Original Article

Feasibility and Safety of One-Minute Step Test in Patients with Heart Failure Hospitalized in the Cardio-Intensive Care Unit: A Pilot Study.

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Abstract

Background: The One-Minute Step Test (1MST) seems to be a useful tool for exploring the component of energy metabolism used in Activities of Daily Living (ADL), but it is still little explored in patients with Heart Failure (HF) in the hospital environment.

Objective: To evaluate the feasibility and safety of performing 1MST in hospitalized patients with HF.

Methods: Data were collected using electronic medical records and evaluative tests from patients with HF. The safety of the 1MST was assessed through vital signs records, perceived exertion, adverse events, and feasibility based on the ability to complete the test. The paired Student's T-test and Wilcoxon test were employed to compare the data before and after the test, depending on the distribution of the data, while the relationship between the variables was examined using Pearson's correlation test. The significance level set was $p < 0.05$.

Results: Twenty patients were evaluated between May and December 2022. All patients completed the test, and no adverse events were recorded. Heart rate (HR) ($p < 0.001$), systolic blood pressure (SBP) ($p = 0.01$), mean arterial pressure (MBP) ($p = 0.03$), and respiratory rate ($p < 0.001$), and peripheral oxygen saturation showed a reduction ($p = 0.04$). A negative correlation was observed between 1MST and age ($r = -0.46$; $p = 0.03$) and a positive correlation between 1MST and length of stay in the CICU ($r = 0.44$; $p = 0.04$).

Conclusion: It is concluded that the 1MST is a safe and viable tool for assessing the anaerobic metabolism of patients with HF.

Keywords: Heart Failure; Hospitalization; Exercise Test.

Introduction

Heart Failure (HF) is a complex clinical syndrome characterized by the heart's inability to eject blood adequately to meet the metabolic demands of peripheral tissues, or by doing so only at the expense of elevated filling pressures.[1,2] Throughout the course and progression of the disease, individuals experience multiple changes in skeletal muscle composition and function, leading to sarcopenia, dyspnea, and cardiac cachexia,[3] often resulting in hospitalizations.

During hospital stays due to HF decompensation, prolonged bed rest is associated with worsening musculoskeletal depletion and reduced exercise capacity,[2,4] leading to a shift in energy metabolism with increased reliance on anaerobic pathways for energy production.[5] These alterations may be attributed to impaired muscle perfusion and a consequent shift from type I to type II muscle fibers, which rely predominantly on anaerobic glycolytic metabolism for energy.[6]

In the early phase of physical exercise, energy production is primarily anaerobic, and this pathway may be impaired in individuals with HF, affecting short-duration daily activities and limiting autonomy. Therefore, assessing this phase of metabolism in patients with chronic conditions becomes relevant when designing short-duration, high-intensity individualized exercise programs.[7,8]

One tool used to evaluate anaerobic metabolism, which can indirectly indicate adaptation to short-duration activities,[6] is the One-Minute Step Test (1MST). The 1MST targets the energy metabolism component required for performing Activities of Daily Living (ADLs).[7]

The 1MST appears to be a promising, low-cost tool for assessing anaerobic metabolism,[8] with the advantage of enabling continuous monitoring in a small physical space.[9]

