Panacea Journal of Medical Sciences 2024;14(1):82–87

Content available at: https://www.ipinnovative.com/open-access-journals

Panacea Journal of Medical Sciences

Journal homepage: http://www.pjms.in/

Original Research Article

Study the beneficial effects of oxygen blender during cardiopulmonary bypass in reducing lactate levels in patients undergoing open-heart surgery

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ARTICLE INFO

Article history:
Received 16-08-2021
Accepted 07-06-2022
Available online 23-03-2024

Keywords:
Hyperlactemia
Cardiopulmonary bypass
Oxygen blender
Hyperoxemia
Hypocarbia

ABSTRACT

Introduction: Serum lactate levels rise during Cardio-Pulmonary Bypass (CPB) surgery for a variety of reasons, including peripheral circulatory failure, haemodilution, or excessive use of inotropic agents. Additionally, it has been reported that elevated serum lactate levels during the perioperative period are strongly associated with the worst postoperative outcomes, including mortality.
Aim: To find out the beneficial effects of an oxygen blender during cardiopulmonary bypass in reducing lactate levels in patients undergoing open-heart surgery.
Materials and Methods: This Prospective comparative study was done on 150 patients who underwent open-heart surgeries. Patients were divided into group A-75 patients: with direct oxygen flow without oxygen blender, group B- 75 patients: with oxygen blender. The serum lactate levels during CPB, postoperative levels and outcomes were monitored and both the groups were compared.
Results: Average FIO2 of 38 % was enough to maintain PO2 of 168 mm Hg by using the oxygen blender with the flow rates. Group A showed severe hyperoxemia (p-value <0.0001) and hypocarbia, resulting in severe respiratory alkalosis during CPB and severe acidosis in the immediate postoperative period in most of the cases. Group B showed a significant reduction in the serum lactate value at CPB one hour with 3.1 mmol/l reductions, 3.8 mmol/L reductions at 2 hours and 4.4 mmol/L reductions at ICU arrival (p-value <0.0001).
Conclusion: Serum lactate values reduced significantly in the patients with oxygen blender. Study proved that application of an oxygen blender during CPB improved the postoperative results following open-heart surgeries. The researchers conclude that using an oxygen mask was beneficial.

1. Introduction

The increase in the serum lactate during Cardio-Pulmonary Bypass (CPB) is well known in patients undergoing open-heart surgery due to various reasons such as peripheral circulatory failure, haemodilution, or high use of inotropic agents.[1–3] In addition to this, the elevated serum lactate levels during the perioperative period have been reported to be well associated with worst outcomes in the postoperative period, including mortality.[4–9]

Previous various studies proved that early postoperative hyperlactatemia was a more sensitive predictor of mortality and morbidity in patients undergoing open-heart surgery under Cardio-Pulmonary Bypass (CPB) than late-onset hyperlactatemia during ICU stay.[10] Furthermore, it was also reported that the maximum serum lactate level during open-heart surgery after CPB was significantly associated with low cardiac output state(LCOS) and ICU-free survival days.[11]

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https://doi.org/10.18231/j.pjms.2024.016
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Following open-heart surgery, early postoperative hyper-lactatemia was associated with inappropriate or excessive oxygen delivery during CPB.[3–6] Thus, the proper management of CPB could avoid the increase in serum lactate levels.Therefore, the study aims to find out the effects of an oxygen blender on serum lactate levels.

2. Aim

To find out the beneficial effects of an oxygen blender during cardiopulmonary bypass in reducing lactate levels in patients undergoing open-heart surgery.

3. Materials and Methods

This Prospective comparative study was done on 150 patients who underwent open-heart surgeries in our Institute from January 2018 to December 2018. Group A-75 patients: with direct oxygen flow without oxygen blender and the serum lactate levels during CPB and postoperative levels and outcomes were monitored. Group B- 75 patients: with oxygen blender. The serum lactate levels during CPB, postoperative levels and outcomes were monitored and both the groups were compared. Ethical committee approval and informed consent were obtained.

Group A 75 patients - the oxygen line is connected directly to the CPB machine without a blender. Baseline serum lactate value in Arterial blood gas (ABG) analysis was noted before induction of anaesthesia after securing arterial line. After starting CPB, another sample is taken. The following sample is after the first cardioplegia administration. Then, every one hour once, Arterial blood gas (ABG) Analysis is done and lactate values are noted. Serum lactate levels at the end of CPB and at the time of arrival to ICU were noted. The following parameters were noted in the postoperative period like mortality, total duration of ventilation, low cardiac output state, respiratory, renal and central nervous system complications and duration of ICU stay.

