Use of VA-ECMO for acute cor pulmonale in an infant ARDS: Challenging management in low- and middle-income country, a case report

Christian Reza Wibowo[1,2], Bambang Pujo Semedi[1,2]

Abstract

Pneumonia is one of the causes of acute respiratory distress syndrome (ARDS) in pediatrics, which can progress to severe conditions such as pulmonary hypertension, leading to right ventricular failure or cor pulmonale. Pediatric patients requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO) support are challenging in our country, from the time of initiation to another critical dilemma between managing massive bleeding and preventing clotting in the ECMO circuit. An 18-month-old boy presented in a ward with a 5-day history of fever, cough, and increased work of breathing over the prior 24 hours. He was diagnosed with bronchopneumonia and treated with antibiotic therapy. The patient had a rapid deterioration, requiring endotracheal intubation. Blood gas analysis showed oxygenation and ventilation failure with pulmonary hypertension resulting in cor pulmonale. The patient then underwent cannulation to central VA-ECMO via sternotomy. During the 11-day intensive care unit (ICU) stay, massive bleeding occurred from the cannulation site, with the team attempting to balance between hemorrhage and preventing clot formation in the circuit. The patient died from the failure of the oxygenator, as lung rest could not be achieved due to systemic complications from massive bleeding. For pediatric patients with acute cor pulmonale, it is necessary to be more aggressive in the timing of ECMO initiation, as indicated in the guidelines, and to evaluate the indications for VA-ECMO carefully. This evaluation should consider the benefits and drawbacks from all aspects, including the complications of bleeding that can lead to multiple organ failures in the patient.

Key words: VA-ECMO, ARDS, cor pulmonale, pediatric, massive bleeding.

Introduction

Cor pulmonale refers to right ventricular (RV) failure caused by pulmonary conditions that increase pulmonary artery pressure and vascular resistance, classified as "group 3 PH" by the World Health Organization (WHO). (1) Acute cor pulmonale can develop suddenly from conditions like pulmonary embolism and acute respiratory distress syndrome (ARDS), particularly in neonates and infants with non-cardiogenic alveolar edema and gas exchange disturbances. Increased pulmonary vascular resistance can impair RV function, contributing to this condition. Despite various mechanical ventilation strategies for ARDS, mortality rates can reach 22%, with patients developing acute cor pulmonale (**Figure 1**). (2,3) Effective management must address both vascular and gas exchange abnormalities, especially for those on extracorporeal membrane oxygenation (ECMO). Venoatrial ECMO (VA-ECMO) provides essential support for cardiac output and gas exchange but carries a higher risk of complications, including bleeding and coagulation issues. This case report explored acute cor pulmonale in pediatric ARDS and the role of VA-ECMO in management.

[1.] Department of Anesthesiology and Reanimation, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
[2.] Department of Anesthesiology and Reanimation, Dr. Soetomo General Academic Hospital, Surabaya, Indonesia

Address for correspondence:
Bambang Pujo Semedi, MD
Department of Anesthesiology and Reanimation, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia
Department of Anesthesiology and Reanimation, Dr. Soetomo General Academic Hospital, Surabaya, Indonesia
Tel: +62315020251
ORCID ID: 0000-0003-4499-3481
Email: bambang-p-s@fk.unair.ac.id

Case report

An 18-month-old male child, weighing 10 kg and measuring 78 cm, was admitted to the pediatric ward on January 23rd, 2023, with a persistent high fever unresponsive to antipyretics. Over five days, he developed shortness of breath and increased work of breathing, experiencing desaturation episodes. Diagnosed with bacterial bronchopneumonia, he was treated with intravenous meropenem. On the fifth day, his condition worsened, necessitating intubation with rocuronium and midazolam. Despite lung-protective ventilator settings, he developed subcutaneous emphysema and continued desaturating. Upon arrival at a tertiary hospital's emergency room, the patient's subcutaneous emphysema had worsened. Blood gas analysis revealed combined respiratory and metabolic acidosis (**Table 1**). With ongoing desaturation, the physician opted for aggressive ventilator settings. A chest X-ray indicated severe ARDS with extensive subcutaneous emphysema but no pneumothorax (**Figure 2**). Thoracic surgeons were consulted for chest tube placement to alleviate pressure and improve compliance. Central and arterial lines were inserted for vasopressor support and hemodynamic monitoring. After stabilization, the patient was transferred to the Intensive Care Unit (ICU).

