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Effect of the alveolar recruitment manoeuvre on pulmonary complications in the immediate postoperative period of cardiac surgery: preliminary results of a randomised controlled trial

Efeito da manobra de recrutamento alveolar em complicações pulmonares no pós-operatório imediato de cirurgia cardíaca: resultados preliminares de ensaio clínico randomizado

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Abstract
Introducion: given the great variability in ventilation protocols, postoperative management, characteristics of the alveolar recruitment maneuver (ARM) (frequency, duration and intensity) and tolerability in patients undergoing cardiac surgery (CS), this study investigates whether ARM is beneficial in this area. situation in order to standardize its use. ***Objective****: we investigated the effectiveness of ARM against pulmonary complications (PCs) immediately after CS.* ***Methods****: this randomised clinical trial included 134 patients aged >18 years who underwent coronary artery bypass graft or valve replacement surgery at our institution between February and September 2019. Participants were allocated to receive standard physiotherapy (control group [CG], n=67) or standard physiotherapy plus ARM (intervention group [IG], n=67).* ***Results****: there was no statistically significant difference in the incidence of PCs between the CG and IG groups (p=0.85). ARM did not improve gas exchange or lower total mechanical ventilation time, reintubation requirement, or intensive care unit and hospital stay.* ***Conclusion****s: prophylactic ARM does not decrease the insufficiency of PCs in the postoperative period of CS, it did not improve gas exchange, nor did it reduce the time of MV. MRA was associated with an increased risk of hemodynamic instability. Patients must be screened before performing ARM.*
Keywords*: Adverse effects. Physiotherapy. Positive-pressure ventilation. Postoperative care. Thoracic surgery*

Resumo
Introdução: dada a grande variabilidade nos protocolos de ventilação, manejo pós-operatório, características da manobra de recrutamento alveolar (MRA) (frequência, duração e intensidade) e tolerabilidade em pacientes submetidos à cirurgia cardíaca (CC), este estudo investiga se a MRA é benéfica nesta área, a fim de padronizar seu uso. **Objetivo**: investigou-se a eficácia da MRA contra complicações pulmonares (CPs) imediatamente após a CC. **Metodologia**: este ensaio clínico randomizado incluiu 134 pacientes com idade > 18 anos submetidos à cirurgia de revascularização do miocárdio ou cirurgia de substituição valvar em nossa instituição entre fevereiro e setembro de 2019. Os participantes foram alocados para receber fisioterapia padrão (grupo controle [GC], n=67) ou fisioterapia padrão com adição da MRA (grupo intervenção [GI], n=67). **Resultados**: não houve diferença estatisticamente significativa na incidência de CPs entre os grupos GC e GI (p=0,85). A MRA não melhorou as trocas gasosas ou reduziu o tempo total de ventilação mecânica, necessidade de reintubação na unidade de terapia intensiva e internação hospitalar. **Conclusão**: a MRA profilática não diminui a incidência de CPs no pós-operatório de CC, não melhora as trocas gasosas, nem reduziu o tempo de VM. A MRA foi associada a um risco aumentado de instabilidade hemodinâmica. Os pacientes devem ser avaliados antes de realizar MRA.
Palavras-chave: Efeitos adversos. Fisioterapia. Ventilação com pressão positive. Cuidados pós-operatórios. Cirurgia torácica.

INTRODUCTION

Cardiac surgery (CS) for severe conditions can be long and complex, with organic repercussions that could alter the physiological mechanisms and can cause critical postoperative complications[1-4].

Pulmonary complications (PCs) after CS are relatively frequent; pleural effusion (27%–95%), atelectasis (16.6%), and postoperative hypoxemia (3%–10%) are the most common complications. CS may also lead to acute respiratory distress syndrome (ARDS), which even though it occurs in only 0.2%–0.7%, entails high mortality (50%–90%). The systemic inflammatory response elicited by CS can cause lung injury through various mechanisms, including anomalies in gas exchange, increased pulmonary shunt fraction and pulmonary vascular resistance, and intrapulmonary aggregation of leukocytes and platelets. Moreover, changes in pulmonary mechanics, such as reduced lung compliance, functional residual capacity, and vital capacity, may occur[5].

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To date, different therapeutic measures have been used to minimise the adverse effects of surgical manipulation for pulmonary re-expansion. These therapeutic measures aim to lower the risk of atelectasis and pulmonary infection[6].

