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ORIGINAL ARTICLE

Correlation between Exercise Stress Test and Echocardiographic Parameters in Elderly Individuals

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Abstract

Background: Maximum oxygen consumption (VO_2 max) in healthy individuals decreases approximately 10% per decade of life, and such decrease is more pronounced after the seventh decade.

Objectives: To assess functional capacity of individuals aged 75 years or older, submitted to ergometric test and transthoracic echocardiogram exam, by means of metabolic equivalent (MET) and VO_2 max measurements.

Methods: A total of 381 patients (205 women; 79 ± 3.7 years) were evaluated. Exclusion criteria were: presence of left ventricular (LV) systolic dysfunction, LV diastolic dysfunction grade II and III, significant valve disease, or coronary artery disease with systolic LV dysfunction or dilatation. Associations between quantitative variables were analyzed by Pearson and Spearman correlation coefficients, and comparisons of quantitative data by Student's t-test for independent samples.

Results: Increasing age was associated with a progressive decrease in the distance covered ($p = 0.021$), in the expected increase in HR ($p < 0.001$), in VO_2 max ($p < 0.001$), and METs ($p < 0.001$) in both genders. There was no correlation of exercise test parameters with the echocardiographic parameters.

Conclusions: Relatively healthy older individuals, with global systolic and diastolic functions of the left ventricle preserved, presented a progressive decrease in their functional capacity due to their natural aging process, comorbidities related to their age range and physical deconditioning. (Int J Cardiovasc Sci. 2018; [online].ahead print, PP.0-0)

Keywords: Cardiovascular Diseases; Risk Factors; Aging; Oxygen Consumption; Exercise Test; Echocardiography / methods; Exercise.

Introduction

Priebe[1] provided a sensible description of the difficulties in defining "aged patients", since there is no clinical definition that precisely classifies elder or advanced-aged individuals. Aging is a continuous process rather than an abrupt event. As age advances, maximal aerobic capacity decreases 8 to 10% per decade in sedentary men and women, and exercise capacity decreases approximately 50% between ages 30 and 80. In addition, comorbidities such as obstructive pulmonary disease, peripheral vascular disease, obesity, arthritis, neuromuscular disease, and generalized deconditioning are more prevalent in elderly patients and should be considered before evaluating their clinical conditions, especially in relation to cardiovascular risk.[2-4]

The prevalence of coronary artery disease (CAD) is high in the elderly. Although it was detected in only 1.8% of men and 1.5% of women above the age of 75, an autopsy study of 5,558 patients revealed significant CAD in 54% of women and in 72% of men above the age of 70.[5-7]

Older patients require a special and careful approach. Functional capacity is evaluated by exercise tolerance in daily life and reflects the quality of biological age. Lower exercise tolerance may reflect the severity of

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an underlying disease such as significant CAD or just poor functional capacity in a sedentary old person. An individual's functional capability may be assessed by means of the maximum oxygen uptake (VO_2 max) that represents the maximum amount of oxygen an individual can take in with incremental exercise. The amount of exercise can be measured using the metabolic equivalent (MET); 1 MET is the amount of oxygen consumption at rest and is equivalent to approximately 3.5 ml $kg^{-1}min^{-1}$ (measured in a healthy, 40-year old man, 70 kg). VO_2 max decreases about 10% per decade in healthy individuals, and such decrease is even more pronounced in individuals older than 70 years. With the increase in life expectancy, many patients aged 75 years or older seek medical care for chest pain and presurgical evaluation for several elective surgeries. Individuals that feel fit enough to perform a physical stress test are submitted to treadmill or bicycle ergometric tests. However, although sensitivity to noninvasive stress testing increases with aging, specificity tends to decline.[5]

The objective of the current study is to correlate exercise test variables with echocardiographic parameters in patients over 75 years old, including functional capacity, measured in MET and VO_2 max (with or without myocardial ischemia at the physical stress test), left ventricular ejection fraction (LVEF), left ventricular mass and left ventricle mass index, left atrial volume and presence of pulmonary arterial hypertension.

