

# Pressure support-ventilation versus spontaneous breathing with “T-Tube” for interrupting the ventilation after cardiac operations

*Pressão de suporte ventilatório versus respiração espontânea em “Tubo-T” para a interrupção da ventilação após as operações cardíacas*

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## Abstract

**Objective:** To compare pressure-support ventilation with spontaneous breathing through a T-tube for interrupting invasive mechanical ventilation in patients undergoing cardiac surgery with cardiopulmonary bypass.

**Methods:** Adults of both genders were randomly allocated to 30 minutes of either pressure-support ventilation or spontaneous ventilation with “T-tube” before extubation. Manovacuometry, ventilometry and clinical evaluation were performed before the operation, immediately before and after extubation, 1h and 12h after extubation.

**Results:** Twenty-eight patients were studied. There were no deaths or pulmonary complications. The mean aortic clamping time in the pressure support ventilation group was  $62 \pm 35$  minutes and  $68 \pm 36$  minutes in the T-tube group ( $P=0.651$ ). The mean cardiopulmonary bypass duration in the pressure-support ventilation group was  $89 \pm 44$  minutes and  $82 \pm 42$  minutes in the T-tube group ( $P=0.75$ ). The mean Tobin index in the pressure support ventilation group was  $51 \pm 25$  and  $64.5 \pm 23$  in the T-tube group ( $P=0.153$ ). The duration of intensive care unit stay for the pressure support ventilation group was  $2.1 \pm 0.36$  days and  $2.3 \pm 0.61$  days in the T-tube group ( $P=0.581$ ). The atelectasis score in the T-tube group was  $0.6 \pm 0.8$  and  $0.5 \pm 0.6$  ( $P=0.979$ ) in the pressure support ventilation group. The study

groups did not differ significantly in manovacuometric and ventilometric parameters and hospital evolution.

**Conclusion:** The two trial methods evaluated for interruption of mechanical ventilation did not affect the postoperative course of patients who underwent cardiac operations with cardiopulmonary bypass.

**Descriptors:** Pulmonary ventilation. Extracorporeal circulation. Ventilator weaning.

## Resumo

**Objetivo:** Comparar a pressão de suporte ventilatório com a respiração espontânea em “Tubo-T” para interrupção da ventilação invasiva em pacientes submetidos à operação cardíaca.

**Métodos:** Adultos de ambos os sexos foram alocados para pressão de suporte ventilatório por 30 minutos ou o mesmo período de ventilação espontânea com “Tubo-T” antes da extubação. Realizou-se manovacuometria, ventilometria e avaliação clínica antes da operação, imediatamente antes e após a extubação, 1h e 12h após extubação.

**Resultados:** Vinte e oito pacientes foram estudados. Não ocorreram mortes ou complicações respiratórias. O tempo de pinçamento da aorta no grupo suporte ventilatório foi  $62 \pm 35$

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#### Abbreviations, acronyms & symbols

CPB Cardiopulmonary bypass
EP Expiratory maximal pressure
IMV Invasive mechanical ventilation
IP Inspiratory maximal pressure
PSV Pressure support ventilation
SIMV Synchronized intermittent mandatory ventilation

minutos e de  $68 \pm 36$  minutos para o "Tubo-T" ( $P=0,651$ ). O tempo de CEC no grupo suporte ventilatório foi  $89 \pm 44$  minutos e para o "Tubo-T" de  $82 \pm 42$  minutos ( $P=0,75$ ). O índice de Tobin para o grupo suporte ventilatório foi  $51 \pm 25$  e para o grupo

"Tubo-T",  $64,5 \pm 23$  ( $P=0,153$ ). O tempo na unidade de terapia intensiva para o grupo suporte ventilatório foi  $2,1 \pm 0,36$  dias e para o grupo "Tubo-T",  $2,3 \pm 0,61$  dias ( $P=0,581$ ). O escore de atelectasia para o grupo "Tubo-T" foi  $0,6 \pm 0,8$  e para o suporte ventilatório foi  $0,5 \pm 0,6$  ( $P=0,979$ ). Não houve diferença significativa na evolução clínica e nos valores de gasometria, manovacuometria e ventilometria entre ambos os grupos.