Alveolar recruitment manoeuvres (ARMs) increase oxygenation post-CS. ARMs are indicated in clinical situations that lead to alveolar collapse, such as anaesthesia, sedation, and neuromuscular blockage, as well as when a patient is weaned from mechanical ventilation[7]. The beneficial effects of postoperative ARM in mechanically ventilated patients, in addition to reversing atelectasis[8], involve improved ventilation in previously collapsed areas, decreased risk of volutrauma, decreased hypoxic pulmonary vasoconstriction, improved performance of the right ventricle (RV) and reduced need for mechanical ventilation (MV)[8].

However, despite its benefits, alveolar recruitment in the immediate POP of CS is still not widely used. Considering the great variability in ventilation protocols, postoperative management, ARM characteristics (frequency, duration, and intensity), and tolerability in patients who undergo CS, more studies are needed to investigate whether ARMs are beneficial in this situation and to standardise their use. ARMs benefit for improving gas exchange and lowering PCs among adult patients in the POP of CS needs to be elucidated.

This study primarily aimed to determine whether ARM lowers the incidence of immediate postoperative PCs in adult patients who undergo CS. Specifically, we investigated the impact of ARM on gas exchange, MV time, reintubation requirement, and length of hospital and intensive care unit (ICU) stay. We also assessed the main adverse effects of ARM.

METHODS

This randomized, parallel, prospective, and monocentric clinical trial was conducted between February and September 2019 in the cardiovascular unit (CVU) from Ana Nery Hospital, Salvador – BA, Brazil. It is registered in the Brazilian clinical trials platform, in accordance with the current norms for research involving human beings, according to Resolution Res. 466/12 CNS/MS. Approved by the Research Ethics Committees of the Institute of Health Sciences (ICS) and Ana Nery Hospital (HAN/SESAB). All participants provided informed consent before the surgery was performed, where it was clarified that ARM would be applied in the immediate immediate POP of CS, still under the effect of general anesthesia and sedation.

We enrolled patients aged >18 years admitted to CVU in the immediate POP of a CS that required cardiopulmonary bypass (CPB) and continued MV for a minimum period of 4-8 h after surgery.

Of the main exclusion criteria, we highlight hemodynamic instability, such as hypotension[9]. The initial sample size was 104 patients in each group to detect a 17% difference in PPCs[19] and obtain a power of 80% and an alpha of 5%.

Patients were randomly assigned to receive the standard physiotherapy treatment used in the CVU (control group [CG]) or the standard physiotherapy treatment plus ARM (intervention group [IG]).

Using R software version 2.15. 1 (Duxbury Press, Boston, Massachusetts), a researcher unrelated to the study generated a simple random allocation list representing each group. Patients were allocated to both groups according to the sequence in the list. Based on a protocol previously prepared for this study, and in agreement with the entire physiotherapy team at the Ana Nery hospital, the physiotherapist on duty continued with the interventions[10].The randomization list was manipulated by a single researcher, stored electronically and kept confidential[11].

Patients in both groups connected to one of the mechanical ventilators available at the unit (Bird® Candle, SERVO-S Maquet® or Savina Drager®) were ventilated under a protective strategy, with a tidal volume of 6 mL/kg of predicted weight.

In IG patients, ARM was performed immediately after setting the ventilator parameters and starting hemodynamic and respiratory monitoring, only once, after ensuring adequate adaptation to MV. Before performing the ARM, preliminary conditions were ensured:[12-17] such as correction of the limitation by the resistive component, if necessary; adequate sedation to suppress the respiratory drive; and continuous hemodynamic and oxygenation monitoring before, during and after the intervention. Performed in pressure-controlled ventilation mode, insufflation pressure and PEEP were adjusted to 15 and 25 cm H2O, respectively, and maintained for 1 minute if hemodynamic conditions permitted. This maneuver was repeated three times at 2 minute intervals. After ARM, ventilatory parameters returned to baseline, including PEEP.

ARM was interrupted when there was a sign of hemodynamic instability, in cases of patient/ventilator asynchrony caused by awakening from anesthesia during the maneuver[9]. In some cases, volume expansions or norepinephrine infusions were necessary to correct hypotension. Due to this intercurrence in some cases, there are chances of increased costs for the use of vasoactive amines.

