencia y la reactancia en pacientes sometidos a cirugía cardíaca.**

Métodos: **Fueron incluidos 77 pacientes remitidos para bypass de arteria coronaria. La variable referente al tiempo de circulación extracorpórea fue clasificada en cuatro grados. Se midió la resistencia y la reactancia y se comparó con el tiempo de circulación extracorpórea y con el número de injertos. Se hicieron 10 mediciones con un equipo de impedancia bioeléctrica.**

Resultados: **La comparación de la reactancia antes de la cirugía con la primera medida el primer día de postoperatorio en los diferentes tipos de circulación extracorpórea mostró una disminución (P = 0,01). En cuanto al sexo, la resistencia y la reactancia mostraron diferencias significativas (P < 0,01). Hubo también una diferencia significativa (P = 0,01) en la relación con el número de injertos.**

Conclusión: **La disminución de la resistencia y de la reactancia está relacionada no solo con el procedimiento quirúrgico sino también con el número de injertos y con el tiempo de circulación extracorpórea.**

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Palabras clave: *Bypass, arteria coronaria. Circulación extracorpórea. Cirugía. Reactancia. Resistencia.*

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Introduction

Coronary artery bypass, as every large surgery, determines metabolic and hormonal alterations. Tissue catabolism is accelerated and characterised by increase in muscular proteins. Glycogen reserves and fats are mobilised for new protein synthesis source and energetic supply. There is also an increase in the releasing of catecholamines, cortisol, insulin and glucagon that act as inductors in the catabolic reactions[1-3]. Cardiac surgery may require the help of extra-corporeal circulation, sometimes with total cardiac and circulatory arrest and hypothermia. Blood contact with a non-endothelial surface can activate several components of immunology response, such as macrophages and polimorphonuclear leukocytes, as well as the release of inflammatory mediators that expose the patient to a general inflammatory response. These conditions, particularly when the function of cellular membrane is altered, can lead to significant changes in vascular temperature and permeability, besides the alteration in the distribution of intra and extra-cellular fluids, even if transitorily[4-8].

The crossing of an electrical current through the body allows the perception of membrane disturbs. The technique for such measurement is known as bioelectrical impedance analysis (BIA)[9, 10].

BIA is a non-invasive, rapid and sensible method, based on the passing of a low amplitude electrical current (500 to 800 mA) with high frequency (50 kHz), which permits to measure resistance (R), reactance (Xc), impedance (Z) and phase angle (ø)[10, 11].

The reactance reflects the dynamic performance of the cellular membrane structure. Fat-free mass, by containing a large quantity of water and electrolytes, is good conductor of electrical current, thus presenting low resistance. On the other side, fat and bone are not good conductors, by having a smaller quantity of fluids and electrolytes and larger electrical resistance. Resistance is inversely proportional to the quantity of fluids[11].

The most important elements of the tissue structure are the size and the volume of the cell, the membrane capacitance and also the conductivity of the intra and extra-cellular environment.

BIA have been used initially with success in stable ambulatory patients and successively in special situations such as hemodialysis[12, 13], AIDS[14], hepatopathyes[15], diabetes[16], cancer[17], surgical interventions[18], and intense physical activity[20], for the evaluation of corporeal composition through predictive equations. Presently, the use of BIA is being studied in critically ill patients, using R and Xc, avoiding the use body weight and additional anthropometric data, to measure hydric distribution in both intra and extra-cellular environments and, indirectly, the cellular function[21-24].

The present study is justified taking into consideration the interest in a new tool with adequate characteristics of sensibility and specificity, which is capable of following the evolution of critical patients rapidly, by patient's bed and with low operational costs. Once BIA is being used to evaluate the changes of water contents and the changes of intra and extra-cellular compartments, there is interest in researching the effectiveness of this method when detecting R and Xc alterations, which would reflect the dynamic performance of the cellular membrane structure.

Our purpose, in patients candidate to coronary artery bypass, was to study the impact of different surgical variables on R and Xc and to verify the response of R and Xc variables during the period.

Methods

The proposed study was performed in 77 patients candidate for coronary artery bypass, being 33 female (42.86%) and 44 male (57.14%), aged over 18 years old, with previous approval by the Ethics Commission. A signed informed consent was obtained from all patients.

Only patients scheduled for elective surgery, without associated clinical diseases, were enrolled.

