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Commentary: Extracorporeal membrane oxygenation: Is it life-saving and cost effective for all patients?

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CENTRAL MESSAGE

ECMO outcomes and costs are related to patient indications. Postcardiotomy syndrome and cardiogenic shock are the most common indications for ECMO but have the highest cumulative costs and the lowest survival.

There has been a tremendous increase in the use of extracorporeal membrane oxygenation (ECMO) over the past decade. Advances in ECMO equipment and technology have expanded the use of this technique to treat not only severe adult respiratory failure (SARF) but also as a temporary form of mechanical support for patients with postcardiotomy syndrome (PCS), cardiogenic shock (CS), and as a bridge to heart transplantation (HT) and lung transplantation (LT). However, ECMO is expensive and costs can range from 20,000 to 40,000 USD per day of hospitalization.[1] In view of the increased costs associated with ECMO support, it is important to identify those patients who will benefit the most from this technique.

In this edition of the *Journal*, Hayanga and colleagues[2] analyzed data from the National Inpatient Sample to review all hospital charges and in-hospital mortality for 15,829 adult patients undergoing ECMO from 2008 to 2016. PCS was the most common indication for ECMO (39%), followed by CS (37%), SARF (15%), HT (3.9%), and LT (5.4%). The mean duration of ECMO support was 5.3 days. The overall in-hospital mortality for the entire cohort was 55%. The greatest mortality was seen in the patients with PCS (53%) and CS (58%), followed by SARF (45%), HT (39%), and LT (32%). There was a decrease in mortality in all patients undergoing ECMO from the latest era (2013-2016) compared with the earlier era (2008-2012). The longest duration on ECMO was seen in patients undergoing HT (15.9 days), followed by LT (8.8 days), SARF (6.6 days), PCS (4.8 days), and CS (3.8 days).

The overall mean hospital charges for the entire cohort was 731,914 USD. The greatest charges were seen in HT (1,448,931 USD) and LT recipients (1,574,378 USD) followed by SARF (824,852 USD), PCS (789,909 USD), and CS (655,099 USD). In all groups, there was a statistically significant increase in hospital charges from the early to late era. However, when cumulative hospital charges (proportion × hospital charges) were calculated, PCS (39%) and CS (37%) accounted for the greatest proportion of charges and the lowest survival. In contrast, patients with SARF and those undergoing transplant had the lowest proportion of charges and the greatest survival.

There are several issues inherent with the National Inpatient Sample database that limit the conclusions that can be made regarding costs associated with ECMO support. No distinction was made between venoarterial and venovenous ECMO. The results pertain only to the period of acute hospitalization and do not include discharges to rehabilitation and long-term assisted-living centers. Longer outcomes (6 months-1 year) were not analyzed. The differences between perfusion and nurse/physician assistant-run ECMO teams were not analyzed. A major reason for the

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increased costs for ECMO has been attributed to the need for perfusionists and ECMO intensivists at the bedside. It has been demonstrated that experienced intensive care unit nurses and physician assistants can manage ECMO circuitry with excellent outcomes and at a lower cost.[3,4] Avoiding the requirement for the continuous presence of perfusionists at the bedside can also reduce hospital costs by ensuring that cardiac procedures (both surgical and interventional) will not be cancelled or delayed because of lack of a perfusionist. No data were provided on the cost for concomitant devices or techniques to enhance left ventricular unloading, such as the Impella device, intra-aortic balloon pump support, and transseptal left atrial venting performed in the catheterization laboratory. Finally, no data are provided regarding the breakdown of costs for those ECMO patients who were survivors versus nonsurvivors.

Despite these limitations, Hayanga and colleagues have raised an important issue in the field of mechanical support, ie, is ECMO life-saving and cost-effective for all patients? In To answer this question, it will be necessary to determine which groups of patients stand to benefit the most from this expensive technology. Three groups of patients have been shown to have extremely poor outcomes following ECMO support. Patients with acute type A dissections have dismal outcomes irrespective of when ECMO is initiated. In the Pennsylvania Health Care Cost Containment Council database, the overall perioperative mortality for patients on ECMO following a type A dissection was 92%.[5] Patients with septic shock also have extremely high mortality despite ECMO support. Ro and colleagues[6] found that only 15% of their patients with septic shock could be weaned from ECMO and only 7% were actually discharged from the hospital.[6] Similarly, ECMO survival for patients with septic shock and infectious endocarditis and multisystemic involvement, especially those patients who are immunocompromised, is poor. Unless the source of sepsis can be identified and successfully treated and patients suffer only from sepsis-induced cardiomyopathy, these patients will not benefit from ECMO support. Finally, as the number of ECMO procedures continues to increase, a percentage of these patients may require a repeat ECMO procedure. Brady and colleagues[7] found that the mortality for patients requiring a repeat period of ECMO support during the same hospitalization was 75% compared with 0% for patients who received ECMO during a subsequent hospitalization as a bridge to a permanent VAD or a heart or lung transplant.

