

05 - SECTION 2 Shock and Cardiac Arrest

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TABLE 313-4 Main Types and Key Features of Extracorporeal Gas Exchange

TERM	DESCRIPTION
KEY FEATURES	IMPORTANT TECHNICAL NOTES
VA-ECMO (venoarterial extracorporeal membrane oxygenation)	Deoxygenated blood drains via venous catheter to a pump and membrane oxygenator; blood is then returned to the arterial system
VV-ECMO (venovenous-ECMO)	Deoxygenated blood drains via venous catheter to a pump and membrane oxygenator; blood is then returned to the venous system
ECCO2R (extracorporeal CO2 removal)	Venous catheter drains blood to a CO2 removal device; blood then returns via a venous catheter

is indicated for patients with hypercapnia after extubation, high-flow oxygen support for all other patients may be preferable given similar efficacy to NIV in preventing reintubation and generally better patient comfort. Although many factors can cause a patient to fail an SBT or require reintubation and continued mechanical ventilation, common processes perpetuating mechanical ventilation include critical illness myopathy and polyneuropathy, myocardial ischemia, congestive heart failure, vascular and extravascular volume overload, delirium, malnutrition, and electrolyte abnormalities (hypophosphatemia, hypokalemia, and hypomagnesemia). These processes should be evaluated and treated, as necessary, in patients failing attempts to discontinue mechanical ventilation.

EXTRACORPOREAL GAS EXCHANGE Despite interventions to optimize oxygenation and alveolar ventilation on mechanical ventilation, some patients suffer life-threatening hypoxemia, refractory respiratory acidosis, and barotrauma, and may be candidates for salvage therapy with extracorporeal gas exchange, a procedure whereby blood continuously circulates outside the body through a device that oxygenates it, removes CO₂, and then returns blood to the patient's circulation. Although often referred to as ECMO, modern gas exchange membranes both deliver oxygen and remove CO₂, replacing the gas exchange function of the lung. The main components of an ECMO "circuit" include vascular cannulas to remove and return blood to the patient, a pump to circulate blood, and a gas exchange membrane. ECMO can provide varying levels of both respiratory and circulatory support depending on the clinical situation (Table 313-4). In a patient both in shock and requiring full respiratory support, the ECMO circuit would include a central venous cannula (V) to remove blood and a central arterial cannula (A) to return oxygenated blood at relatively high flow rates (up to 6 L/min) providing mechanical circulatory support, so-called VA-ECMO. In the absence of shock, both the draining and return vascular cannulas can be central

venous, or VV-ECMO, but blood flow is still relatively high (2–5 L/min) to provide adequate oxygen delivery to tissues. In situations where a patient's lungs can provide adequate oxygenation but insufficient CO₂ removal, such as severe obstructive lung disease exacerbations, a venovenous circuit with low blood flows (0.25–2 L/min) is often adequate to remove CO₂ and treat refractory respiratory acidosis, a process called extracorporeal CO₂ removal (ECCO₂R). ECMO continues to evolve, including the use of hybrid circuits. For example, if patients on traditional VA-ECMO have asymmetric hypoxia in the upper body, an additional venous return catheter can be placed in an internal jugular vein to deliver additional oxygenated blood; this hybrid circuit would be V (removal)-VA (dual arterial and venous return)-ECMO. Moreover, several ECMO centers now have mobile ECMO equipment and teams, allowing patients who are too unstable for transfer to an ECMO center to start on ECMO and facilitate transfer to an ECMO center for further care. Although technologic advances in the ECMO pumps, gas exchange membranes, and even vascular catheters have reduced ECMO-related complications, the procedure is resource-intensive and still associated with several adverse events, including cannula site hemorrhage and vascular injury, catheter-related infection, pneumothorax, pulmonary and gastrointestinal hemorrhage, limb ischemia, intracranial hemorrhage, and disseminated intravascular coagulation (DIC). Clinical outcomes for ECMO patients remain promising, including for patients

Circulatory and respiratory support Requires large vascular catheters (16–30 Fr) Higher blood flow rates (2–6 L/min) Respiratory support Requires large vascular catheters (20–30 Fr) Higher blood flow rates (2–5 L/min) Partial respiratory support, CO₂ removal only Requires smaller vascular catheters (14–18 Fr) Lower blood flow rates (0.25–2 L/min) with severe respiratory failure from SARS-CoV-2 infection treated with ECMO. However, the overall mortality benefit from ECMO, especially in ARDS, remains unclear. Selecting patients most likely to benefit from ECMO, therefore, is very important, and in addition to exhausting traditional mechanical ventilatory support, patients being considered for ECMO should have a reversible underlying illness or be eligible for organ transplant (heart and/or lung), no chronic severe end-organ disease (e.g., severe kidney disease), no contraindication to systemic anticoagulation, a good functional status before the acute illness requiring ECMO, and a good neurologic prognosis. CHAPTER 314 Approach to the Patient with Shock ■ ■ FURTHER READING Acute Respiratory Distress Syndrome Network et al: Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med* 342:1301, 2000. Barrot L et al: Liberal or conservative oxygen therapy for acute respiratory distress syndrome. *N Engl J Med* 328:999, 2020. Bertini P et al: ECMO in COVID-19 patients: A systematic review and meta-analysis. *J Cardiothorac Vasc Anesth* 36:2700, 2022. Girard T et al: An official American Thoracic Society clinical practice guideline: Liberation from mechanical ventilation in critically ill adults. *Rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. Am J Respir Crit Care Med* 195:120, 2017. Hernandez G et al: Effect of post extubation high-flow nasal cannula vs non-invasive ventilation on reintubation and post extubation respiratory failure in high-risk patients: A randomized clinical trial. *JAMA* 316:1565, 2016. Moss M et al: Early neuromuscular blockade in the acute respiratory distress syndrome. *N Engl J Med* 380:1997, 2019. Murphy PB et al: Effect of home noninvasive ventilation with oxygen therapy vs oxygen therapy alone on hospital readmission or death after an acute COPD exacerbation. A randomized clinical trial. *JAMA* 317:2177, 2017. Tramm R et al: Extracorporeal membrane oxygenation for critically ill adults. *Cochrane Database Syst Rev* 1:CD010381, 2015. Section 2 Shock and Cardiac Arrest Rebecca M. Baron, Anthony F. Massaro

Approach to the Patient

with Shock Shock is the clinical condition of organ dysfunction resulting from an imbalance between cellular oxygen supply and demand result ing in cellular and tissue hypoxia. This life-threatening condition is common reason for requiring care in the intensive care unit (ICU).

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