In the ICU, oxygenation deteriorated further, with saturation dropping to 80%. Despite switching back to lung protective strategies, employing prone positioning, and inverse ratio ventilation (IRV), significant improvement only occurred after thoracic surgeons performed multiple incisions to relieve thoracic pressure. Blood gas evaluations indicated severe respiratory acidosis due to IRV. By the third ICU day, chest X-ray showed mild improvement; however, echocardiography revealed right heart dilation and failure from pulmonary hypertension. A multidisciplinary team decided on VA-ECMO via sternotomy due to unavailable pediatric cannulas. Following central cannulation and heparin loading, blood gas analysis post-oxygenator showed excellent oxygenation (arterial oxygen pressure [pO2] of 545 mmHg). Hemodynamic stability required support from adrenaline and dobutamine. Three hours post-ECMO, the activated clotting time (ACT) was >1000 seconds, and significant substernal drainage was noted.

On the fourth ICU day, the patient experienced massive bleeding, totaling 4100 ml, 24 hours post VA-ECMO cannulation. The ACT remained stable without heparin. A thoracic surgeon explored the wound but found no specific bleeding source, only drainage from the cannulation site and sternum. Stable clotting times helped the bleeding to slow down, yet posed a risk to the oxygenator. Heparin was restarted, but oozing persisted. On the sixth ICU day, a fiberoptic bronchoscopy was performed to investigate potential tracheobronchial injury and culture bronchoalveolar lavage but was halted due to mucoid bloody secretions. Infection parameters worsened, with increased purulent sputum production and elevated leukocyte and procalcitonin levels indicating a bacterial infection. By the seventh day, the bleeding trend deteriorated, with visible blood in the endotracheal tube and cannulation site. The heparin pump was stopped due to high ACT (>1000 sec). Blood gas analysis revealed decreased oxygenator function (pO2 203 mmHg), and bleeding reached 1800 ml in 24 hours, necessitating fluid replacement with whole blood, thrombocyte concentrate, and fresh frozen plasma (**Table 2**).

On the eighth day, blood supplies were depleted, leading to dilution with 5% albumin. Coagulopathy emerged with thrombocytopenia and prolonged hemostasis. Despite broad-spectrum antibiotics, infection parameters continued to rise, revealing a bacterial infection. Reverse transcription-polymerase chain reaction (RT-PCR) revealed Influenza B virus as the cause of the initial bronchopneumonia. A second bronchoscopy aimed to evacuate mucus plugs but showed no improvement. Blood gas analysis indicated severe metabolic acidosis and oxygenator failure, leading to increased gas sweep and heparin re-initiation. However, ACT remained >1000 sec. The patient passed away on the tenth day due to oxygenator failure.

Discussion

In this case, ARDS developed from viral bronchopneumonia, with studies indicating that 14% of influenza B patients in ICU settings experienced ARDS. (3) The mortality rate for ARDS in the pediatric intensive care unit (PICU) is notably high at 24.5%. (4) The Pediatric Acute Lung Injury Consensus Conference (PALICC) recommends various mechanical ventilation strategies for pediatric ARDS management, including a lung protective strategy with low tidal volumes (3-6 ml/kg) and permissive hypoxemia targeting an oxygen saturation of 88%-92%. (5) Additional strategies include prone positioning, sedation, and muscle relaxants. If these methods fail to improve gas exchange, ECMO is advised. In this case, IRV was also utilized to enhance oxygenation, though it risked excessive end-expiratory gas trapping and increased partial pressure of carbon dioxide (pCO2), complicating the management of permissive hypercapnia.

The worsening pneumonia in this patient, categorized as ARDS, is primarily attributed to ventilator-

induced lung injury (VILI) due to aggressive mechanical ventilation beyond lung protective strategies upon initial admission. High lung volume likely caused overdistension, leading to barotrauma and air leaks. Both high and low lung volumes can have detrimental effects, releasing mediators that exacerbate lung injury and increase alveolar-capillary permeability, potentially resulting in systemic complications. To prevent VILI, ECMO can be employed alongside mechanical ventilation to reduce the intensity of ventilation needed while improving gas exchange and CO2 elimination. For this patient, ECMO was initiated following Extracorporeal Life Support Organization (ELSO) guidelines, which recommend intervention when the ratio of pO2 to the fraction of inspiratory oxygen concentration (P/F ratio) is <80 mmHg or pH<7.25 with elevated pCO2 for more than six hours, despite implementing strategies like prone positioning and neuromuscular blockade. An echocardiogram on day three revealed pulmonary hypertension with cor pulmonale, confirming the need for VA-ECMO to manage right ventricular failure effectively.