**Conclusão:** O método utilizado para testar a adequação da interrupção da ventilação mecânica invasiva não afetou a evolução pós-operatória dos pacientes submetidos a operações cardíacas com circulação extracorpórea.

**Descritores:** Ventilação pulmonar. Circulação extracorpórea. Desmame do respirador.

## INTRODUCTION

Invasive mechanical ventilation (IMV) is often essential in the first hours after cardiovascular operations as patients recover from anesthesia and reestablish homeostatic balance. When IMV is no longer required, the respiratory therapist and the physician must decide the most appropriate method to interrupt IMV.

A simple and widespread method to determine whether a patient tolerates the discontinuation of ventilatory support is a trial of spontaneous breathing [1,2]. According to the III Brazilian Consensus on Mechanical Ventilation this trial is straightforward and effective way to wean off IMV [3]. However, the spontaneous breathing trial has been replaced by other techniques, mainly by pressure support ventilation (PSV) and synchronized intermittent mandatory ventilation (SIMV) [4]. These techniques are optional modes of ventilatory support provided by modern ventilators, which are especially useful for weaning patients recovering from pulmonary dysfunctions who require prolonged IMV. Yet, there is limited evidence that such methods of transition from IMV are superior to spontaneous breathing through a T-tube followed by extubation [1], especially in patients with good cardiopulmonary reserve.

Therefore, this study aims to compare PSV with a spontaneous breathing trial using a T-tube for weaning from IMV in patients who underwent cardiovascular operations to correct valve dysfunction and/or coronary artery bypass grafting surgery. We considered weaning as the transition from controlled ventilation to spontaneous breathing before extubation.

## METHODS

This prospective randomized trial was conducted in the Division of Thoracic and Cardiovascular Surgery of the

Ribeirão Preto Medical School, University of São Paulo (HCFMRP-USP) and was approved by the Ethics Committee (process number 5672/2006).

### Patients

We recruited 30 patients with coronary artery disease and/or valve disease, of both genders and older than 18 years-old. The basic protocols of perioperative care were not modified, with the exception of procedures for extubation. The volunteers were randomized according to a random number table generated by StatMate GraphPad 1.01 (GraphPad Software, Inc, San Diego, CA, USA). The StatMate software generated a random sequence of 15 numbers "1" (T-tube group) and 15 numbers "2" (PSV group). The first patient to participate in the study was allocated to the group corresponding to the first number generated, the second patient to the group corresponding to the second randomly generated number and so on.

The exclusion criteria were postoperative bleeding requiring reoperation in the immediate postoperative period, ejection fraction  $\leq 0.40$ , postoperative hemodynamic instability precluding extubation, not understanding the procedures proposed and refusal to participate in the study at any stage.

### Study groups

The PSV group was comprised of patients who underwent a period of PSV for 30 minutes before interruption of IMV. These patients were extubated immediately after the IMV period with PSV.

The T-tube group was comprised of patients who were disconnected from the ventilator when they met the criteria for interrupting the IMV then kept under spontaneous ventilation with their tracheal tube connected to a T-tube while receiving supplemental oxygen for 30 minutes before extubation.

Clinical history, baseline measurements of blood

pressure, heart rate, respiratory rate, minute volume, tidal volume, vital capacity, peak flow, maximal inspiratory pressure, and expiratory pressure were obtained from all patients before surgery. All patients underwent conventional chest physical therapy consisting of diaphragmatic breathing exercises associated with active and/or active-assisted mobilization of the upper and lower limbs. In addition, all patients participated in daily respiratory therapy sessions including cough, lung expansion maneuvers and airway clearance techniques training twice a day in the preoperative and postoperative periods.

