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ORIGINAL ARTICLE

Impact of non-invasive ventilation immediately after extubation on clinical and functional outcomes in patients submitted to coronary artery bypass grafting: a clinical trial

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ABSTRACT

Background: The use of non-invasive ventilation (NIV) after coronary artery bypass grafting (CABG) may help reduce loss of functional capacity and complications in patients. However, the evidence regarding its immediate versus conventional use is controversial.
Aim: The aim of the study was to assess the impact of immediate NIV after extubation on oxygenation and the functional capacity of patients undergoing CABG.
Methods: This study was a randomized clinical trial involving patients of both sexes, aged 18 years or older, who have undergone elective CABG with median sternotomy and cardiopulmonary bypass. Patients were assessed before and after surgery using the Functional Independence Measure (FIM), 6-min walk test (6MWT), and the Medical Research Council (MRC) scale for peripheral muscle strength. On the 1st day after the surgery, two groups were formed: immediate NIV (NIVI) and conventional NIV (NIVC). Hemogasometry was performed before and after NIV, and complication rates were assessed. NIVI was administered 1 h after orotracheal extubation, while NIVC was performed on the first post-operative day, 24 h after extubation. After discharge, the above variables were re-evaluated.
Results: A total of 79 patients were evaluated; 46 (58.22%) were men, with a mean age of 65 ± 9 years. NIVI reduced the reintubation rate in one patient (3%) compared to NIVC with five patients (12%) ($p = 0.01$). In the post-intervention period, the inspired oxygen fraction (F_IO_2) was 0.43 ± 0.07 in the NIVC group and 0.30 ± 0.10 in the NIVI group ($p = 0.01$). The post-intervention PaO_2/F_IO_2 ratio was 191 ± 45 in the NIVC group and 266 ± 29 in the NIVI group ($p < 0.001$); the ratio one day later was 210 ± 39 in the NIVC group and 279 ± 37 in the NIVI group ($p < 0.001$). From the 6MWT, the INVI group reported a reduction of 51 ± 36 m compared to a reduction of 95 ± 40 m in the NIVC group ($p < 0.01$).
Conclusion: NIVI after extubation of patients undergoing CABG reduced the loss of functional capacity, improved blood gas levels, and decreased the rate of reintubation.
Relevance for Patients: This study suggests that the use of NIVI after extubation in patients undergoing CABG may improve recovery, preserve lung function, and reduce complications such as reintubation.

1. Introduction

Cardiac surgery (CS) is a widely utilized treatment due to the high incidence of cardiovascular diseases worldwide [1]. Among the most common procedures, coronary artery bypass grafting (CABG) stands out as a method that improves blood flow in patients

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with symptomatic myocardial ischemia, particularly when one or more coronary arteries are obstructed by atheromatous plaques [2]. Although patients undergoing CABG often display significant results, most of them would develop post-operative pulmonary disorders [3].

Approximately 30% of patients undergoing heart surgery experience a decrease in muscle strength and lung function after the procedure [4]. Consequently, the emergence of pulmonary complications can lead to unfavorable clinical outcomes, such as atelectasis, pneumonia, pulmonary edema, and acute respiratory failure, negatively impacting functional recovery [5,6]. Several factors, including age, overweight, sex, type of surgery, and intraoperative conditions, can contribute to the development of these complications [7].

Non-invasive ventilation (NIV) can be employed immediately after extubation to minimize pulmonary dysfunction, reduce the length of stay in the intensive care unit (ICU), and enhance the functional capacity of these patients [8-11]. According to the Brazilian mechanical ventilation (MV) guideline, NIV should be performed immediately after extubation. However, in some institutions, it is typically implemented on the first post-operative day per the institution's protocol [12]. There is still limited evidence regarding the validation of clinical and functional outcomes when comparing NIV administered immediately after extubation to that performed on the first post-operative day.

