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Extracorporeal Membrane Oxygenation Utility in Postpartum Patients

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Abstract: Although extracorporeal membrane oxygenation (ECMO) has been used in many different populations, its use in pregnant or postpartum patients has not been widely studied. This article reviews the ECMO experience in this population at a large urban hospital. Electronic medical records for all pregnant or postpartum patients who required ECMO between 2012 and 2019 were retrospectively reviewed. Data on clinical characteristics, outcomes, and complications were gathered. Comparisons between survivors and nonsurvivors were completed. Ten postpartum patients were identified. The patients presented as follows: four with cardiac arrest, one with a massive pulmonary embolism, three with acute respiratory distress syndrome (ARDS), one with combined ARDS and cardiogenic shock, and one with suspected amniotic embolism. Survival to decannulation was 70%, and survival to discharge was 60%. When comparing survivors vs. nonsurvivors, ECMO survivors tended to have shorter support times vs. nonsurvivors. Otherwise, no differences were noted in age, mechanical ventilation time, or length of stay. Disseminated intravascular coagulation was a common phenomenon in this patient cohort. After initiation of ECMO, elevated serum lactate levels, lower systolic blood pressure, and acute renal failure were predictors of mortality. In a single institution at a large metroplex, we present data regarding the use of ECMO in postpartum patients. ECMO can be successfully used in selected postpartum patients with severe cardiac or respiratory dysfunction. Multidisciplinary collaboration on a regular basis will streamline the ECMO referral in a timely manner. Furthermore, larger studies are indicated to understand the utility of ECMO in larger cohorts. **Keywords:** ECMO, postpartum, heart failure, ARDS. *J Extra Corpor Technol. 2020;52:191–5*

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Pregnancy-related mortality has been a growing concern in the United States in recent years. Since the initiation of national surveillance of pregnancy-related mortality by the Centers for Disease Control and Prevention in 1987, there has been a 2.5-fold increase in pregnancy-related deaths as of 2014 (the most recent available data) (1). According to the CDC, "Pregnancy-related death is defined as the death of a woman while pregnant or within 1 year of the end of a pregnancy, regardless of the outcome or duration, from any cause related to or aggravated by the pregnancy or its

management but not from accidental or incidental causes (1)." This increase in risk is likely due to the higher prevalence of chronic health conditions, leading to a higher risk of pregnancy complications. When deaths due to cardiovascular conditions and cardiomyopathies are combined, diseases of the heart and blood vessels are now the leading cause of maternal mortality in the United States compared with hemorrhage in the past (2). In the inpatient setting, acute cardiac conditions contribute to more than 50% of deaths in the intrapartum and postpartum periods (3). This is substantially greater than amniotic fluid embolisms which are noted to be present in only 8.75% of cases despite being the second most frequent comorbidity in inpatient maternal deaths (3).

When patients experience refractory cardiopulmonary failure, mechanical cardiopulmonary support may be considered. Prolonged mechanical cardiopulmonary support outside of the operating room is called extracorporeal membrane oxygenation (ECMO). Although ECMO has been used in many different populations, its use in pregnant or postpartum patients has not been widely studied. Unfortunately, there are no accepted guidelines for the use of veno-venous (VV) or venoarterial (VA) ECMO in pregnant and postpartum patients from the Extracorporeal Life Support Organization, Society for Maternal-Fetal Medicine, or American College of Obstetricians and Gynecologists (4). Our medical center, a tertiary referral hospital, has about 5,200 deliveries a year (5) and is an ECMO-capable center. In this article, we describe our experience with ECMO use in this unique patient population.

METHODS

This retrospective study was completed under local Institutional Review Board approval (HSC-MS-18-079). For the period of 2012–2019, electronic medical records were reviewed retrospectively for all pregnant or postpartum patients admitted to our facility who required additional cardiopulmonary support via the institutional ECMO team.

This cohort of patients used either of the following circuits: Cardiohelp system and Sprinter Cart XL with HLS Set Advanced 7.0 Bioline coating circuitry (Getinge, Wayne, NJ) or the Stocker centrifugal pump system (SCPC System) with Trolly (LivaNova, Houston, TX) using Balance Biosurface coating tubing pack (Medtronic, Minneapolis, MN), Revolution Ph.I.S.I.O Centrifugal Blood Pump (LivaNova, Houston, TX), and Quadrox ID Adult diffuse membrane oxygenator with Bioline coating (Getinge, Wayne, NJ). Regardless of the circuitry type, the prime consists solely of Isolyte® S pH 7.4 with no additional additives (B. Braun Medical Inc., Bethlehem, PA). Intravenous heparin is primarily used for anticoagulation in this patient cohort. Anticoagulation is titrated to a target with an activated partial thromboplastin time of 40–60 seconds while on VV ECMO and 60–80 seconds while on VA ECMO, unless there was concomitant bleeding diathesis.