The protocol for postoperative analgesia was the same for all patients. Postoperatively all the patients received IMV using a Savina ventilator (Dräger, Lübeck, Germany) with SIMV, 12–14 bpm, inspiration/expiration ratio of 1:2, PEEP of 5 cmH<sub>2</sub>O, tidal volume of 8 mL/kg body weight, and inspired fraction of O<sub>2</sub> to maintain arterial oxygen saturation above 95% (pulse oximetry). Before interrupting the IMV, arterial gasometry and hemodynamic parameters were checked. All evaluations were performed in the preoperative period, immediately before extubation, and 1 and 12 hours after extubation. All patients had daily follow-ups until hospital discharge.

The criteria for interrupting IMV were: a) patient should be conscious and cooperative; b) PaO<sub>2</sub>: 80–100 mmHg, arterial saturation >95%, pH: 7.35–7.45, and PaCO<sub>2</sub>: 35–45 mmHg; c) tidal volume ≥4 mL/kg; and d) inspired fraction of O<sub>2</sub> ≤0.4. The Tobin index [5] was calculated for both groups before extubation.

Patients in the PSV group who fulfilled the criteria for interrupting IMV were submitted to 30 minutes of pressure support ventilation of 10 cmH<sub>2</sub>O. Patients in the T-tube group who fulfilled the criteria for interrupting IMV were allowed to breath spontaneously through their tracheal tube connected to a T-piece and received supplemental O<sub>2</sub> (aerosol with 0.9% saline and oxygen flow to 10L/min) for 30 minutes. At the end of the trial period, a blood sample for gasometric analysis was collected and ventilometric and hemodynamic parameters were measured. The patients were then extubated. A clinical and laboratory evaluation was performed again 1 and 12 hours after extubation.

A physician, blinded to the study, compared the preoperative chest radiograph with a radiograph obtained in the morning after the operation. The following scores and criteria were used to grade lung atelectasis: 0) no abnormality: no image suggestive of atelectasis; 1) laminar atelectasis: linear opacities located mainly in lung bases; 2) segment atelectasis: opacities compatible with pulmonary segments; 3) lobar atelectasis; and 4) whole lung atelectasis.

### Statistical analysis

The results were expressed as mean ± standard deviation or percentages. The Shapiro-Wilk test was used to determine the data distribution (normality). Paired or unpaired "T" tests

were used for continuous variables with normal distribution, otherwise we used the Mann-Whitney or Wilcoxon test. For comparing proportions, we used the Fisher exact test. To compare intra-and inter-group repeated measurements (three or more), we used a two-way ANOVA; the first measurement was obtained postoperatively, or the pre-operative measure, when available, served as the control/baseline against which the later measurements were compared. Statistical analysis was performed using SPSS software version 18.0 (SPSS Inc., Chicago, IL, USA) with a significance level of 0.05.

## RESULTS

### Clinical characteristics

Data from 28 patients, 14 in each group, were analyzed. One patient in the PSV group was excluded due to postoperative bleeding requiring reoperation, and one patient in the T-tube group who needed prolonged (>24h) invasive ventilation due to hemodynamic instability was excluded. The demographic data are shown in Table 1. There were no significant differences between groups.

In the PSV group, 10 (71%) patients underwent revascularization and 4 (29%) underwent valve surgery. In the T-tube group, 11 (78%) patients underwent revascularization, two (14%) had valvular surgery and one underwent revascularization plus valvular surgery. The differences in the distribution of type of surgery were not significant ( $P=0.648$ ).

Table 1. Clinical characteristics.

Variable	"T-Tube" N = 14	PSV N = 14	P
Age (y)*	58 ± 9	53 ± 9	0.193
Gender (n, %)			
male	7 (50%)	10 (71.4%)	0.440
Weight (kg)*	73.25 ± 9.83	74.79 ± 18.45	0.793
Height (m)*	1.65 ± 0.11	1.65 ± 0.07	0.983
BMI (kg/m <sup>2</sup> )*	27.1 ± 3	27.6 ± 6.6	0.812
Risk factors (n,%)			
Functional class NYHA	2 (15.4%)	1 (7.7%)	0.539
Class III/IV	9 (69.2%)	11 (84.6%)	0.645
Arterial hypertension	6 (46.2%)	2 (15.4%)	0.202
Diabetes mellitus	4 (30.8%)	3 (23.1%)	0.658
Smoking	3 (23%)	0 (0%)	0.220
Renal dysfunction	1 (7.7%)	0 (0%)	0.308
COPD	2 (15.4%)	1 (7.7%)	0.539
Peripheral vascular disease	8 (61.5%)	5 (38.5%)	0.434
Myocardial infarction	0.58 ± 0.12	0.55 ± 0.17	0.628
Ejection fraction			
Systolic pulmonary pressure > 40 mmHg	2 (15.4%)	2 (15.4%)	0.715