Therefore, this study aims to demonstrate the impact of administering NIV at different times on patients undergoing CABG [12]. While many ICU services routinely use NIV on the first post-operative day, we hypothesize that its use immediately after extubation may increase the likelihood of favorable outcomes. The purpose of this study was to compare the clinical and functional impact of two post-extubation (or prophylactic) non-invasive MV protocols for patients undergoing CABG surgery.

2. Methods

2.1. Study design

This was a randomized controlled clinical trial conducted with patients admitted to the ICU at the Noble Institute of Cardiology (Instituto Nobre de Cardiologia; INCARDIO) in Feira de Santana, Brazil, from January 2016 to October 2019. The study was approved by the Research Ethics Committee of Noble College (Faculdade Nobre) in Feira de Santana, Brazil (approval number: 1,405,821). All patients were informed about the study's objectives and provided written informed consent. The trial was registered in the Brazilian Registry of Clinical Trials (ReBEC; trial number RBR-9wkvm5b).

2.2. Eligibility criteria

This study included patients of both sexes, aged 18 years or older, who underwent elective CABG with median sternotomy and cardiopulmonary bypass. Patients with hemodynamic instability (mean arterial pressure lower than 60 mmHg) before NIV, those who were uncooperative, or those with contraindications for NIV were excluded. In addition, patients with chronic pulmonary disease, physical limitations that compromised functional testing (such as amputations), difficulty understanding the test instructions, the need for surgical reintervention, more than 24 h on invasive MV, and those who refused to sign the consent form were also excluded. The eligibility criteria were assessed by a researcher specifically assigned to this task.

2.3. Outcomes

The primary outcome was oxygenation and functional capacity. Secondary outcomes included the impact on functional variables, such as the Functional Independence Measure (FIM), peripheral muscle strength, pulmonary complications, mortality, and length of stay in the ICU and hospital. The primary oxygenation outcome was assessed before, immediately after, and one day following the application of NIV. Functional capacity was evaluated preoperatively and on the day of hospital discharge. Likewise, secondary outcomes were also assessed preoperatively and on the day of hospital discharge.

2.4. Study protocol

In the pre-operative phase, all patients underwent functional assessment using FIM, a 6-min walk test (6MWT), and the Medical Research Council (MRC) scale for peripheral muscle strength.

The following day, patients were taken to the operating room, where the surgery was performed by the same surgical team using median sternotomy and cardiopulmonary bypass, employing grafts from the internal thoracic artery or bypass. All patients left the operating room with subxiphoid and intercostal drains and were transferred to the ICU with full analgesia. Anesthetic agents included induction with midazolam, propofol, or etomidate; analgesia with fentanyl and/or morphine; neuromuscular blockade with rocuronium, vecuronium, or cisatracurium; and maintenance with isoflurane, transitioning to an infusion of propofol or dexmedetomidine before transport to the ICU. Intubation was performed using a 7.5- or 8.0-mm internal diameter endotracheal tube. Physiotherapists typically employed a pressure-controlled volume-guaranteed ventilation mode throughout the study, targeting normocapnia or mild hypocapnia while avoiding hypoxemia. Default ventilator settings included a tidal volume (VT) of 500 mL and positive end-expiratory pressure (PEEP) of 0 cm H_2O. All patients received pain relief with 1 g paracetamol four times daily as needed after discharge. On arrival in the ICU, they were managed according to routine procedures, without any influence from the researchers. Following established weaning criteria, patients were guided toward extubation, after which low-flow oxygen support was initiated to maintain saturation levels at 94 – 97%.

At the hospital where the research was conducted, NIV is routinely performed on the first post-operative day. Shortly after extubation, eligible patients were randomized using an electronic system (http://randomizer.org/form.htm) by a professional not part of the research team, ensuring the confidentiality of

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the procedure. Sealed, opaque, and sequentially numbered envelopes were used to conceal the allocation sequence until interventions were assigned. Researchers responsible for evaluations were blinded to the intervention and control groups.