Methods

We assessed 381 patients (205 women; 53.8%), mean age of 79 ± 3.7 years, who underwent exercise test and bidimensional transthoracic echocardiography (2DEcho) in a private cardiologic clinic. Subjects were selected by convenience. Each patient had results of blood tests and imaging tests to be analyzed before the exercise test.

Before the study, data on demographic characteristics and risk factors were collected from the private cardiologist's records and blood test results. Body mass index (BMI) was calculated by dividing the subjects' weight (kg) by the square of their height (m). Patients were queried about the presence of hypertension, diabetes mellitus, dyslipidemia, coronary artery disease, and current smoking habit. Hypertension was defined as a history of treated hypertension or the presence of systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, measured by the private cardiologist. Smoking history was coded as never or current smoker.[8] Subjects were classified as having diabetes when treated for insulin-dependent or non-insulin-dependent diabetes or having elevated fasting glucose levels (≥ 126 mg/dL). The use of lipid-lowering drugs or the presence of total cholesterol > 200 mg/dL, HDL-cholesterol < 40 mg/dL, LDL - cholesterol > 100 mg/dL or triglycerides > 150 mg/dL was recorded.[9-10] A history of myocardial infarction, angioplasty, or coronary artery bypass surgery was recorded, and the presence of any of these conditions was considered a positive CAD history.

Indications for the 2DEcho included referral from a physician, information from close relatives, or patients' complaints. We analyzed echocardiographic and carotid ultrasonography data, including left ventricular ejection fraction, left ventricular diastolic function, left atrial volume, left ventricular mass and the presence of pulmonary arterial hypertension and carotid plaque. Exclusion criteria included the presence of left ventricular systolic dysfunction (ejection fraction < 50% on echocardiogram), left ventricular diastolic dysfunction grade II and III, significant valve disease such as mitral and aortic regurgitation or stenosis, CAD with left ventricular systolic dysfunction or dilatation, unstable cardiovascular or metabolic disease, and major orthopedic/neurological disability.

Subjects underwent treadmill electrocardiogram (ECG) testing (TET) or bike ECG testing (BET), according to the private physician request. Treadmill ECG test included Ellestad, Kattus, Naughton, Ramp, Bruce and modified Bruce protocols, and Balke and male Balke protocols, following standard recommendations.[11,12] The distance covered on the treadmill was automatically calculated by the protocol, according to the number of laps covered by each patient. Blood pressure and a 12-lead ECG were recorded before the test, during the test (during the last minute of each stage), and every 3 minutes in the recovery phase. During the test, three ECG leads were continuously monitored. The test was stopped in case of a) ST-segment elevation (> 1.0mm) in leads without preexisting Q waves due to prior myocardial infarction (other than aVR, aVL, and V1); b) drop in systolic blood pressure > 10 mmHg despite an increase in workload, when accompanied by any other evidence of ischemia; c) moderate to severe angina; d) central nervous system symptoms (e.g. ataxia, dizziness, near syncope); signs of poor perfusion (cyanosis or pallor); e) sustained ventricular tachycardia or other arrhythmias, including second- or third-degree atrioventricular block, which may affect cardiac output during exercise; f) marked ST-segment depression (≥ 3mm); g) exercise-limiting symptoms such as angina, dyspnea, exhaustion, or the subjects' request to stop the test; and h) technical difficulties in monitoring the ECG or systolic blood pressure. An abnormal response of the ST-segment to exercise was defined as horizontal or downsloping ST-segment depression ≥ 1 mm measured at 80 ms after the J point or an elevated ST-segment ≥ 1 mm in leads without pathological Q-wave (excluding lead aVR). Measurements of left ventricular systolic and diastolic dysfunction, left atrial volume, valve disease, and systolic pulmonary artery pressure were performed according to recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging.[13-14] The study was approved by the local ethics committee and written informed consent was obtained from each participant to undergo the ergometric tests (treadmil ECG testing or bike ECG testing) , bidimensional transthoracic echocardiography and carotid ultrassonography, and to participate in the study.

