Original Article
Virtual reality on pulmonary function and functional independence after coronary artery bypass grafting: clinical trial

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Abstract: Introduction: Coronary artery bypass grafing (CABG) is responsible for the decrease in pulmonary function and functionality. In this case the virtual reality is an alternative to reduce the impact of the surgical procedure. Objective: To evaluate the effect of virtual reality on pulmonary function and functional independence in patients undergoing CABG. Methodology: This is a clinical trial. In the preoperative period, pulmonary function was assessed using maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP), vital capacity (VC), peak expiratory flow (PEF) and functionality through the measurement of functional independence (FIM) and time up and go (TUG). On the first postoperative day, patients were randomized into two groups: the control group (CG), submitted to conventional physiotherapy, and the virtual rehabilitation group (VRG), increased through virtual reality. On the day of hospital discharge, patients were reassessed. Results: 56 patients were analyzed, 25 in the CG, with a mean age of 51 ± 10 years, male prevalence 17 (68%), 31 in the VRG aged 54 ± 8 years, 21 (68%) men. All variables showed an intragroup reduction. At the end, the MIP of the CG was 74 ± 15 vs 92 ± 12 cmH$_2$O of the VRG (P < 0.001), the MEP of the GC was 54 ± 14 vs 75 ± 16 cmH$_2$O of the VRG (P < 0.001), the VC was 1.9 ± 0.6 ml/Kg in GC vs 2.4 ± 0.7 ml/Kg in VRG (P = 0.22), PEF in GC was 231 ± 28 vs 311 ± 26 L/min in VRG (P < 0.001), TUG of CG 22 ± 9.1 seconds vs 10 ± 1.6 seconds in the VRG (P < 0.001), the CG's FIM was 112 ± 5 vs 120 ± 3 in the GRV (P < 0.001). Conclusion: Based on the results obtained, it was found that the intervention with virtual reality was effective in reducing the loss of pulmonary function and functional independence after CABG.

Keywords: Virtual reality, lung function, functional independence

Introduction

Cardiovascular diseases (CVD) are the leading cause of death in the world [1]. Despite not being the leading cause of death in many low and middle income countries, 80% of them and 88% of premature deaths from CVD occur exactly in these countries [2]. Coronary artery bypass grafting (CABG) is one of the most commonly performed types of surgery, in which a patient's own blood vessel is used to reestablish the circulatory communication conditions of the heart [3].

Although cardiac surgery favors the improvement of the patient's cardiac state, its impact on pulmonary function can cause postoperative changes, according to surgical conditions such as: cardiopulmonary bypass (CPB), anesthesia, sternotomy, drains, surgical time or physiological stability of the patient, which can cause pneumonia, pneumothorax, pulmonary edema, pleural effusion, atelectasis, among others [4].

In addition, the functionality of these patients can be affected in up to five years, due to the functional inactivity of the muscles during the hospital stay, where most of the time the patient is in the supine position for fear of the pain caused in the surgical incision and without the due presence of weight-bearing on the lower limbs, which can decisively interfere with the respiratory function and quality of life [5].

Virtual reality (VR) promotes an environment that seeks to provide a moment of entertainment, motivation and fun with varied stimuli, with movements that favor physical and cognitive development, as well as the active participation of the patient in the rehabilitation process.

With the platform, through a low cost, it is possible to assist in the relief of pain, through the playfulness provided at the time of rehabilitation, with an efficient consumption of oxygen, range of motion and use of the respiratory muscles more efficiently [6].

Pain is a limiting factor, causing physiological and psychological changes for the patient, who, for fear of getting around and performing physiotherapy in the post-surgical period, can cause tachycardia, elevated blood pressure, among other respiratory complications and delayed hospital discharge thus starting to occupy the hospital bed for a longer time [7, 8].

This study aims to test the hypothesis that virtual reality modifies pulmonary function and can promote the functional independence of patients undergoing coronary artery bypass grafting.

Material and methods

This is a clinical trial conducted with patients undergoing cardiac surgery at the Instituto Nobre de Cardiologia (INCARDIO), in Feira de Santana, Bahia. The work was approved by the Research Ethics Committee of Faculdade Nobre under Opinion No. 2,150,434. All volunteers signed an Informed Consent Form.