Patients were divided into two groups: The immediate NIV group (NIVI) and the conventional NIV group (NIVC). The NIVI group received NIV immediately following orotracheal extubation, while the NIVC group received NIV on the first post-operative day, approximately 24 h after extubation.

NIV was administered using the Servo-S ventilator (Dräger Medical, Germany) in pressure support ventilation mode, with pressure sufficient to maintain tidal volume between 6 to 8 mL/kg, PEEP starting at 5 cm H_2O and increasing to 12 cm H_2O, and an inspired oxygen fraction (F_IO_2) of 30%. A face mask was utilized, and PEEP adjustments were protocol-driven for all patients. This therapy was maintained for 40 min in both groups and was performed only once. Arterial blood gas analysis was conducted before and after NIV for evaluation of gas exchange, with a follow-up analysis performed one day later for assessment of oxygenation.

On the day of discharge from the ICU, patients were reassessed using FIM and the MRC scale, and they were also evaluated for pulmonary complications, mortality, and length of stay in the ICU. These assessments were repeated on the day of hospital discharge, along with a repetition of the 6MWT. All patients received standard physiotherapy assistance, which included kinesiotherapy, cycle ergometry, and walking exercises.

Outcomes related to post-operative complications were assessed by a blinded radiologist. Gasometric and functional evaluations were conducted by a blinded physician and physiotherapist, respectively. Due to the nature of the intervention, blinding of patients and unit staff was not feasible.

2.5. Measurements

The 6MWT was conducted following the recommendations of the American Thoracic Society (ATS) in a flat, obstacle-free corridor measuring 30 m [13]. Before the test, patients were given a rest period of at least 10 min. During this time, contraindications were assessed, and vital signs were recorded, including blood pressure (using a Premium Aneroid Sphygmomanometer [Welch Allyn, United States of America [USA] and Littmann 3M® stethoscope [USA]), pulse oximetry (pulse oximeter from Rossmax® [USA]), dyspnea level (assessed using the Borg scale), heart rate (measured by palpating the radial artery for 1 min), and respiratory rate (evaluated by observing respiratory movements over 1 min).

Patients were instructed to walk as quickly as possible – without running – around the corridor for 6 min. Encouragement was provided at intervals throughout the test. At the end of the 6 min, the examiner recorded the total distance covered.

Throughout the entire protocol, patients were monitored closely. The test would be interrupted if there was an increase in systolic or diastolic blood pressure greater than 30% from baseline, a heart rate drop of more than 20% from baseline, peripheral oxygen saturation below 90%, or a respiratory rate exceeding 30 breaths/min.

The FIM aims to assess what a person can actually achieve, regardless of diagnosis, generating a valid score for functional limitations. This scale evaluates the patient's ability to perform self-care, maintain sphincter control, transfer, and ambulate, as well as cognitive functions such as communication and memory. Scores range from 1 to 7, with the lowest score indicating total dependence and the highest score reflecting complete independence from a functional perspective. The maximum possible score is 126 points when all variables are combined [14].

The MRC scale evaluates peripheral muscle strength by assessing the ability to overcome resistance in six muscle groups: shoulder abductors, elbow flexors, wrist extensors, hip flexors, knee extensors, and ankle dorsiflexors. Each group is scored bilaterally from 0 to 5, where 0 indicates the absence of contraction and five represents the patient overcoming maximum resistance imposed by the examiner. The minimum score for this test is 0 (indicative of quadriplegia), while the maximum score is 60 (indicating preserved muscle strength). A score below 48 may suggest the presence of polyneuromyopathy [15].

2.6. Measurement of pulmonary function

To assess vital capacity (VC), the Ferraris Mark 8 Wright Respirometer (Wright, USA) was used. The respirometer was unlocked and cleared; a facial mask was then placed on the individual's face. The patient was instructed to take a deep breath until reaching total lung capacity, followed by a slow and gradual expiration until reaching residual volume. After this, the respirometer was locked, and the result was recorded. The test was repeated three times, with the highest value being considered.

