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Benefits of non-invasive ventilation after extubation in the postoperative period of heart surgery

Benefícios da ventilação não-invasiva após extubação no pós-operatório de cirurgia cardíaca

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Abstract

Objective: **to show the benefits of the use of non-invasive positive pressure ventilation (NPPV) in the process of weaning from mechanical ventilation in the immediate postoperative period of heart surgery.**

Methods: **A prospective, randomized and controlled study was performed involving 100 consecutive patients submitted to coronary artery bypass grafting or valve surgery. The subjects were admitted into the Intensive Care Unit (ICU) under mechanical ventilation and randomized in a study group (n=50), which used NPPV with bilevel pressure for 30 minutes after extubation, and a control group (n=50) which only used a nasal O_2 catheter. Anthropometric variables and the times of the intra-operative periods corresponding to anesthesia, surgery and cardiopulmonary bypass, as well as the time required for weaning from invasive mechanical ventilation were analysed. The arterial blood gases and hemodynamic variables were also assessed before and after extubation.**

Results: **The evolution was similar for the control and study groups without statistically significant differences of the variables analyzed except for the PaO_2. On comparing the groups, the PaO_2 improved significantly (p = 0.0009) with the use of NPPV for 30 minutes after extubation, but there was no statistically significant difference in the $PaCO_2$ (p = 0.557).**

Conclusion: **The use of NPPV for 30 minutes after extubation improved oxygenation in the immediate postoperative period of heart surgery.**

Descriptors: **Heart surgery procedures. Intensive care unit. Respiration, artificial. Ventilator weaning. Intermittent positive-pressure ventilation.**

Resumo

Objetivo: **Demonstrar os benefícios da utilização da ventilação não-invasiva (VNI) no processo de interrupção da ventilação mecânica, no pós-operatório de cirurgia cardíaca.**

Métodos: **Estudo prospectivo, randomizado e controlado, com 100 pacientes submetidos a cirurgia de revascularização do miocárdio ou cirurgia valvar. Os pacientes foram admitidos na Unidade de Terapia Intensiva (UTI), sob ventilação mecânica e randomizados posteriormente em grupo estudo (n= 50) que utilizou VNI com dois níveis pressóricos após a extubação por 30 minutos, e grupo controle (n= 50) que fez uso apenas de cateter nasal de O_2. Foram analisadas as variáveis antropométricas, os tempos correspondentes à anestesia, cirurgia e circulação extracorpórea, bem como o tempo necessário para a supressão da ventilação mecânica invasiva. As variáveis gasométricas e hemodinâmicas também foram avaliadas antes e após a extubação.**

Resultados: **Os grupos controle e estudo evoluíram de forma semelhante e não apresentaram diferença estatisticamente significante na análise das variáveis, exceto para a PaO_2. A utilização da VNI por 30 minutos após a extubação promoveu melhora na PaO_2 quando comparados os grupos, com p= 0,0009, mas não apresentou diferença estatisticamente significante na $PaCO_2$ (p=0,557).**

Conclusão: **O uso da VNI por 30 minutos após extubação produziu melhora na oxigenação do pacientes em pós-operatório imediato de cirurgia cardíaca.**

Descritores: **Procedimentos cirúrgicos cardíacos. Unidades de terapia intensiva. Respiração artificial. Desmame do respirador. Ventilação com pressão positiva intermitente.**

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INTRODUCTION

The study of surgical and anesthetic management of patients submitted to heart surgery as well as improvements in the techniques have contributed to a reduction in the morbidity and mortality rates. Some factors that influence the cost of heart surgery, such as mechanical ventilation time and its complications, have been studied since the 1990s, when programs to improve the assistance to patients submitted to heart surgery were adopted [1].

The so-called fast-track program is characterized when tracheal extubation occurs within the first eight postoperative hours. There is even the possibility of extubation within the surgical center, however the occurrence of hypothermia, bleeding and hemodynamic instability offset potential benefits and may increase the costs [2,3].

Frequently, postoperative complications are due to associated diseases or factors such as age, gender, left ventricular dysfunction, type of surgery, the use of an intra-aortic balloon, congestive heart disease, recent myocardial infarction, renal failure, associated surgeries, reoperations and obesity [2]. Intra-operative factors, such as cardiopulmonary bypass (CPB) time, surgical manipulation and the number of pleural drains can also interfere in pulmonary function [3].