Eligibility criteria

Individuals of both genders, aged over 18 years, who underwent to CABG, via median sternotomy and cardiopulmonary bypass, were included. Individuals with severe hemodynamic instabilities were excluded, such as mean arterial pressure (MAP < 70 mmHg or > 110 mmHg), hypo or hypertension, drop in oxygen saturation (SPO_2 < 90%), arrhythmias before or during the game, tachycardia (HR > 100 bpm), bradycardia (HR < 60 bpm), tachypnea (RF > 20 ipm) and bradypneia (RF < 12 ipm), angina or dyspnea at rest, inability to perform the proposed techniques (physical limitations and/or psycho-

logical alteration), withdrawal during the practice of the VR protocol, reintubation, time in the intensive care unit longer than three days, time on mechanical ventilation over 24 hours, proven lung disease and death.

Study protocol

In the preoperative period, both groups responded to an evaluation form, containing sociodemographic information and related to comorbidities. The pulmonary function evaluation consisted of the Maximum Inspiratory Pressure (MIP), Maximum Expiratory Pressure (MEP), Peak Expiratory Flow (PEF) and Vital Capacity (VC). Functionality was assessed using the Time Up and Go (TUG) test and the Functional Independence Measure (MIF) questionnaire.

The day after the evaluation, the patients were referred to the operating room and later to the ICU being managed according to the routine of the unit itself, without any interference from the researchers. At the time of discharge from the ICU, which corresponded to the second postoperative day, patients were randomized, by simple drawing, to two groups: control group (CG) and virtual reality group (VRG). The CG did not receive any specific intervention, being managed according to the routine of the unit itself, performing free active kinesiotherapy, cycle ergometry, ambulation and reexpansive ventilatory patterns. This intervention took place twice a day for five days. VRG, in addition to conventional physiotherapy, performed activities with the XBOX 360 platform, in addition to the Kinect electronic device, and the game used was the Kinect Sports Ultimate Collection, table tennis mode.

The patients were positioned in orthostasis, facing the TV, with 20 minutes of daily practice time, over a period of five consecutive days, performing functional movements such as: elbow flexion-extension, internal and external rotation of the upper limbs, as well as adduction and abduction, hip dissociation and lowering of weight in lower limbs. VR was performed twice a day for five days. On the fifth day of rehabilitation at the inpatient unit, patients in both groups were reassessed for lung function and functionality. It is worth mentioning that these pre and postoperative evaluations were

performed by a blind examiner. In addition, analgesia was optimized in both groups.

Evaluation of muscle strength variables

The evaluations of MIP and MEP were performed using an Instrumentation Industries analog manovacuometer of the MV-120 model, with an interval from zero to 120 cmH$_2$O, following the guideline for pulmonary function assessment. During the evaluation of the inspiratory force, a maximum exhalation until the residual volume was requested and, then, a maximum and slow inhalation until the total lung capacity, being that this test was done through the method with the unidirectional valve. The participant repeated this procedure three times and the highest value was used. For expiratory strength, the patient also repeated three times. However, maximum inspiration until full lung capacity was requested and then a maximum and slow exhalation until residual volume [9].

Evaluation of pulmonary function variables

The VC was assessed using the Wright Respirometer Mark 8 Ferraris®, England, with a 35 mm display, two displays of 0-1 L and 0-100 L. The patient was asked to perform a maximum inspiration until the total lung capacity and, then after, a slow and maximum expiration until reaching the residual volume. All patients were seated and underwent three measurements, with a one-minute interval between them, using the highest value obtained as a reference. For the measurement of PEF, the patient was asked to perform a maximum inspiration until the total lung capacity and, soon after, a maximum expiration until reaching the residual volume. All patients were seated and underwent three measurements, with a one-minute interval between them, using the highest value obtained as a reference [10].

Functional performance evaluation

The functional assessment was carried out through the FIM, which aims to measure and evaluate what the individual actually accomplishes, regardless of the diagnosis, generating valid score for limitation or not.

This scale assesses the patient's ability to develop body care, sphincter control, transfer and locomotion, as well as cognitive function (communication and memory). A score from 1 to 7 is assigned, with the lowest value corresponding to the patient totally dependent and the highest value to that patient completely independent from the functional point of view, reaching a maximum value of 126 points, when other variables are added together [11].