Arterial blood samples were collected from all patients to assess the arterial partial pressure of oxygen (PaO2)/FiO2 ratio immediately after admission to the CVU. Measurements were collected at admission, 1 h after admission, and 6 h after admission.

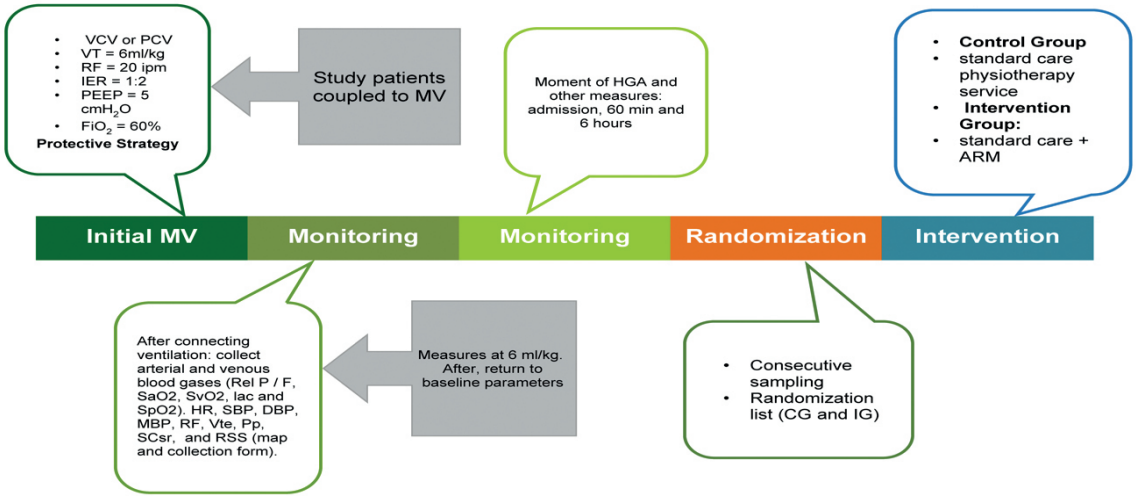
The occurrence of PC within 5 days post-CS was the primary outcome. Data were collected regarding the total time of MV; UVC time and hospitalization; presence of respiratory distress; need for reintubation or non-invasive ventilation (NIV); and occurrence of apnea, desaturation, pulmonary complications (PPC) or death, considered secondary outcomes, in addition to gas exchange.

Some of the PCs considered included: pneumonia, leukopenia or leukocytosis; change in tracheal secretion (new purulent secretion); wheezing; rhonchi on pulmonary auscultation and gas exchange worsening; atelectasis diagnosed based on imaging or physical examination; pleural effusion and pneumothorax; pulmonary hemorrhage[18].

Other complications considered in the study: postoperative wound infection (mediastinitis); septic shock; reoperation, performed in case of bleeding unresponsive to clinical measures or cardiac tamponade; hemodynamic instability associated with ARM (10% drop in mean arterial pressure after the maneuver); use of NIV after extubation, due to desaturation, poor gas exchange or respiratory distress; reintubation; adverse events in the 48 hours after extubation; and death.

Figure 1 shows the research and intervention timeline in the postoperative period.

Figure 1 – *Study timeline*



Fonte: Autoria própria

Statistical Analysis

Categorical variables were expressed as absolute and relative frequencies (percentages). Mean±standard deviation and median (interquartile range) used for numerical variables. The chi-square test used to compare categorical variables; when appropriate, use of Fisher's exact test or likelihood ratio. Numerical variables were compared using Student's t test or Mann-Whitney test in the case of non-parametric distribution. The Kolmogorov-Smirnov test was used to assess the normality of quantitative variables.