The greatest incidence of complications in the postoperative period is related to the respiratory system with the most common including atelectasis and infections. These are responsible for high morbidity rates, prolongation of hospitalization and mortality. In patients submitted to heart surgery, the self-regulation of respiration might not be effective to prevent atelectasis and alterations in gas exchange due to prolonged CPB, which can trigger other complications [4].

The routine methods used for prevention of postoperative respiratory complications include encouraging the patient to get out of bed as soon as possible, ambulation, stimulation of deep respiration, use of incentive inspirometers and coughing. However, often, these measures are not efficacious, requiring other techniques that utilize positive pressure [4].

Non-invasive ventilation is an easy-to-use method which does not require invasion of the airways. Even so, it is possible to increment gas exchange utilizing different levels of positive end-expiratory pressure [5].

The aim of this study was to analyze the benefits of utilizing non-invasive ventilation after early extubation in the immediate postoperative period of heart surgery.

METHODS

A controlled randomized prospective study was carried out after approval of the Research Ethics Commission of the Heart Institute (InCor) and the Ethics Commission for Analysis of Research Projects (CAPPesq) of Hospital das Clínicas Medical School of the University of Sao Paulo (HC FMUSP - Nº 979/00).

One hundred consecutive patients, submitted to heart surgery with CPB between February and December 2005, were evaluated. Fifty patients underwent coronary artery bypass grafting (CABG) and 50 were submitted to valve surgery. There was no loss of patients during the study as the inclusion and exclusion criteria were strictly respected during randomization of patients. In this period, 511 patients were submitted to CABG and 374 patients to valve surgery in InCor – HC FMUSP.

The ages of the patients of both groups varied between 20 and 80 years old. Patients were enrolled one day after giving their informed consent and after confirmation of the surgery. The patients were randomized by means of stratified sampling achieved using a statistical analysis computer system (SAS), performing randomization for the sequential composition of the groups denominated as: Control and Study Groups. The Control Group was composed of patients who only used an oxygen (O_2) catheter after extubation; the Study Group utilized non-invasive ventilation for 30 minutes.

The same anesthetic technique was employed for all patients. Pre-anesthetic medication consisted of oral midazolam (0.1 to 0.2 mg/kg) up to a maximum dose of 15 mg 30 minutes before the operation. After pre-oxygenation, anesthetic induction was achieved using fentanyl (20 to 50 µg/kg) and midazolam (0.3 to 0.5 mg/kg), followed by muscle relaxant using pancuronium bromide (0.1 to 0.2 mg/kg). After tracheal intubation, with an appropriately sized tube, and establishing mechanical ventilation, maintenance of anesthesia employed fractional doses of fentanyl, midazolam and pancuronium bromide. Varying concentrations of isoflurane were also utilized. All the surgeries were performed using median sternotomy.

The patients were transported, after surgery, to the surgical intensive care unit (ICU) of the Heart Institute of HC-FMUSP, under orotracheal intubation and mechanical ventilation using Veolar or Amadeus models produced by Hamilton (Switzerland) in the controlled mandatory ventilation (CNV) mode with a volume current (VC) of 8 mL/kg, respiratory frequency (f) of 12 rpm; Inspired oxygen fraction (iOF) of 0.6 and positive end-expiratory pressure (PEEP) of 5 cmH_2O as is routine in the surgical ICU.

After considering the inclusion and exclusion criteria, randomization allocated the patients to the Control and Study Groups thereby dictating the method utilized after extubation.

Criteria for inclusion in the study were: left ventricular

ejection fraction in the preoperative period ≥ 0.5; patients without signs of curarization, presenting with a spontaneous opening and capable of maintaining the head lowered for 5 seconds without support, responding to simple orders and without apparent motor impairment; urinary outflow ≤ 2 mL/kg/h; arterial gasometry (pre-extubation) within the normal range; hemoglobin ≥ 9 g/dL; rapid and superficial respiratory rate -(Tobin)- f/VC ≤ 100; hydroelectrolytic stability (without metabolic acidosis or alkalosis); absence of potentially lethal arrhythmias and body temperature ≥ 36ºC.

