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Arterial blood gas analysis in two different intra-hospital transport methods for postoperative cardiac surgery patients

Gasometria arterial em dois diferentes métodos de transporte intra-hospitalar no pós-operatório imediato de cirurgia cardíaca

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ABSTRACT

Objective: To evaluate the effects on blood gases by two methods of ventilation (with transport ventilation or self-inflating manual resuscitator) during intra-hospital transport of patients after cardiac surgery.

Methods: Observational, longitudinal, prospective, randomized study. Two samples of arterial blood were collected at the end of the surgery and another at the end of patient transport.

Results: We included 23 patients: 13 in the Group with transport ventilation and 10 in the Group with self-inflating manual resuscitator. Baseline characteristics were similar between both groups, except for higher acute severity of illness in the Group with transport ventilation. We observed significant differences in comparisons of percentage variations of gasometric data: pH (transport ventilation + 4% x MR -5%, p=0.007), $PaCO_2$ (-8% x +13%, p=0.006), PaO_2 (+47% x -34%, p=0.01) and $SatO_2$ (+0.6% x -1.7%, p=0.001).

Conclusion: The use of mechanical ventilation results in fewer repercussions for blood gas analysis in the intra-hospital transport of cardiac surgery patients.

Keywords: Respiration, artificial; Transportation of patients; Blood gas analysis; Pulmonary gas exchange; Intensive care; Patient transfer

INTRODUCTION

Extracorporeal circulation (ECC) might cause lung damage during the postoperative period of cardiac surgery, thus contributing to the mortality of patients due to physiological modification of the acid-base and metabolic balance, increased inflammatory response, increased vascular permeability, increased pulmonary shunt or reduced lung compliance and gas exchange.[1-3] Most patients subjected to myocardial revascularization (MR) exhibit a reduction in lung compliance, whereas approximately one-third exhibit increased airway resistance. In half of patients presenting with comorbidities, the index of gas exchange decreases by 50%.[4] MR is associated with high rates (25 to 40%) of considerable postoperative complications.[5]

Disorders in the ventilation/perfusion ratio (V/Q ratio) cause a reduction in functional residual capacity (FRC) and hypoxemia. Age, body weight, left ventricular dysfunction and ECC are factors predictive of risk for hypoxemia; these factors could indicate the need for strategies such as positive end-expiratory pressure (PEEP) during transportation to reduce complications.[6-8] The state of a postoperative cardiac surgery patient upon his or her arrival at the coronary care unit (CCU) exerts a direct influence on cost, the possibility of immediate ventilator weaning, and perhaps morbidity and mortally, especially when patients develop

more serious complications. Appropriate ventilation during and after surgery might improve the patient's safety and could minimize metabolic and ventilatory repercussions that appear within a short period of time.[1,9,10]

Most of the studies that report physiological alterations during the transportation of severe patients were observational and associated such alterations with higher morbidity during stays in closed units.[11-13] The degree of arterial gas alteration during transportation of potentially severe patients using ventilatory methods (either by bag and mask ventilation or mechanical ventilator) has not been quantified; this is a dynamic process that requires appropriate monitoring, coordination, communication and equipment.[14,15] We selected a population of patients in the postoperative period of cardiac surgery because it is a very homogeneous group that has been subjected to the inflammatory stimulus of ECC and is transported with tracheal intubation still in place to closed units after the end of the surgical procedure. Due to the scarcity of randomized controlled trials on this subject, we performed a systematic comparison of the blood gas alterations exhibited by patients transported using a transport ventilator (TV) and a self-inflating manual resuscitator (SMR).

METHODS

This was an prospective and randomized study (by random pickup of envelopes) conducted at a tertiary hospital. Intubated patients in the immediate postoperative period of cardiac surgery who were transported from the surgical center (SC) to the CCU were consecutively included. This study was approved by D'Or Network Research Ethics Committee (protocol nº 186/08). The participants and/or their caretakers were given all of the pertinent information and explanations of the aims and procedures of the study. Those that agreed to participate signed an informed consent form according to the Norms to Conduct Research on Human Beings, resolutions nº 196/96 and nº 404/2008 of the Brazilian National Health Council and the Declaration of Helsinki.