Peak expiratory flow was measured using the Mini Wright® peak flow meter (Wright, USA). During the evaluation, the patient was seated with the head in a neutral position and a nasal clip to prevent air escape through the nostrils. The patient took a deep breath to total lung capacity, followed by a forced expiration into the device. After three measurements, the highest value was selected, ensuring that no individual measurement differed by more than 40 L from the others.

2.7. Calculation of statistical power

In our study, 79 patients were evaluated, revealing a standard deviation in average oxygenation of 191 mmHg in the control group and 266 mmHg in the training group, resulting in a difference of 75 mmHg between the two groups.

The convenience sample provided a statistical power of 30% (alpha = 5%). A convenience sample is a non-random sampling method where participants are selected based on their easy availability or proximity to the researcher, rather than through a random or systematic process. This sample type is often used in exploratory research, where time, cost, or access to a specific population is limited. However, as it is not random, a convenience sample may not be representative of the broader population, potentially introducing bias into the results.

In addition, the standard deviation in average distance walked was 322 m in the control group and 378 m in the training group,

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with a difference of 56 m between the groups. This sample allowed for a statistical power of 10% (alpha = 5%).

2.8. Statistical analysis

Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 20.0 (IBM, USA). Normality was assessed using the Shapiro–Wilk test. Categorical variables were analyzed using the Chi-square test, while continuous data were expressed as the mean ± standard deviation. To evaluate oxygenation, functional capacity, and length of stay – both intra- and intergroup – paired Student's *t*-test and independent *t*-test were employed, respectively. Pulmonary complications and mortality were assessed using the Chi-square test. A *p*-value of < 0.05 was considered statistically significant.

3. Results

During the study period, 101 patients were admitted for CS. Of these, 22 were excluded for the following reasons: three required surgical reintervention before extubation, 10 remained on MV for more than 24 h, five refused to participate in the study, two died before extubation, and two patients could not provide blood gas data before NIV (Figure 1). Consequently, 79 patients were included in the study, with no loss to follow-up after randomization; 42 were allocated to the NIVC group, and 37 to the NIVI group.

Table 1 presents the clinical and surgical characteristics of the patients. Among them, the male gender was predominant, comprising 46 patients (58.22%), with a mean age of 65 ± 9 years. Arterial hypertension was the most prevalent comorbidity. The other variables are detailed in Table 1.

Significant differences were observed in F_IO_2 and the PaO_2/F_IO_2 ratio. Post-intervention, the F_IO_2 in the NIVC and NIVI groups were 0.43 ± 0.07 and 0.30 ± 0.10, respectively ($p = 0.01$). One day later, the F_IO_2 for the NIVC group was 0.40 ± 0.09, compared to 0.30 ± 0.05 in the NIVI group ($p = 0.04$). The PaO_2/F_IO_2 ratio in the NIVI group was significantly higher at 75 (95% confidence interval [CI]: 45 – 91) immediately after NIV and 69 (95%CI: 33 to 82) one day later. Additional values are presented in Table 2.

Table 3 displays the functional outcomes between the studied groups at various time points during the research. The FIM and MRC scores did not display statistically significant variation when comparing the groups at pre-operative assessment and hospital discharge. However, a significant reduction was noted when analyzing pre-operative scores compared to ICU discharge. The NIVI group demonstrated better performance on 6MWT, with a mean distance loss of 51 ± 36 m, compared to the NIVC group, which experienced a loss of 95 ± 40 m ($p < 0.01$). The difference between the groups in the 6MWT was 44 m (95%CI: 25 to 59).

Regarding post-surgical pulmonary complications, Table 4 presents the results between the groups. The only statistically significant variables were reintubation and pleural effusion, with five NIVC patients versus one NIVI patient for reintubation ($p = 0.01$).

Table 5 illustrates the pulmonary function results, displaying no significant differences between the studied groups.