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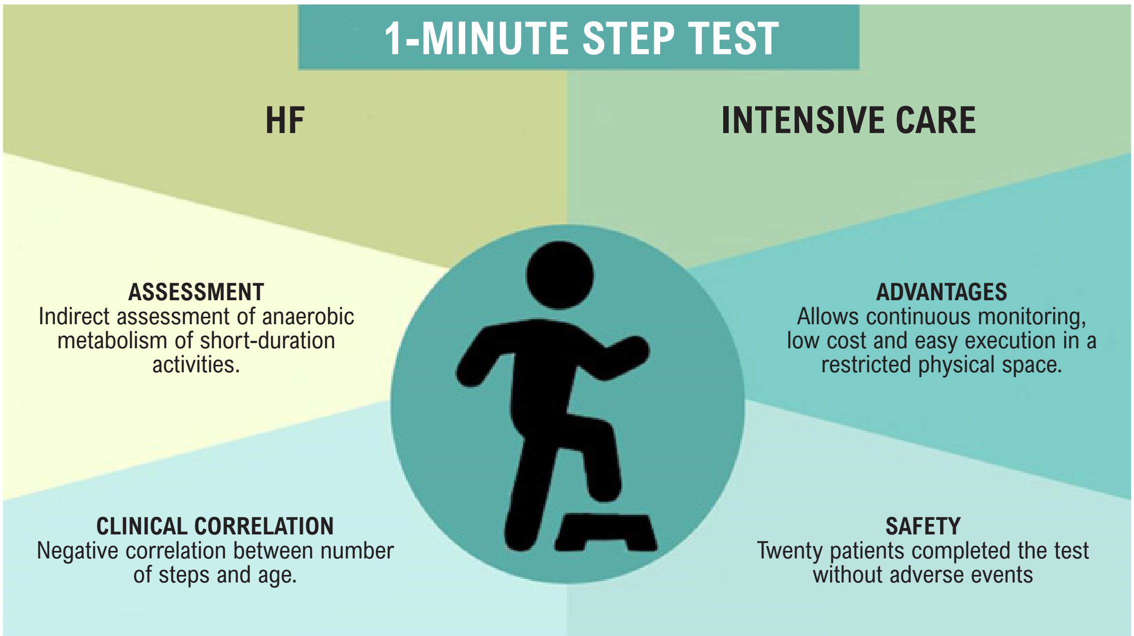
Central Illustration: Feasibility and Safety of One-Minute Step Test in Patients with Heart Failure Hospitalized in the Cardio-Intensive Care Unit: A Pilot Study.

KEY:



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HF: Heart Failure

However, to date, the test has only been used in studies involving healthy individuals and those with coronary artery disease and chronic lung disease[7,10-12] with no prior reports of its use in intensive care therapy for HF patients.

This study aimed to evaluate the safety and feasibility of performing the 1MST in hospitalized HF patients and, additionally, to assess physiological changes before and after the test.

Methods

Study design and sample

This cross-sectional observational study was conducted in the Cardio-Intensive Care Unit (CICU) of a university hospital in Rio de Janeiro. Patients hospitalized in the CICU with HF in a clinically compensated phase were recruited between May and December 2022. The study was approved by the institutional ethics committee (CAAE: 52759221.3.0000.5259). All patients were approached and invited to participate, and they voluntarily signed an informed consent form prior to evaluation, in accordance with national regulations.[13]

Individuals over the age of 18, of either sex, hospitalized in the CICU between May and December 2022 with a diagnosis of HF were included. Exclusion criteria were: Left Ventricular Ejection Fraction (LVEF) less than 20%, patients listed for heart transplantation, pregnancy, symptomatic orthostatic hypotension, severe obstructive cardiomyopathy, severe aortic valve stenosis, clinically unstable ventricular or supraventricular arrhythmias, atrioventricular block, severe pulmonary arterial hypertension with Pulmonary Artery Systolic Pressure (PASP) > 70 mmHg, diagnosed pulmonary disease, osteomyoarticular and/or neurological limitations, cognitive conditions that impaired evaluation test performance, hemodynamic instability (defined as: Systolic Blood Pressure (SBP) ≤ 90 mmHg or Mean Arterial Pressure (MBP) ≤ 65 mmHg, Heart Rate (HR) < 40 or > 130 bpm, SpO_2 < 88%) and/or signs of low cardiac output (such as peripheral hypoperfusion, altered mental status, cold and cyanotic extremities, and/or reduced urine output < 0.5 mL/kg/hour, vomiting, and/or complaints of dizziness or headache).[1,14]

Data Collection

Sociodemographic data and complementary test results were collected from electronic medical records, and bedside evaluations were performed when the patient was clinically stable and discharge from the CICU was anticipated. During the 1MST, hemodynamic and clinical variables were recorded.