The exclusion criteria were: hemodynamic instability characterized by the necessity of an intra-aortic balloon and/or the administration of high doses of vasoactive or inotropic agents; signs of ventilatory failure: difficulty in the elimination of carbon dioxide (CO_2), increase in respiratory muscle effort, bronchospasm, bronchial hypersecretion; hypoxia with the PaO_2/FiO_2 ratio < 150; alterations in the level of awareness such as : sleepiness, torpor, agitation, significant mental confusion and diminished respiratory neural activity; presence of significant motor deficits; radiological alterations such as diffused pulmonary infiltration, presence of lobar or total atelectasis, great pleural effusions or the presence of pneumothorax.

Arterial blood samples were drawn to analyze the pH, blood gases and venous samples to evaluate the venous oxygen saturation (SVO_2). The first sample was drawn at admittance of the patients to the ICU and then at 30, 120 and 360 minutes after extubation. In the control group, gasometric samples were collected after extubation, always with a 5 L/min supplement of oxygen using a nasal catheter. In the Study Group, the samples were collected 30 minutes after extubation, on non-invasive ventilatory support using the BiPAP ® equipment (S/T-D model manufactured by Respironics) connected to a face mask of the same brand; and the other subsequent samples just with a nasal catheter with oxygen at 5 L/min. To collect the samples at 120 and 360 minutes after extubation, in cases where the patient was still being weaned from BiPAP ®, the mask was removed for 15 minutes to collect blood under the same conditions as the Control Group, that is, with the O_2 catheter at 5 L/min.

During weaning from the mechanical ventilator, the patients were re-evaluated at intervals of between 5 and 15 minutes. As criteria to reduce the respiration frequency of the ventilator, the state of awareness and the presence of spontaneous breaths intercalated with those supplied by the ventilator were used with pulse oximetry being utilized to gradually reduce the FiO_2. Discontinuation of mechanical ventilation and removal of the orotracheal tube occurred depending on the following parameters: ventilatory mode: Pressure support ventilation (PSV) of 5 cmH_2O above the PEEP; PEEP = 5 cmH_2O; FiO_2 = 0.4; total respiratory rate (ft) > 12 rpm and ≤ 30 rpm; expired current volume (CV exp) ≥ 5 mL/kg and Tobin index ≤ 100.

Control Group

The patients followed the protocol of weaning from ventilation and after extubation they only received O_2 at 5 L/min using a nasal catheter.

Study Group

The patients were extubated and connected to the BiPAP ® for a minimum of 30 minutes, utilizing a face mask, in spontaneous ventilation mode with a inspired positive pressure (IPAP) to produce a CV ≥ 5 mL/kg, expired positive pressure (EPAP) at 5 cm/H_2O, and a 5 L/min supplement of oxygen, or sufficient to maintain the SpO_2 ≥ 95%, through the mask.

If necessary, the value of the IPAP could be changed to obtain a CV ≥ 5 mL/kg. However, the EPAP was always maintained at 5 cmH_2O and an additional supplement of oxygen was offered using the face mask until saturation stabilized if it was less than 95%. The oxygen flow was increased for a period of up to 2 hours to increase saturation when another gasometry sample was collected and the O_2 catheter was again set at 5 L/min.

In both groups, extubation was performed when the body temperature was ≥ 36ºC.

Statistical analysis

Statistical analysis only considered differences between the Control and Study Groups as the surgery groups (CABG and Valve) presented with similar characteristics in this study.

The student t-test was utilized to assess the anthropometric data, time of intra-operative procedures, causes of delay in weaning and for hemodynamic analysis. To analyze gasometry variables and their evolution over time, the two-tailed ANOVA test was used and for confirmation (*post hoc*), the Tukey test was used. A simple linear correlation was utilized to analyze the correlation between causes and delay in extubation of patients submitted to heart surgery. A level of significance of 0.05 was considered acceptable.

RESULTS

The general anthropometric characteristics of the patients were homogenous between the two groups without statistically significant differences when compared, as is illustrated in Table 1.

Analysis of the intra-operative times

A comparison of the mean intra-operative times of the

Control and Study Groups of both types of surgeries (CABG and Valve) did not present statistically significant differences on considering the anesthesia time (p-value = 0.749), duration of surgery (p-value = 0.874) and CPB time (p-value = 0.387) (Table 1).