*Mann-Whitney Test and Exact Fisher test. BMI = body mass index; COPD = chronic obstructive pulmonary disease; NYHA = New York Heart Association*

The mean aortic clamping time of the PSV group was  $62 \pm 35$  minutes and  $68 \pm 36$  minutes in the T-tube group ( $P=0.651$ , Mann-Whitney test). The mean cardiopulmonary bypass (CPB) times were  $89 \pm 44$  minutes and  $82 \pm 42$  minutes in the PSV and T-tube groups, respectively ( $P=0.75$ , Mann-Whitney test).

The mean Tobin index immediately before extubation in the PSV group was  $51.1 \pm 25$  and  $64.5 \pm 23$  in the T-tube group ( $P=0.153$ ).

### Clinical and radiologic postoperative evolution

The mean duration of stay in the postoperative intensive care unit was  $2.1 \pm 0.36$  days in the PSV group and  $2.3 \pm 0.61$  days in the T-tube group ( $P=0.581$ , Mann-Whitney test). The mean duration of hospital stay for the PSV and T-tube groups, respectively, was  $9.6 \pm 4.83$  days and  $8.6 \pm 2.8$  days ( $P=0.829$ , Mann-Whitney test). There were no deaths and no patient required reintubation. One patient (T-tube group) experienced renal dysfunction, which was managed without dialysis ( $P=0.308$ ). Forty-three percent of the patients had some degree of atelectasis. The mean atelectasis score in the T-tube group was  $0.6 \pm 0.8$  and  $0.5 \pm 0.6$  in the PSV group ( $P=0.979$ , Mann-Whitney test).

### Postoperative ventilatory parameters

In both groups the minute volume, tidal volume, vital capacity and peak expiratory flow declined significantly postoperatively, compared with the preoperative period (Figure 1).

There was a significant decrease in both groups in the inspiratory (IP) and expiratory (EP) maximal pressures after extubation compared with preoperative values (Figure 2). However, we found that the IP was significantly lower in the PSV group ( $P=0.024$ ). Notably, patients in this group already had a significantly lower IP preoperatively ( $P=0.028$ ). As a result, the temporal pattern was similar in both groups, since there was no interaction between groups ( $P=0.150$ ). Similar to the IP, the mean preoperative maximum EP was significantly lower in the PSV group ( $P=0.035$ ). The differences between groups were not statistically significant ( $P=0.068$ ) and the temporal pattern was similar in both groups ( $P=0.133$ ).

There were significant changes in the postoperatively respiratory rate, heart rate, PaO<sub>2</sub> and arterial oxygen saturation compared to the preoperative values, but the temporal patterns were similar in both groups and the differences were not significant (Figure 3).

