REVIEW ARTICLE

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Alveolar recruitment in patients in the immediate postoperative period of cardiac surgery

Recrutamento alveolar em pacientes no pós-operatório imediato de cirurgia cardíaca

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Abstract

Lung complications during postoperative period of cardiac surgery are frequently, highlighting atelectasis and hypoxemia. Alveolar recruitment maneuvers have an important role in the prevention and treatment of these complications. Thus, this study reviewed and updated the alveolar recruitment maneuvers performance in the immediate postoperative period of cardiac surgery. We noted the efficacy of alveolar recruitment through different specific techniques and the need for development of new studies.

Descriptors: **Thoracic Surgery. Pulmonary Atelectasis. Positive-Pressure Respiration. Physical Therapy (Specialty). Postoperative Care.**

Resumo

Complicações pulmonares no pós-operatório de cirurgia cardíaca são frequentes, destacando-se a atelectasia e a hipoxemia. As manobras de recrutamento alveolar contribuem significativamente para a prevenção e o tratamento destas complicações. Desta forma, este estudo buscou agrupar e atualizar os conhecimentos relacionados à utilização das manobras de recrutamento alveolar no pós-operatório imediato de cirurgia cardíaca. Observou-se a eficácia do recrutamento alveolar por meio de diferentes técnicas específicas e a necessidade do desenvolvimento de novas pesquisas.

Descritores: **Procedimentos Cirúrgicos Cardíacos. Atelectasia Pulmonar. Respiração com Pressão Positiva. Fisioterapia (Especialidade). Cuidados Pós-Operatórios.**

INTRODUCTION

Cardiac surgery is responsible for the reduction of symptomatology, besides optimizing survival and quality of life in cardiac patients. However, pulmonary complications are frequently observed and represent an important cause of morbidity and mortality for patients in the immediate postoperative period of cardiac surgery [1].

Pulmonary complications in this population have multifactorial pathophysiology. Its development is a result of the combined effects of anesthesia, surgical trauma and extracorporeal circulation (EC) [2]. Atelectasis and hypoxemia are the most important complications. The incidence of atelectasis in patients undergoing cardiac surgery with EC is high, ranging from 60% to 90% [2,3]. The development of atelectasis in the postoperative period of cardiac surgery is approximately six times higher than that observed after abdominal surgery [4].

In recent years, scientific studies have investigated therapeutic strategies that could prevent or minimize

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pulmonary complications after cardiac surgery [5,6]. When approaching these cases, respiratory physiotherapy has been increasingly requested, since it uses techniques that can improve respiratory mechanics, reexpansion pulmonary and bronchial hygiene. Physiotherapy contributes to adequate ventilation and leads to successful extubation in the postoperative period, after the patient's arrival in the intensive care unit. [5,7-9].

The physiotherapeutic assistance for cardiac surgery patients is essential and involves several strategies, including the alveolar recruitment maneuver (ARM), a technique that uses the increase in transpulmonary pressure with the aim of recruiting collapsed alveolar units, increasing the lung area available for gas exchange and, consequently, arterial oxygenation [10,11].

The aim of this study was to review current concepts related to alveolar recruitment maneuvers in the immediate postoperative period of cardiac surgery and to identify the indications, alveolar recruitment techniques, possible benefits and adverse effects, as well as everything that should be taken care of when implementing this maneuver in a cardiac surgery patient.

PULMONARY COMPLICATIONS AFTER CARDIAC SURGERY

Atelectasis, defined as the alveolar collapse in a particular area of the lung parenchyma, usually from the dependent regions of the lung, is the most common complication in the postoperative period of cardiac surgery [2.12].

During the surgical procedure, cardiopathic patients are exposed to several factors that contribute to atelectasis formation. These factors are: cephalic displacement of the diaphragm caused by anesthetics and neuromuscular blockers, the compression of the lung by mediastinal structures, sternotomy, the surgical management of pleural cavity, the inactivity of the lungs during EC and mechanical ventilation with high inspired oxygen fraction during the intraoperative period [13,14].