Group B 75 patients- Oxygen blender was used per the Gas/ blood flow ratio given in Table 1 . Target Po2 was 150 to 200 mmHg and Pco2 of 40 mmHg and the FIO2 % and flow rates adjusted according to the ABG values. Lactate levels were noted similar to Group A, the postoperative outcome was monitored, and both groups were compared.

4. Results

Among the 150 study population, 36 pediatric patients (24%) and 114 adult patients (76%) were included. In Group A, 26.7% belong to the pediatric age group and 73.3 % belong to the adult age group. In Group B, 21.3% belong to the pediatric age group and 78.7 % belong to the adult age. (Table 2)

In Group A, 40 % (30 patients) of the study population were adult males and 46.7% were adult females. Whereas in Group A, 36 % (27 patients) of the study group were adult males. 54.7% (41 patients) were adult females. In Group A, 4% (3 patients) were male children and 9.3% (7 patients) were female children, whereas in Group B, 5.3% (4 patients) were male children and 4% (3 patients) were female children. (Table 3)

Ostium Secundum type (ASD-OS) Atrial septal defect. Pericardial patch closure (PPC) contributes the majority of congenital heart disease (CHD) open-heart surgeries done with 65 % (13 cases) in Group A and 50 % (8 cases) in Group B. (Table 4)

Mitral valve replacement (MVR) contributes the majority of the acquired heart disease surgeries done with 49 % (27 cases) in Group A and 55 % (33 cases) in Group B, followed by the ON pump Coronary Artery Bypass Graft surgery (CABG) with 23 % (13 cases) in Group A and 17 % (10 cases) in Group B with oxygen blender usage (Table 5)

In Group A, 27 % (20 cases) of surgeries done for congenital heart diseases and 73% (55 cases) were done for acquired heart diseases whereas, in Group B, 21.3% (16 cases) of surgeries done for congenital heart diseases and78.7% (59 cases) done for acquired heart diseases (Table 6)

Totally 4 patients died in Group A, which is 5.33% and the mortality is 2.7% in Group B. Respiratory complications like reintubation rate 8 % in Group A whereas 2.7 % in Group B. Non-fatal non-cardiogenic pulmonary edema rate is 34.7% in Group A whereas 17 % in Group B. post-operative cognitive dysfunction was higher in Group A around 22.7% whereas it was 8 % in Group B. (Table 7)

Group B showed a significant reduction in the serum lactate value at CPB one hour with 3.1 mmol/l reduction, 3.8 mmol/L reduction at 2 hours and 4.4 mmol/L reduction (p value <0.0001 statistically significant) at ICU arrival.(Table 8)

Group B showed a significant reduction in the late-onset hyperlactatemia six hours after ICU arrival with 3.8 mmol/L reductions (p-value <0.0001) (Table 9)

Average FIO2 of 38 % was enough to maintain PO2 of 168 mm Hg by using the oxygen blender with the flow rates according to Table 1. Group A showed severe hyperoxemia (p-value <0.0001) and hypocarbia, resulting in severe respiratory alkalosis during CPB and severe acidosis in the immediate postoperative period in most of the cases. (Table 10)

5. Discussion

We have demonstrated, via this prospective cardiac surgery series, that an Average FIO2 of 38% was enough to maintain PO2 of 168 mm Hg by using the oxygen blender with the flow rates according to Table 1. Specifically, we showed that most major complications, including reintubation rate, pulmonary edema, renal complications, stroke, postoperative cognitive dysfunction and mortality,

Table 1: Gas/blood flow ratio chart

Temperature	Cardiac Index /pump flow rate	FIO2	Gas/Blood Flow Ratio
37 C	2.4 L	0.80	1 : 1
34 C	2.2 L	0.70	0.8 : 1
30 C	2.0 L	0.65	0.7 : 1
28 C	1.8 L	0.60	0.6 : 1
22 C	1.6 L	0.50	0.5 : 1

(Ref:Gravlee - Cardiopulmonary bypass principles and practice 4^{th} edition)