Two samples of arterial blood were obtained directly from the arterial line circuit using a 3 mL syringe previously lubricated with heparin (without any residual heparin) that was closed using the needle cap. The time between sample collection and obtaining the results of the blood gas analysis was no longer than 10 minutes.[16] A blood gas analyzer Radiometer ABL 5 (Reagentes/Eletrodos & Acessórios, São Paulo, SP, Brazil) was used for blood gas analysis. The first sample for blood gas analysis was obtained before disconnection of the ventilator used during surgery, and the second one was obtained at the end of transportation before connection to the ventilator in the CCU. The allocation of patients to the ventilatory methods to be investigated was performed randomly (by a simple envelope raffle). Ventilation during transport was performed by the anesthesiologists. In the patients ventilated with SMR, the oxygen flow varied between 5 and 6 L/min, which was transformed into the corresponding fraction of inspired oxygen (FiO_2) according to a reference table.[17] In the patients ventilated with TV, FiO_2 was 100%, and PEEP was maintained at 5 cm H_2O according to the protocol established for this study.

The following data were collected from the clinical records: demographic information (age, gender, body mass index – BMI, Acute Physiology and Chronic Health Evaluation – APACHE II, European System for Cardiac Operative Risk Evaluation – EuroSCORE, length of hospitalization in the CCU and in the hospital) and surgical parameters (type, nature [emergency vs. elective] and length of surgery; length of ECC; and type of transport). The blood gas variables assessed in both groups were: arterial CO_2 pressure ($PaCO_2$), arterial O_2 pressure (PaO_2), base excess (BE), oxygen saturation (SaO_2) and ratio of PaO_2 to fraction of inspired O_2 (PaO_2/FiO_2 ratio) before and after transport.

The main aim of this study was to establish whether the use of mechanical ventilation during the transport of patients after cardiac surgery could prevent the occurrence of blood gas alterations at the moment of arrival in the intensive care unit (ICU). Adopting a $PaCO_2$ of 40 mmHg as a basis, we calculated a 20-patient sample to show 10% of alteration with 80% of study power, an error of 0.05 and 10% loss estimates. The numerical results were expressed as medians and interquartile intervals, whereas the categorical variables were expressed as absolute numbers and percentages. The statistical tests applied were selected as functions of the distribution of the data (Kolmogorov-Smirnov test). The Student's t-test was used to compare numerical variables, and a chi-square test was used for categorical parameters. Statistical significance was established at $p<0.05$.

RESULTS

A total of 23 patients were included, of which 15 were male. Eight men and five women were transported using TV, and seven men and three women were transported using SMR. Table 1 shows that the TV and SMR groups exhibited significant differences in regard to the severity of the acute disease according to APACHE II (16 versus 12 points, p=0.03) and EuroSCORE (7 versus 3 points, p=0.02) assessments. Demographic parameters, such as age, BMI and left ventricular ejection fraction (LVEF) (%), and other parameters, such as lengths of stay in the CCU and in the hospital, did not display statistically significant differences.

Table 1 – Demographic characteristics of the transport ventilator and self-inflating manual resuscitator groups

Characteristics	TV (N=13)	SMR (N=10)	p value
Age	66 (55-72)	65 (59-69)	0.94
Male gender	8	7	0.98
BMI	29.3 (24.6-31.6)	25.9 (22.3-27.8)	0.08
LVEF (%)	60 (47-68)	60 (57-60)	0.96
APACHE II	16 (13-19)	12 (10-16)	0.03
EuroSCORE	7 (5-11)	3 (1-5)	0.02
Δt CCU	6 (4-10)	4 (4-6)	0.31
Δt H	12 (10-20)	9 (8-10)	0.09
Surgery type (MR/VR)	6/7	8/2	0.20
Nature (El/Em)	7/6	4/6	0.68
Δt surgery (min)	310 (290-355)	320 (295-355)	0.45
Δt ECC (min)	90 (75-100)	90 (80-106)	0.68
Δt transport (min)	10 (9-13)	8 (6-10)	0.62

