EXTRACORPOREAL LIFE SUPPORT ORGANIZATION
30th ANNUAL ELSO CONFERENCE ABSTRACTS

Austin, TX
September 12-15, 2019

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Published in cooperation with the ASAIO Journal and available online at www.asaiojournal.com.
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Evaluation of Combined Extracorporeal Life Support (ECLS) and Continuous Renal Replacement Therapy on Hemodynamic Performance and Gaseous Microemboli Handling Ability in a Simulated Neonatal ECLS System

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Abstract
The objective of this study was to evaluate the hemodynamic performance and gaseous microemboli (GME) handling ability of a simulated neonatal ECLS circuit with an in-line continuous renal replacement therapy device.

The circuit consisted of a RotaFlow centrifugal pump or HL20 roller pump, Quadrox-iD Pediatric oxygenator, 8-Fr arterial cannula, 10-Fr venous cannula, and Better Bladder. The circuit was primed with packed human red blood cells (HCT 40%). All trials were conducted at ECLS flow rates 200-600 ml/min and CRRT flow rate 75ml/min at 36°C. CRRT was added between the pump and oxygenator (A), recirculated through the pump (B) or bypassed the pump (C).

With the centrifugal pump, all CRRT positions had similar flow rates, mean arterial pressure (MAP) and total hemodynamic energy (THE) loss. With the roller pump, C demonstrated increased flow rates (293.2-686.4 ml/min) and increased MAP (59.4-75.5 mmHg) (P<0.01); B had decreased flow rates (129.7-529.7 ml/min) and MAP (34.2-45.0 mmHg) (p<0.01); A maintained the same when compared to without CRRT. At 600 mL/min C lost more THE (81.4%) (P<0.01) with a larger pressure drop across the oxygenator (95.6 mmHg) (P<0.01) than without CRRT (78.3%; 49.1 mmHg) (P<0.01). C also demonstrated a poorer GME handling ability using the roller pump, with 87.1% volume and 17.8% count reduction across the circuit, compared to A and B with 99.9% volume and 65.8-72.3% count reduction.

These findings suggest that, in contrast to A and B, adding CRRT at position C is unsafe and not advised for clinical use.

Sterility Duration of Pre-Primed Extracorporeal Membrane Oxygenation Circuits

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Abstract
Objectives: There is a paucity of supporting data regarding the duration for which pre-assembled and pre-primed extracorporeal membrane oxygenation (ECMO) circuits are expected to be sterile. The purpose of this study is to therefore prospectively evaluate whether such pre-assembled and pre-primed circuits would maintain sterility for a period of up to 65 days.

Design: Nineteen (19) ECMO circuits (9 neonatal/pediatric ¼” and 10 adolescent/adult ⅜”) were assembled and primed under sterile conditions and maintained at room temperature. The first four circuits were sampled on day 0 when assembled and primed, and then every 5 days up to day 65; subsequent circuits were sampled on day 35 and then every 5 days up to day 65. Each sample was obtained in a sterile fashion by authorized personnel and plated within one (1) hour on several different media. These included a blood agar plate, trypticase soy agar with 5% sheep blood, MacConkey agar and thioglycollate broth. They were then incubated at 35 degrees Celsius for 3 days.

Results: There was no fungal or microbial growth detected in any of the samples from the ¼” or ⅜” ECMO circuits for the 65-day study period.

Conclusion: These pilot data suggest that pre-primed ECMO circuits may maintain sterility for a period of up to 65 days. Additional studies to evaluate a larger number of ECMO circuits are needed to confirm these findings, and to potentially further extend their longevity.
Left Ventricular Cardiac Dysfunction is Seen in the Fetus in an Ovine Diaphragmatic Hernia Model in the Extraplurine Environment for Neonatal Development

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Abstract
Background: Congenital Diaphragmatic Hernia is complicated by pulmonary hypoplasia and pulmonary hypertension. New studies show decreased left ventricular cardiac output (LVCO) after birth. However, little is known about cardiac function while fetal physiology is still in effect. Here we demonstrate that left ventricular dysfunction can be seen even during fetal development in a lamb model of severe diaphragmatic hernia.