Exclusion criteria included patients aged under 18 years old, submitted to coronary artery bypass in the last 12 months, carriers of cardiac insufficiency grade III or IV, renal insufficiency, diabetes mellitus, neoplasia, acquired immunodeficiency syndrome, in chronic use of corticoids and those that presented amputation of either lower or superior limbs.

BIA was performed in the pre-operative period (immediately before surgical intervention), in the immediate post-operative period (up to 2 hours after surgery), and then daily, 2 times a day, in the morning (before breakfast) and in the afternoon (before dinner), until the fourth post-operative day.

The variable duration of perfusion was classified in 4 levels, each of the limits corresponding to the quartiles of the sample as follows: level 0: ≤ 60 minutes; level 1: > 60 and ≤ 70 minutes; level 2: > 70 and ≤ 90 minutes; level 3: > 90 minutes.

BIA was always performed, using RJL Systems Quantum BIA-101Q equipment, by the same attendant, with the patient lying in dorsal decubitus, being the head in the same direction of the body, limbs apart enabling hands to be open, avoiding the same to touch the body and also avoiding right leg to touch left leg. Two electrodes were placed on the left foot (the distal electrode at the basis of medium toe and the proximal electrode slightly over the articulation of the ankle, between medial and lateral malleolus) two on the left hand (the distal electrode at the basis of medium finger and the proximal electrode slightly over the articulation of the wrist, coinciding with the styloideus process). The measurement lasted approximately 5 seconds and was taken 3 consecutive times, being obtained the arithmetic average.

With the assistance of the software STATA 5.0[25] the following statistical methods were employed: 1) descriptive analysis: the figures obtained were described in terms of average, standard-deviation, minimum and maximum value and expressed in frequency curves whenever necessary; 2) modelling of response variables: the variables were studied as an average of two daily measurements, once the differences between morning and afternoon were not expressive; 2.1) analysis of variance (ANOVA)[26] was used to test the differences of the average between groups of comparison (grafts, duration of perfusion and gender) of recovery measurements (differences between pre-operative and post-operative resistance and reactance measurements). For each individual, the measurement value of R and Xc obtained at immediate post-operative and at first measurement of first post-operative day was subtracted from the value obtained at pre-operative. This difference was named decrease of R or decrease of Xc; 2.2) analysis of multivaried covariance (MANCOVA)[26] was employed to compare the profile of repeated measurements of resistance and reactance through polynomial adjustment. This method enables to detect the differences in the general averages of the profiles as well as the differences in the tendencies (recovering speed) represented in the interaction parameters of the model employed, controlling the adjustment for a confounding co-variable, in this particular case, the pre-operative measurements which reflect the condition of the patient in the beginning of the study.

A significance level of 0.05 or 5% was assumed in all tests.

Results

The consecutive assessments of R and Xc presented a statistically significant decrease ($p < 0.001$) between the measurement of R and Xc at pre-operative and at immediate post-operative and also between the measurement of R and Xc at pre-operative and in the first morning after post- operative. From this moment and until the end of the study, the electrical resistance remained inferior if compared with the results of pre-operative (figure 1 and 2).

In order to understand the response of electrical measurements of R and Xc, it was studied the distribution of further variables considered as an explanation of phenomenon to be investigated (number of grafts and duration of perfusion) together with control variables (gender and age).

In this population there was a prevalence of male individuals (57.14%).

The average age was 58.84 ± 9.34 years old, being 39 years old the minimum value and 79 years old the maximum value. Patients presented a normal distribution regarding the age.

The number of grafts to which patients were submitted was divided evenly between two and three grafts.

The modelling of response variables (R and Xc) followed the same procedure for three explanatory variables (gender, number of grafts and duration of perfusion), that were studied in comparison of pre-operative versus immediate post-operative and pre-operative versus first post-operative day.

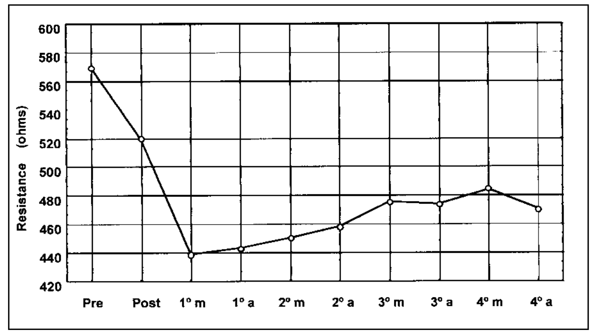

Fig. 1.—Graphic representation of resistance during different periods of pre and post-operative valuation.

