

Expansion Pulmonary Therapy in Blood Oxygenation and Lactate Serum Level in Postoperative Cardiac Surgery

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Abstract

Background: Cardiovascular and pulmonary complications often occur in the immediate post-surgery period and may be prevented and/or treated with lung expansion techniques.

Objective: To evaluate the efficacy of lung expansion techniques in serum arterial lactate levels and oxygenation in patients in this surgical recovery phase.

Method: A prospective and analytical study was carried out in postoperative cardiac surgery patients, hemodynamically stable. Measurements of artery lactate levels and partial pressure of oxygen were obtained from arterial blood samples drawn before and after lung expansion techniques, including alveolar recruiting maneuver and intermittent positive pressure breathing.

Results: 40 patients with average age of 51.1 ± 14.9 years, 55% female, were included. It is possible to observe the statistically significant difference ($p < 0.05$) in the comparison between values of baseline and post-operative arterial lactate, oxygen level, oxygen saturation / fraction of inspired oxygen in both procedures. In relation to the outcome of oxygen blood pressure, only the group on intermittent positive pressure breathing achieved significant improvement.

Conclusion: The lung expansion techniques used have contributed with the reduction of lactate level, improvement in oxygenation and oxygen saturation in this population, but did not alter intensive care unit length of stay. (Int J Cardiovasc Sci. 2018;31(1)63-70)

Keywords: Thoracic Surgery; Physical Therapy Modalities; Postoperative Care; Oxygenation; Oxygen Level; L-Lactate Dehydrogenase.

Introduction

Cardiovascular diseases are among the main causes of morbidity and mortality around the world, involving great financial investment and affecting the population's health. Therapeutic strategies include prevention, medication, *endocardiovascular intervention* and cardiac surgery.¹ Cardiac surgery, notably revascularization and valve replacement, have changed patient's life expectancy and improved their survival and quality of life.²

In spite of the evident benefits of cardiac surgery, cardiovascular and pulmonary complications frequently occur in the *immediate postoperative period*, compromising

the evolution of patients with reduced oxygenation and elevated arterial lactate levels attributed to tissue hypotension, hypoxemia and *intrapulmonary shunt*, increasing hospital stay, *with a potential to cause death*.³⁻⁶

Pulmonary complications may cause *deviation to anaerobic metabolism* with *metabolic acidosis*, elevated lactate levels and *microvascular circulation damage*,⁷⁻¹⁰ which may be prevented or resolved by *lung expansion techniques*, inducing an increase in lung volumes and capacities, through increased *transpulmonary pressure gradient* and thus improve them, whether the patient is receiving *mechanical ventilation* or *breathing ambient air*.¹¹

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Among the lung expansion techniques, we can cite *alveolar recruitment maneuver in patients attached to a mechanical ventilator* to improve oxygenation, reduce *ventilator-associated lung injury* and facilitate weaning and extubation,¹² and *intermittent positive pressure in patients breathing spontaneously*, aiming to increase *tidal volume*, improve gas exchange and direct air into *hypoventilation zones*.^{13,14}

Studies have shown the significant effects of lung expansion techniques in patients with lung disease, however there are few studies that have tested the use of the techniques in patients with cardiac disease, especially in the postoperative of cardiac surgery. As a result, the purpose of this study was to evaluate the effects of lung expansion techniques in arterial lactate levels and oxygenation in patients in the *immediate cardiac surgery postoperative phase*.

Methods

A prospective and analytical study was carried out at the postoperative cardiac surgery unit of Hospital Ana Nery - UFBA/SESAB, a *reference center in the treatment of cardiovascular diseases in the State of Bahia, Brazil*.