Statistical analysis

Quantitative variables were described as means, medians, minimum and maximum values, quartiles and standard deviations, and categorical variables as frequency and percentiles. Associations between quantitative variables were analyzed by Pearson and Spearman correlation coefficients. Comparisons of quantitative variables between the two groups were made using the Student's t test for independent samples. Statistical testing of data normality was performed using the Kolmogorov-Smirnov test. Associations between categorical variables were assessed by the Fisher's exact test. A p-value ≤ 0.05 indicated statistical significance. Data were analyzed by means of the SPSS statistical software, version 20.

Results

Patients' baseline characteristics and echocardiographic and ergometric results are shown in Tables 1, 2 and 3. Only five patients (1.3%) performed cycle ergometer test, and then were excluded from the final analysis. Three hundred seventy-six patients performed treadmill test (Bruce protocol 203, 53.4%; Kattus 113, 29.7%; Ramp 28, 7.4%; modified Bruce 15, 3.9%; Naughton 12, 3.2%; Ellestad 5, 1.3%; Balke 3, 0.8%; Balke male 1, 0.3%). Nineteen (5%) patients did not achieve the submaximal heart rate (HR) expected for the age and 58 (15%) had previous ECG at resting conditions showing left bundle branch block and ST segment alterations. Forty (10.5%) of the patients tested positive for myocardial ischemia and 79 (21.8%) showed abnormal heart rate response in the first minute. As age increased, the distance covered by participants decreased ($p = 0.021$), as well the expected increase in HR ($p < 0.001$), VO_2 max ($p < 0.001$) and METs ($p < 0.001$) (Tables 3 and 4; Figure 1) in men and women. Women showed lower values of VO_2 max and METs when compared to men (Table 2). Inverse correlation was noted of the distance covered, VO_2 max and METs with the BMI (Table 3 and 4). Only 4 patients (1%) showed systolic pressure in the pulmonary artery above 40 mmHg in the echocardiogram at rest, which did not influence the distance covered by the subjects, HR at the first minute ($p = 1$), VO_2 max ($p = 0.5$), MET ($p = 0.5$) or ischemia ($p = 1.0$) (data not shown). The volume of the left atrium and left ventricular mass had no influence on the ergometric test variables (Table 5). Ischemia at stress test did not correlate with any echocardiographic variable (Table 5). In 198 patients (67.3%), atherosclerotic plaques in the extracranial carotid arteries were detected, which also did not correlate with any of the variables analyzed (data not shown). Severity of stenosis was not considered relevant, only the presence of the atherosclerotic plaque.

Discussion

The present study showed that relatively healthy patients aged 75-81 years, with similar demographic and echocardiographic characteristics, showed a progressive decrease in METs and VO_2 max, associated with a decrease in the distance covered during ergometric test with increasing age. These findings corroborate previous studies showing a marked decrease in VO_2 max with aging.[15-18] Considering that only individuals with preserved left ventricular systolic function was studied, we did not expect an influence of this parameter on the results. Similarly, no influence of left ventricular diastolic function was expected,[19] as individuals with grade II and III diastolic dysfunction were excluded from the study.

Regarding the left atrial volume, since there was no significant variation in its values among the patients, its influence on the ergometric parameters was not expected either, unlike previous studies that reported a worsening of functional capacity due to the increase in left atrial volume.[20-23] The same was observed with left ventricular mass and left ventricular mass index.[24]

Therefore, no correlation between ergometric and echocardiographic variables was found, which

Table 1 - Patients' baseline characteristics

Variable	N	Mean	Median	1st quartile	3rd quartile	Standard deviation
Age	381	79.0	78	76	81	3.7
Weight (kg)	381	70.4	70	60	79	13.9
Height (cm)	381	163.8	164	157	170	9.5
Body mass index (kg/m²)	380	26.2	25,6	23.4	28.5	4.2
Sex						
Female (N/%)	205/53.8					
Male (N/%)	176/46.2					
Hypertension						
Yes (N/%)	258/67.7					
No (N/%)	123/32.3					
Diabetes						
Yes (N/%)	91/23.9					
No (N/%)	290/76.1					
Dyslipidemia						
Yes (N/%)	178/46.7					
No (N/%)	203/53.3					
Coronary artery disease						
Yes (N/%)	43/11.3					
No (N/%)	338/88.7					
Carotid plaque						
Yes (N/%)	198/67.3					
No (N/%)	93/32.7					

