



Case Report

Dual-Membrane Oxygenator Use in a Pediatric Patient Undergoing Emergency Congenital Heart Surgery: A Case Report

Amirhossein Jalali^{1,2}, Alireza Yaghoubi Golverdi², Mahmoud Ganjifard³, Fatemeh Shakhs Emampour⁴, Mehdi Hosseini Yazdi², Saeid Heydari Nia², Seyyed Ebrahim Hosseini Zargaz^{5*}

¹Congenital Heart Diseases Research Center, Rajaie Cardiovascular Institute, Tehran, Iran

²Cardiovascular Research Center, Rajaie Cardiovascular Institute, Tehran, Iran

³Department of Anesthesiology and Critical Care, Faculty of Medicine, Birjand University of Medical Sciences, Birjand, Iran

⁴Department of Anesthesiology, School of Medicine, Birjand University of Medical Sciences, Birjand, Iran

⁵Cardiovascular Diseases Research Center, Birjand University of Medical Sciences, Birjand, Iran

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*Corresponding Author:

Seyyed Ebrahim
Hosseini Zargaz, Email:
ebrahimhosseini134zargaz@gmail.com

Abstract

Cardiopulmonary bypass is employed for surgical procedures in these cases. Reports exist of using two membranes in overweight adults and patients; however, to the best of our knowledge, the use of two membranes in infants and children has not been reported yet.

Our case was a 4-year-old child, with a weight of 14 kg, a height of 93 cm, and a body surface area (BSA) of 0.6(m²), who was a candidate for the Rastelli procedure and pulmonary branch reconstruction. Given the child's BSA, the long duration of the surgery, and the unavailability of an appropriate oxygenator at our center, an oxygenator with two membranes was used for the child.

In cases like ours, where the necessary equipment and an appropriate oxygenator are unavailable, the use of two membranes allows for the safe isolation of the heart and lungs from the circulation, enabling surgical procedures to be performed.

Keywords: Membranes, Pediatric patients, Cardiopulmonary bypass, Oxygenator, Congenital heart disease

Introduction

Approximately, 1.25 million patients undergo open-heart surgery using a cardiopulmonary bypass (CPB) annually.¹ Congenital heart disease (CHD) encompasses a broad spectrum of abnormalities arising from the abnormal development of the heart and major blood vessels during fetal life. CHD is the most common congenital defect, with an incidence of 6 to 13 cases per 1000 live births, equivalent to approximately 1 in every 120 to 166 births. It is estimated that around 1,310,000 infants with CHD are born worldwide each year.² The prevalence of CHD has considerably increased since the survival rate to adulthood has now reached 90-95% in high-income countries, compared to less than 20% in the pre-surgical era. Approximately 52-66% of patients with CHD require heart surgery during their lifetime. One of the most critical factors for these patients is the oxygenator's capacity to provide the patient with adequate oxygenation, particularly during prolonged procedures. The ability to deliver adequate oxygen during CPB depends on various factors, including hemoglobin concentration, percent of oxygen saturation of arterial hemoglobin (SaO₂), cardiac output (CO), oxygen

consumption (VO₂), and hemoglobin-oxygen affinity.^{3,4} The physical characteristics of the perfusion equipment also play a significant role. Up to now, there have been limited reports of using two membranes in patients with high weight and body surface area (BSA). One such case involved a patient with a BSA of 2.75(m²) and a flow rate of 6.5 liters. No studies have been conducted yet on the use of oxygenators in pediatric patients. Due to the unavailability of an appropriate oxygenator based on the patient's BSA, we employed two oxygenators in parallel and concurrently.

Description of the Case

A four-year-old child, with a weight of 14 kg, a height of 95 cm, and a BSA of 0.6(m²), underwent a Rastelli procedure and pulmonary branch reconstruction. The patient's laboratory parameter values included hemoglobin (17.4 g/dL), hematocrit (56.2%), platelets (212,000/μL), blood group (A+), potassium (4.4 mmol/L), and creatinine (0.5 mg/dL). Due to the patient's age, cardiac index was estimated at 2.9 L/min/m², and the flow rate was calculated at 1750 mL/min. Considering the available oxygenators (D 901 Sorin Group Italia), Terumo 0.5(Capiox Japan), and