Timed up and go

The TUG test performed consisted of getting up from a chair with arms, walking three meters in a straight line, turning around, returning to the starting point and sitting in the chair. During its execution, the individual must walk in a comfortable, safe and without any physical assistance. To initiate the test, the verbal command "go" was given and the timer was started at the first previous movement of the trunk and stopped when it leaned against the chair [12].

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences version 20.0. Normality was assessed using the Shapiro-Wilks test. The data were expressed as means and standard deviations. Categorical variables were verified using Fisher's exact test. For intergroup comparison, the independent Student T test was used and intra-group analysis was the dependent Student T test. P < 0.05 was considered significant.

Results

General clinical characteristics of the sample

In the period from August 2017 to April 2018, 76 patients were evaluated, 20 of whom were excluded due to withdrawal, rehospitalization and inability to perform the proposed techniques (**Figure 1**). The mean age was 52.5 ± 9 years, 38 (68%). The prevalent comorbidity among them was SAH, comprising 17 (68%) of the patients in the CG and 17 (58%) in the VRG. The other data are shown in **Table 1**.

General surgical characteristics of the sample

The mean CPB time of the CG was 73 ± 17 vs 63 ± 22 minutes in the VRG without significant difference (P = 0.21). The mean MV time was 8 ± 2 hours vs 7 ± 3 hours (P = 0.56) for the CG

Figure 1. Study flowchart.

Eligible for study (n = 76)

Excluded (n = 20)
Withdrawal - 8
Readmission to the ICU - 2
Lack of understanding - 10

Randomized (n = 56)

Control group (n = 25)

Virtual reality group (n = 31)
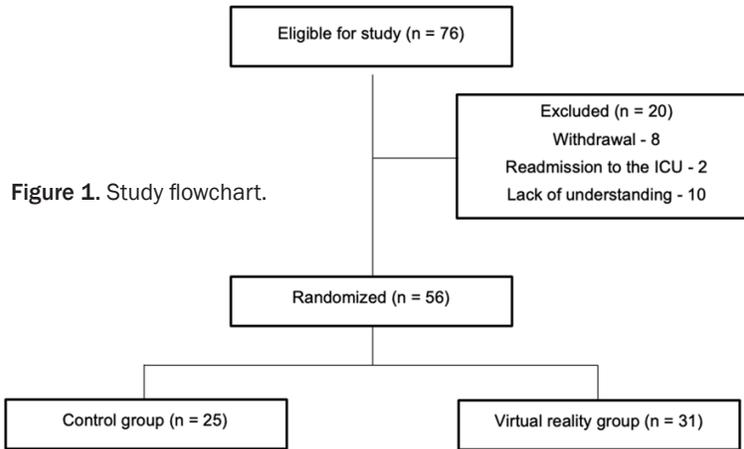
Table 1. Clinical characteristics of the patients included in the research

Variable	CG (n-25)	VRG (n-31)	P
Age (years)	51 ± 10	54 ± 8	0.43[a]
Gender			0.22[b]
Male	17 (68%)	21 (68%)	
Female	8 (32%)	10 (32%)	
BMI (kg/m^2)			
Eutrophic	16 (64%)	22 (71%)	0.34[b]
Overweight/Obesity	9 (36%)	9 (29%)	0.24[b]
grade I and II Comorbidity			
SAH	17 (68%)	18 (58%)	0.58[b]
DM	4 (16%)	7 (23%)	0.19[b]
DLP	10 (40%)	10 (32%)	0.65[b]
AMI	8 (32%)	7 (23%)	0.22[b]
Alcoholism	7 (28%)	8 (26%)	0.13[b]
Sedentary lifestyle	16 (64%)	20 (65%)	0.21[b]

Variables expressed as mean and standard deviation or absolute value and percentage. [a]Independent Student's T test was used to analyze continuous variables; [b]Fisher's exact test was used to analyze categorical variables; Abbreviations: BMI - Body Mass Index; SAH - Systemic Arterial Hypertension; DM - Diabetes Mellitus; DLP - Dyslipidemia; AMI - Acute Myocardial Infarction.