Table 2: Age-wise Distribution of Study patients

Age group	Group A	Group B	Total
< 12 years	20 (26.7%)	16 (21.3%)	36 (24%)
Adults	55 (73.3%)	59 (78.7%)	114 (76%)
Total	75	75	150

Table 3: Sex wise distribution of study patients

Gender	Group A	Group B	Total
Adult Male	30 (40%)	27 (36%)	57 (38%)
Adult Female	35 (46.7%)	41(54.7%)	76 (50.7%)
Male child	3 (4%)	4 (5.3%)	7 (4.7%)
Female child	7 (9.3)	3 (4%)	10 (6.6%)
Total	75	75	150

Table 4: Surgical Procedure wise Distribution of Study patients – congenital heart disease

Procedure	Group A					Group B				
	Adult male	Adult female	Male Child	Female child	Total	Adult male	Adult female	Male child	Female child	Total
Ostium secundum type (ASD-0S) Atrial septal defect .Pericardial patch closure (PPC)	1	7	1	4	13 (65%)	1	4	2	1	8 (50%)
Sinus venosus type ASD- PPC	0	0	0	1	1	1	0	0	1	2
Ventricular septal Defect (VSD)-PPC	1	1	0	2	3	2	0	0	0	2
Atrio ventricular canal defect (AVCD-VSD)- Intra Cardiac repair (ICR)	0	0	1	0	1	0	0	0	0	0
Tetrology of Fallot	0	0	1	0	1	0	0	0	0	0
Double chambered right ventricle DCRV-VSD-ICR	0	0	0	0	0	0	0	1	0	1
Double outlet right ventricle DORV-VSD-ICR	0	0	0	0	0	0	1	0	0	1
Supra cardiac TAPVC- Total anomolus pulmonary venous connection- ICR	0	0	0	0	0	0	0	0	1	1
Sub mitral aneurysm (SMA) – ICR with Mitral valve replacement	0	0	0	0	0	0	1	0	0	1
Total	2	8	3	7	20	4	6	3	3	16

Table 5: Surgical procedure wise distribution of study patients– Acquired heart disease

Procedure	Group A					Group B				
	Adult male	Adult female	Male child	Female child	Total	Adult male	Adult female	Male child	Female child	Total
Mitral valve replacement (MVR)	8	19	0	0	27 (49%)	7	26	0	0	33 (55%)
Aortic valve replacement (AVR)	2	3	0	0	5 (9%)	1	2	0	0	3 (5%)
Double valve replacement (DVR)	4	2	0	0	6 (10%)	4	2	0	0	6 (10%)
ON pump Coronary Artery Bypass Graft surgery (CABG)	12	1	0	0	13 (23%)	10	0	0	0	10 (17%)
MVR + CABG	0	1	0	0	1	0	0	0	0	0
Excision of left atrial myxoma with PPC	0	1	0	0	1	0	1	0	0	1
Pulmonary Thrombo Endarterectomy (PTE)	1	0	0	0	1	0	0	0	0	0
Cardiac transplantation	1	0	0	0	1	0	0	0	0	0
MVR + Tricuspid valve repair	0	0	0	0	0	0	2	0	0	2
Open pericardectomy	0	0	0	0	0	0	1	0	0	1
Hypertrophic Obstructive Cardiomyopathy (HOCM)- Extended septal myectomy	0	0	0	0	0	1	0	0	0	1
Mitral valve repair	0	0	0	0	0	0	1	1	0	2
Total	28	27	0	0	55	23	25	1	0	59

Table 6: Surgicalprocedure wise distribution of study patients- both congenital and acquired

Procedure	Group A					Group B				
	Adult male	Adult female	Male child	Female child	Total	Adult male	Adult female	Male Child	Female child	Total
Congenital heart surgeries	2	8	3	7	20 (27%)	4	6	3	3	16 (21.3%)
Acquired heart surgeries	28	27	0	0	55 (73%)	23	25	1	0	59 (78.7%)
Total	30	35	3	7	75	27	31	4	3	75

Table 7: Comparison of postoperative outcomes

Postoperative outcome and complications	Group A (75 cases)	%	Group B (75 cases)	%
Mortality	4	5.33	2	2.7
Duration of ventilation (hours- average)	25.17		19.77	
ICU stay in days- average	3.5		2	
Reintubation	6	8	2	2.7
Pulmonary edema	26	34.7	13	17
Renal failure requiring dialysis	2	2.7	1	1.3
Low cardiac output state (Requiring high inotropes support)	7	9.4	3	4
Stroke/Cerebro vascular accidents	2	2.7	1	1.3
Postoperative cognitive dysfunction	12	22.7	6	8
Others	8	10.7	2	2.7