indicates that, in relatively healthy individuals older than 75 years old, the decrease in functional capacity is associated with age, progressive physical deconditioning and comorbidities, which will negatively affect their independence and daily physical activity.[25-28] Nevertheless, comorbidities such as previous stroke, bone and articular diseases, and chronic obstructive pulmonary disease were not analyzed in the present study. In regard to HR at the first minute after the test, it is known that its restoration to baseline values reflects the integrity of the vagal system, which is compromised in older ages, in patients with diabetes, cardiac failures, and increased BMI.[29-31] In this regard, in the present study, only 21.8% of the individuals showed an abnormal HR response at the first minute after the exercise test. Also, there was no correlation of this variable with echocardiographic parameters, age, sex or BMI. This finding was expected, as the studied cohort comprised an aged population with similar clinical and echocardiographic characteristics. Another relevant finding was the fact that only 10% of the individuals in the present study showed positive for myocardial ischemia. Sensitivity of the ergometric test was similar to that documented by Vacanti et al.,[6] using myocardial perfusion scan with dipyridamole in individuals older than 75. However, it is known that elderly patients have a high prevalence of severe CAD, with low tolerance to exercise. Thus, results of exercise stress testing in

Table 2 - Echocardiographic and ergometric results

Variable	n	Mean	Median	Q1	Q3	SD	*p value
Maximum heart rate	381	128.2	129	118	140	20.7	
Distance	377	0.418	0.410	0.290	0.530	0.198	
VO_2 max	381	23.7	23.4	16.9	29.1	8.1	
MET	381	6.80	6.76	4.84	8.35	2.36	
Left ventricle mass	381	159.4	152	123	181	50.2	
Left ventricle/SA	381	91.1	85	74	103	33.1	
Left ventricle EF	381	69.5	70	67	73	6.3	
Left atrium	381	37.1	36	34	40	5.6	
VO_2 max female	205	21.0	20.9	16.7	25.1	7.3	
VO_2 max male	176	26.7	25.9	20.9	32.2	8.0	< 0.001
METs female	205	6.1	6.0	4.8	7.2	2.1	
METs male	176	7.7	7.5	6.0	9.2	2.3	< 0.001

** Student's t- test for independent samples, $p < 0.05$. VO_2 max: maximum oxygen consumption; MET: metabolic equivalent; SA: surface area; EF: ejection fraction.*

Table 3 - Correlation of heart rate (HR) and distance covered in exercise stress ECG test with echocardiographic data, age, surface area (SA) and body mass index (BMI) of patients

Variable	n	Spearman coefficient	p value
HR max x left ventricle mass	381	-0.09	0.082
HR max x left ventricle mass/ SA	381	-0.03	0.556
HR max x age	381	-0.23	< 0.001
HR max x BMI	380	-0.06	0.249
HR max x left ventricle ejection fraction	381	0.13	0.010
HR max x left atrium	381	-0.05	0.325
Distance x left ventricle mass	377	0.03	0.520
Distance x left ventricle mass/ SA	377	0.08	0.101
Distance x age	377	-0.12	0.021
Distance x BMI	376	-0.17	0.001
Distance x left ventricle ejection fraction	377	0.04	0.450
Distance x left atrium	377	0.01	0.833

Table 4 - Correlation of metabolic equivalent (MET) and maximum oxygen consumption (VO_2 max) with echocardiographic data, age, body mass index (BMI) and surface area (SA) of patients

Variable	N	Spearman coefficient	p value
MET x left ventricle	381	0.03	0.581
MET x left ventricle/SA	381	0.06	0.217
MET x age	381	-0.21	<0.001
MET x BMI	380	-0.13	0.011
MET x ejection fraction	381	0.05	0.327
MET x left atrium	381	0.00	0.959
VO_2 max x left ventricular mass	381	0.04	0.488
VO_2 max x left ventricular mass/SA	381	0.07	0.167
VO_2 max x age	381	-0.19	<0.001
VO_2 max x BMI	381	-0.16	0.002