It included patients over 18 years of age, *hemodynamically stable, with an average blood pressure of 60 mmHg or higher, and who needed to be treated with lung expansion techniques due to their clinical evolution. Patients who presented the following were excluded: psychomotor agitation, intracranial hypertension, pulmonary hypertension, pneumopathy and/or previous pneumonectomy, chronic obstructive pulmonary disease, non-drained pneumothorax, pneumomediastinum, hemothysis, reduction in cardiac output and on intra-aortic balloon, body mass index greater than 30 kg/m². The project was approved by the Ethics Committee of Hospital Ana Nery – UFBA/SESAB, under protocol 861.257.*

Measurements of lactate level and partial pressure of oxygen in arterial blood, inspiratory fraction and oxygen saturation, were drawn before and after intervention of lung expansion techniques, in order to determine variations of arterial lactate levels and oxygenation index resulting from the use of these techniques in the recovery phase.

Clinical, surgical, laboratory and hemodynamic parameters, such as heart rate and mean arterial pressure were monitored using a multi-parameter monitor (Portal DX2020 DIXTAL®). *Partial pressure of oxygen in arterial blood, lactate, fraction of inspired oxygen and oxygen saturation were analyzed through a hemogasometer (Roche COBAS b20®), every six hours, after patients*

arrived in the postoperative care unit, or while on invasive mechanical ventilation, in conformity with the standards of that intensive therapy unit. Oxygen relation was calculated as the arterial blood oxygen partial pressure divided by the fraction of inspired oxygen, according to the 3rd Brazilian Consensus on Mechanical Ventilation.¹⁵ In the anesthesia sheet, it was recorded the aortic clamping time or period of anoxia, time of extracorporeal circulation and the total anesthesia time, the surgery performed and if the patient had undergone volume expansion after admission to the postoperative unit.

The mechanical ventilation protocol used included admission of all patients to a volume-controlled ventilation mode (VCV), with inspired oxygen fraction of 0.6 (60%), positive end-expiratory pressure of 5 cmH₂O, respiratory frequency from 12 to 20 rpm and tidal volume ranging from 6 to 8 ml/Kg. After the result of the first hemogasometry, the ventilation mode was replaced by pressure-controlled ventilation (PCV), with decreasing inspiratory flow rate from 40 to 50 l/min, inspiratory pause of 0.2 seconds, respiratory frequency from 12 to 15 rpm, positive end-expiratory pressure of 5 cmH₂O. If the ratio of partial pressure arterial oxygen and fraction of inspired oxygen were less than 200, positive end-expiratory pressure should be increased to 8 cmH₂O with a fraction of inspired oxygen of 0.6 (60%). To proceed to extubation, pressure support ventilation (PSV) was used, and afterwards all patients received oxygen supplementation via a nasal catheter, respiratory and motor physiotherapy, including coughing exercises.

The lung expansion techniques used were: *alveolar recruitment maneuver or intermittent positive pressure breathing using the Maquet Servo ventilator or the VELA TBird Series®. They were chosen to follow the hospital's operating procedures, and the way they are performed in the postoperative unit. The blood for hemogasometric evaluation was collected of the artery fifteen minutes before and after any procedure of lung expansion techniques was made, in order to assess lactate level dosage and oxygenation. Each individual was compared with himself, before and after hemogasometric evaluation.*

The choice of the procedure of the lung expansion technique to be performed and the physiotherapist's conduct depended on the evolution and respiratory condition of the patient, verified using the hemogasometry analysis and the result of a chest radiograph. If the patient were attached to mechanical ventilation, the technique applied was *alveolar recruitment maneuver*; when he was breathing to the ambient air, *intermittent positive pressure breathing* was applied.

Alveolar recruitment maneuver was applied when the patient presented a *ratio of partial pressure arterial oxygen and fraction of inspired oxygen* less than or equal to 201 or less than 250 before extubation. Pressure-controlled ventilation, PCV,^{16,17} was used with a positive-end expiratory pressure of 25 cmH₂O^{18,19}, below what is recommended by the 3rd *Brazilian Consensus on Mechanical Ventilation*¹⁵ to ensure security and avoid alveolar collapse during the expiratory phase¹⁸. It was performed progressively from baseline positive-end expiratory pressure, raised at 20 seconds intervals in increments of 5 cmH₂O, until the determined value of positive-end expiratory pressure was reached¹⁸, with an inspiratory pressure of 15 cmH₂O, performed using three cycles for 40 seconds.^{6,20,21} At one-minute intervals between each cycle, positive-end expiratory pressure decreased back to 15 cmH₂O.²¹ At the end of the procedure, a new complete evaluation was performed. The results obtained were observed and registered. In addition, in all patients the positive-end expiratory pressure was 2 cmH₂O above the positive end-expiratory pressure before initial recruitment.