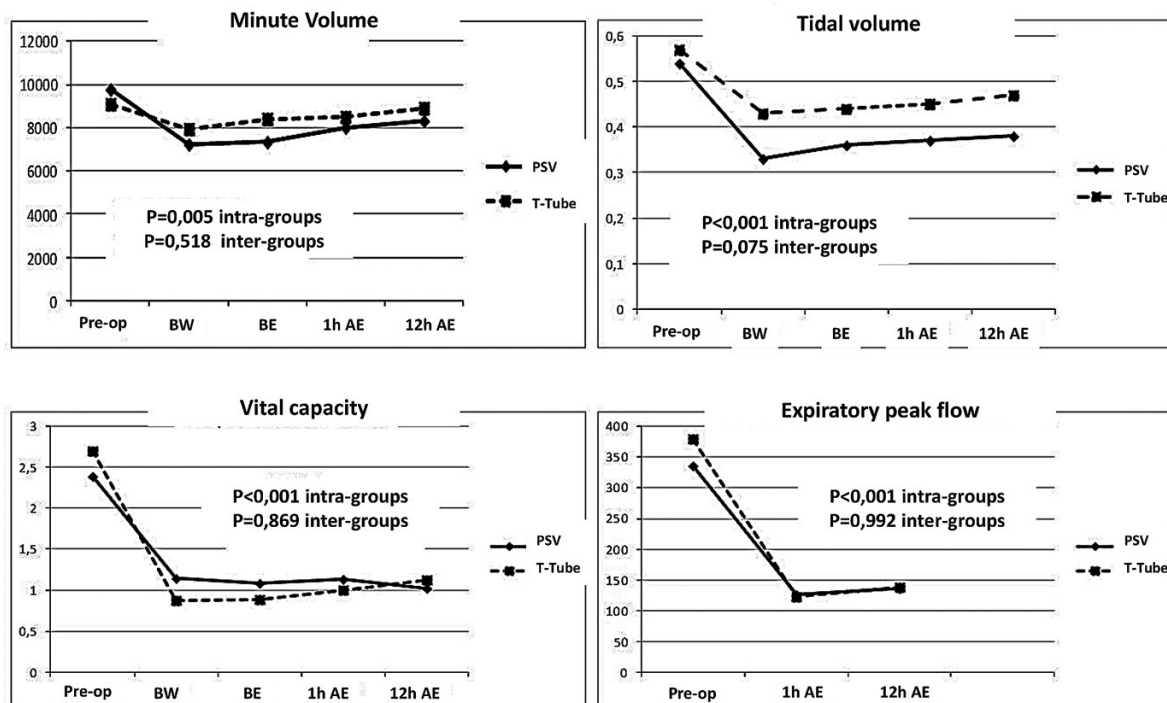


Fig. 1 - Perioperative evolution of the minute volume, tidal volume vital capacity and expiratory peak flow. Preo-op: preoperative; BW: before weaning; BE: before; 1h AE: 1 hour after extubation; 12h AE: 12 h after extubation

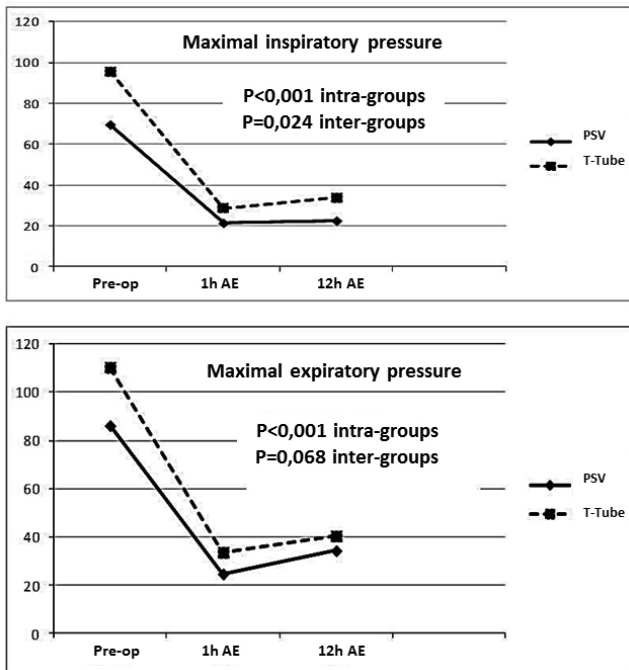


Fig. 2 - Perioperative evolution of the maximal inspiratory and expiratory pressures. Preo-op: preoperative; 1h AE: 1 hour after extubation; 12h AE: 12 h after extubation

## DISCUSSION

We found that there was no significant difference in weaning from IMV using a trial period of either PSV or spontaneous breathing using a T-tube piece in low-risk patients who underwent valve and/or coronary artery bypass grafting surgery.