In patients undergoing cardiac surgery intervention with EC, the increase in extravascular lung water and changing the normal activity of the surfactant system, secondary to inflammatory cascade activation and coagulation by blood contact with non-endothelial surfaces, contributes to the weight gain of the lung parenchyma and alveolar unit collapses, decreasing the efficiency of gas exchange [14,15]. These changes reverberate in ventilation-perfusion ratio, causing a decrease in functional residual capacity, increase of intrapulmonary shunt and hypoxemia development [10.16].

The presence of collapsed lung regions has also been associated with increased risk of respiratory infections in the postoperative period [13]. Pneumonia is one of the most common nosocomial infections in the postoperative period of cardiac surgery intervention and it is considered the leading cause of morbimortality in this population [17,18].

ALVEOLAR RECRUITMENT MANEUVERS (ARM)

They are defined as procedures that are intended to increase transpulmonary pressure in order to promote the opening of the largest possible number of alveoli and then improve the distribution of alveolar gas [10,11]. Therefore, this approach maximizes gas exchange, improves arterial oxygenation and reduces lung lesions induced by mechanical ventilation, known as volutrauma, atelectrauma and biotrauma [19].

Indications

ARM has a well-established indication for patients with moderate to severe hypoxemia and also for patients who meet the diagnostic criteria for Acute Respiratory Distress Syndrome (ARDS). It is believed that the use of these strategies in clinical practice determines an important reduction of morbidity and mortality [19,20].

ARM has also been used to increase oxygenation after cardiac surgery intervention. The hypoxemia conditions in these patients occurs due to intrapulmonary shunt fraction caused by collapsed alveoli [21,22]. According to Neves et al. [19], ARM is particularly indicated in clinical situations that can cause alveolar collapse, such as anesthesia, sedation and neuromuscular blockade, as well as to disconnect the patient from the mechanical ventilation.

Recent studies have shown that ARM may be indicated and monitored by means of oxygenation markers, in which the most used ones are: pressure of oxygen in arterial blood (PaO2), the relationship PaO2/fraction of inspired oxygen (FiO2), the oxygenation index and peripheral oxygen saturation (SpO2). These markers associated with computed tomography can clarify, quantify and assess the effectiveness of lung recruitment [19,22].

Alveolar recruitment techniques

Different methods are proposed for the realization of alveolar recruitment, such as: inflation sustained with high levels of continuous positive airway pressure (CPAP), a simultaneous increase of positive end-expiratory pressure (PEEP) and tidal volume (TV); progressive increase of PEEP with a fixed value of inspiratory pressure (IP) and simultaneous increase of inspiratory pressure (IP) and PEEP in pressure controlled ventilation mode [11,13,22].

According to the literature, the most commonly used ARM in the postoperative period of cardiac surgery is sustained inflation. The technique involves the application of CPAP with pressure levels ranging from 30 to 45 cmH2O

for 30 to 40 seconds [10,14,19]. Although alveolar recruitment in pressure controlled ventilation mode is employed less frequently, they are also observed in some studies. The authors use for the recruitment the gradual and combined increase of IP and PEEP until it reaches peak pressure and PEEP of 40 cmH2O and 20 respectively for up to 2-3 minutes; or the use of fixed IP at 15 or 20 cmH2O associated with the gradual increase of PEEP for up to 2 minutes, reaching a final PEEP of 35 cmH2O with a consequent increase in peak pressure up to 50 cmH2O [16,19,23].

ARM has short duration and can be performed several times a day and / or when necessary, as the deterioration of oxygenation, mechanical ventilator disconnection and after aspiration of the tracheal tube [24,25]. In general, ARM should be followed by the setting of PEEP levels, which plays a vital role in maintaining the effectiveness of this maneuver, stopping the disrecruitment and preventing atelectrauma. PEEP provides higher alveolar stability after the recruitment. The ideal PEEP can be determined by the best gas exchange point, in other words, 2 cmH2O above the lower inflection point of pressure-volume curve of the respiratory system, observing the hemodynamic stability [10,20,26

Benefits

Studies have shown that alveolar recruitment strategies can improve respiratory function in the postoperative period of cardiac surgery by reducing atelectasis and intrapulmonary shunt, improving ventilation-perfusion ratio and, consequently, arterial oxygenation [11,13,16].