Step Test

The test was performed using a standardized step measuring 17.5 cm in height, 29 cm in depth, and 60 cm in width. Before the test, the evaluator demonstrated the movement, and the volunteer was asked to repeat it to ensure correct performance. The volunteer remained seated at rest for ten minutes for baseline vital sign collection. Next, volunteers were instructed to "step up and down continuously for one minute, as many times as possible".[7,10] Each full cycle was recorded as a complete step up and down, always starting each new cycle with the same foot.[8] Hand support on the wall was permitted if needed. Upon completion, participants remained seated at rest for ten minutes or longer, as needed. Adverse events are described in Figure 1.[15-20]

HR monitoring and recording were performed continuously; measurements of Blood Pressure (BP), Mean Blood Pressure (MBP), and SpO_2 were taken before and immediately after the test using the bedside multimodal monitor (Mindray IPM 12). Hemodynamic changes were recorded before and after the test. Additionally, subjective dyspnea and lower limb fatigue were measured using the Rate of Perceived Exertion (RPE), rated from 0 to 10 (0 = "no exertion" and 10 = "extremely difficult"),[21,22] along with the number of step-up/step-down cycles and musculoskeletal pain assessed using the Visual Analog Scale (VAS).[8]

Test feasibility was determined based on the total number of individuals who completed the test,[8] patient acceptance of the evaluation, the participation of two or more physical therapists during assessment, availability of required materials (step, continuous monitoring system with BP cuff, pulse oximeter, 5-lead ECG cable), and practicality (test duration not exceeding 30 minutes on average).[23]

Statistical analysis

Descriptive statistics were presented as absolute frequencies and percentages for categorical variables, and as mean (standard deviation) or median (25-75 percentile) for continuous variables, depending on the distribution as determined by the Shapiro-Wilk normality test. Paired Student's T-test was used to compare HR, BP, MBP, and RR variables, and the Wilcoxon test was used for SpO_2, dyspnea RPE, lower limb RPE, and lower limb VAS.

Pearson correlation coefficients were used to assess associations between the number of step cycles and both age and hospital length of stay. Values of r = 0.3–0.5 were considered low correlation, r = 0.5–0.7 moderate, and r = 0.7–0.9 high correlation.[24] All analyses were conducted using JAMOVI software version 2.3.2.1, with P-values < 0.05 were considered statistically significant.

Results

During the data collection period, 245 patients were admitted to the CICU. Of these, 40 met the inclusion criteria. Twenty individuals were excluded based on predefined criteria (Figure 2). The study participants had a mean age of 60.9 years, were predominantly male, and had an average hospital stay of seven days. Additional clinical and demographic characteristics are presented in Table 1. The central figure summarizes the main benefits and findings of this study.

No adverse events occurred during the 1MST or the recovery period. All volunteers completed the test, and 26% used upper limb support. Evaluation required at least two physical therapists, a standardized step, and continuous monitoring equipment. The physiotherapist demonstrated the test, and vital signs and RPE were recorded before and after. The entire evaluation process, including chart review, informed consent, test execution, and data collection, took approximately 30 minutes.

1	Increased SBP > 180 mmHg.
2	MBP < 65 mmHg accompanied by low output symptoms, such as sweating, nausea, abdominal pain, paleness, and cold extremities.
3	HR > 130 bpm, or a 70% increase in maximum HR predicted for age.
4	HR < 40 bpm or a 20% reduction in resting HR.
5	Conduction disorders, including atrioventricular block of grades 2 and 3, atrial fibrillation, supraventricular tachycardia, or complex ventricular arrhythmia.
6	Exertional angina and vascular claudication.
7	Occurrence of a fall or injury.
8	Muscular or osteoarticular pain with a VAS ≥ 6 points difference before and after the test.
9	Displacement of devices such as tracheostomies, femoral dialysis catheters, venous and arterial catheters, nasogastric tubes, pleural drains, and bladder catheters.

Figure 1 – *Classification of adverse events. SBP: Systolic Blood Pressure; MBP: Mean Blood Pressure; HR: Heart rate; VAS: Visual Analog Scale.*