The main goal of a weaning trial is to identify patients who are able to breathe without a ventilator with the minimum risk of extubation failure and its potential complications [6]. Even though many institutions that perform cardiovascular surgery have routinely used pressure support as a weaning trial before extubation, there is no consensus that a specific method of weaning is superior. The majority of patients can be successfully weaned from mechanical ventilation irrespective of whether this is executed by intermittent mandatory ventilation, pressure support, or a T-tube trial [7,8]; a spontaneous breathing trial using a T-tube is still routinely performed in patients who fulfill weaning criteria [9].

A study reported by IMV Esteban et al. [10], which compared four methods of weaning, found that once-daily trials of spontaneous breathing led to about three times more rapid extubation than intermittent mandatory ventilation and was about twice as rapid as PSV. There are hospitals

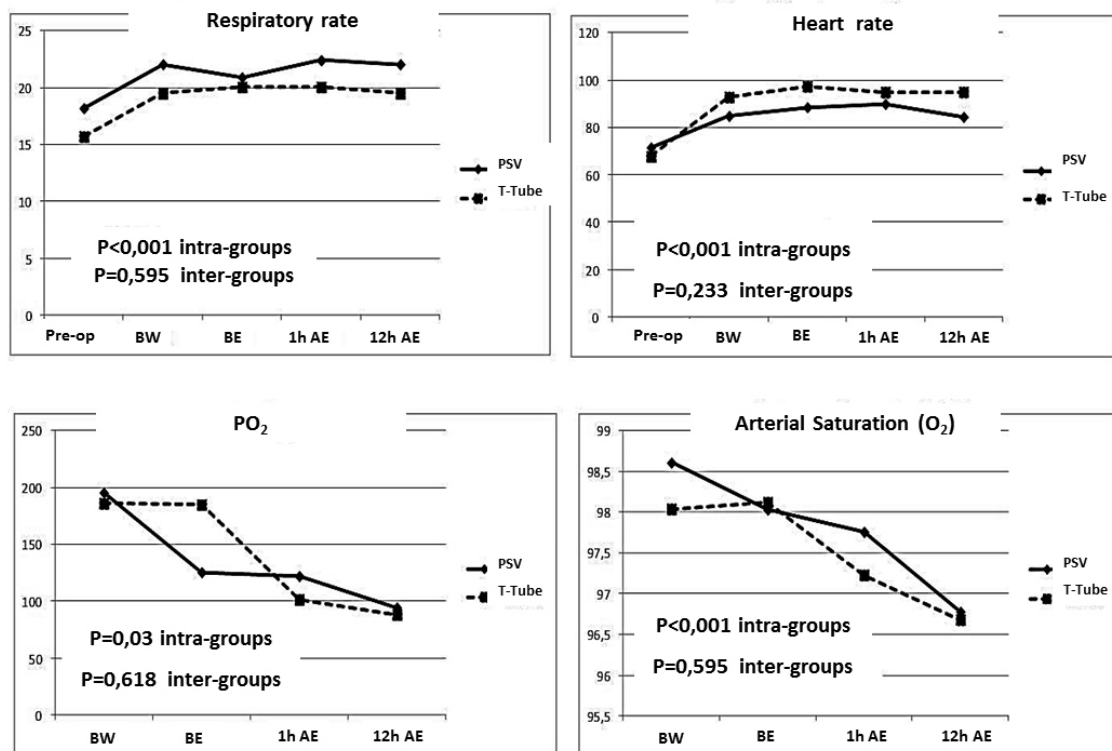


Fig. 3 - Perioperative evolution of the respiratory rate, heart rate, PO<sub>2</sub> and arterial oxygen saturation. Preo-op: preoperative; BW: before weaning; BE: before; 1h AE: 1 hour after extubation; 12h AE: 12 h after extubation

in developing countries that may have limited resources and/or more simple mechanical ventilators. Therefore, in a resource limited setting more rapid weaning might result in more efficient use of scarce ventilators and a shorter period of intubation related discomfort.