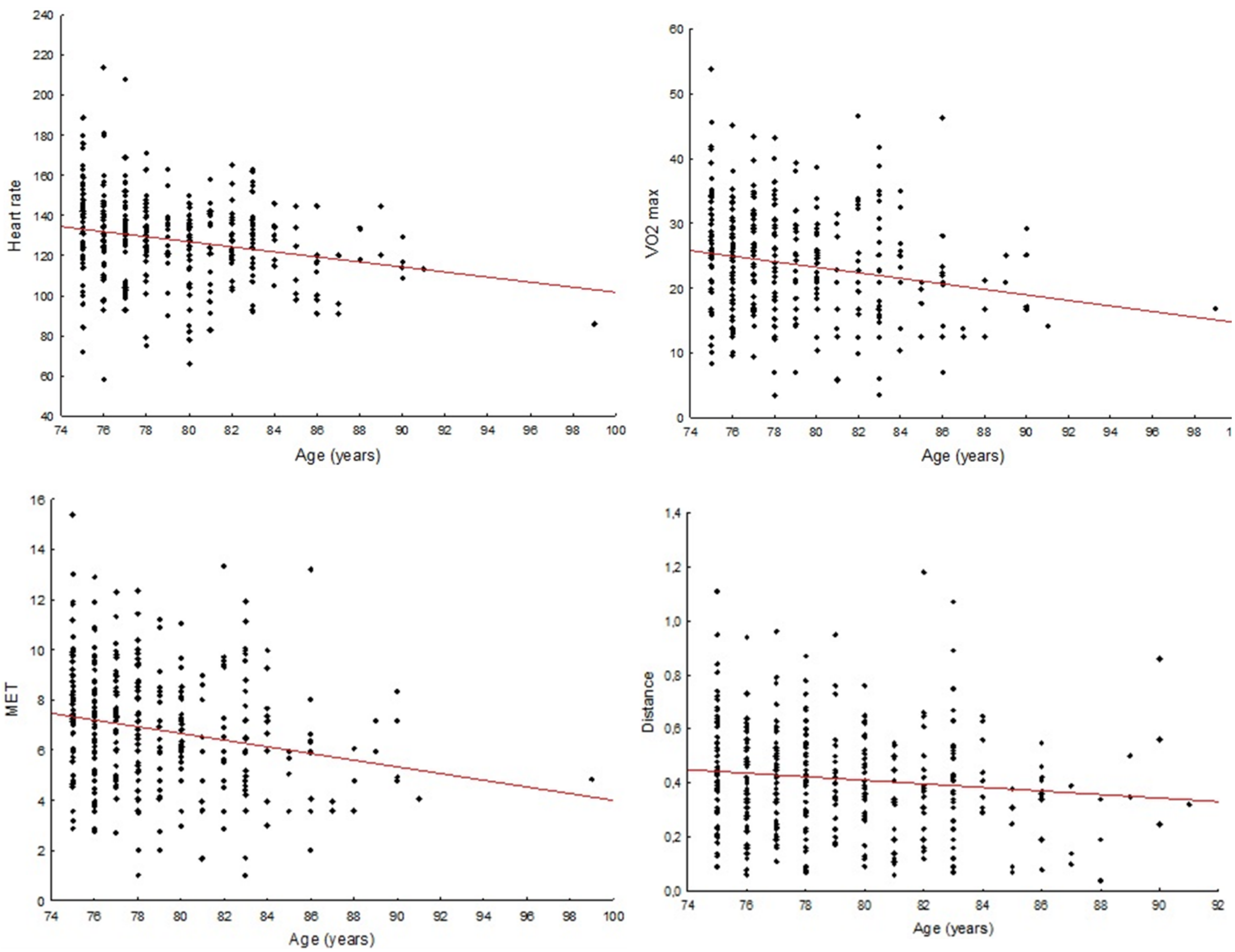

Figure 1 - Correlation of age with heart rate, VO_2 max, metabolic equivalent (MET), and distance (m) covered in exercise stress ECG test.

this population must be interpreted differently than in younger individuals, since even in patients classified as low risk by risk stratification scores, an annual cardiac mortality rate of 2% was found in patients aged 75 years or older.[32,33] These findings confirm the need for specific protocols and instruments for elderly patients,[34] considering the great heterogeneity in aging process and its biological consequences.[33]

In addition, considering the presence of atherosclerotic plaques in the extracranial carotid arteries in our patients, we expected its correlation with the other variables analyzed, which did not happen. In fact, its presence was previously shown to be correlated with systolic functions and left filling ventricular pressures,which revealed to be similar in all patients of this study.