For ECMO to remain cost effective, better patient selection will be required for patients with PCS and CS. In patients with CS, it is important to remember that ECMO does not cure the underlying condition. It merely provides a period of stability for patients to recover or for a long-term solution such as a ventricular assist device or heart transplant. Patients with CS who are not candidates for corrective cardiac surgery, a ventricular assist device, or transplant will not benefit from ECMO support. Schmidt and colleagues[8] developed a SAVE (Survival After Veno-arterial ECMO) score from data involving 3846 adult patients enrolled in the International Extracorporeal Life Support Organization registry that can predict survival after ECMO for refractory cardiogenic shock. Patients with improved survival had potentially reversible causes of myocardial injury such as acute fulminant myocarditis in an otherwise-healthy patient; or refractory ventricular tachycardia/ventricular fibrillation; and were younger than 70 years of age. Determinants of poor survival included older patients, patients with increased body mass index and weight >90 kg, patients with chronic obstructive pulmonary disease, renal, hepatic, and central nervous system dysfunction before ECMO, a long duration (>10 hours) of mechanical ventilation before ECMO support, elevated lactate levels before and following ECMO, and poor baseline cardiac function before CS. The importance of age in determining outcomes following ECMO for CS was reported by Lorusso and colleagues.[9] In their series, survival to hospital discharge in patients >70 years of age was only 30.5% compared with 43.1% in patients <70 years ($P < .001$).

Determinants of improved survival in ECMO patients following PCS have also been documented. The greatest rates of survival are seen in younger patients (<70 years), with minimal preoperative comorbidities and preserved cardiac function, who have experienced an unexpected intraoperative event and can be weaned off ECMO within 4 days.[10-13] Patients with underlying cardiomyopathies and reduced preoperative ejection fraction, those with preoperative right ventricular dysfunction, and those patients with elevated serum lactate levels (>10 mmol/L) before ECMO have especially poor survival. A 60-year-old patient undergoing a CABG for a 90% left main lesion with preserved ejection fraction and minimal preoperative comorbidities who develops intraoperative cardiogenic shock despite intra-aortic balloon pump support will benefit from ECMO support. In contrast, a 72-year-old patient undergoing a CABG with the same anatomy who has insulin-dependent diabetes, chronic renal dysfunction, and COPD who develops PCS is unlikely to benefit from ECMO.

Another source of increased cost associated with ECMO following PCS and CS involves quality-of-life issues. Although short-term survival following ECMO has been extensively studied, few studies have reported on the long-term sequelae of ECMO on quality of life. In a retrospective, single-center review of patients undergoing venoarterial ECMO, Ruckert and colleagues[14] found that >40% of ECMO survivors were either dependent on others for activities of daily living or were left with persistent

cognitive and mental status issues requiring additional health care services. In another study focusing on psychiatric outcomes after ECMO, 39% of survivors had 1 or more mental health disorders, including cognitive dysfunction, anxiety, depression, and post-traumatic stress disorders requiring professional assistance.[15]

Is ECMO life-saving and cost effective for ALL patients? ECMO can be life-saving but not for all patients. As Centers for Medicare & Medicaid Services and third-party payers attempt to lower reimbursement for ECMO, it is imperative that health care professionals work diligently to identify those patients who will benefit the most from this potentially life-saving technology. The widespread use of ECMO to all patients under all circumstances will continue to increase health care costs and ultimately result in reductions in reimbursement, which will limit its use for those patients who stand to derive the greatest benefit from ECMO. It will be imperative for societies such as the American Association for Thoracic Surgery, Society of Thoracic Surgeons, American Heart Association, and American College of Cardiology to develop guidelines and treatment pathways that can be used to determine which patients are most appropriate for ECMO support and not wait until regulations are enforced by non-physician health care administrators. Only then will ECMO become both life-saving and cost effective.

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