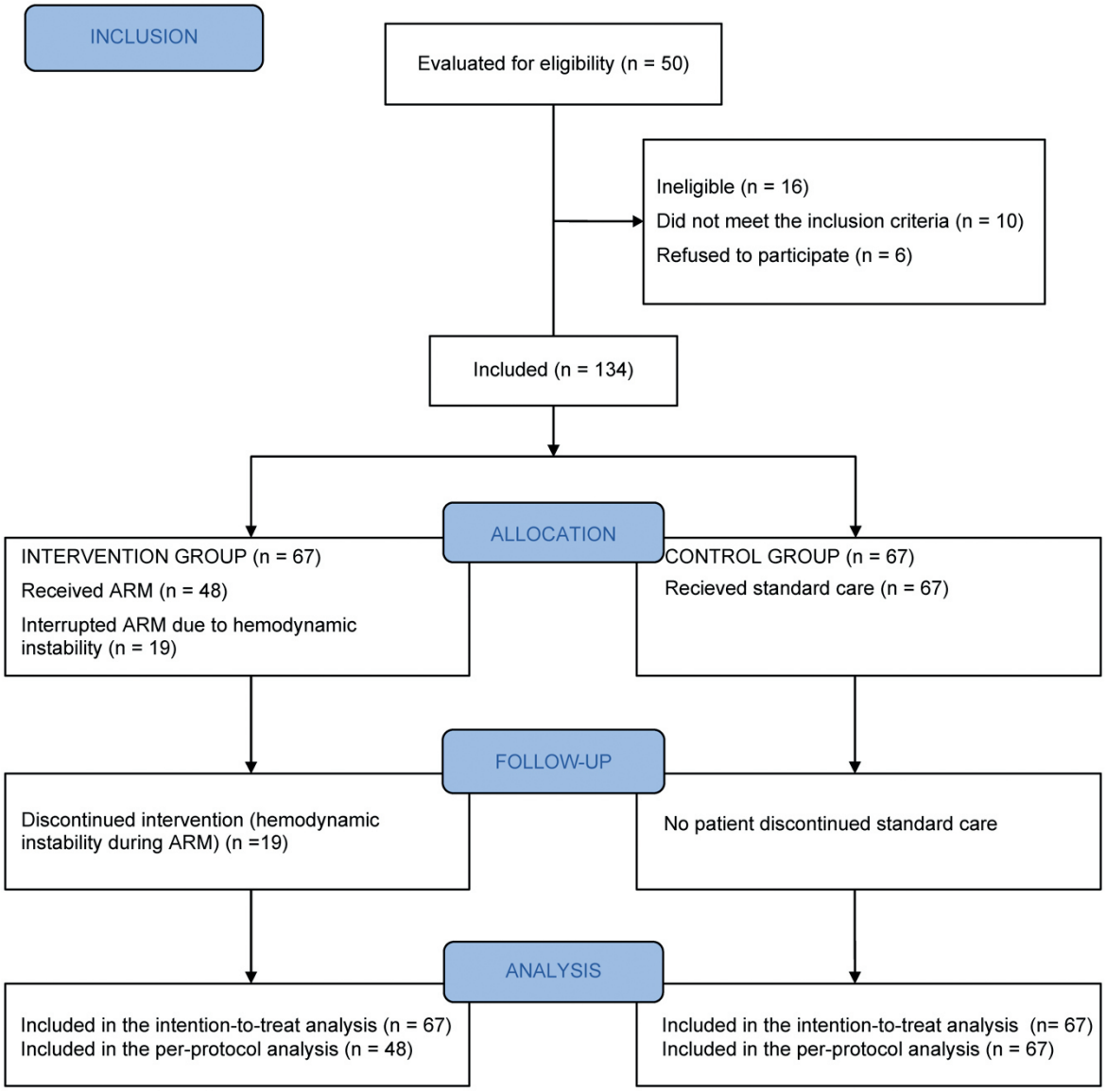
The analysis of variance (ANOVA) test for repeated measures was used to assess differences among functional variables over time and between groups. To analyze the effect of the intervention on the primary and secondary outcomes, two analyses were performed: a per-protocol analysis that included only patients who effectively received the intervention and an intention-to-treat analysis that considered all patients, regardless of whether the intervention was administered.

To evaluate the trends in gas exchange over time, the PaO2/FiO2 ratio was evaluated at three time points: (1) immediately after unit arrival and immediately after the patient's accommodation on the ventilator; (2) after 60 min of the new gas admission, and (3) after 6 hours. The level of significance was set at 5%.

RESULTS

For our results, figure 2 presents a flowchart of the study participants. All patients received the originally assigned intervention. ARM was interrupted in 19 patients due to hemodynamic instability. Thus, 67 GI patients were eligible for the final analysis.