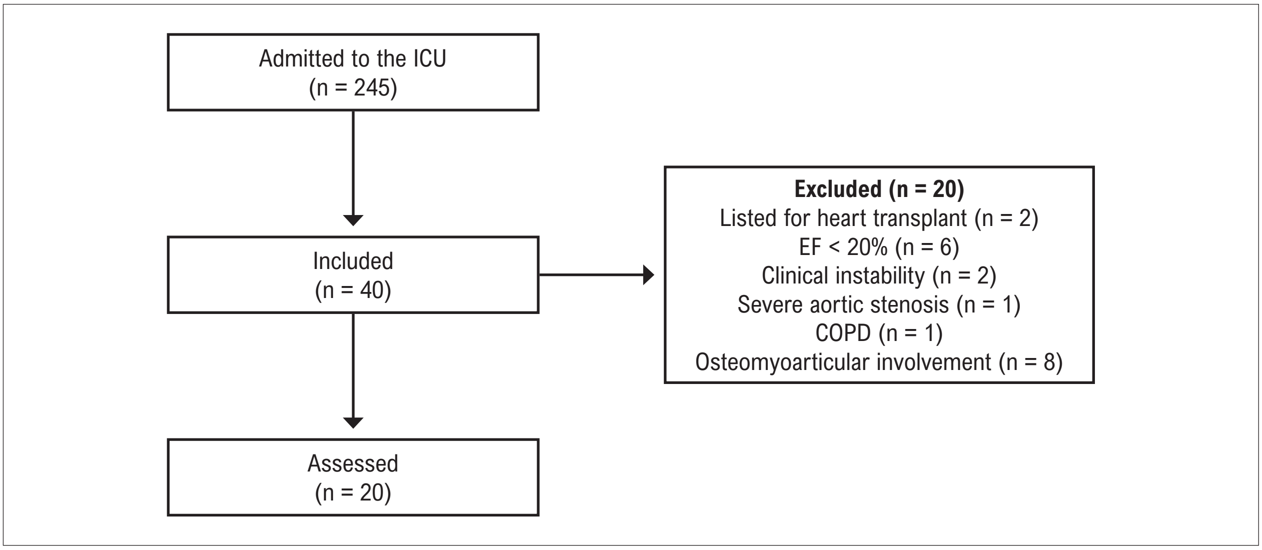

Figure 2 – *Study flowchart. EF: Ejection Fraction; COPD: Chronic Obstructive Pulmonary Disease.*

Key clinical and physiological characteristics before and after the 1MST are listed in Table 2. A statistically significant increase in hemodynamic variables and perceived exertion was observed post-test, including HR, SBP, MBP, respiratory rate, and lower limb RPE. A statistically significant decrease in SpO_2 was also noted. An average of 11 step cycles was recorded, and the number of test cycles showed a weak negative correlation with age and a weak positive correlation with CICU length of stay (Figures 3A and 3B, respectively).

Discussion

This study demonstrated that performing the 1MST in hospitalized HF patients is both feasible and safe, suggesting it may be a useful tool for evaluating anaerobic metabolism in clinically stable ICU patients. It is a simple test that adds to the physiotherapist's toolkit for exercise assessment and prescription in this population. This was the first study to use this tool in the ICU setting with this patient profile.

In an outpatient study with patients with Coronary Artery Disease (CAD), the 1MST was shown to be safe in over 90% of cases.[8] No studies were found in the literature assessing the safety of the 1MST in HF patients or its use in intensive care settings.

Feasibility was determined by test adherence and practical applicability in the ICU. Laroche *et al.* reported that 13% of healthy individuals stumbled at least once during the test, with no falls or need to interrupt the evaluation.[7] In Besson *et al.*'s study,[8] which included patients with CAD performing the 1MST after exercise, three patients were unable to complete the test due to difficulty and poor coordination. In contrast to those studies, all volunteers in our study completed the test without reports of difficulty or stumbling. This may be attributed to prior performance for familiarization and the option to use support in case of imbalance.

During the 1MST, a significant increase in the analyzed hemodynamic variables, respiratory rate, and lower limb RPE was observed, along with a small but statistically significant drop in SpO_2. These findings show that the 1MST induces cardiovascular load, as expected during physical effort, and did not result in adverse events, suggesting it may serve as a non-invasive functional assessment tool for anaerobic metabolism.[8] Previously, Besson *et al*. assessed 1MST hemodynamic variables at three different points and observed increases in HR, SBP, and Diastolic Blood Pressure (DBP), but found no significant difference between pre- and post-test periods.[8]

The number of step cycles completed in one minute has been used in clinical practice as a criterion for evaluating anaerobic metabolism.[7] The average of 11 cycles observed in this study showed a negative correlation with age, similar to other studies involving individuals without heart disease. In those studies, younger individuals (mean age 25 years) averaged 76 cycles,[25] while another group (mean age 32 years) performed 52 cycles.[7]