Table 2. Intra and postoperative clinical data

Variable	CG (n-25)	VRG (n-31)	P[a]
CPB time (minutes)	73 ± 17	63 ± 22	0.21
MV time (hours)	8 ± 2	7 ± 3	0.56
Number of grafts Number of drains	2 ± 1	2 ± 1	0.78
	2 ± 0.4	2 ± 0.2	0.91

Variables expressed as mean and standard deviation. [a]Independent Student's T test was used to analyze continuous variables; Abbreviations: CPB - Extracorporeal Circulation; MV - Mechanical Ventilation.

and VRG, respectively. The number of grafts in the CG was 2 ± 0.9 vs 2.1 ± 0.7 in the VRG (P =

0.78) and the number of drains 2 ± 0.4 for the CG and 2 ± 0.2 for the VRG (P = 0.98), as shown in **Table 2**.

Pulmonary function behavior

Significant differences were observed in the behavior of pulmonary variables in the pre and postoperative period during intergroup analysis. Except for the VC variable, which did not present a significant value (P = 0.02), when exclusively studying the VRG before and after the intervention. When comparing the analysis of the variables MIP, MEP and PEF between the two groups of patients, a significant difference was found (P < 0.05).

The final MIP of the CG was 74 ± 15 vs 94 ± 12 of the VRG (P < 0.05). The final MEP of the CG was 54 ± 14 vs 75 ± 16 in the VRG, showing a significant difference between the groups (P < 0.05). The other variable analyzed, the VC, did not obtain significant difference (P = 0.22), when compared between the groups. The PEF in the CG was 231 ± 28 vs 311 ± 26 of the VRG (P < 0.05), as shown in **Table 3**.

Behavior of functional capacity and functionality

The effect of virtual reality on the FIM score, when analyzed between both groups, showed a statistically significant difference (P < 0.05), with the final FIM of the CG being 112 ± 5 vs 120 ± 3 in the VRG. In the evaluation of TUG, patients had an average time, in seconds, of 22 ± 9.1 for the CG vs 10 ± 1.6 in the VRG (P < 0.05), according to **Table 4**.

Table 3. Behavior of pulmonary variables between groups

Variable	CG (n-25)	VRG (n-31)	P^a
MIP (cmH$_2$O)			
Preoperative	115 ± 20	117 ± 6	0.87
Postoperative	74 ± 15	92 ± 12	< 0.001
P^b	< 0.001	< 0.001	
MEP (cmH$_2$O)			
Preoperative	102 ± 18	108 ± 13	0.53
Postoperative	54 ± 14	75 ± 16	< 0.001
P^b	< 0.001	< 0.001	
VC (cmH$_2$O)			
Preoperative	3,2 ± 0.6	3.7 ± 1.1	0.38
Postoperative	1.9 ± 0.6	2.4 ± 0.7	0.22
P^b	< 0.001	0.02	
PEF (l/min)			
Preoperative	433 ± 23	423 ± 25	0.68
Postoperative	231 ± 28	311 ± 26	< 0.001
P^b	< 0.001	< 0.001	

Variables expressed as mean and standard deviation. ^{a}Independent Student's T-test was used for comparison between groups; ^{b}Dependent Student's T-test was used for intra-group comparison; Abbreviations: MIP - Maximum Inspiratory Pressure; MEP - Maximum Expiratory Pressure; VC - Vital Capacity; PEF - Peak Expiratory Flow.

Table 4. Behavior of functional variables between groups

Variable	CG (n-25)	VRG (n-31)	P^a
TUG (l/min)			
Preoperative	13 ± 5	11 ± 3	0.57
Postoperative	22 ± 9	10 ± 2	< 0.001
P^b	< 0.001	0.76	
FIM			
Preoperative	123 ± 2	125 ± 2	0.39
Postoperative	112 ± 5	120 ± 3	< 0.001
P^b	< 0.001	0.25	

Variables expressed as mean and standard deviation. ^{a}Independent Student's T-test was used for comparison between groups; ^{b}Dependent Student's T-test was used for intra-group comparison; Abbreviations:TUG - Timed Up and Go; FIM - Functional Independence Mensure.

Discussion

Based on the findings described, it appears that virtual reality was associated with decreased pulmonary function and functionality in patients undergoing myocardial revascularization, although less significant when compared to the results of the control group. It was observed that the patients in this study, in general, had a decrease in lung function after surgical intervention. Similar result verified by others authors, who associated this finding with the use of cardiopulmonary bypass, anesthesia, surgical incision and pain, which, in turn, modifies the ventilatory mechanics, reducing the expansion of the rib cage and favoring a non-positive prognosis, in addition to previous factors, such as age and lifestyle of individuals undergoing this procedure [13].