TV – transport ventilator group; SMR – manual resuscitator group; BMI – body mass index; LVEF – left ventricular ejection fraction; APACHE II - Acute Physiology and Chronic Health Evaluation; EuroSCORE: European System for Cardiac Operative Risk Evaluation; CCU – stay in the Coronary Care Unit; H – stay in the hospital; MR – myocardial revascularization; VR – valve replacement; El - elective; Em - emergency; ECC – extracorporeal circulation. Results expressed as medians (minimum – maximum).

Table 2 – Comparison of blood gas analyses before and after transport of transport ventilator and self-inflating manual resuscitator groups

Parameters	Sample collection time	TV (N=13)	SMR (N=10)	p value
pH	Pre-transport	7.36 (7.33-7.40)	7.37 (7.31-7.37)	0.17
	Post-transport	7.39 (7.36-7.43)	7.29 (7.28-7.35)	0.007
$PaCO_2$	Pre-transport	43.8 (38.3-47.2)	40.4 (39.4-45.0)	0.87
	Post-transport	38.8 (35.7-44.0)	49.0 (42.4-54.1)	0.006
PaO_2	Post-transport	184 (145.2-222.6)	213.5 (192-328.7)	0.06
	Post-transport	259.3 (224.1-349.2)	173 (103.9-233.1)	0.01
HCO_3	Pre-transport	23 (22.1-24.4)	22.2 (20.9-24.8)	0.35
	Post-transport	22.4 (21.9-24)	22.7 (21-26.8)	0.71
BE	Pre-transport	-1.3 (-3-0)	-2.9 (-3.7-0.3)	0.26
	Post-transport	-1 (-3--0.9)	-3 (-4.4-0.3)	0.15
SaO_2	Pre-transport	96.2 (94.5-99)	95 (94.9-95.3)	0.53
	Post-transport	96 (95.7-100)	94.7 (94-94.9)	0.001
PaO_2/FiO_2	Pre-transport	188.6 (178-239.4)	332 (224.8-357.2)	0.08
	Post-transport	259.3 (224.1-349.2)	432.5 (236.1-529.8)	0.11

TV – transport ventilator group; SMR – self-inflating manual resuscitator group; $PaCO_2$ – arterial CO_2 pressure; PaO_2 – arterial O_2 pressure; BE – base excess; SaO_2 – O_2 saturation; PaO_2/FiO_2 – ratio of PaO_2 to fraction of inspired O_2. Results are expressed as medians (minimum – maximum).

Although the patients subjected to TV exhibited greater severity, the length of surgery, ECC and transportation were similar in both groups. The TV group included a larger number of heart valve replacements (VRs) compared to the SMR group, although this difference was not statistically significant (6 versus 8 MRs and 7 versus 2 VRs, p=0.20). The nature of the surgery (elective versus emergency) was not significantly different between groups (7 versus 4 elective and 6 versus 6 emergency procedures, p=0.68) (Table 1).

The patients in the TV group exhibited fewer blood gas alterations during transport compared to the SMR group, and their values were close to normal ranges upon arrival in the CCU. The arterial blood gas values prior to transportation were similar in both groups. The results of blood gas analysis after arrival in the CCU revealed significant differences in regard to pH (TV 7.39 [7.36-7.43] versus SMR 7.29 [7.28 – 7.35], p=0.007), $PaCO_2$ (TV 39 [36 - 44] versus SMR 49 [42 - 54] mmHg, p=0.006), PaO_2 (TV 259 [224 - 349] versus SMR 173 [104 - 233] mmHg, p=0.01) and SaO_2 (TV 96 [96 - 100] versus SMR 95 [94 - 95]%, p=0.001). Neither the bicarbonate levels nor the gas exchange ratios exhibited differences (Table 2).