Among cardiac patients without HF, Besson *et al.* reported an average of 43 cycles in patients with a mean age of 57 years.[8] This discrepancy may be explained by the progressive musculoskeletal depletion seen in HF,[2] compounded by inflammation and autonomic imbalance, which contribute to physical dysfunction and reduced exercise tolerance.[2,26] Additionally, the aging process and hospitalization may further exacerbate functional decline,[27,28] impacting 1MST performance. A correlation was found between ICU length of stay and 1MST cycles, indicating that patients who stayed longer in our unit performed better on the test. This finding may be explained by the volunteers' exposure to an individualized cardiac rehabilitation protocol, which is performed daily during their hospitalization in our unit. It is worth noting that although different populations have been evaluated regarding the measurement of anaerobic metabolism through the 1MST, there is still no cutoff point related to the performance of this test. Nevertheless, the 1MST performance appears to be a reliable and valid criterion for evaluating the short and intense demand of metabolism, being independently related to blood lactate concentration and EPOC.[2] The results of this

Table 1 – Participants' clinical and demographic characteristics

Characteristics	Participants (n = 20)
Age (years)	60.9 ± 14
Men (%)	70.0 (14)
Race (%)	
White	30.0 (6)
Black	45.0 (9)
Mixed-race	25.0 (5)
Body mass index (kg/m²)	28.5 ± 6
LVEF (%)	37.6 11.4
HF classification (%)	
HFrEF < 40	60.0 (12)
HFmrEF 40–49	30.0 (6)
HFpEF > 50	10.0 (2)
NYHA (admission - %)	
I – II	15.0 (3)
III – IV	85.0 (17)
ADHERE (%)	
Low	60.0 (12)
Intermediate	40.0 (8)
Comorbidities (%)	
Systemic arterial hypertension	65.0 (13)
Diabetes mellitus	55.0 (11)
Dyslipidemia	25.0 (5)
Coronary artery disease	35.0 (7)
Atrial fibrillation / Flutter	45.0 (9)
Orovalvular disease	20.0 (4)
Chronic renal failure - non-dialysis	25.0 (5)
Obesity	35.0 (7)
Others	15.0 (3)
Medications (%)	
Vasodilators	30.0 (6)
Antiarrhythmics	35.0 (7)
ACEI/ARB	35.0 (7)
Beta blockers	40.0 (8)
Diuretics	50.0 (10)
Others	30.0 (6)
CICU stay (days)	7.0 (3.7 – 12)
Hospital stay (days)	21.0 (12 – 29)

Data are expressed as mean ± standard deviation, median (25 – 75% interquartile range), or absolute frequency and percentage. NYHA: New York Heart Association functional classification of HF; ADHERE: predictor of in-hospital mortality in patients with HF; LVEF: left ventricular ejection fraction; HFrEF: heart failure with reduced ejection fraction; HFmrEF: heart failure with intermediate ejection fraction; HFpEF: heart failure with midrange ejection fraction; CVA: cerebrovascular accident; TIA: transient ischemic attack; ARB: angiotensin receptor blocker; ACEI: angiotensin-converting enzyme inhibitor; CICU: cardio-intensive care unit; HF: Heart Failure.

Table 2 – Clinical variables before and after the 1MST

	Before	After	P-value
HR	78.8 ± 14.1	92.2 ± 19.4	< 0.001
SBP	119 ± 16.6	125 ± 16.2	0.01
DBP	74.5 ± 17.2	78.4 ± 14.6	0.07
MBP	89.2 ± 14.8	93.9 ± 12.7	0.03
RR	17.4 ± 3.2	22.8 ± 7.3	< 0.001
SpO_2	98.5 (94.0 – 100.0)	97.5 (93.0 – 99.0)	0.04
Dyspnea RPE	0 (0 – 5)	1 (0 – 10)	0.22
LE RPE	0 (0 – 8)	0 (0 – 5)	0.005
LE VAS	0 (0 – 10)	0 (0 – 8)	0.41

Data expressed as mean ± standard deviation, or median (25 – 75% interquartile range). HR: Heart rate; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MBP: Mean Blood Pressure. RR: Respiratory Rate; SpO_2: Peripheral Oxygen Saturation; RPE: Rate of Perceived Exertion; LE: Lower extremity; VAS: Visual Analog Scale. Statistically significant p-values are in bold.