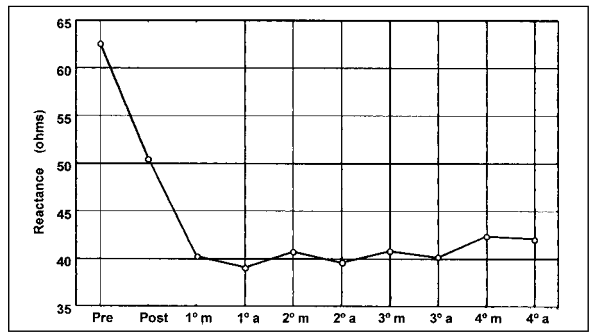

Fig. 2.—Graphic representation of reactance during different periods of pre and post-operative valuation.

Just the comparison of the decreasing of Xc between pre-operative and first morning after post operative, regarding the different duration of perfusions, revealed a statistically significant difference ($p = 0.01$) between a duration of perfusion ≤ 60 minutes and > 90 minutes (table I).

Considering gender, the multivaried comparison of the measurements of R and Xc has not detected significant differences ($p = 0.12$ and $p = 0.91$ respectively) in any moment of the study. Notwithstanding, the quadratic profile ($p < 0.001$) for R and Xc and the interaction ($p = 0.04$) for R indicated significant differences between the two curves (figure 3 and 4).

The averages of R and Xc were performed in all periods and classified in two groups: patients with two grafts and patients with three grafts. The averages did not present significant differences between the two groups in any moment of the study. Notwithstanding, the analysis of the quadratic profile indicated a statis-

Table I

Mean, standard deviation and frequency of the decreasing of reactance, regarding the different duration of perfusions

ECCt (n)	*Mean*	*SD*
0 (14)	18.86	11.93
1 (20)	25.25	7.97
2 (22)	20.36	7.25
3 (21)	25.43	9.77

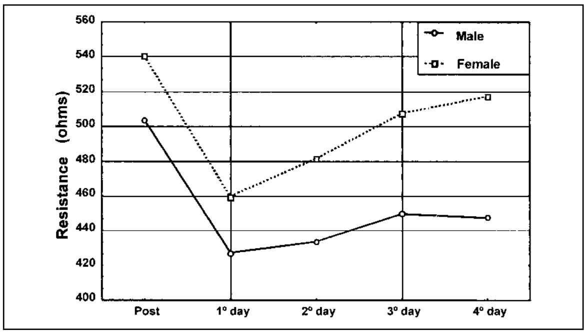

Fig. 3.—Graphic representation of the multivaried comparison of means of resistance regarding sex during different periods of post-operative.

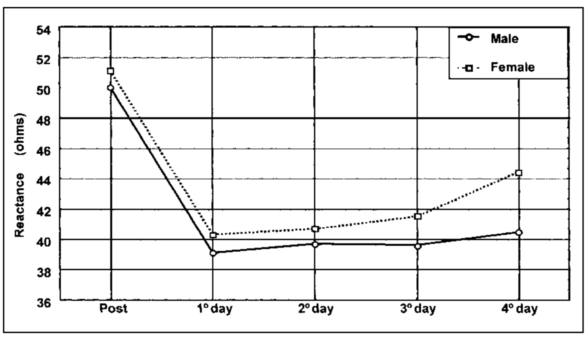

Fig. 4.—Graphic representation of the multivaried comparison of means of reactance regarding sex during different periods of post-operative.

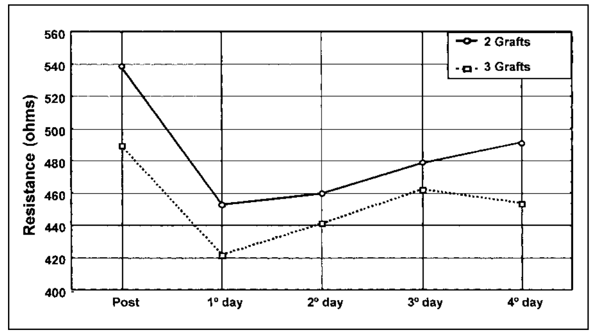

Fig. 5.—Graphic representation of the multivaried comparison of means of resistance regarding number of grafts during different periods of post-operative.

