Use of two oxygenators during extracorporeal membrane oxygenator for a patient with acute respiratory distress syndrome, high-pressure ventilation, hypercapnia, and traumatic brain injury

Editor—A 27-yr-old man (98 kg, 1.88 m, body surface area 2.77 m^2) was admitted to our intensive care unit with periventricular cerebral traumatic haemorrhage, without swelling, and a bilateral haemo-pneumothorax with pulmonary contusions. He had also fractured both wrists and the right femoral shaft. Because of acute respiratory distress syndrome (ARDS), we were unable to maintain a Pa_{O_2} of >6.5 kPa, an Sa_{O_2}>80%, even with $F_{I_{O_2}}$ 100%, PEEP of 12 cm H_2O, and 10 ppm nitric oxide. The thoracopulmonary compliance was <10 ml cm H_2O^{-1}, and there was no response to alveolar recruitment manoeuvres. A veno-venous extracorporeal membrane oxygenator (ECMO) was inserted (centrifugal Rotaflow© pump with capillary Quadrox© membrane oxygenator, and the cannulae had a Bioline© coated system). The ECMO provided extracorporeal oxygenation (pumping 4315 rounds min^{-1}, at a blood flow 5.1 litre min^{-1}, gas flow 6 litre min^{-1}, $F_{I_{O_2}}$ 100%) and pressure-controlled ventilation [a plateau pressure of 35 cm H_2O, a tidal volume (V_T) of 2.5 ml kg^{-1}, 100% $F_{I_{O_2}}$] resulted in a Pa_{O_2} of 7.3 kPa, Sa_{O_2} of 90%, and Pa_{CO_2} of 7.9 kPa. Haemodynamic and cardiac function remained stable. Pump flow rate was high: >5 litre min^{-1}, with 300 mm Hg of oxygenator inflow gradient pressure. The gas flow rate was 6 litre min^{-1}, giving an almost 1:1 gas/pump flow ratio. A higher gas flow rate was insufficient to reduce Pa_{CO_2} or the inspiratory pressure. Therefore, a second oxygenator was used to increase the surface area for gas exchange, and to decrease Pa_{CO_2} and inspiratory pressure. As expected, the second oxygenator only improved CO_2 removal: oxygen delivery was unchanged (Table 1). A small reduction in V_T allowed plateau pressure to decrease to <32 cm H_2O and reduced respiratory frequency. The patient was weaned off ECMO after 7 days, and was discharged with normal neurological status and without needing supplementary oxygen.

ECMO can be highly effective in reversing hypoxia and delivering life support for long enough to facilitate treatment and recovery.[1 2] In patients with brain injury, the management of severe ARDS is difficult.[3] Thus, the use of ECMO is increasing in ARDS patients with refractory hypoxaemia or hypercapnia.[1 2] With ECMO, O_2 consumption and CO_2 exhalation rates are unknown in patients with a high body surface area, severe ARDS, infection, and traumatic brain injury. In our patient, we had to deal with poor arterial blood gases, despite maximal ECMO and 'aggressive' ventilation. ECMO may allow clinicians to prioritize lung protection over 'aggressive' ventilation, by providing extrapulmonary gas exchange and the injured lungs are not forced to work and this may assist the healing process.

Hypercapnia may cause elevated intracranial pressure, pulmonary hypertension, decreased myocardial contractility, decreased renal-blood flow, and release of endogenous catecholamines.[4] Therefore, the use of two oxygenators in our patient with a high body surface area to reduce hypercapnia and limit 'aggressive' ventilation was clinically necessary in this instance. A second membrane oxygenator added in parallel has been reported during a cardiopulmonary bypass, but pump flow was halved for each oxygenator.[5] Oxygen saturation with one oxygenator was 100% and P_{O_2} in cannula 54.9 kPa, and thus, the impact of two oxygenators on oxygen delivery was limited. It is cannula diameter, position, and ECMO pump flow that need to be optimized if oxygen delivery remains low. In relation to CO_2 removal, the second oxygenator increased the gas-exchange surface by 100%, thus allowing Pa_{CO_2} to decrease by 38%. The Fick principle explains the relationship between the low P_{CO_2} gradient and increased membrane-surface area and decreased Pa_{CO_2}.[6] Adding a

Table 1 Gas exchange data with one or two oxygenators during ECMO. The gas flow was 6 litre min^{-1} for each oxygenator. The blood gas, oxygen concentration (oxygen saturation × 1.3 × haemoglobin concentration + 0.003 × Pa_{O_2}) and oxygen delivery (oxygen concentration × flow pump) were analyzed in the cannula after all the oxygenators. Sv_{O_2}, oxygen venous saturation measured in the cannula before oxygenation; Pa_{CO_2}, arterial carbon-dioxide tension; Pa_{O_2}, arterial oxygen tension; HCO_3, bicarbonate

	One oxygenator	Two oxygenators
Pump flow (litre min^{-1})	5.1	5.1
Pressure gradient oxygenator (mm Hg)	20	40
Oxygen concentration (ml O_2 blood ml^{-1})	168.6	183.2
ECMO oxygen delivery (ml min^{-1})	857	934
P_{CO_2} in cannula after oxygenators (kPa)	7.4	4.5
Arterial blood gases		
pH	7.32	7.5
Pa_{CO_2} (kPa)	7.8	4.8
Pa_{O_2} (kPa)	7.3	7.4
HCO_3 (mmol $litre^{-1}$)	30	28.8
Sv_{O_2} (%)	*60*	60

second oxygenator, in a serial manner during veno-venous ECMO effectively removes CO_2 and protects ventilation.

Conflict of interest

None declared.

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