Figure 2 – *Flow diagram of study participants*



Fonte: Autoria própria

As for baseline characteristics, there were no significant differences between groups (Table 1). In Table 2, which shows the characteristics of the patients in the postoperative period by group, it is possible to see that the time of cardiopulmonary bypass (CPB) was significantly shorter in the control group (CG) than in the intervention group (IG) (71. 4 min vs. 84.7 min, p=0.01). The most common systemic complications were bleeding and arrhythmia. Table 3 shows the mechanical ventilatory and respiratory characteristics of both groups. Of the 67 patients in the CG, 19 (28.4%) and 46 (68.7%) patients were ventilated in the assisted-volume-controlled and pressure-assisted-controlled modes, respectively. In the IG, 15 (22.4%) and 50 (74.6%) patients were ventilated in the assisted-volume controlled and pressure-assisted controlled modes, respectively.

Table 1 – *Patient characteristics according to study group (n=134)*

	Control group (n=67)	Intervention group (n=67)	p-value
Demographic characteristics			
Age, years	*56.7±12.1*	*54.4±12.0*	*0.27*
Male sex	*43 (64.2%)*	*34 (50.7%)*	*0.12*
BMI (kg/m2)	*26.6±4.3*	*25.7±4.5*	*0.23*
Clinical background			
Current smoker	*10 (14.9%)*	*10 (14.9%)*	*1.00*
Former smoker	*10 (14.9%)*	*8 (11.9%)*	*0.61*
CHF	*20 (29.9%)*	*24 (35.8%)*	*0.46*
LVEF, %	*56.8±13.3*	*57.2±13.9*	*0.86*
SAH	*46 (68.7%)*	*49 (73.1%)*	*0.57*
Diabetes mellitus	*16 (23.9%)*	*18 (26.9%)*	*0.70*
DVT	*1 (1.5%)*	*1 (1.5%)*	*1.00*
Alcoholism	*9 (13.4%)*	*5 (7.5%)*	*0.26*
Lung disease	*1 (1.5%)*	*2 (3.0%)*	*1.00*
DLP	*14 (20.9%)*	*15 (22.4%)*	*0.83*
Preoperative risk			
EuroScore II	*0.94 (0.76–1.64)*	*1.15 (0.82–2.11)*	*0.40*
STS Risk mortality	*1.4 (0.58–1.83)*	*1.07 (0.45–2.21)*	*0.52*
STS Risk morbidity and mortality	*8.98 (5.89–12.69)*	*9.46 (6.12–14.50)*	*0.80*

Values are expressed as means ± SDs, n (%), or medians (interquartile ranges), as appropriate.
BMI = body mass index; CHF = congestive heart failure; DLP = dyslipidaemia; DVT = deep vein thrombosis; EuroScore II = European System for Cardiac Operative Risk Evaluation II; LVEF = left ventricular ejection fraction; SAH = systemic arterial hypertension; STS Risk = Society of Thoracic Surgeons risk score

Fonte: dados da pesquisa

Table 2 – *Perioperative patient characteristics according to study group (n=134)*

	Control group (n=67)	Intervention group (n=67)	p-value
Type of surgery			
MR	*42 (62.7%)*	*34 (50.7%)*	*0.57*
VR	*20 (29.9%)*	*27 (40.3%)*	
MR + VC	*3 (4.5%)*	*4 (6.0%)*	
Valve repair	*2 (3.0%)*	*2 (3.0%)*	
CPB			
CPB time, min	*71.4±26.4*	*84.7±32.3*	*0.01*
Anoxia time, min	*60.2±24*	*72.3±26.2*	*0.01*
Systemic complications	*31 (46.3%)*	*30 (44.8%)*	*0.86*
Sepsis	*5 (7.5%)*	*8 (11.9%)*	*0.39*
Bleeding	*8 (11.9%)*	*5 (7.5%)*	*0.38*
Arrhythmias	*9 (13.4%)*	*6 (9.0%)*	*0.41*
Pulmonary hypertension	*1 (1.5%)*	*1 (1.5%)*	*1.00*
ARF	*3 (4.5%)*	*4 (6.0%)*	*1.00*

Values are expressed as means ± SDs or n (%).
ARF = acute renal failure; CPB = cardiopulmonary bypass; min = minute; MR = myocardial revascularisation; VR = valve replacement
Fonte: dados da pesquisa

Table 3 – *Mechanical ventilatory and respiratory characteristics according to the study group*

	Control group (n=67)	Intervention group (n=67)	p-value
Ventilatory mode			
VCV	*19 (28.4%)*	*15 (22.4%)*	*0.73*
PCV	*46 (68.7%)*	*50 (74.6%)*	
SPV	*2 (3.0%)*	*2 (3.0%)*	
Respiratory mechanics			
Stc Rs, mL/cmH2O	*36.6±11.6*	*36.2±14.7*	*0.42*

Values are expressed as n (%) or means ± SDs.
PCV = pressure-controlled ventilation; SPV = support pressure ventilation; StcRs = static compliance of the respiratory system; VCV = volume--controlled ventilation.