4. Discussion

NIV performed immediately after extubation has proven to be an effective resource in reducing the loss of functional capacity,

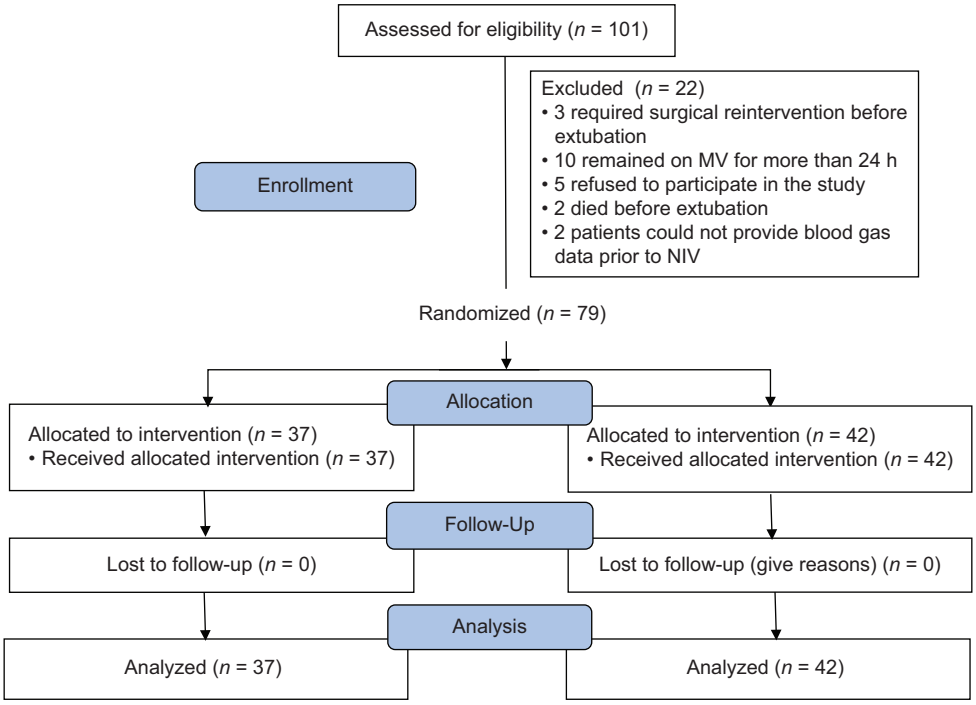

Figure 1. Flowchart related to patient participation in the study
Abbreviation: MV: Mechanical ventilation

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Table 1. Clinical and surgical characteristics of patients randomized according to the NIV groups

Variable	NIV group		*p*
	Conventional (*n*=42)	Immediate (*n*=37)	
Gender			0.52[a]
Male	25 (60%)	21 (57%)	
Female	17 (40%)	16 (43%)	
Age (years)	66±8	64±9	0.36[b]
BMI (kg/m²)	25±3	27±4	0.14[b]
Comorbidities			
SAH	28 (67%)	22 (59%)	0.31[a]
DLP	24 (57%)	17 (46%)	0.21[a]
Diabetes	19 (45%)	14 (38%)	0.54[a]
AMI	5 (12%)	3 (8%)	0.75[a]
Sedentary lifestyle	11 (26%)	9 (24%)	0.69[a]
Surgery time (min)	237±88	244±87	0.23[b]
CPB time (min)	88±21	92±25	0.18[b]
Aortic clamping time (min)	77±18	72±21	0.35[b]
MV time (h)	7±2	8±3	0.76[b]
LVEF (%)	58±6	59±5	0.59[b]

Note: [a]*p*-value obtained from Chi-square test; [b]*p*-value obtained from independent Student's *t*-test. Abbreviations: BMI: Body mass index; SAH: Systemic arterial hypertension; DLP: Dyslipidemia; AMI: Acute myocardial infarction; CPB: Extracorporeal circulation; MV: Mechanical ventilation; LVEF: Left ventricular ejection fraction; NIV: Non-invasive ventilation.

decreasing the rate of reintubation, improving oxygenation up to one day following its use, and shortening hospital stays for patients undergoing CABG. Through this study, we were able to achieve our objective and demonstrate that NIV after extubation has an impact on clinical and functional outcomes. Therefore, hospital services may adopt this type of intervention as a routine practice for this patient profile.