At our center, two primary issues contributed to this patient's failure to follow ECMO procedures. First, ECMO initiation was delayed until the sixth-day post-intubation or the ninth day of hospital treatment. ELSO registry data shows that early ECMO intervention significantly improves outcomes: a 72% survival rate for initiation within six days after intubation and only 30% thereafter. (6) This underscores the importance of timely ECMO initiation. The delay was due to concerns about stability, uncertainty regarding respiratory failure, attempts at prone or high-frequency ventilation, and lack of interfacility ECMO capabilities. Another study advises aggressive ARDS treatment from influenza via ECMO or referral within the first 48 hours; (7) however, this patient was only referred to an ECMO-capable facility on the fifth day. Timely ECMO initiation is crucial for better survival rates.

Second, we lacked sufficiently small cannulas for peripheral cannulation, necessitating central cannulation—placing the outflow cannula into the right atrium and inflow into the proximal ascending aorta—associated with a 62% bleeding rate at the surgical site and an 18% rate at the cannulation site. (8) ACT is crucial for managing anticoagulation during ECMO, primarily monitoring unfractionated heparin (UFH) targets of 180-200 seconds to prevent thrombus formation in the circuit. Nearly 40% of ECMO patients experience clot formation, primarily in the oxygenator. (9) In this case, resuscitation with fresh frozen plasma (FFP) and platelet concentrate was necessary to maintain hemostasis despite stopping the heparin pump and normalizing ACT levels. A multicenter study indicated that central and direct cannulation in pediatric VA-ECMO patients is linked to higher bleeding risks independent of cardiac diagnosis or heparin use at cannulation. (10) Coagulopathy remained a concern during ECMO management. The patient faced massive blood loss, complicating efforts to control bleeding while maintaining target ACT levels. This management dilemma ultimately contributed to oxygenator failure; the patient's lung condition did not improve enough for weaning off ECMO. The case highlights the importance of timely ECMO intervention and careful management of anticoagulation and bleeding risks.

Conclusion

For pediatric patients with acute cor pulmonale, early ECMO initiation is crucial for improving outcomes. A thorough evaluation of VA-ECMO indications is necessary, considering both its benefits and potential risks, including bleeding complications that may lead to multiple organ dysfunction.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgment

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Table 1. Blood gas analysis and ventilator trends

Blood gas analysis parameter	ICU before referral	Emergency Room	ICU day 1	ICU day 3	ICU day 4 on ECMO
- pH	-	7.151	7.199	7.38	7.341
- pCO2 (mmHg)	-	59.3	75.9	48	31.5
- pO2 (mmHg)	-	112	70	55	545
- BE (mEq/l)	-	-8	2	4	-9
- HCO3 (mEq/l)	-	20.7	29.6	32	17.1
- SaO2 (%)	-	97	88	88	100
- P/F	-	112	70	55	
Ventilator mode	PSIMV	PCV	PCV	PCV	PCV
Pins/Pcontrol (cmH2O)	16	30	20	18	8
PEEP (cmH2O)	8	5	14	13	10
Rate	30	45	20	20	12
I:E	1:1.5	1:1.5	2.5:1	2.5:1	1:2.8
FiO2 (%)	100	90	100	100	40
TV (ml)	50-60	106	63	50	9.4
MV (ml)	1.5-1.8	5.6	1.26	0.99	0.11
Ppeak (cmH2O)	25	45	37	32	17
Ftotal (breaths/min)	30	48	20	20	12
SpO2 (%)	89-92	95-96	90	86	100