Fonte: dados da pesquisa

Norepinephrine and nipride were used in hypotensive patients not responsive to volume expansions and patients with difficult-to-control hypertension, respectively. All patients were extubated on a scheduled basis, except for those who died within 5 days postoperatively. Table 4 shows the overall PPC incidence according to the intention-to-treat analysis. No difference was observed in this regard between the CG and IG groups (32.8% vs. 31.3%, p=0.85); similar results were observed for each type of PPC. All PPCs occurred up within the first 5 days postoperatively.

Table 4 – *Incidence of postoperative pulmonary complications according to the study group in the intention-to-treat analysis*

	Control group n=67	Intervention group n=67	p-value
Pulmonary complications	*22 (32.8%)*	*21 (31.3%)*	*0.85*
Pneumonia	*4 (6.0%)*	*10 (14.9%)*	*0.90*
Atelectasis	*7 (10.4%)*	*6 (9.0%)*	*0.77*
Pleural effusion	*10 (14.9%)*	*9 (13.4%)*	*0.80*
Pneumothorax	*2 (3.0%)*	*1 (1.5%)*	*1.00*
Acute pulmonary oedema	*3 (4.5%)*	*1 (1.5%)*	*0.62*

Values are expressed as n (%).

Fonte: dados da pesquisa

Nineteen patients were included in the per-protocol analysis (Table 5). There was no difference in the overall incidence of PPCs between the CG and IG patients who presented with hemodynamic instability during ARM. Additionally, there were no differences when individual PPCs were analysed.

Table 5 – *Incidence of postoperative pulmonary complications according to the study group in the per-protocol analysis*

	Control group (n=67)	Intervention group (n=48)	p-value
Pulmonary complications	22 (32.8%)	13 (27.1%)	0.51
Pneumonia	4 (6.0%)	6 (12.5%)	0.32
Atelectasis	7 (10.4%)	4 (8.3%)	0.76
Pleural effusion	10 (14.9%)	4 (8.3%)	0.29
Pneumothorax	2 (3.00%)	1 (2.1%)	1.00
Acute pulmonary oedema	3 (4.5%)	0 (0.0%)	0.26

Values are expressed as n (%).

Fonte: dados da pesquisa

Regarding secondary outcomes, the intention-to-treat analysis showed that there were no significant between-group differences in the total MV time, total length of ICU or hospital stay, NIV requirement, need for reintubation, and mortality (Table 6). Similar results were obtained in the per-protocol analysis (Table 7).

Table 6 – *Secondary outcomes according to the study group in the intention-to-treat analysis*

Variables	Control group (n=67)	Intervention group (n=67)	p-value
Total MV time, h	8.9 (4.7–12.2)	8.5 (5.5–12.0)	0.87
Total ICU stay, days	3.0 (2–5.0)	3.0 (2–5.0)	0.50
Total length of hospital stay, days	9.0 (7–15.0)	9.0 (7–16.0)	0.86
Use of NIV	10 (14.9%)	5 (7.5%)	0.20
Reintubation	2 (3.0%)	4 (6.0%)	0.68
Death	**3 (4.5%)**	**4 (6.0%)**	**1.00**

Values are expressed as medians (interquartile ranges) or n (%).
ICU = intensive care unit; MV = mechanical ventilation; NIV = non-invasive ventilation.