An additional important finding was the inverse correlation of the distance covered, functional capacity (METs) and VO_2 max with BMI. There is a progressive BMI increase as age advances and the prevalence of obesity has considerably increased in the elderly.[36] This has a direct impact on individuals' health and life quality, since weight gain is associated with a decrease in functional capacity and vitality, body pain, emotional and physical problems, and increased risk for morbidity and disability.[37,38]

Some limitations of the present study should be mentioned. First, the choice of the exercise protocols was made by the physician who examined the patients, based on the physical limitations of each patient. This led to the use of different ergometric protocols, making

Table 5 - Echocardiographic variables, presence of ischemia and heart rate in the first minute of the exercise stress ECG test (HR 1st min) of the patients

Variable	Ischemia	n	Mean	Median	1st quartile	3rd quartile	SD	p* value
LV mass	No	341	160.1	152	123	185	51.5	
	Yes	40	153.6	146.5	122.5	181	36.9	0.315
LV mass/SA	No	341	91.9	87	75	103	34.5	
	Yes	40	84.2	81	74	94	16.7	0.018
Age	No	341	79.1	78	76	81	3.7	
	Yes	40	78.3	77	76	79	4.1	0.188
BMI	No	340	26.0	25.6	23.4	28.4	3.9	
	Yes	40	27.4	26.7	23.3	28.9	6.2	0.166
LVEF	No	341	69.5	70	67	73	6.4	
	Yes	40	69.0	70	66.5	72.5	5.4	0.628
Left atrium	No	341	36.9	36	33	40	5.6	
	Yes	40	38.5	37	35	41.5	5.0	0.107
Variable	**HR 1st min**	**n**	**Mean**	**Median**	**Qst**	**Qth**	**SD**	**p* value**
LV mass	Normal	283	157.6	148	122	181	48.9	
	Abnormal	79	163.3	158	132	181	47.0	0.354
LV mass/SA	Normal	283	90.8	85	73	103	35.5	
	Abnormal	79	91.1	88	77	104	21.7	0.928
Age	Normal	283	78.9	78	76	81	3.7	
	Abnormal	79	79.1	79	76	81	3.7	0.566
BMI	Normal	282	26.0	25.5	23.1	28.4	4.3	
	Abnormal	79	26.7	26.4	23.9	29.3	4.3	0.241
LVEF	Normal	283	69.5	70	67	73	6.3	
	Abnormal	79	69.5	70	67	73	6.7	0.975
Left atrium	Normal	283	37.1	36	34	40	5.6	
	Abnormal	79	36.4	36	33	40	5.4	0.269

** Student's t- test for independent samples, $p < 0.05$. LV: left ventricular; SA: surface area; EF: ejection fraction; BMI: body mass index.*

it difficult to accurately analyze and compare the ergometric variables between the subjects. Second, since only patients with preserved left ventricular systolic and diastolic functions were selected, no significant difference was expected in VO_2 max, METs, HR, and distance covered. Thus, further studies including patients with different degrees of left ventricular dysfunction in the elderly are necessary.

Conclusions

Individuals aged 75 years or older, of both genders, relatively healthy, with preserved left ventricular systolic and diastolic functions, showed progressive decrease in the distance covered, VO_2 max, METS and at the expected increase in HR in exercise stress ECG test, due to aging and related comorbidities and physical deconditioning.

Author contributions

Conception and design of the research: Baroncini LAV, Baroncini CV, Leal JF. Acquisition of data: Baroncini LAV, Baroncini CV, Leal JF. Analysis and interpretation of the data: Baroncini LAV, Baroncini CV, Leal JF. Statistical analysis: Baroncini LAV. Writing of the manuscript: Baroncini LAV. Critical revision of the manuscript for intellectual content: Baroncini LAV, Baroncini CV, Leal JF. Supervision / as the major investigador: Baroncini LAV.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Hospital do Trabalhador / SES / PR under the protocol number 57759416.5.000.5225. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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