Data collection included demographics, reason for admission, body mass index, and preexisting conditions, such as diabetes or hypertension. The outcome measures examined included mortality, cardiopulmonary resuscitation time, vasopressors, mechanical ventilation days, and complications such as renal failure. In addition, information on ECMO-related complications was gathered and classified as intracranial hemorrhage or ischemic event, cerebral edema or herniation, or vascular complications such as acute limb ischemia, hematoma, or compartment syndrome. The primary end point was maternal survival at discharge. Statistical analysis was performed using SPSS 25 (IBM Software, Chicago, IL). Significance was defined as $p < .05$. Multivariate analysis excluded any confounders.

RESULTS

Ten patients were identified who required ECMO because of cardiorespiratory failure. Key features of their clinical status are outlined in Table 1. All patients underwent femoral–femoral cannulation. Six patients underwent VA ECMO cannulation at the offset, and four patients underwent VV ECMO cannulation at initial evaluation. Two of the VV ECMO patients had to be escalated to VA ECMO within 24 hours of cannulation. The patients presented as follows: four with cardiac arrest, one with a massive pulmonary embolism, three with acute respiratory distress syndrome (ARDS), one with combined ARDS and cardiogenic shock, and one with suspected amniotic embolism. The mean duration of ECMO support was 3 days in survivors and 6 days in nonsurvivors. The length of stay was 18 days in survivors vs. 10 days in nonsurvivors (Table 2). Seven of the 10 patients (70%) survived decannulation. Six of the 10 patients (60.0%) survived to discharge. In comparing survivors and nonsurvivors, a higher risk of mortality was noted in patients with higher total bilirubin (20.82 vs. 2.18; $p = .03$) and lower systolic blood pressure (78 vs. 120; $p = .01$). Five of the 10 patients experienced disseminated intravascular coagulation (DIC) during their hospital course. The Survival after VA ECMO (SAVE) score was lower in patients who did not survive (-6.75 vs. .66, $p < .12$). Higher levels of serum lactate showed a trend toward worsening mortality both at cannulation and at day 3; however, this did not reach statistical significance.

DISCUSSION

Maternal mortality has risen in the United States. The American Heart Association's Get with the Guidelines

Table 1. Comparison of characteristics between survivors and nonsurvivors after ECMO.

	Survivors (n = 6)	Nonsurvivors (n = 4)	*p* value
Age (years), mean	33.00	26.00	.07
ECMO duration (days), mean	3.00	6.00	.07
ICU stay (days), mean	12.66	8.5	.32
Duration of mechanical ventilation (days), mean	8.66	5.75	.57
Length of stay (days)	18	10	.22
Arterial cannula size (Fr)	16.33	16	.72
Venous cannula size (Fr)	21.6	22.25	.69
ECMO pump flow (L/min)	3.5	3.8	.13
Weight (kg)	82.48	86	.77
Serum lactate level at day of cannulation (mmol/L)	8.9	14.6	.28
Highest serum lactate level while on ECMO cannulation (mmol/L)	8.98	16.57	.12
SAVE score	.66	-6.75	.12
Systolic BP within 6 hours of initiation	120	78	.01*
Diastolic BP within 6 hours of initiation	71	52	.13
Pulse pressure within 6 hours of initiation	44	26	.11
SAVE score	.66	−6.75	.12
Highest total bilirubin	2.18	20.83	.03*

CPR, cardiopulmonary resuscitation.

Resuscitation voluntary registry from 2000 to 2016 has indexed 462 cases of maternal cardiac arrest (2000–2016), and in-hospital death accounts for 59.3% of the cases (6). In the setting of cardiac arrest, VA ECMO can be used as a bridge to allow definitive therapy and treatment of the underlying cause of the arrest. According to the ELSO registry (7), the current survival-to-discharge trend of adult patients who receive ECMO-assisted cardiopulmonary resuscitation is about 38%. This survival rate has steadily increased over the period that the data have been registered in the registry. Obstetric patients are often young with minimal comorbidities, which are ideal factors when determining ECMO candidacy. Given the potential benefit, ECMO needs to be considered in obstetric patients who have in-hospital witnessed cardiac arrests. VA ECMO has a wide variety of clinical applications and can be used in impending cardiac arrest patients with fatal conditions such as massive pulmonary embolism, which is a well-recognized entity in maternal mortality and is responsible for approximately 10% of maternal mortalities in the United States (8). The use of VA ECMO in patients with high-risk pulmonary embolism (PE) has been suggested to confer a mortality benefit, with an odds ratio for in-hospital mortality of .34 (95% confidence interval [CI] = .25–.45, $p < .001$) (9). Development of PE response teams across hospital systems in the United States is aimed at decreasing in-hospital mortality of pulmonary emboli; however, rarely are these teams equipped with the capabilities to provide emergency ECMO support (10).

Table 2. Comparison of complications between survivors and nonsurvivors after ECMO.