The decrease in pulmonary variables in both pre and post-surgery groups was noted. However, patients, who participated in the virtual reality group daily, when compared to patients in the control group, demonstrated significant differences assessed on the day of hospital discharge. It was observed that the fact of carrying out an activity that promoted entertainment, even if momentary, attenuating the presence in a hospital environment, causing a decrease in pain and minimizing the fear of moving the upper limbs. Therefore, patients were more willing to reestablish themselves and perform physical therapy exercises [14].

Virtual reality appears as an alternative for this population. Brazilian group found an improvement in functionality, also influencing the length of hospital stay. Similar results were found in our study, in which the group of patients who underwent VR had a lower loss of functionality at the time of hospital discharge, when compared to the group that received conventional physiotherapy [15].

This study noted that the use of VR can be a tool capable of accelerating the rehabilitation process, as it is a platform that allows greater patient participation, stimulating joy and pleasure in its practice and promoting a state of perception and contribution to the its recovery, making it reach functional capacity more quickly and playfully within the hospital. The use of VR provides greater motivation and commitment to these patients, contributing to greater motor learning, physical capacity and a better quality of life [16].

In the analysis of the Peak Expiratory Flow (PEF) variable, a decrease was observed post-intervention, an effect that contradicts the result found by other authors who, when researching

the applicability of VR in post-surgical rehabilitation, found that the group that benefited the physiotherapeutic protocol as a form of treatment, combined with the use of VR showed better results [17].

The results found in this study were unfavorable for the variables of inspiratory muscle strength (MIP) and expiratory muscle strength (MEP), suggesting that the exercise protocol established for participants in the RV group resulted in a decrease in the values of respiratory muscle strength. This finding corroborates the study by Pereira and Borges, where they report that cardiac surgery via sternotomy significantly compromises postoperative respiratory function, causing a significant reduction in lung volumes and impaired respiratory mechanics [18]. Therapeutic sections with exercise through VR are able to develop increased respiratory activity, effectively collaborating for the evolution of cardiorespiratory conditioning [19].

After analyzing the present study, it was possible to verify unfavorable results of the variables of respiratory muscle strength, suggesting that the exercise protocol established for the members of the RV group did not allow an increase in these, due to the dynamic activation of the respiratory muscles, especially the diaphragm. According to Cacau et al., due to the adopted postural kyphotic pattern and the retraction of the respiratory musculature, in order to protect the pain after the surgical procedure, the movements performed during the intervention with virtual reality improve chest expansion [15].

The use of the muscle groups during treatment caused the energy demand to increase, due to the caloric expenditure, making the individuals need oxygen to supply their physiological needs [19, 20]. It was observed that during the practice of intervention with VR, patients were able to move, even with the presence of drains, with more freedom, spontaneity, showing safety and satisfaction.

Individuals undergoing the cardiac surgery procedure may present, during the post-surgery period, changes in respiratory dynamics due to trauma to the midline of the chest and pain, resulting in reduced lung volumes, in addition to dysfunction in the ventilation/perfusion and change in breathing pattern [21]. The factors that favor a non-positive prognosis, such as the

age range and lifestyle of individuals [19]. Through the current research, it was observed that patients had a significant decrease in pulmonary variables, regardless of groups. However, patients who participated in the GRV evolved with a lower drop in their ventilatory function, showing a significant difference at the time of hospital discharge.

Because it is a platform that allows greater patient participation, playful therapy within the hospital sector provides greater motivation and commitment to these patients, contributing to greater motor learning, physical capacity and better quality of life [15]. Contributing to this study, it was observed that the use of virtual reality can be a tool capable of accelerating the rehabilitation process.

Some limitations of this study were observed, such as not having done a sample calculation, not assessing the level of pain, with no fixed shift for the intervention with the game and the lack of a specific environment for its practice.

Conclusion

Based on the results, it was found that the intervention with virtual reality was effective to minimize the loss of postoperative pulmonary function, especially when comparing the results presented with those of the control group.

Disclosure of conflict of interest

None.

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