Table 8: Comparison of lactate values

Arterial blood lactate levels average (mmol/L)	Baseline	CPB-Onset	CPB- 1 hour	CPB- 2 hours	ICU arrival
Group A	0.8	1.2	8.2	11	10.4
Group B	0.8	1.2	5.1	7.2	6.0
Difference			3.1 P = 0.0008	3.8 p<0.0001	4.4 p<0.0001

Table 9: Late onset hyperlactatemia

Arterial blood lactate levels average (mmol/L)	6hours after ICU Arrival
Group A	11.2
Group B	7.4
Difference	3.8 (p<0.0001)

Table 10: Average$FiO_2$and PO_2 PCO_2 levels

Arterial blood levels average	FiO_2 %	PO_2 level mmHg average	PCO_2 level mmHg average
Group A	100%	406	20
Group B	38%	168	41
Difference	62% (p<0.0001)	238 (p<0.0001)	

are increased correlating with high lactate levels in Group A.

Cardiopulmonary bypass(CPB) produced various changes in the body hemodynamics. Unfortunately, most of them are harmful to the patients. But many advances during the last few decades targeted towards reducing the harmful effects of CPB on the human body. One of the advancements is the oxygen blender. The function of the blender is to control the FIO2% and oxygen flow rates during CPB, which prevents hyperoxemia and its adverse effects.

Excess oxygen exposure (hyperoxia) induces excessive reactive oxygen species (ROS) production in cell-culture and ischemia-reperfusion experiments.[12–14] Similarly, hyperoxic reperfusion of ischemic tissues is associated with tissue damage and poor outcomes in some patient populations.[15–17] During cardiac surgery, anesthesiologists typically ventilate patients with an FIO2 of 1.0 and if we do not use an oxygen blender patient will get 100% oxygen during the entire CB. In normal conditions, approximately 99% of the oxygen in the blood is bound to hemoglobin, and administering oxygen at concentrations higher than those needed to saturate hemoglobin does not increase oxygen content in the blood by a clinically significant amount. It does, however, increase the partial pressure of oxygen in the plasma to supraphysiologic levels. These super-physiologic levels may increase the production of reactive oxygen species (ROS),[18] which could induce oxidative stress and lead to organ injury. Oxidative stress causes direct damage to proteins at the cellular level, including deoxyribonucleic acid (DNA) and lipids, resulting in organelle autophagy, cellular apoptosis and necrosis, organ injury and dysfunction, and death.[19]

Preclinical studies have also demonstrated that ROS impair endothelial function.[20] The endothelium regulates perfusion. Thus, endothelial dysfunction may contribute to the associations among patient oxygenation, oxidative stress, and organ injury following cardiac surgery. The ROCS (Risk of Oxygen during Cardiac Surgery) trial.[21] will test the hypothesis that physiologic oxygenation during surgery will decrease the production of ROS, oxidative damage, and organ injury compared to hyper-oxygenation

6. Conclusion

We conclude that avoiding hyperoxemia by using an oxygen blender with average FIO2 of 38% is enough to maintain PO2 of 168 mmHg by this study. Serum lactate values reduced significantly in the study Group B with a significant reduction in the serum lactate value at CPB one hour with 3.1 mmol/l reductions, 3.8 mmol/L reductions at 2 hours and 4.4 mmol/L reductions at ICU arrival (p-value <0.00001). Postoperative complications were significantly reduced in the study group B with a 2.7% reduction in mortality, 17.7% decrease in respiratory complications and 14.7% reduction in postoperative cognitive dysfunction.

Optimal use of oxygen blender during CPB as per the calculation to maintain optimal PO_2 will significantly improve the postoperative outcomes, as shown in our study. Our study proved that application of an oxygen blender during CPB thereby improving the postoperative results following open-heart surgeries.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Rajesh B, Karthikeyan B, Mughilan AS, Anbukumar P, Baylis MM. Study the beneficial effects of oxygen blender during cardiopulmonary bypass in reducing lactate levels in patients undergoing open-heart surgery. *Panacea J Med Sci* 2024;14(1):82-87.