Comparisons between both groups in regard to the average blood gas values before and after transportation indicated that the pH, $PaCO_2$, PaO_2 and SaO_2 levels were significantly different; the TV group presented better results (Figure 1). The percentages of variation in the SMR group before and after transportation were pH: -5%, paO_2: -34%, $paCO_2$: +13%, HCO_3: +1.6% and SaO_2: -1.7%; the corresponding values in the TV group were pH: +4%, pO_2: +47%, pCO_2: -8%, HCO_3: -2.5% and $SatO_2$: +0.6%. Comparisons between the variations of the blood gas data indicated significant differences in pH (p=0.007), pO_2 (p=0.01), pCO_2 (p=0.006) and $SatO_2$ (p=0.001) parameters, whereas the variations in bicarbonate levels were not different.

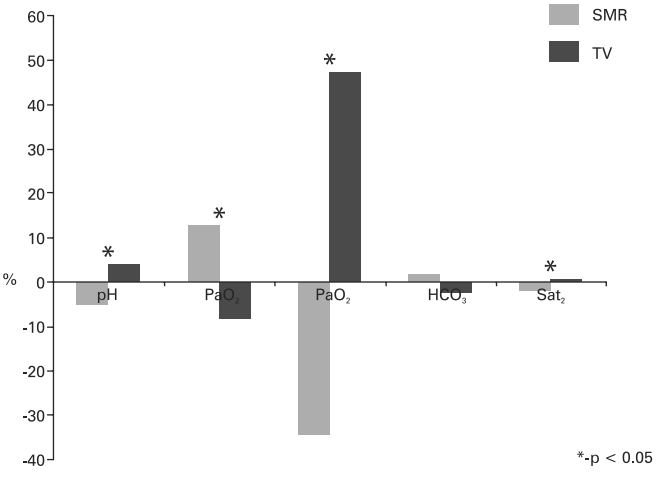

Figure 1 - Comparison between the averages of blood gas data before and after transportation of the self-inflating manual resuscitator and transport ventilation groups.
SMR - self-inflating manual resuscitator group; TV - transport ventilator group. * - p<0.05.

DISCUSSION

Adverse effects of intra-hospital transportation causing impairment of respiratory function might occur more often among more severe patients or those exhibiting pre-transport lesions.[18] In this study, we were able to show that ventilation using a transport-specific device caused less blood gas alterations

compared to ventilation using SMR. Significant alterations in pH, oxygenation and retention of carbon dioxide were more frequent among patients transported with SMR.

The better results achieved in this study with the use of TV might be explained as a function of the advantages exhibited by the mechanical ventilator, which include continual monitoring of airway pressures, breathing rate, tidal volume given, PEEP and FiO_2. Conversely, transportation using SMR with an oxygen reservoir involves variations in tidal volume and breathing rate and does not provide PEEP or safety parameters, such as peak pressure alarms or real FiO_2 support. In addition, PEEP has the theoretical advantage of increasing oxygenation due to the expansion of collapsed alveoli, thus restoring the FRC and reducing the physiological shunt.[9]

Physiological alterations in severe patients during intra-hospital transport are a common occurrence. An observational study that assessed more than 3,000 clinical records identified 59 adverse events (1.7%), most of which were related to hypoxia (25/59) or alterations in arterial blood pressure (25/59). Most of the interventions performed involved the adjustment of oxygen therapy (22/59) and the management of vasopressors (18/59). Because only 12 transport cases with adverse events (20%) needed to be aborted, one might conclude that the rate of clinically significant adverse events during transportation of patients is relatively low and needs little correction.[19] Although the sample in our study was small, no adverse events, such as accidental extubation or risk of cardiac arrest, were observed. The blood gas alterations identified were reported to the team that received the patients in the CCU, and they were promptly treated by means of ventilation adjustment.