Fonte: dados da pesquisa

Table 7 – *Secondary outcomes according to the study group in the per-protocol analysis*

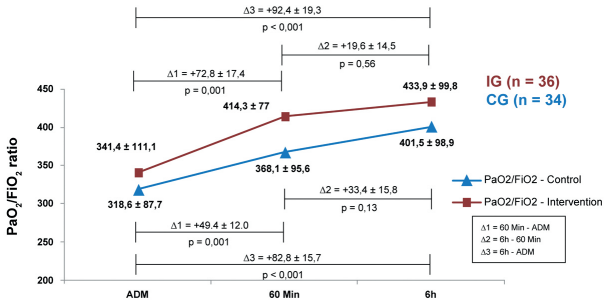
Variables	Control group (n=67)	Intervention group (n=48)	p-value
Total VM time, h	8.9 (4.7–12.2)	8.2 (5.2–12)	0.90
Total ICU stay, days	3.0 (2–5.0)	3.0 (2–4.0)	0.61
Total length of hospital stay, days	9.0 (7–15.0)	9.0 (7–16.0)	0.92
Use of NIV	10 (14.9%)	6 (9.1%)	0.31
Reintubation	2 (3.0%)	3 (6.3%)	0.65
Death	**3 (4.5%)**	**4 (8.3%)**	**0.45**

Values are expressed as medians (interquartile ranges) or n (%).
ICU = intensive care unit; MV = mechanical ventilation; NIV = non-invasive ventilation.

Fonte: dados da pesquisa

Figure 3 shows the changes in the PaO2/FiO2 ratio over time. Overall, the data of 34 and 36 participants from the CG and the IG, respectively, were evaluated; this data loss was attributed to the technical limitations. In both groups, there was a significant increase in gas exchange within 60 min of admission (CG: 49.4±12.0, p=0.001; IG: 72.8±17.4, p=0.001), but not between 60 min and 6 h. A significant difference was observed after 6 h in relation to admission (CG: 82.8±15.7, p<0.001; IG: 92.4±19.3, p<0.001). No significant between-group difference was observed in the changes in the PaO2/FiO2 ratio (p=0.58).

Figure 3 – *Behaviour of intragroup gas exchanges*



DISCUSSION

The effectiveness of ARM for managing PCs in the immediate POP of CS has not yet been established. Our preliminary results demonstrate that MRA does not decrease the incidence of PC in the immediate POP of CS. We will continue this study and enroll more patients to ensure the power of affirmation of the primary outcome or at most its tendency.

In our study, ARM was used prophylactically, and our patients did not exhibit severe PC or significant hypoxemia in the first hours of admission or during the first 5 days of hospitalisation. Other studies have included patients with different characteristics. For example, a randomised clinical trial comparing intensive and moderate ARMs in hypoxemic patients found that the former was associated with a lower incidence of severe PPCs within 5 days after CS[20].

Unlike ARMs applied in other studies, we used moderate prophylactic manoeuvres. Despite this, interruption was required in a subgroup of patients who were unable to proceed, even when using vasoactive drugs. Although the procedure improves oxygenation, high intrathoracic pressures can seriously affect cardiovascular functions due to interactions between the heart and the lung and between the right and left ventricles[21].

We believe that individuals with hemodynamic instability and requirement of vasoactive amines should not undergo ARMs. In this regard, studies conducted in patients with ARDS and severe pneumonia have not performed ARMs to avoid increasing the insult to healthy and homogeneous pulmonary areas[22]. By observing the subgroup requiring ARM interruption, we investigated other factors involved. Atrial fibrillation was the most prevalent systemic complication, followed by bleeding;

comorbidities included smoking, hypertension, and type 2 diabetes mellitus.

In 2017, Longo et al.[23] conducted a study in a population similar to ours and found that CS with CPB affected RV function in 95% of patients with normal preoperative cardiac function. This mechanism of RV dysfunction may have relevant clinical implications[23]. In this regard, the incidence of arrhythmia in this study was higher in the CG than in the IG.

Additionally, anaesthesia-induced atelectasis and CPB can affect the RV function during the perioperative period. Lung collapse increases RV impedance through a hypoxic pulmonary vasoconstriction reflex and due to geometric changes in the pulmonary capillaries within the atelectatic lung. Consequently, the RV can become dysfunctional post-CPB[23]. Similar to Longo et al.'s findings, the patients who underwent ARM in our study presented improved pulmonary aeration with a consequent reduction in hemodynamic and systemic responses similar to how protective ventilation and individualised positive end-expiratory pressure (PEEP) improve RV dysfunction.