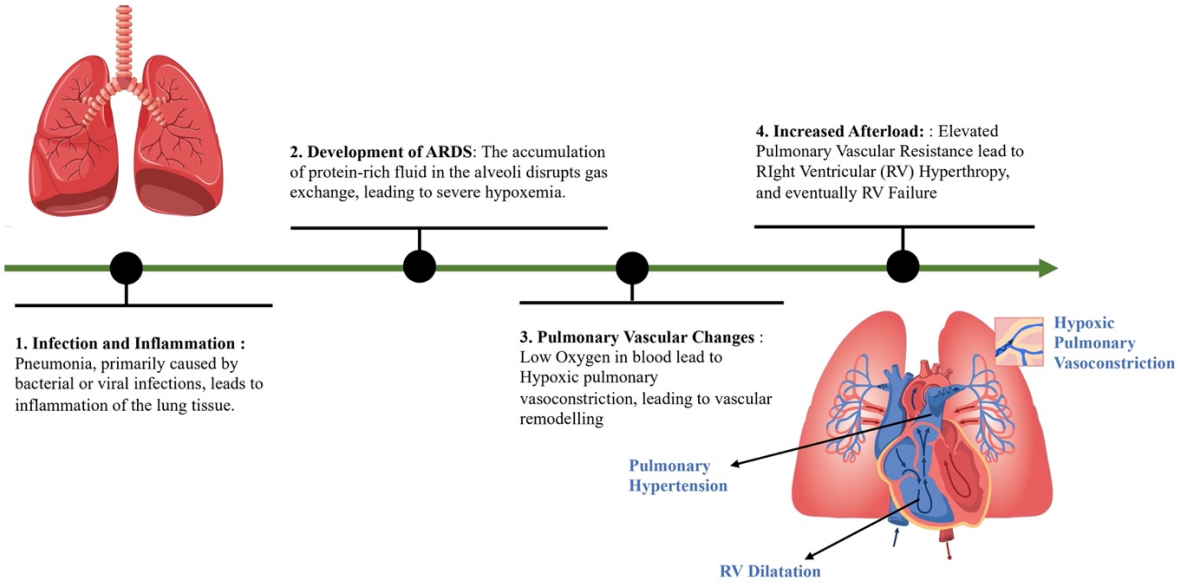
Legend: pCO2=partial pressure of carbon dioxide; pO2=arterial oxygen pressure; BE=base excess; HCO=bicarbonate; SaO2=oxygen saturation of arterial blood; P/F=the ratio of pO2 to the fraction of inspiratory oxygen concentration; ICU=intesinve care unit; ECMO=extracorporeal membrane oxygenation; PSIMV=pressure synchronized intermittent mandatory ventilation; PCV=pressure controlled ventilation; PEEP=positive end-expiratory pressure; I:E=inspiratory to expiratory ratio; FiO2=fraction of inspired oxygen; TV tidal volume; MV=minute volume; Ppeak=peak inspiratory pressure; SpO2=oxygen saturation as detected by the pulse oximeter.

Table 2. Fluid replacement for hemorrhage during ECMO

Fluid intake (ml)	ICU day						
	4	5	6	7	8	9	10
Whole blood	1200	400	-	1600	-	-	-
Packed red cells	1800	200	600	-	240	250	230
Thrombocyte concentrate	350	210	400	150	220	350	180
Fresh frozen plasma	-	-	-	200	-	-	
Albumin 5%	750	-	-	-	500	-	
Blood loss (ml)	4100	500	1000	1800	1100	600	300

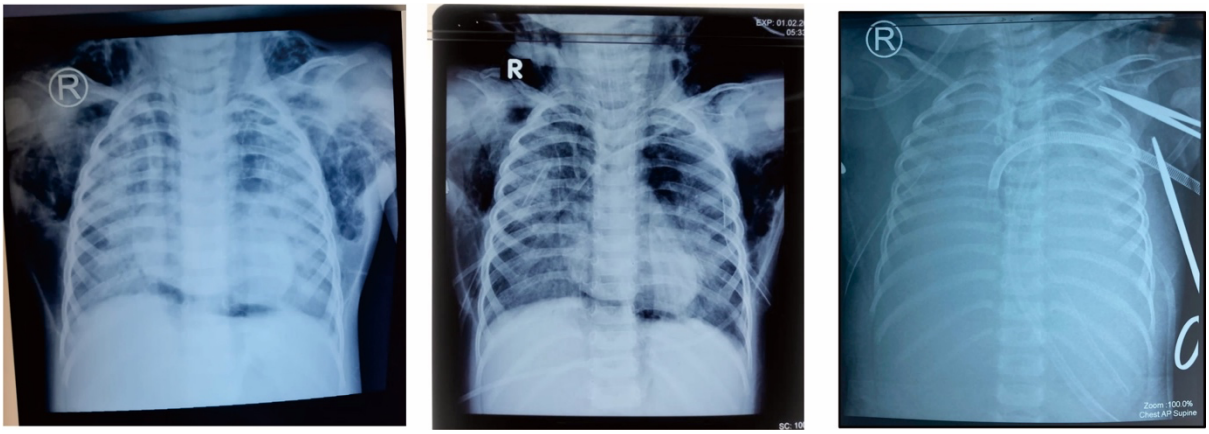
Legend: ECMO=extracorporeal membrane oxygenation; ICU=intesinve care unit.

Figure 1. Pathophysiology of acute cor pulmonale



Legend: ARDS=acute respiratory distress syndrome.

Figure 2. Trends in chest X-ray from left to right: (i) before referral, (ii) after chest tube insertion, (iii) tenth day in ICU



Legend: ICU=intensive care unit.

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