PSV is a form of ventilatory support provided during IMV in which a predetermined, constant, positive inspiratory pressure is maintained by the ventilator, while the patient controls the respiratory cycle. In this ventilatory mode the patient controls the respiratory rate, the inspiratory flow, and the inspiration/expiration ratio, thereby reducing the oxygen demand as a consequence of reduced respiratory muscle work. It also provides a better synchrony between patient and ventilator [11,12]. Although the use of pressure support has been justified by reducing the imposed work of the ventilator circuit and the endotracheal tube [13], the use of even low levels of pressure support may lead to an underestimation of the risk of extubation failure [8]. Hence, a spontaneous breathing trial using a T-tube might be especially interesting in a population in which the risk of reintubation is particularly high [14].

The present study demonstrated that several parameters of respiratory function were lower in the first hours after extubation than they were preoperatively. These declines resulted primarily from pain and changes related to the anesthesia, CPB and the use of mechanical ventilation, as observed by other investigators [15-18]. Thus, even though spontaneous breathing with a T-tube may be an adequate method for weaning from mechanical ventilation in the majority of the cases, the method might confer a higher risk for reintubation [19], especially in patients with less cardiorespiratory reserve.

Extubation failure seems to be determined more by the conditions inherent to the patient than by the method of weaning from the ventilator [9,20,21]. Pain, a major factor in the postoperative period [22], induces ventilation with smaller amplitude in an attempt to minimize discomfort. Moreover, the residual effect of anesthetic drugs and analgesics on the central nervous system also contributes to this breathing pattern. However, the respiratory parameters tend to improve gradually in the subsequent hours after surgery. The two methods for interrupting IMV that we evaluated had no influence on the postoperative evolution of such parameters.

The significant difference of maximal inspiratory pressures that we observed between the groups was probably caused by the fact that patients in the T-tube group had higher ventilatory pressure preoperatively; however there was no apparent effect on the postoperative evolution in favor of this group. Additionally, there was no significant difference in the Tobin index [5] between the groups, ensuring a safe interruption of IMV; hence, the expected extubation success was similar for both groups.

The incidence of pulmonary complications in the

postoperative period of heart surgery depends on the diagnostic technique. Vargas et al. [23], in a prospective study using chest computed tomography scans, found that 86.7% of the patients who underwent CABG had some degree of pulmonary atelectasis in the second postoperative day. We believe that in our study the incidence of atelectasis was lower due to the lower sensitivity of chest radiographs to detect atelectasis. However, the extent of atelectasis, as measured by atelectasis scores, did not differ significantly between the methods used for interrupting the IMV, even though the PSV method had a greater theoretical potential to reduce the incidence and/or severity of atelectasis.

Postoperative pulmonary atelectasis is multifactorial: anesthesia, cardiopulmonary bypass, type of operation performed, preoperatively pulmonary function and mode and the duration of IMV play a role. It is unlikely that a short trial period of pressure support ventilation or spontaneous breathing without airway pressure before extubation would noticeably influence the incidence of postoperative pulmonary atelectasis in patients with good cardiopulmonary functional reserve.

Although we believe our study contributes to demonstrate the safety of using T-tube supported spontaneous breathing for weaning from IMV after cardiac surgery, it is not free of limitations. It is a study with a small sample of low-risk patients with good cardiopulmonary reserve, whose mean age was below 60 years old, and with uneventful operations. Because changing from mechanical to spontaneous ventilation increases preload and afterload [24] and because cardiac dysfunction is probably one of the most common causes of weaning failure [25,26], studies with larger numbers of patients at higher risk of cardiac and/or pulmonary dysfunction, including the elderly ( $\geq 65$  years), are required to evaluate the methods for weaning from IMV in patients undergoing cardiovascular operations with greater external validity.

In conclusion, our results showed that in low-risk patients who underwent cardiac surgery with cardiopulmonary bypass the method used to interrupt invasive mechanical ventilation, a short trial of either spontaneous breathing through a T-tube or pressure support ventilation, did not significantly affect the postoperative course.

**Author's roles & responsibilities**

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AJR	Co-author

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