In our study, NIVI patients presented a reduction in the loss of functional capacity, as evidenced by the distance covered in the 6MWT, similar to the findings by Araújo-Filho *et al*. [16] involving patients in the post-operative period of valve replacement. This reduction may be due to the meta-reflex. The realization of NIV increases pulmonary capacity and oxygenation, thus attenuating the metaboreflex, which improves the perfusion of peripheral muscles and leads to an increase in functional performance [17-19].

Performing the 6MWT raises the patient's metabolic rate, requiring greater blood flow to the peripheral muscles. The muscle fibers recruited during the 6MWT are primarily Type I fibers, which rely on oxygen. Therefore, when lung function improves and blood flow rich in oxygen is enhanced, the functional capacity of these patients is significantly better. In the present study, the difference in 6MWT was 44 m between the NIVC and NIVI groups. Gremeaux *et al*. [20] reported that a difference of at least 25 m is clinically important for this patient profile.

Table 2. Blood gas analysis of patients randomized according to the NIV groups

Variable	NIV group		Difference between groups (95%CI)	*p*
	Conventional (*n*=42)	Immediate (*n*=37)		
F_IO_2				
Pre-intervention	0.45±0.11	0.49±0.09	0.04 (−0.1 to 0.2)	0.67
Post-intervention	0.43±0.7	0.30±0.10	0.13 (0.05 to 0.22)	0.01
One day later	0.40±0.09	0.30±0.05	0.1 (0.03 to 0.3)	0.04
PaO_2 (mmHg)				
Pre-intervention	91±15	90±14	1 (−3 to 4)	0.76
Post-intervention	82±12	80±16	2 (−4 to 5)	0.68
One day later	84±11	81±14	3 (−7 to 8)	0.67
PaO_2/F_IO_2				
Pre-intervention	202±34	183±48	19 (−11 to 28)	0.12
Post-intervention	191±45	266±29	75 (45 to 91)	< 0.001
One day later	210±39	279±37	69 (33 to 82)	< 0.001
$PaCO_2$ (mmHg)				
Pre-intervention	37±5	39±4	2 (−4 to 5)	0.78
Post-intervention	41±6	42±3	1 (−4 to 3)	0.87
One day later	40±4	40±2	0 (−2 to 2)	0.91
Tidal volume (mL)				
Pre-intervention	367±22	359±25	8 (−2.53 to 18.53)	0.53
Post-intervention	392±31	411±29	−19 (−32.51 to −5.49)	0.32
One day later	382±21	399±24	−17 (−27.08 to -6.92)	0.39
RR (rpm)				
Pre-intervention	19±2	18±2	1 (0.10 to 1.90)	0.64
Post-intervention	17±2	15±3	2 (0.87 to 3.13)	0.43
One day later	16±2	15±3	1 (−0.13 to 2.13)	0.72

Note: *P*-value obtained from independent Student's *t*-test.
Abbreviations: CI: Confidence interval; FIO_2: Inspired oxygen fraction; PaO_2: Arterial oxygen pressure; $PaCO_2$: Blood pressure of carbon dioxide; RR: Respiratory rate; NIV: Non-invasive ventilation.