Intermittent positive pressure breathing was performed in patients with spontaneous breathing and if they needed pulmonary reexpansion according to the physical exam and the result of chest radiograph. The patient was placed in a 90-degree sitting position, evaluated and oriented about the procedure. Inspiratory pressure was set at 10 cmH₂O and positive end-expiratory pressure at 15 cmH₂O, with facemask use. Three two-minute cycles were performed with a one-minute interval between the cycles, once each turn. Afterwards, a new complete evaluation was performed and the results obtained were observed and registered.

All the patients were evaluated before, during and after any intervention of lung expansion techniques. As a result, data collection was interrupted in case the patient, monitored using a multi-parameter monitor, presented hemodynamic instability. During any procedure of lung expansion techniques, the hemodynamic instabilities considered were: mean blood pressure less than 60 mmHg or peripheral oxygen saturation less than 90% and heart rate greater or less than 30% of the value obtained in the evaluation performed prior to the execution of the techniques.

Statistical analysis

Data collected were stored using tables in the *software Microsoft Excel®* (Microsoft Corporation, Mountain View, CA, EUA, version 2003). Demographic and

clinical data were analyzed using descriptive statistics. Continuous variables data were analyzed using measures of central tendency and dispersion, expressed as mean and standard deviation, using parametric statistical tests. Dichotomous or Categorical Variables were analyzed using frequency measures and expressed as percentage. To compare before and after periods, data normality was calculated using the normality test. Afterwards, a paired T-test was used, considering the significance level of 5%. The *Statistical Package for Social Science (SPSS) for Windows (SPSS Inc., Chicago, IL, EUA, version 20 or superior)* was used to analyze the data.

Results

Forty patients of convenience were admitted to the post-surgical unit, who required the following, according to their clinical evolution and respiratory condition: alveolar recruitment maneuver, used in 18 patients, intermittent positive pressure breathing, applied in 22 individuals. No patient required both techniques, ven in different moment of their recovery period. The description of the demographic and clinical characteristics are shown in Table 1.

Alveolar recruitment maneuver was performed in 18 patients and intermittent positive pressure breathing was applied to 22 patients. The demographic and clinical characteristics are described in tables 2 and 3, respectively.

Values of baseline and post-intervention of the alveolar recruitment maneuver and intermittent positive pressure breathing groups are described in Table 4, for the following variables: arterial lactate, oxygenation rate, partial pressure of oxygen in arterial blood, inspired fraction and in oxygen saturation. It is possible to observe the significant statistically difference in the comparison of baseline values and post-intervention in both procedures in all variables, with the exception of the Partial Pressure of Oxygen in the arterial blood variable in the alveolar recruitment maneuver group.

Discussion

The results found in this study leads to the conclusion that the procedures of lung expansion techniques contribute reduce arterial lactate levels and improve oxygenation in patients in the postoperative of cardiac surgery. Our results are attributed to airway and alveolar expansion as a result of the use of positive pressure, which promoted better ventilation in areas previously collapsed.

Table 1 – Total Sample Characterization. n = 40 patients

	Mean ± Standard Deviation	Frequency (%)
Age (years)	51.1±14.9	--
Gender (female)	--	22 (55%)
MBI (Kg/m ²)*	24.4±4.3	--
Civil Status		
Single	--	13 (32.5%)
Married	--	23 (57.5%)
Divorced	--	3 (7.5%)
Widow	--	1 (2.5%)
Non-diabetic	--	32 (80%)
Non-smoker	--	24 (60%)
LV Ejection Fraction (%)†	59.6±9.7	--

* BMI: Body Mass Index; † LV:Left Ventricular

Alveolar recruitment maneuver provides better distribution of alveolar gas, maximizing gas exchange and improving arterial oxygenation.²² It was observed that this technique contributed to the reduction of arterial blood lactate level. Auler Jr et al.²³ carried out a prospective study with 40 patients, in which they evaluated the effects of alveolar recruitment maneuver on oxygenation and exhaled tidal volume, in patients with hypoxemia in the immediate postoperative period of cardiac surgery, and concluded that, after this technique was performed, there was an increase in the oxygenation rate and peripheral oxygen saturation, which corroborates the results of this study.