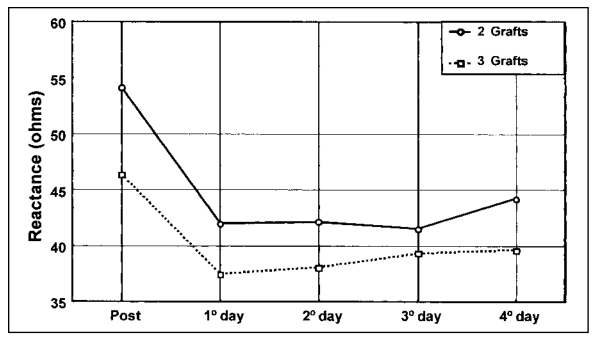

Fig. 6.—Graphic representation of the multivaried comparison of means of reactance regarding number of grafts during different periods of post-operative.

tically significant difference ($p < 0.001$) according to the number of grafts (figure 5 and 6).

The comparison of the decreasing of R and Xc between patients submitted to a larger duration of perfusion (> 90 min.) and those submitted to perfusions of 60 minutes or less presented, in all periods, a statistically significant difference ($p = 0.008$ and $p = 0.006$ respectively). The analysis of the quadratic profile has also presented a significant difference ($p < 0.001$). The interaction has not shown a significant difference (figure 7 and 8).

Discussion

The measurement of trauma intensity and metabolic aggressions, as well as the assessment of the hydro-electrolytic and tissue losses are points of medical concern[3]. The present study is characterised by using of the bioelectrical conditions of human body to verify the response to a defined stress.

The crossing of an electrical current through the cell depends on its frequency, once cellular membranes are bad electricity conductors but good capacitors. Under low frequency current, there is not good electrical cellular conduction and current flows mainly through extra-cellular spaces. Under high frequency, electric current passes immediately through cellular membrane[11].

R varies inversely to body hydro-electrolytic content and degree of hydration. R serves as practical parameter and as an indication of hydric balance, results of dialytic methods and the action of drugs and substances that modify the hydric balance in the different compartments. Low resistance values are typical of situations that develop with volume overcharge, such as renal insufficiency, cardiac insufficiency and ascites. In the other hand, high resistance values denote a lower volume of water, as exemplified in dehydration. Besides the relation between resistance and body water volume, it has been demonstrated that the electrolytic composition and the osmolarity of organic liquids are inversely related to resistance[11, 27].

A long hyper-hydration situation is prejudicial to protein synthesis, and can explain the difficulty in obtaining the positive nitrogen balance in hyper-catabolic patients with progressively positive hydric balance, a condition that is frequently observed in patients with sepsis. The monitoring of resistance can be very important in this particular clinical situation[11, 28].

Reactance reflects the dynamic performance of biologically active structure, the body cell mass. Its clinical meaning is not yet completely clarified and interpreted, but its linked to the fluid state of cellular membrane, its complex biochemical activity and its capacity to store energy[9, 11, 29].

Cardiac surgical interventions, particularly coronary artery bypass, are large surgical procedures that require extra-corporeal circulation, blood and other fluids transfusion. These procedures, considered to-

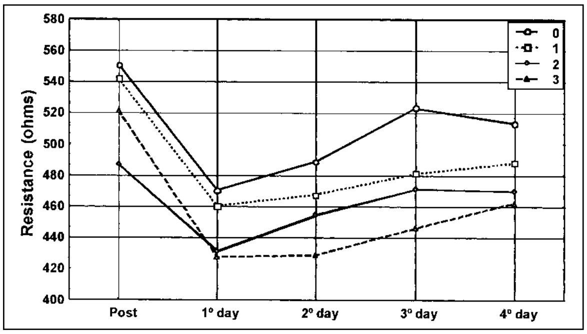

Fig. 7.—Graphic representation of the multivaried comparison of means of resistance regarding duration of perfusion during different periods of post-operative.

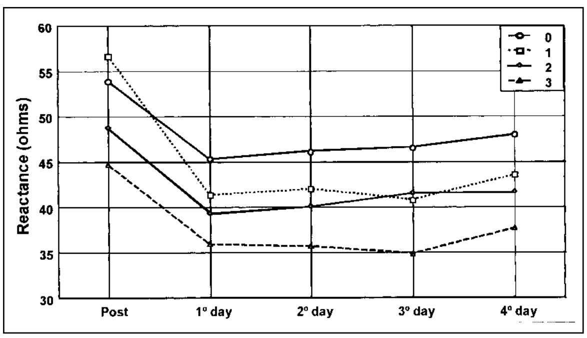

Fig. 8.—Graphic representation of the multivaried comparison of means of reactance regarding number of grafts during different periods of post-operative.

gether with body temperature and vascular permeability changes, can alter intra and extra-cellular fluids distribution and promote electrolytic disturbs, even if transitorily. The metabolic response originated from surgical trauma and the manner it is handled can forward the changes in the permeability of cellular membrane[6, 7].