There are reports on respiratory impairment during and after transportation of severe patients.[20] Other studies observed that the use of SMR is acceptable when appropriate oxygen flow is maintained.[21,22] Nevertheless, our results indicate that the use of a mechanical ventilator makes transportation safer, even when it is performed quickly, as it occurs after cardiac surgery. An observational study with 49 intubated patients with TV identified ventilatory alterations in which 41 (84%) patients exhibited worse PO_2/FiO_2 ratios, and 21 (43%) experienced reductions of more than 20% compared to the baseline.[20] The effect on respiratory function lasted more than 24 hours in 10 patients (20%). Ventilation with positive pressure by means of PEEP exhibited significant correlation with fewer changes in PO_2/FiO_2 ratios after transportation. The authors further concluded that patients ventilated without PEEP are at higher risk for adverse events.[20] In turn, patients ventilated with high values of PEEP exhibit divergences between pulse oximetry and arterial blood gas analyses.[23] Our study also shows this same effect in a randomized and controlled manner, along with fewer repercussions on gas exchange and CO_2 retention when patients were ventilated with a mechanical ventilator.

During manual ventilation, the volume of air must be adjusted to the patient's weight, the ventilation rate must be the same as that used during surgery, and the SMR reservoir must be able to supply FiO_2 above 85%.[24] To guarantee further safety, the equipment should have a pressure manometer and a PEEP valve. However, these parameters are difficult to achieve, and hyper- or hypoventilation might occur even when ventilation is performed by experienced professionals.[25] Our results corroborate this possibility on the grounds of the differences identified, not only in regard to the $PaCO_2$ level (as also reported in a pediatric study)[25] but also the oxygenation level (PaO_2 and SaO_2).

As a limitation of this study, we point to the fact that its design included sample size calculations to demonstrate differences above 20% in the parameters directly related with blood gas analysis. The study power is not sufficient to correlate our results with adverse events or outcomes, such as postoperative complications or mortality. In spite of randomization, the distribution of patients resulted in a greater level of severity in the TV group (a larger number of valve replacements and higher APACHE II and EuroSCORE assessments). This fact might reduce the power of our results. However, even with their theoretical disadvantage, the TV group exhibited a lower incidence of blood gas alterations. Finally, the methods used in this study could not be blinded because the anesthesiologists were informed as to the ventilatory method that had to be applied for transportation after the end of surgery.

CONCLUSION

Transportation using a mechanical ventilator causes fewer blood gas repercussions in patients after cardiac surgery. Therefore, it should be the choice method for intra-hospital transportation of such types of patients.

RESUMO

Objetivo: Avaliar as repercussões gasométricas de dois métodos de ventilação (ventilador de transporte e ressuscitador manual autoinflável) durante o transporte intra-hospitalar de pacientes submetidos à cirurgia cardíaca.

Métodos: Estudo observacional, longitudinal, prospectivo e randomizado. Foram coletadas gasometrias arteriais ao final da cirurgia e ao final do transporte do paciente.

Resultados: Foram incluídos 23 pacientes: 13 no Grupo ventilador de transporte e 10 no ressuscitador manual autoinflável. As características dos pacientes entre os grupos foram semelhantes, exceto pela maior gravidade no Grupo ventilador de transporte. Observaram-se diferenças significativas nas comparações das variações percentuais dos dados gasométricos: pH (VT: + 4% vs RMA: - 5%, p=0,007), $PaCO_2$ (VT: - 8% vs RMA: + 13%, p=0,006), PaO_2 (VT: + 47% vs RMA: - 34%, p=0,01) e $SatO_2$ (VT: + 0,6% vs RMA: - 1,7%, p=0,001).

Conclusão: O uso de ventilador mecânico causa menor repercussão nos gases sanguíneos no transporte intra-hospitalar de pacientes após de cirurgia cardíaca.

Descritores: Respiração artificial; Transporte de pacientes; Gasometria; Troca gasosa pulmonar; Terapia intensiva; Transferência de pacientes

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