Celebri et al.¹¹ randomized 60 patients in the postoperative of myocardial revascularization in three groups of 20 patients, G1 (CPAP + alveolar recruitment maneuver), G2 (PEEP-20 + alveolar recruitment maneuver) e G3 (PEEP-5 + positive end-expiratory pressure). It was concluded that the maneuvers have increased oxygenation, reduced atelectasis and that G2 provided better hemodynamic stability, which also corroborates the results presented in this study. Alveolar recruitment maneuver is highly important for clinical practice, since it improves oxygenation, facilitates weaning from mechanical ventilation among patients, restores the tidal volume and ventilation capacity and finally is effective in correcting pulmonary complications that are often observed in this recovery phase.^{24,25}

In this study, intermittent positive pressure breathing has also contributed to the reduction of arterial lactate levels, improvement in oxygenation rate, partial pressure of oxygen in arterial blood and oxygen saturation. These results are in accordance with Romanini et al.,²⁶ who carried out a randomized clinical trial with 40 patients undergoing myocardial revascularization surgery divided into two groups, patients under intermittent positive pressure breathing and respiratory incentive techniques and concluded that intermittent positive pressure breathing was more efficient, since it improved peripheral oxygen saturation and the rate of oxygen.

A systematic review conducted by Silveira et al.²⁷ verified the effectiveness of positive pressure (intermittent positive pressure breathing, CPAP and BIPAP), conventional physiotherapy techniques and respiratory incentive techniques in the recovery of pulmonary function in patients in the postoperative period of cardiac surgery. In spite of the benefits observed, it was not possible to differ the level of evidence between the techniques, thus it is not possible to identify which technique is superior, since no study has compared the three modalities of positive pressure simultaneously.

Ferreira et al.²⁸ revised studies between 2006 and 2011, in order to verify the superiority between the modalities of non-invasive mechanical ventilation – CPAP, BiPAP®, intermittent positive pressure breathing and PSV + PEEP. Although studies are few, intermittent positive pressure

Table 2 – Characteristics of the 18 patients who underwent Alveolar Recruitment Maneuver (ARM)

	Mean ± Standard Deviation	Frequency (%)
Age (years)	49.6 ± 16.8	--
Gender (female)	--	8 (42.1%)
MBI (Kg / m ²)*	23,2 ± 4,1	--
Civil Status		
Single	--	4 (21.1%)
Married	--	10 (52.6%)
Divorced	--	3 (15.8%)
Widow	--	1 (5.3%)
Non-diabetic	--	17 (89.5%)
Non-smoker	--	10 (52.6%)
LV Ejection Fraction (%)†	61.1 ± 7.7	--
Surgery Performed		
Mitral Valve Replacement	--	3 (15.8%)
Aortic Valve Replacement	--	1 (5.3%)
Double Valve Replacement	--	5 (26.3%)
Myocardial Revascularization	--	5 (26.3%)
Aortic Valve Replacement + Myocardial Revascularization	--	2 (10.5%)
Mitral Valve Replacement + Myocardial Revascularization	--	1 (5.3%)
Tetralogy of Fallot	--	1 (5.3%)
Time of Surgery (Hours)	5.9 ± 1.1	
Anoxia (minutes)	87.3 ± 42.4	--
CEC (minutos)†	118.3 ± 54.8	--
POU length of stay (days)‡	5.2 ± 6.9	--

* BMI: Body Mass Index; † EC: Extracorporeal Circulation; ‡ POU: Postoperative Unit

breathing has proved to be more efficient in reverting hypoxemia and BiPAP in improving oxygenation levels and respiratory and cardiac frequencies compared to the other modalities. The use of lung expansion techniques increased the level of arterial oxygenation due to lungs expansion and consequently the pulmonary function, a better elimination of secretion and airway permeability, which corroborates the conclusions found in this study.