Inspire6 (Liva Nova Italy) and a 20% flow reserve when necessary, a flow rate of 2080 mL/min was planned. The optimal choice would have been the D902 oxygenator, but due to our limited pediatric options (Terumo 0.5 and Inspire6) in the pediatric and adolescent oxygenator center, two Terumo 0.5 membranes were used in parallel with a reservoir to ensure adequate oxygenation during the prolonged procedure. The oxygen line was split into two using a Y-connector, but the gas flow rate was maintained at the same level as for a single oxygenator and used for two oxygenators. Two heater-cooler heat exchangers were also used, and we obtained the line sample from the two membranes. (Figure 1,2) The prime volume for both membranes and the circuit was 500 cc (ringer lactate solution), and 60 cc of mannitol was administered to the patient during the procedure. Furthermore, 3500 units

of heparin were added to the prime. The arterial and venous lines were 3/8, divided into two lines of 1/4 using a Y-connector to discharge in the main reservoir. The pre-cannulation activated clotting time (ACT) was 700. Post-cannulation swing pressure was 68 mmHg. Aortic and venous cannula sizes were 14 Fr and 14 Fr curved, and 18 Fr straight, respectively. Total pump time was 3 hours, and cross-clamp time was 130 minutes. A total of 800 cc of cardioplegic solution Del Nido was used. Arterial blood gas (ABG) was drawn every 40 minutes as mixed from both oxygenators. When ABG was drawn from a single membrane, PO₂ was 120 mmHg, but when drawn from both membranes, it was 320 mmHg. (Table.1) Pulse oximeter was 60 percent, and mean arterial pressure (MAP) was maintained 50-60 mmHg. Ultimately, the patient was successfully weaned from CPB without complications,

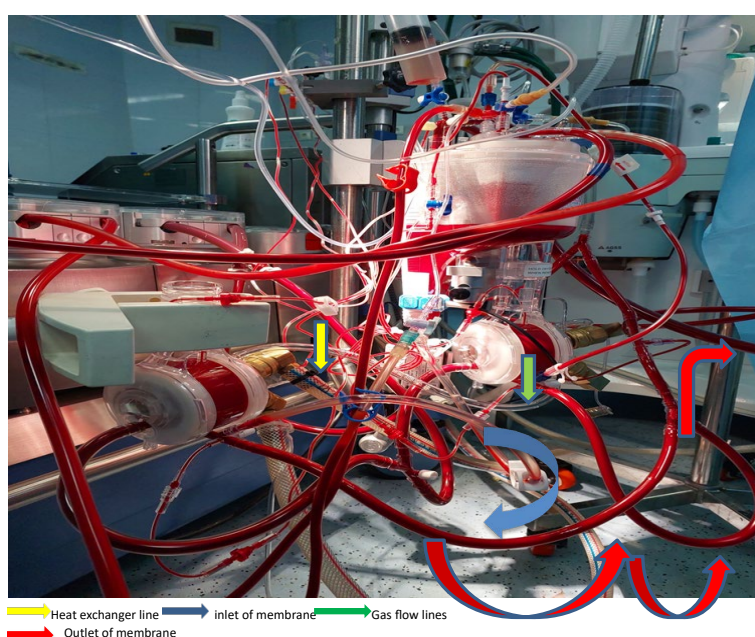


Figure 1. This figure shows the inlets and outlets of the two membranes, two heat exchanger lines, and two gas flow lines

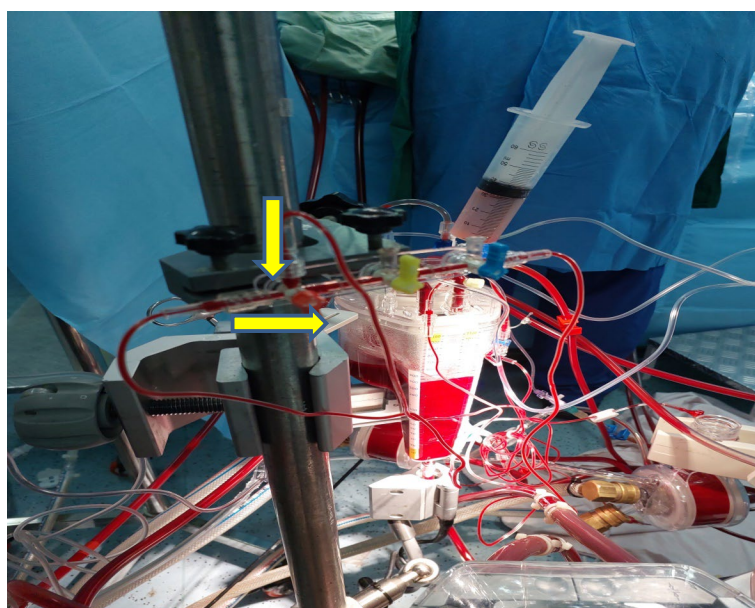


Figure 2. This figure shows two sample lines that are mixed

Table1. The Arterial blood Gas (ABG) during surgery

Time	Ph	Po2	O2sat	Pco2	Hco3	BE	Na	K	Hg	Hct	BS	Lactate	Ca
After anesthesia induction	7.43	63	93	30	20	-3	126	3.6	18.6	60	93	0.7	2.2
Initiate CPB	7.35	405	100	35	19	-6	134	3	12.1	39	123	1.8	2.1
40 minute after starting CPB	7.30	318	100	48	23	-3	133	6.5	10.9	35	180	0.9	1.9
80 minute	7.32	338	100	40	20	-6	133	6.5	10	32	204	0.9	2.1
120 minute	7.42	358	100	36	23	-1	139	6.9	8.6	28	187	1.1	2
150 minute	7.45	363	100	27	19	-3	132	5	12	38	204	1.7	1.7
ABG (one membrane)	7.41	120	98	32	20	-3	134	4.9	13.7	43	149	1.8	1.5
after separation from CBP	7.43	434	100	25	16	-5	135	4.3	14	45	150	1.2	2

and postoperative ABG analysis revealed normal PO₂ and PCO₂ levels.