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Table 3. Functional results of patients randomized according to the NIV groups

Variable	NIV group		Difference between groups (95%CI)	p^a
	Conventional (n=42)	Immediate (n=37)		
FIM				
Pre-operative	125±1	125±1	0 (−1 to −1)	0.96
ICU discharge	111±3	115±2	4 (−3 to 9)	0.69
Delta[b]	14±2	10±2	4 (−2 to 8)	0.54
Hospital discharge	121±2	123±2	2 (−4 to 5)	0.84
Delta[c]	4±2	2±1	2 (−5 to 6)	0.45
6MWT (m)				
Pre-operative	417±36	429±43	12 (−15 to 22)	0.74
Hospital discharge	322±45	378±39	56 (35 to 71)	0.03
Delta[b]	95±40	51±36	44 (25 to 59)	< 0.01
MRC scale				
Pre-operative	59±1	58±1	1 (−3 to 4)	0.92
ICU discharge	48±4	50±3	2 (−3 to 4)	0.76
Delta[b]	11±3	8±2	3 (−4 to 8)	0.45
Hospital discharge	53±3	55±2	2 (−4 to 6)	0.79
Deltac	6±2	3±1	3 (−5 to 8)	0.43

Note: [a]p-value obtained from independent Student's t-test; [b]delta value obtained from paired Student's t-test between pre-operative and ICU discharge scores; [c]delta value obtained from paired Student's t-test between pre-operative and hospital discharge scores.
Abbreviations: FIM: Functional Independence Measure; ICU: Intensive care unit; 6MWT: 6-min walk test; MRC: Medical Research Council; CI: Confidence interval; NIV: Non-invasive ventilation.

Table 4. Clinical results of patients randomized according to the NIV groups

Variable	NIV group		p
	Conventional (n=42)	Immediate (n=37)	
Complication			
Pneumothorax	5 (12%)	4 (11%)	0.69[a]
Pleural effusion	22 (53%)	10 (27%)	<0.01[a]
Atelectasis	5 (12%)	4 (11%)	0.68[a]
Severe respiratory discomfort	1 (3%)	1 (3%)	0.87[a]
Reintubation	5 (12%)	1 (3%)	0.01[a]
Infection in the sternal wound	2 (5%)	2 (5%)	0.83[a]
In-hospital death	2 (5%)	0 (0%)	0.21[b]
ICU time (days)	3±1	2±1	0.86[b]
Hospital stay (days)	13±5	9±3	0.04[b]

Note: [a]p-value obtained from Chi-square test; [b]p-value obtained from independent Student's t-test.
Abbreviations: ICU: Intensive care unit; NIV: Non-invasive ventilation.

Another fundamental point in this discussion is that NIV tends to enhance the performance of the left ventricle, optimizing cardiac output and improving tissue perfusion [21], thereby improving the functional capacity of these patients. It is important to understand that the application of NIV immediately after extubation effectively optimizes lung function, but improved performance in the walking test can be achieved with enhanced cardiovascular function and peripheral muscles. However, we note that the latter aspect did not influence the result, as there was no difference in the MRC scores between groups. Hence, further validation should be employed using an echocardiogram or assessing myocardial behavior such as ejection fraction, stroke volume, and ventricular mass.

Shoji *et al*. [22] reported a high rate of reintubation among patients undergoing CS and attributed this to various comorbidities (e.g., hypertension and diabetes mellitus) and complications (e.g., pneumonia and renal dysfunction). Therefore, our study suggests using NIVI as a preventive factor for these complications and to reduce the risk of extubation failure.

According to Wu *et al*., [23] the role of NIV remains controversial, as the rate of reintubation does not present a significant difference; however, some authors have proposed immediate NIV application to avoid complications and reduce hospital stay [24,25]. One possibility for the divergent results is the variation in the duration of NIV application, the selection of patients, and the protocols performed.

According to the Brazilian guideline on MV, the use of NIV is indicated in obese, elderly, and patients with more than one comorbidity [12]. As a result, we realized that the patients in our study were older, overweight, and had two or more comorbidities, with satisfactory results after using immediate NIV, including a reduction in the reintubation rate.