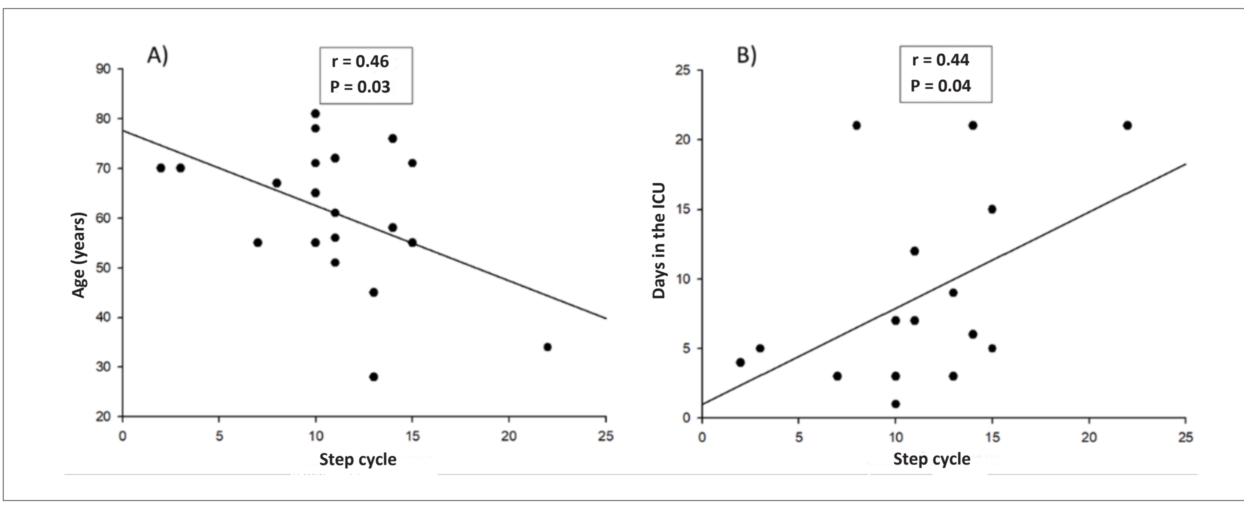

Figure 3 – *3A: Correlation between age and number of cycles performed in the 1-minute step test (1MST). 3B: Correlation between days of hospitalization in the CICU I and number of cycles performed in the 1MST.*

evaluation can be used to support the prescription of individualized training that resembles the daily activities of individuals.[8]

Limitations

Regarding limitations, we highlight that direct quantification of anaerobic metabolism was not performed, such as through lactate, due to the difficulty in collecting the test and the need for central venous access, since most of the volunteers already had no access. Another limitation was the absence of a scale that assessed daily activities and frailty for comparison purposes with the performance on the 1MST.

Conclusion

The 1MST proved to be a safe and viable tool for assessing the anaerobic metabolism of patients with HF admitted to the ICU, since no participant presented any adverse events, and the exam was completed by all volunteers. In addition, a correlation was observed between the 1MST performance and age and length of ICU stay, which has never been demonstrated in the current literature. Therefore, it is expected that the 1MST will be a tool capable of assisting in the prescription of exercises, on an individualized basis, for heart disease patients, since it is easily reproducible in clinical practice.

Author Contributions

Conception and design of the research: Volotão AN, Diniz CP, Silva VFM, Rodriguez ACC, Di Leone CN, Oliveira JR; acquisition of data: Volotão AN, Silva VFM; analysis and interpretation of the data: Volotão AN, Diniz CP, Carneiro APN, Di Leone CN; statistical analysis: Diniz CP, Di Leone CN; writing of the manuscript: Volotão AN, Carneiro APN, Avila MB; critical revision of the manuscript for intelectual content: Diniz CP, Carneiro APN, Avila MB, Rodriguez ACC, Di Leone CN; formatting: Avila MB, Rodriguez ACC, Oliveira JR.

Potential Conflict of Interest

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

Sources of Funding

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Study Association

This article is part of the thesis of completion of residency submitted by Andresa Volotão Narciso, from Hospital Universitário Pedro Ernesto.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Hospital Universitário Pedro Ernesto under the protocol number 52759221.3.0000.5259. 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.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Research Data

All datasets supporting the results of this study are available upon request from the corresponding author.

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