Despite being controversial to our study, and knowing that ARM induces significant hemodynamic changes in patients undergoing CS, ARM when properly applied, and with safe parameters, can be used, due to its ability to improve arterial oxygenation. Thonnerieux et al.[24] showed that, through cardiopulmonary interactions, ARM influences cardiac output reversibly and safely. Some of the patients undergoing ARM in our study presented hemodynamic changes that resolved partly with clinical measures, while others required interruption of the manoeuvre.

In a systematic review, Hartland et al.[25] showed that atelectasis occurs in up to 100% of patients undergoing general anaesthesia. After myocardial revascularisation surgery, atelectasis causes hypoxemia and pulmonary shunting. Performing ARMs in this population has been suggested to prevent PCs[25]. Our results are consistent with the cited review because atelectasis was the second most common PC, and most patients underwent myocardial revascularisation (MR) surgery.

Although MR is the most commonly performed surgery, valve replacement remains the most commonly performed surgery in women. Wong et al.[26] showed that the post-surgical performance of women differs because of innate sex differences in cardiovascular physiology[15]. Women have a 5%–10% higher cardiac output, an adjusted maximum aerobic capacity of 10–15%, and lower body mass. Moreover, compared with men, women have lower haemoglobin levels and body surface areas. and smaller left and atrial ventricle dimensions[26].

In our intragroup analysis, the gas exchange for both groups at 6 h after CVU arrival increased. However, there was no significant between-group difference in this regard. We also observed that using ARM did not result in a reduction in the MV time, length of stay, NIV or reintubation requirement, or number of deaths[26].

In our study, both groups had maintained gas exchange. The maintenance of a baseline PEEP of 8 cm H2O since admission to MV, as well as the use of the protective strategy, seemed to ensure gas exchange maintenance for both groups. We believe that gas exchange maintenance for both groups and absence of results in agreement with other studies on the other outcomes is a result of some strategies we adopted for patient management. The maintenance of a baseline PEEP of 8 cm H2O from the beginning of MV, as well as the use of a protective strategy, seemed to ensure gas exchange maintenance in both groups. Therefore, we recommend the use of protective ventilation with low volumes and PEEP ≥8 cm H2O in the POP of CS[27]. As stated in a previous study,[28] PEEP has advantages and disadvantages, as the beneficial effect on alveolar recruitment and compliance is counterbalanced by the risk of lung hyperinflation and hemodynamic worsening. A protective strategy can improve the pulmonary function and contribute to a shorter ICU and hospital stay in patients undergoing CS[27].

ARM should be applied carefully in older patients because of the risk of significant hemodynamic deterioration[29]. Our findings confirm that ARM causes significant hemodynamic changes, which our study, to date, has not included.

An important consideration in our study was that both groups were exposed to an early mobilisation protocol on the 1st postoperative day. Those who were extubated without vasoactive drugs were encouraged to resume walking and seated in an armchair. Extubated patients who required low and stable doses of vasoactive drugs were seated in an armchair or with their lower limbs dangling over the side of the bed.

Finally, our results revealed that prophylactic ARMs assure an adequate gas exchange in the POP of CS, especially in patients without severe PCs, implying that the use of protective MV strategies is an interesting tool to be considered in this population. Additionally, early patient mobilisation can likely increase the chances of a positive outcome in these individuals. Another point to consider is that an elevated PEEP should be used with caution in patients with an increased postoperative risk, because of the possibility of inducing hemodynamic instability.

This study had several limitations. First, it had a small sample size. Additionally, the control of other variables, such as early mobilisation, was not performed in any group. Finally, as this was a single-centre study, our results cannot be extrapolated to populations with different clinical or ethnic characteristics. Future studies addressing the role of ARM in CS should include a larger number of patients and adequately control for mobilisation variables.

Despite these limitations, to the best of our knowledge, this is one of the first clinical trials conducted in Bahia to focus specifically on pulmonary re-expansion techniques for CS patients. Considering that CS usually

generates multiple physiological repercussions in the POP, the findings can be helpful to improve the outcomes of CS patients. Future studies should distinguish the profile of the CS patients who will optimally benefit from ARM.

CONCLUSION

Prophylactic ARM did not lower the incidence of immediate PCs during the POP of CS and was not effective in improving gas exchange and reducing MV time, reintubation occurrence, and length of ICU and hospital stay. ARM did not improve the primary and secondary outcome measures and was associated with an increased risk of hemodynamic instability. Patients should be screened thoroughly before undergoing ARM.

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