Liu *et al*. [26] demonstrated that the prophylactic use of NIV significantly reduced the rate of post-surgical complications and enhanced gas exchange. The immediate use of NIV significantly reduced the rate of atelectasis in our study. The main effect of positive pressure at the end of expiration during NIV is to reopen collapsed alveoli and keep the lung aerated. This reversal of alveolar collapse tends to improve the ventilation/perfusion ratio, generating an increase in gas exchange, which was found in the present study.

In addition, a higher PaO_2/F_IO_2 ratio was observed in NIVI patients even after 24 h from the intervention. Despite the lack

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Table 5. Analysis of pulmonary function of patients randomized according to the NIV groups

Variable	NIV group		Difference between groups (95%CI)	*p*
	Conventional (*n*=42)	Immediate (*n*=37)		
VC (mL/kg)				
Pre-intervention	61±5	62±6	−1 (−3.46 to 1.46)	0.78
Post-intervention	44±6	45±7	−1 (−3.91 to 1.91)	0.87
One day later	45±5	45±5	0 (−2.24 to 2.24)	0.79
PEF (L/min)				
Pre-intervention	475±67	482±69	−7 (−37.50 to 23.50)	0.69
Post-intervention	333±59	356±55	−23 (−48.67 to 2.67)	0.67
One day later	342±55	360±59	−18 (−43.55 to 7.55)	0.56

Abbreviations: VC: Vital capacity; PEF: Peak expiratory flow; NIV: Non-invasive ventilation.

of significance in arterial oxygen pressure, alveolar recruitment resulted in a reduced need for supplemental oxygen, which was reflected in the improved effectiveness of gas exchange.

Therefore, it was possible to maintain the oxygenation levels of patients for a longer duration with a lower O_2 supply, thereby decreasing the toxicity associated with oxygen use. In line with our results, Landoni *et al*. [17] demonstrated that NIV is a useful tool to decrease respiratory work, reduce atelectasis, prevent respiratory failure, and improve gas exchange.

According to Laizo *et al*. [27], complications related to respiratory function are the main causes of increased length of hospital stay. Since the rate of respiratory complications was low in our study, particularly in the NIVI group, this may justify the reduction in the length of hospital stay. This decrease can contribute to lower hospital costs and as a preventive factor for future complications associated with prolonged hospital stay, such as infections and loss of muscle mass.

Systematic reviews found that immediate NIV did not achieve a significant result in terms of length of stay in the ICU or hospital [17,28]. This can be justified by the patient profiles studied, who had low ejection fractions, hypoactivity, and important deficits in muscle strength associated with heart failure. Contrary to our study, the patients evaluated did not present any hemodynamic instability before NIV, did not need surgical reintervention, and mainly obtained positive results on the functionality scale.

In the literature and clinical practice, the choice of whether to perform NIV on the first day after surgery or immediately after extubation remains controversial. This work is evidence that NIV immediately after extubation generates better clinical and functional results a few hours after surgery. Therefore, performing NIV immediately after extubation in selected patients should be adopted as a routine practice.

One of the limitations of this study is the lack of sample size calculation, which would have helped reduce the error margin and effectively strengthen the conclusion. Other limitations include the absence of a pain assessment scale, such as the Visual Analog Scale (VAS), which could have allowed patients to report the degree of pain at the moment. In addition, the study did not use a blind examiner for variables, such as blood gas analysis. Other limitations are the small sample size and the fact that the study was conducted at only one participating institution.

5. Conclusion

The use of NIV immediately after extubation for patients undergoing CABG demonstrated significantly positive impacts, such as reducing the loss of functional capacity, decreasing the rate of reintubation, and improving blood gas exchange, F_IO_2, and the PaO_2/F_IO_2 ratio.

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None.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethics Approval and Consent to Participate

The study was approved by the Research Ethics Committee of Noble College in Feira de Santana, Brazil (approval number: 1,405,821). All patients were informed about the study's objectives and provided written informed consent.

Consent for Publication

All research participants authorized the release of their data through a written and signed document.

Availability of Data

Data are available from the corresponding author on reasonable request.

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