Caution should be taken in the interpretation of these results, due to study limitations, such as lack of complete studies in the literature, which could have been

used to compare the results, its being a before and after self-controlled study and the absence of a control group, which makes it difficult to prove the results obtained. However, the gains demonstrate the trend towards the benefits outlined here.

Conclusion

The techniques of lung expansion therapy resulted in decreased arterial lactate level, improved oxygenation rate – indirectly improving partial pressure of oxygen

Table 3 – Characteristics of the 22 patients who underwent Intermittent Positive Pressure Breathing (IPPB)

	Mean ± Standard Deviation	Frequency (%)
Age (years)	52.3 ± 13.6	--
Gender (female)	--	14 (46.7%)
MBI (Kg/m ²)*	25.4 ± 4.4	--
Civil Status		
Single	--	9 (30%)
Married	--	13 (43.3%)
Divorced	--	15 (50%)
Widow	--	19 (63.3%)
Non-diabetic	58.5 ± 11.2	--
Non-smoker		
LV Ejection Fraction (%)†	--	5 (16.7%)
Surgery Performed		
Mitral Valve Replacement	--	4 (13.3%)
Aortic Valve Replacement	--	9 (30%)
Double Valve Replacement	--	1 (3.3%)
Miocardial Revascularization	--	1 (3.3%)
Aortic Valve Replacement + Myocardial Revascularization	--	--
Mitral Valve Replacement + Myocardial Revascularization	5.6 ± 0.8	--
Tetralogy of Fallot	76.1 ± 31.2	--
Time of Surgery (Hours)		
Anoxia (minutes)	3.3 ± 1.8	--

* BMI: Body Mass Index; † EC: Extracorporeal Circulation; ‡ POU: Postoperative Unit.

and inspired fraction of oxygen - and peripheral oxygen saturation in the immediate postoperative period of cardiac surgery. However, new studies, preferably controlled, must be carried out to confirm these results.

Author contributions

Conception and design of the research: Oliveira SS, Neto M, Aras Junior R. Acquisition of data: Oliveira SS. Analysis and interpretation of the data: Oliveira SS, Neto M. Statistical analysis: Oliveira SS, Neto M. Writing of the manuscript: Oliveira SS, Neto M, Aras Junior R. Critical revision of the manuscript for intellectual content: Oliveira SS, Neto M, Aras Junior R.

Potential Conflict of Interest

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

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Study Association

This study is not associated with any thesis or dissertation work.

Table 4 – Mean, standard deviation and p value before and after the following techniques: alveolar recruitment maneuver (ARM) of n = 18 and intermittent positive pressure breathing (IPPB) of n = 22

		Pre-evaluation	Post-evaluation	p value
		Mean ± Standard Deviation	Mean ± Standard Deviation	
Arterial Lactate (mmol/L)	ARM	5.7 ± 2.4	3.8 ± 1.6	0.002
	IPPB	3.4 ± 0.9	2.0 ± 0.7	≤ 0
Oxygenation Rate (mmHg)	ARM	287.4 ± 121.3	432.0 ± 186.3	0.005
	IPPB	337.4 ± 133.9	513.6 ± 198.8	≤ 0
Pressure of Oxygen (mmHg)	ARM	123.6 ± 34.4	132.1 ± 54.1	0,579
	IPPB	94.2 ± 31.6	108.8 ± 41.0	= 0.016
Inspired Fraction (%)	ARM	46.1 ± 10.9	31.5 ± 6.7	≤ 0
	IPPB	31.7 ± 16.9	21.3 ± 0.9	= 0.008
Oxygen Saturation (%)	ARM	96.4 ± 2.1	98.5 ± 1.1	≤ 0
	IPPB	95.6 ± 1.5	98.0 ± 0.8	≤ 0

Ethics approval and consent to participate

Trabalhos experimentais envolvendo seres humanos:

This study was approved by the Ethics Committee of the Hospital Ana Nery – UFBA/SESAB under the

protocol number 861.257. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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