Discussion

The oxygenator failure during CPB faces the surgical team a serious and potentially life-threatening challenge. Unfortunately, the incidence of oxygenator failure is on the rise.⁵ Membrane oxygenators have a constant oxygen transfer rate and, regardless of venous saturation, transfer a specific amount of oxygen to the blood with each pass through the oxygenator.⁴

A limited number of studies have reported the simultaneous use of two oxygenators so far. In one study, a patient with a weight of 142 kg, a height of 197 cm, and a BSA of 2.76 m² underwent open-heart surgery for aortic dissection. The patient's flow rate was 6.63 L/min, and two oxygenators were set in parallel. The bypass time was 259 minutes, and the cross-clamp time was 141 minutes. The researchers reported that they used both oxygenators from the beginning of CPB and did not wait for ABG results. The arterial line pressure did not exceed 350 mmHg (4). In another case, where two oxygenators were also used in a patient with a weight of 159 kg, a height of 189 cm, BSA of 2.88 m², and a flow rate of 6900 cc/min undergoing aortic dissection surgery. In this case report, it was stated that the second oxygenator was set in parallel but was not used initially. They reported that after three minutes of CPB, a drop in saturation occurred, and the second oxygenator was immediately added to the circuit.⁶ In the case we reported, unlike the two previously reported cases, the patient was a kid. However, it shared similarities with the other two studies in that the oxygenator was small due to the patient's weight. On the other hand, since the significant distance between the available oxygenator and the patient's BSA, we were forced to use two 0.5 square meter membranes. Given that in our reported case, we did not use two oxygenators but rather two membranes, we had less hemodilution. Additionally, we used a 3/8 inch venous return line and divided its input to the reservoir into two 1/4 (quarter-inch) lines, thus ensuring no issues with venous return. Moreover, since the size of the aortic cannula was appropriate for the patient's BSA, the aortic line pressure did not increase. Previous studies have reported that two methods can be used for the simultaneous use of two membranes: Parallel and series. In terms of the benefits and drawbacks of these two methods, it has been

stated that the series method increases resistance to blood flow, culminating in a decrease in delivered flow to the patient despite identical rotation of the main pump head or an increase in membrane blade pressure in order to achieve the same flow compared to the parallel method. Additionally, it has been reported that the parallel method increases the risk of hemolysis. Moreover, in the series method, the CO₂ removal and level of exchange are lower than those in the parallel method due to a lower level of gas exchange in the series method compared to the parallel method. Another point we reported in our case was the gas flow, which despite using two membranes, we did not increase it because CO₂ removal is more dependent on oxygen flow than on the membrane surface, as the diffusion rate of CO₂ is 18 times higher than oxygen.

Conclusion

Considering the increased rate of oxygenator failure reported in numerous studies and the potentially catastrophic consequences, the use of two oxygenators in parallel has emerged as an influential, efficient, and safe method for patients requiring higher perfusion rates compared to the available membrane. This approach allows for the delivery of optimal flow and oxygenation during CPB.

Authors' Contribution

Conceptualization: Alireza Yaghoubi Golverdi, Amirhossein Jalali, Seyyed Ebrahim Hosseini Zargaz

Data Curation: Mehdi Hosseini Yazdi

Formal Analysis: Saeid Heydari Nia

Investigation: Seyyed Ebrahim Hosseini Zargaz, Fatemeh Shakhsh Emampour

Methodology: Seyyed Ebrahim Hosseini Zargaz, Amirhossein Jalali

Project Administration: Amirhossein Jalali

Resources: Alireza Yaghoubi Golverdi, Amirhossein Jalali

Software: Seyyed Ebrahim Hosseini Zargaz

Supervision: Amirhossein Jalali

Validation: Seyyed Ebrahim Hosseini Zargaz

Visualization: Seyyed Ebrahim Hosseini Zargaz

Writing-Original Draft: Seyyed Ebrahim Hosseini Zargaz, Mahmoud Ganjifard

Writing-Review & Editing: Seyyed Ebrahim Hosseini Zargaz

Competing Interests

The authors declare no conflict of interest financial or otherwise.

Ethical Approval

The ethical code was obtained from Rajaie Cardiovascular Medical and Research Institute IR.RHC.REC.1404.095

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