The benefits of ARM go beyond the atelectasis reversal. By promoting better distribution of ventilation to previously collapsed areas, the possibility of volutrauma and pulmonary vascular resistance associated with hypoxia can be reduced, improving the right ventricular performance and reducing the need for mechanical ventilation in the postoperative period [14, 27].

In order to improve the assessment results of ARM, the oxygenation markers (PaO2 PaO2 / FiO2, SpO2, oxygenation index) should be determined at the beginning of the procedure and during the patient evolution. Moreover, during each intervention, the effectiveness of the recruitment should also be assessed by imaging techniques such as chest computed tomography, studies of static and dynamic respiratory mechanics, as well as the measurement of lung volume [19,22].

Auler Jr et al. [13] found significant improvement in arterial oxygenation after arterial recruitment maneuver (CPAP 20, 30 and 40 cmH2O for 30 seconds) in 40 hypoxemic patients in the postoperative period of cardiac surgery. Similar results were described by Dyhr et al. [10] who used the alveolar recruitment technique in CPAP mode with airway pressure of 45 cmH2O during four 10-second inflations associated with the application of 12 cmH2O PEEP after maneuver. These authors found that in the postoperative period of cardiac surgery, ARM combined with maintenance of PEEP results in increased exhaled lung volume and improves oxygenation.

Claxton et al. [22] studied a similar population, but with PEEP of 15 cmH2O, allowing peak inspiratory pressure of 40 cmH2O. There was significant improvement in oxygenation measured by PaO2/FiO2 ratio in the recruitment group, 30 minutes and one hour after the maneuver when compared with the groups with and without PEEP of 5 cmH2O. There were no significant changes in hemodynamic parameters during the application of ARM. Scohy et al. [28] used ARM followed by PEEP of 8 cmH2O in 20 children in the postoperative period of cardiac surgery. The authors observed significant improvement in oxygenation, dynamic compliance and expiratory lung volume of the children studied.

Table 1 summarizes the most important articles, authors, year of publication, study population, type of alveolar recruitment used and the results found.

Adverse effects and contraindications

Despite all the benefits observed, the alveolar recruitment in the immediate postoperative period of cardiac surgery has still shown controversial results. ARM can also cause undesirable effects such as the reduction of venous return, decreased cardiac output and hypotension. The occurrence of hypotension, with rapid improvement after the maneuver interruption, is more common in hypovolemic patients [11.29-31].

The major complications that can occur are barotrauma and hemodynamic compromise, during ARM. Two mechanisms are responsible for hemodynamic instability, one of them for increasing the airway pressure, leading to decreased venous return and right ventricle preload and, the second one, for increased alveolar pressure, which may increase pulmonary vascular resistance and the right ventricle postload [26.29].

A recent systematic review showed that the most frequent complications of ARM were hypotension (12%) and desaturation (9%). Barotrauma, despite being a major complication, has a low incidence (1%). These complications seem to have low impact on the need to improve oxygenation in severe hypoxemia [32].

There are some main contraindications to perform alveolar recruitment, such as the presence of hemodynamic instability, as hypotension, psychomotor agitation, chronic obstructive pulmonary disease, previous pneumonectomy, bronchopleural fistula, hemoptysis, undrained pneumothorax and intracranial hypertension [23,24,33].

