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Neurocognitive outcomes after extracorporeal membrane oxygenation

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Extracorporeal membrane oxygenation (ECMO) has been a therapy of last resort for the treatment of severe cardiorespiratory failure since the 1970s [1]. In recent years, ECMO has seen a resurgence in its use in adults. Recent work examining rates of ECMO use in the US adult population, using Nationwide Inpatient Sample data, quotes an increase in use of 433% from 2006 to 2011 [2]. While much research has focused on neurologic injury after cardiac surgery and cardiopulmonary bypass (CPB), the effects of ECMO on neurocognitive function are less well described. This review aims to summarize recent findings as they pertain to pathophysiology, monitoring techniques, prevention, therapy, and emerging experimental concepts in the context of ECMO for adult patients. Given that neurocognitive outcomes after cardiac surgery have been recently reviewed [3,4], we will limit the discussion of findings from the cardiac surgery/CPB literature to those especially relevant for ECMO.

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Veno-venous versus veno-arterial ECMO

Extracorporeal membrane oxygenation (ECMO) can be applied with gas exchange as the primary goal: providing oxygen (O_2) to and removing carbon dioxide (CO_2) from the blood. In this case, venous blood is drained from a large vein and returned to the right atrium (or another large vein): veno-venous (VV) ECMO (Fig. 1). Many cannulation approaches exist and include femoral, internal jugular, subclavian, and superior/inferior vena cava access points. Especially during the 2009 H1N1 influenza pandemic, VV ECMO use surged for the therapy of acute respiratory distress syndrome [5]. The highly cited "CESAR" study found that patients with severe acute respiratory distress syndrome (ARDS) utilizing ECMO had a higher disability-free survival at 6 months as compared to conventional care [6].

If a patient requires support of heart function, venous blood is routed to an oxygenator and then pumped into the arterial circulation, thereby bypassing the heart. This configuration is termed veno-arterial (VA) ECMO. Cannulation can be central, for example, from the right atrium to the ascending aorta, or peripheral, for example, from the femoral vein to the femoral artery. VA ECMO is used for the treatment of acute cardiac failure, including cardiogenic shock from acute myocardial infarction, ischemic and non-ischemic cardiomyopathy, acute myocarditis, postcardiotomy syndrome, or failure to wean from cardiopulmonary bypass (CPB) postoperatively (to name a few) [7,8]. ECMO is being increasingly utilized as a bridge to a durable ventricular assist device, heart–lung transplant, or as a rescue modality for primary graft dysfunction following cardiac or lung transplantation.

Definition of neurocognitive dysfunction

Neurocognitive dysfunction ranges from subtle neurologic or neuropsychologic impairment to overtly symptomatic stroke or even brain death [9]. As described by the World Health Organization (WHO), stroke is defined as follows: "rapidly developing clinical signs of focal (or global) disturbance of

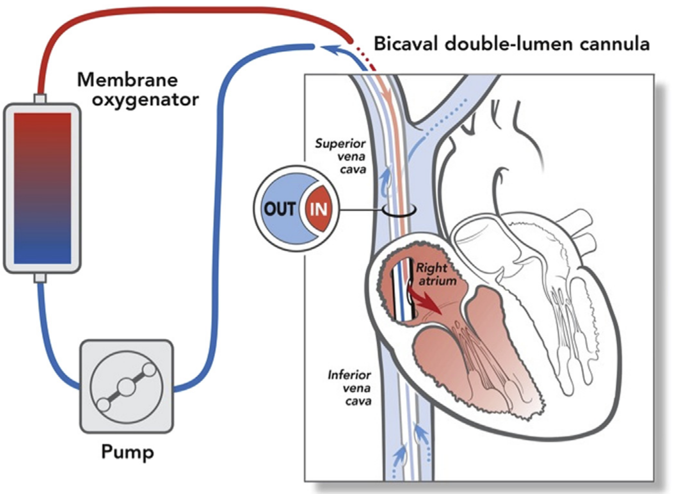

Fig. 1. Veno-venous extracorporeal membrane oxygenation (VV ECMO). A bicaval, double-lumen central venous cannula is placed in the right internal jugular vein. Deoxygenated blood is collected from both the inferior and the superior vena cava. After passing through a centrifugal pump and a membrane oxygenator, the oxygenated blood is then returned to the right atrium through the cannula's second lumen's orifice. Various configurations are currently in use, including pumpless systems and alternative cannulation techniques. Reproduced with permission from: Bartels K, et al. Perioperative organ injury. *Anesthesiology*. Dec 2013; 119 (6):1474–1489. Copyright Wolters Kluwer Health 2013 [22].