Complication	Survivors (n = 6)	Nonsurvivors (n = 4)
Acute renal failure	50%	100%
DIC	50%	50%
Infection	33%	75%
Any bleeding	33%	75%
Vascular complications*	33%	25%
Liver failure†	33%	100%

*Amniotic fluid embolism and pelvic vein thrombosis.
†Defined as total bilirubin ≥33 μmol/L or aspartate transaminase or alanine aminotransferase >70 UI/L at ECMO cannulation.

Another indication for ECMO support is ARDS. In 2016, a meta-analysis by Moore et al. (11) examined 45 pregnant patients requiring ECMO from 26 different publications, including case reports. The most common indication was ARDS from H1N1 influenza, with 41 patients receiving VV ECMO and four receiving VA ECMO (11). The mean gestational age was 26.5 weeks (range 12–38 weeks), and postpartum patients were excluded (11). The maternal survival rate was 77.8% (35/45) (11), which was similar to the data from our institution. The most common cause of maternal death was multi-organ failure (3/10), and intrauterine fetal death occurred in five patients while on ECMO (11). The most common complication was major bleeding, including intracranial, uterine, pulmonary, or multiple sites, which was noted in seven articles (11). Another meta-analysis of five retrospective studies by Saad et al. (12) included 39 pregnant and postpartum patients from 1946 to 2015 who required ECMO exclusively because of H1N1-related ARDS. Mortality rates in peripartum patients diagnosed with ARDS from any cause can be up to 40%, with a four-fold increase in mortality with H1N1 influenza infection compared with the nonpregnant population (12). For peripartum patients, early initiation of ECMO may also be beneficial, as positioning can be difficult in late pregnancy because of anatomical constraints. Only three of the studies reviewed by Saad et al. (12) indicated whether they used VV or VA ECMO, and those

three used VV ECMO. This review showed an overall survival rate of 74.6% (28/39) (12). Bleeding complications were also discussed in only two studies and occurred in eight peripartum patients, with multiple sources of bleeding, including the uterus and the cannula insertion sites (12).

In addition, VA ECMO has not been widely discussed in peripartum patients, except for very few case reports. One patient had a prosthetic mitral valve causing left heart dysfunction and was cannulated on VA ECMO during cesarean section, resulting in both maternal and fetal survival (13). Another case discussed VA ECMO in the setting of circulatory failure from *Streptococcus pyogenes* toxic shock syndrome with maternal survival (14). Vitulo et al (15). discussed two pregnant patients who required VA ECMO, one after cardiac arrest and one preemptively before cesarean section of a successful delivery.

Our retrospective study showed that elevated serum lactate levels, lower systolic blood pressure, and acute renal failure may be predictors of mortality in peripartum patients on ECMO. Of the 10 patients in our study, one peripartum patient suffered from amniotic fluid embolism—a life-threatening complication. Studies are limited for ECMO use in patients with amniotic fluid embolism, but some suggest a mortality benefit with early ECMO initiation (16). It should be noted that DIC was noted in 68% (5/8) of the patients, which is more frequent than the 5% incidence that is reported in ECMO patients in the general population (17). This is likely a product both of the ECMO support device and the pregnancy state itself, as DIC is another widely studied high-mortality complication in peripartum patients (18). DIC can complicate the necessity of anticoagulation in ECMO use and increase the likelihood of thrombus formation and hemorrhage in these patients. Although mortality may seem high in these patients, without ECMO use, survival may have been more unlikely.

Although ECMO can be a useful tool to provide support for critically ill patients, the use of this mechanical support device does come with some inherent risk. Patients who require ECMO cannulation, particularly with VA ECMO, can experience renal failure requiring dialysis, bleeding, hemolysis, infection, liver dysfunction, leg ischemia, central nervous system complications, venous thrombosis, and DIC (17). Although some of these complications may be related to the underlying pathologic condition that is affecting the patient, several of the adverse effects are related to the presence of the mechanical support device itself. These complications are of particular concern in obstetric patients, where adverse events such as bleeding or liver failure can have catastrophic effects on both the mother and fetus. It is for this reason that appropriate and rapid patient selection remains an essential consideration for shock teams that are assessing obstetric patients in distress. Ideally, ECMO candidates should have minimal comorbidities, good neurologic prognosis, and a reversible condition which can be salvaged during the ECMO support period. As ECMO use is a resource-intensive initiative that requires dedicated personnel, rapid and efficient identification of potential candidates is important to facilitate transfer of patients to an experienced center where they can receive the supportive measures as quickly and safely as possible. Given the increased risk of mortality, ECMO is now being considered more often for these patients (19–24). Frequent multidisciplinary team meetings should be held with colleagues from obstetrics, emergency medicine, maternal-fetal medicine, perfusion, nursing, anesthesia, and critical care to ensure the process is streamlined, and when ECMO is indicated and needed, it can be deployed rapidly and effectively.

The main limitation of our article is the small case cohort and as such survival data cannot be extrapolated. Although studies on the utility and use of ECMO in this patient population are limited, this fact should not preclude the consideration of ECMO use. ECMO should be considered in peripartum patients with severe cardiac or respiratory dysfunction.

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