Table 1. Characteristics of patients submitted to heart surgery

Variable	Control	Study	P-value
Age (years)	57.02 ± 17.02	53.24 ± 23.33	0.189
Gender (men)	34 (68%)	27 (54%)	0.333
BMI (Kg/m2)	24.88 ± 4.04	25.25 ± 4.76	0.681
Anesthesia time (min)	322.4 ± 71.80	326.6 ± 60.22	0.749
Surgery time (min)	252.00 ± 63.44	253.86 ± 47.38	0.874
CPB time (min)	84.46 ± 30.34	89.62 ± 28.40	0.387

CPB – cardiopulmonary circulation

Analysis of the time for weaning from mechanical ventilation

Considering the total sample, the mean time of weaning from mechanical ventilation was 226.1 ± 56.7 minutes, without statistically significant differences between the two groups (p-value = 0.526).

Analysis of the main causes for delay of extubation

Three causes were detected that led to a delay in the removal of the orotracheal tube, as their stabilization was necessary as a criterion for extubation and inclusion in the study: sleepiness (n = 37), hypothermia (n = 18) and bleeding (n = 8), with the rest of the patients (n = 37) being extubated within a time considered adequate. The simple linear correlation demonstrated that there is a correlation coefficient between these causes and delay in extubation with an r-value = 0.6 revealing a moderate association between these variables (p-value = 0.031 for the Control Group and p-value = 0.010 for the Study Group).

No patient was re-intubated or evolved with unsuccessful weaning.

Analysis of the pressures utilized during non-invasive ventilation

All the patients submitted to non-invasive ventilation utilized pressure levels similar to those utilized during invasive mechanical ventilation. The mean values of the IPAP EPAP were 10 ± 2.124 cmH_2O and 5.28 ± 0.00 cmH_2O, respectively.

Analysis of the gasometric variables

pH variable

There was no significant difference between the two groups of patients (p-value = 0.9385) and the pattern of this variable did not significantly alter with time.

$PaCO_2$ variable

There were no statistically significant differences between the groups (p-value = 0.5575). However, there was an effect over time when all the patients were compared from the pre-extubation period, at 120 minutes (p-value = 0.0152) and also at 360 minutes (p-value = 0.0009) after extubation (Table 2).

PaO_2 variable

There were statistically significant differences between the Control and Study Groups (p-value = 0.0009) as well as over time comparing the time at extubation and 30, 120 and 360 minutes after the procedure (p-value = 0.00008 for all these intervals) (Table 3).

Table 2. Gasometric variables of the Control and Study Groups of patients submitted to heart surgery

Variable	0 minutes	30 minutes	120 minutes	360 minutes
$PaCO_2$ (mmHg)				
Control	39.27 ± 6.65*†	38.00 ± 5.60	37.40 ± 6.96*	36.60 ± 6.34†
Study	39.72 ± 4.65*†	38.00 ± 7.00	34.70 ± 6.29*	35.80 ± 6.01†
PaO_2 (mmHg)				
Control	149.90 ± 40.02*†‡	115.53 ± 40.02*	118.68 ± 40.40†	115.47 ± 42.78‡
Study	167.46 ± 49.73*†‡	132.10 ± 56.73*	131.29 ± 39.80†	139.07 ± 36.52‡

Table 3. Hemodynamic variables of the Control and Study Groups of patients submitted to heart surgery

	MAP		HF		SVO_2	
	Pre	Post	Pre	Post	Pre	Post
Control Group						
Mean (SD)	8.16±14.61	81.2±14.90	97.42±16.42	95.5±21.00	74.98±7.56	67.17±11.12
p-value	0.722		0.618		0.0001*	
Study Group						
Mean (SD)	79.6±12.5	81.19±10.3	96.7±20.38	98.57±22.48	76.16±7.03	68.04±5.13
p-value	0.498		0.671		0.0000*	

MAP – Mean arterial pressure; HF – heart frequency

Analysis of the hemodynamic variables in the pre- and post-extubation periods

There were no significant differences in the variables before and after extubation. In the Control Group, the mean values of heart rate presented a p-value = 0.618 and mean arterial pressure a p-value = 0.722, while in the Study Group the p-values were 0.671 and 0.498, respectively.

Only the venous oxygen saturation (SVO_2) presented statistically significant differences comparing the pre- and post-extubation periods (Control Group p-value = 0.0012 and Study Group p-value = 0.0000) however there was no clinical significance as variations outside the normal range did not occur (Table 3).

DISCUSSION

Analyses of the intra-operative times, as well as the time necessary for weaning from mechanical ventilatory assistance, did not show statistically significant differences between the Control and Study Groups. The hemodynamic evaluation did not reflect clinically significant differences, when comparing the pre- and post-extubation periods of the two groups.