Table 1. Characteristics of Revised Studies

Authors / Year	Population	Recruitment Mode Recrutamento	Description ofStudy	Results
Malbouisson et al. [14] / 2008	Postoperative period of cardiac surgery (n = 10)	CPAP	3 x 40 cmH_2O for 40 seconds	Oxygenation improvement (increased PaO2/FiO2 ratio and reduction of pulmonary shunt) without inducing significant alterations in the hemodynamic performance.
Auler Jr et al [13] / 2007	Postoperative period of cardiac surgery (n = 40)	CPAP	3 x 20, 30 ou 40 cmH_2O for 30 seconds	Significant improvement in oxygenation characterized by increased PaO2/FiO2 ratio, SpO2 and exhaled tidal volume.
Tusman et al. [23] / 2004	Postoperative period of thoracic surgery (n = 12)	IP - PEEP combination	Gradual increase of pressure until it reaches PP of 40 cmH2O and PEEP 20 of cmH2O for 10 respiratory cycles.	Increased efficiency of ventilation and exhalation of CO2. There were no adverse effects in relation to and / or ventilated hemodynamic performance.
Dyhr et al. [21] / 2002	Postoperative period of cardiac surgery (n = 16)	CPAP	A: 2 x 45 cmH_2O for 20 seconds + PEEP 14 cmH_2O after maneuver vs B: 2 x 45 cmH_2O for 20 seconds + ZEEP after maneuver	PEEP is necessary after the alveolar recruitment to maintain lung volumes and increase oxygenation.
Dyhr et al. [10] / 2004	Postoperative period of cardiac surgery (n = 30)	CPAP	A: 4 x 45 cmH_2O for 10 seconds + PEEP 12 cmH_2O after maneuver vs B: 4 x 45 cmH_2O for 10 segundos + ZEEP after maneuver vs C: PEEP 12 cmH_2O	PEEP is necessary after the alveolar recruitment to maintain lung volumes and increase oxygenation.
Garutti et al. [16] / 2009	Postoperative period of thoracic surgery (n = 40)	IP - PEEP combination	Gradual increase of pressure until it reaches PP of 40 cmH2O and PEEP 20 of cmH2O for 10 respiratory cycles.	Significant improvement in oxygenation without inducing significant hemodynamic alterations.
Celebi et al. [4] / 2007	Postoperative period of cardiac surgery (n = 60)	-CPAP -Combination PEEP and TV	A: CPAP 40 cmH_2O for 30 seconds vs B: Increased VT and PEEP up to 20 cmH2O, allowing PP up to 40 cmH2O vs C: PEEP 5 cmH_2O	Decreased atelectasis and significant improvement in oxygenation. Greater hemodynamic stability in recruitment with PEEP 20cmH2O compared to CPAP
Claxton et al. [22] / 2003	Postoperative period of cardiac surgery (n = 78)	Combination PEEP and TV	A: ZEEP vs B: PEEP 5 cmH_2O vs C: Increased VT and PEEP up to 15 cmH2O, allowing PP up to 40 cmH2O	Significant improvement in oxygenation without adverse effects. The application of PEEP 5 cmH2O in isolation shows no significant effect upon oxygenation.

PO: postoperative; PEEP: positive end expiratory pressure, TV: tidal volume; IP: inspiratory pressure, PP: peak pressure, ZEEP: *Zero PEEP; PaO2/FiO2: arterial pressure of inspired oxygen pressure; SpO_2: peripheral oxygen saturation, CO_2: carbon dioxide*

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Pulmonary complications in the postoperative period of cardiac surgery are often observed. Atelectasis and hypoxemia are the most relevant ones. ARM may be considered an important adjuvant to clinical practice, with an effective method for correction of atelectasis in improved oxygenation and restoration of tidal volume, facilitating weaning from mechanical ventilation in patients in the postoperative period of cardiac surgery.

Besides the benefits observed, ARM can also have undesirable effects such as barotrauma and hemodynamic compromise. Therefore, its implementation in patients in the postoperative period of cardiac surgery should be performed only under strict monitoring, hemodynamic control and experienced team.

Ideal values †of airway pressure and standardization of alveolar recruitment technique have not reached a consensus in the specialized literature yet. Hence, further studies are necessary to better assess their impact and to establish more definite guidelines for its use, in order to ensure the effectiveness of ARM for patients in the immediate postoperative period of cardiac surgery.

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