Coronary artery bypass is a cardiac surgery performed under precise indication, in a standardised manner and according to technical protocols. The variables implied in coronary artery bypass, such as number of grafts and duration of perfusion, enable to qualify and quantify the stress degree of this procedure. Consequently, coronary artery bypass groups encompass conditions to be a good model for the study of bioelectrical modification during pre and post-operative periods.

The methodology of present research comprised the sequential measurement of resistance and reactance bioelectrical variables in the pre and post-operative periods of coronary artery bypass. The measurements of bioelectrical variables were divided in periods which comprehended the surgical event (pre- operative and immediate post-operative) and the usual post-operative evolution in coronary artery bypass, which includes discharge from intensive care unit in the second day of post-operative, with resuming of oral ingestion and physical activities.

The variable gender deserved special attention in present study once women present a larger resistance due to larger fat mass[30].

It was observed that R and Xc decreased in 23% and 37% respectively, in the first 24 hours of coronary artery bypass post-operative. The surgical intervention provoked a decrease of the two variables, independent by gender, number of grafts and duration of perfusion. These data agree with previous observations. Meguid[19], measuring R and Xc in nine patients submitted to coronary artery bypass, found decrease of 28% and 40% respectively. In a study performed by Franchi 31 in 20 patients submitted to cardiac surgery, the decrease of R and Xc in the first 24 hours of post- operative was respectively 17% and 29%.

It is possible that the decrease of R and Xc is caused by the surgical trauma of coronary artery bypass associated to the presence of extra-corporeal circulation. In this sense, the bioelectrical variables were tools for the evaluation and measurement of trauma and its response. Reinforces this point of view the fact that, in this research, reactance suffered significant decrease, directly related to duration of perfusion.

The statistical analysis did not identify changes in the bioelectrical variables (R and Xc) during the first days of the post-operative period (until the fourth day of post operative). Similar results were reported by Meguid[19] and Franchi[31]. Apparently, hydric alterations and cellular membrane alterations occurred because of coronary artery bypass are recovered later than the fourth post operative day. Although there was no statistical difference, in absolute values, when one observes the quadratic profiles of the curves for the multivaried analysis, one can note that there are significant differences in terms of the recovery of bioelectrical variables in the group of patients that received less grafts and had shorter duration of perfusion under extra-corporeal circulation.

It is possible that a longer observation of post-operative days enables to identify the reflection point of bioelectrical variables recovery.

The present study has shown a different response between men and women in concerning the profile of R curves. Women presented a higher recovery rate than men.

BIA has been broadly used in the evaluation of corporeal composition. Recently, bioelectrical variables are being valued in the care of critical patients and their clinical evolution. The monitoring of R and Xc revealed larger decreasing of bioelectrical variables in patients with sepsis that died than patients discharged from intensive care unit[21-24].

Large surgical interventions are not exempt of morbidity and mortality. It is observed that patients in the intensive care unit can be divided in two groups: those with good immediate evolution and those presenting complications. Patients presenting complications can recovery or further succumb.

For the prognostic evaluation of the evolution of critically ill patients it is available nowadays a series of rates such as APACHE (Acute Physiology and Chronic Health Evaluation) II, APACHE III, SAPS (Simplified Acute Physiology Score System) and MPM (Mortality Probability Model)[32]. Nevertheless these rates require several laboratory exams, which demand time and special calculation.

The sequential and consecutive employment of bioelectrical variables (R and Xc) if compared to the prognostic rates available nowadays could became a new useful tool for attending critically ill patients.

Considering the conditions that the present study was performed and when verifying the bioelectrical variables in pre and post-operative of coronary artery bypass, one can conclude that: electric resistance and reactance decrease with surgical intervention; the decrease of bioelectrical variables (R and Xc) is directly related to the intensity of trauma; the recovery of bioelectrical variables (R and Xc) is not immediate and can endure until the fourth post-operative day.

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