The use of non-invasive ventilation for 30 minutes, immediately after extubation, caused a significant improvement in the PaO_2, however without presenting statistically significant differences in the $PaCO_2$ in this group of patients in the immediate postoperative period of heart surgery.

Publications have reported that general anesthesia affects the function of the respiratory muscles, reduces the reserve functional capacity, alters the ventilation-perfusion ratio, increases the alveolo-arterial oxygen difference and favors the appearance of atelectasis. The duration of CPB presented a correlation with postoperative respiratory complications. The severity of interstitial edema observed is proportional to the duration of CPB; severe acute pulmonary injury with pulmonary edema occurs more frequently when the period of CPB exceeds 150 minutes [6-8]. In valve surgeries, hospital mortality is associated to intra-operative variables including CPB times greater than 120 minutes [7,8].

Thus, pulmonary complications are a significant cause of morbidity and mortality in patients submitted to heart surgery with CPB. A large number of mediators produced during CPB may diminish the vascular contractility, increase the vascular permeability and cause alterations in the vascular resistance of several organs. In the pulmonary circulation, there is an increase of extravascular water with alveolar filling by inflammatory cells that leads to inactivation of the pulmonary surfactant and alveolar collapse in some regions. This modifies the ventilation/pulmonary perfusion with reductions in complacency and increases in respiratory work in the postoperative period [6,7].

The majority of studies on non-invasive positive pressure ventilation are related to patients with chronic obstructive pulmonary disease, acute lung edema, restrictive thoracic disease, neuromuscular disease or sleep apnea; mainly demonstrating its benefits to avoid orotracheal intubation and invasive mechanical ventilation, as well as the related complications. However few studies have demonstrated the efficacy of non-invasive ventilation after weaning from invasive ventilation for acute respiratory failure [9,10].

The patients who presented respiratory dysfunction and were submitted to non-invasive ventilation after extubation presented with an improvement in oxygenation and a reduction in the re-intubation rate. Authors have reported that non-invasive ventilation prevents an increase in the

pulmonary extravascular water, thereby reducing complications after extubation in the postoperative period of CABG [11-13].

The literature also demonstrates that this technique diminishes the occurrence of pulmonary dysfunction in the postoperative period and that its use after extubation, for a period of between 30 minutes and four hours, is associated with an increase in the PaO_2 and a reduction in $PaCO_2$, when compared to the period of spontaneous ventilation with or without an oxygen supplement [5,14,15]. Hence, similar to this study utilizing non-invasive ventilation for 30 minutes immediately after extubation, there was a statistically significant improvement in the PaO_2 and a slight reduction in the $PaCO_2$.

An important factor associated to success of the utilization of non-invasive mechanical ventilation is the adjustments of IPAP and EPAP according to the individual needs of each patient. Adjustments to the IPAP for adequate ventilation should be performed by specialized professionals, as each patient requires a different level of ventilatory support. This individualized adjustment may justify the differences observed among the various studies on non-invasive ventilation. The adjustment of the EPAP depends on conditions that favor alveolar collapse, such as stability of the airways and mechanical alterations of the abdomen.

Thus, adjustment of the IPAP maintained an adequate volume-minute for the body weight of the patient, thereby preserving satisfactory ventilation. The individualized adjustments of the EPAP may have affected the results reported by this study, based on studies on the hemodynamic effects of continuous positive airway pressure (CPAP). Hence, a constant value of EPAP was maintained to prevent any event related to a reduction in the cardiac output [16-19].

Studies that evaluated patients submitted to CABG to detect the effects of facial CPAP and nasal BiPAP on extravascular water during weaning from invasive ventilation, observed that, both the use of CPAP and BiPAP for a minimum of 30 minutes after endotracheal extubation prevent increases in the extravascular water and this effect can last for up to 60 minutes after ceasing the treatment, thereby reducing complications after extubation [13]. Other authors reported that non-invasive ventilation utilizing the BiPAP mode was more effective than CPAP and respiratory physiotherapy to improve pulmonary mechanics and oxygenation after CABG [20,21].

This study demonstrated that non-invasive ventilation for a period of 30 minutes was efficacious after extubation in the immediate postoperative period of heart surgery. On comparing the two groups, a statistically significant difference was observed in the mean values of PaO_2.

CONCLUSION

The utilization of non-invasive ventilation for 30 minutes after extubation provided a significant improvement in the oxygenation of patients in the immediate postoperative period of heart surgery

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