Methods: Diaphragmatic hernias (DH) were surgically created in fetal sheep at gestational age 70-76 days. Fetuses were cesarean delivered at ~120 days gestational age, cannulated onto pumpless ECMO via the umbilical vein and arteries, and placed in the Extraplurine Environment for Neonatal Development (EXTEND): a DH group (n=5), and a Normal group (age-matched controls without DH, n=11). All groups were supported on the EXTEND system for 1-28 days (average = 15.0 days). Echocardiography was performed every 12-24 hours.

Results: The DH Animals’ RV-to-LV ratio increased to 2.08 (Std Err 0.07, 95% CI 1.93-2.22) by Day 11 of the study, while the Normal Animals’ RV-to-LV ratio remained stable at 1.39 (Std Err 0.01, 95% CI 1.33-1.45). Combined cardiac output was lower in the DH group. RVCO was equivalent in both groups; the decreased RV-to-LV ratio can be explained by a decreased LVCO. While LVCO remained constant in the Normal group, it dropped rapidly in the DH group. The LVCO drop was a result of a decreased LVSV.

Conclusion: Left ventricle dysfunction, previously seen only in neonates, exists even when fetal cardiac physiology is intact, as shown in this diaphragmatic hernia animal model.
Antithrombin III administration alters time to therapeutic anticoagulation in neonatal and pediatric patients receiving respiratory extracorporeal life support.

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Abstract

Background: Shorter time to therapeutic anticoagulation (TTAC) is associated with improved survival in patients receiving extracorporeal life support (ECLS). Exogenous antithrombin (AT3) supplementation may impact TTAC by mitigating acquired AT3 deficiency during ECLS. We hypothesized patients receiving AT3 supplementation in the first 48 hours of ECLS will have shorter TTAC than patients who did not receive AT3.

Methods: A single center retrospective chart review of neonatal and pediatric patients requiring respiratory ECLS between January 2016 through December 2018 was performed. Demographics, ECLS characteristics, coagulation profiles, fresh frozen plasma (FFP) and cryoprecipitate (cryo) receipt, and bleeding/thrombotic complications within 48 hours of ECLS initiation were compared between those with and without AT3 supplementation using Kaplan-Meier curves and log rank tests. Patients were censored 48 hours after cannulation if anticoagulation had not been achieved by that time.

Results: Twenty-six patients were included (17 neonatal and 9 pediatric). Those receiving AT3 did not have shorter TTAC, nor were there significant differences in the Anti-Xa levels, AT3 levels, or heparin drip rates at time of therapeutic anticoagulation or within 48 hours. FFP/cryo receipt and thrombotic/hemorrhagic complications did not differ between groups. Subgroup analysis of neonates revealed significantly delayed TTAC with AT3 supplementation (median 23 hrs, 95% CI 11-26 hrs) versus those without (median 11 hrs, 95% CI 8-14 hrs, p=0.03) (See Figure 2).

Conclusions: Contrary to our hypothesis, we did not demonstrate shortened TTAC with exogenous AT3 supplementation. ELSO center AT3 use varies substantially with few studies demonstrating efficacy, warranting further investigation.
Extracorporeal Life Support in Pregnancy: A Systematic Review and Meta-analysis

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Abstract

Background: The use of extracorporeal life support (ECLS) has expanded substantially in the last decade. While uncommon, it has been successfully implemented in the peripartum period. The reported maternal and fetal survival rates are higher than overall survival with adult ECLS for pulmonary or cardiac etiologies. The aim of this review is to perform a comprehensive literature search of ECLS in the peripartum period and to define the reported indications, timing, and outcomes.

Methods: OVID MEDLINE, Embase, Web of Science, and CINAHL databases were searched to capture studies regarding ECLS in the peripartum period.

Results: Overall 2,116 studies were reviewed and 228 studies met inclusion criteria with a total of 368 cases reported. The most common indications for ECLS overall in pregnancy included ARDS 185 (50.3%), cardiac failure 67 (18.2%), and cardiac arrest 57 (15.5%). The maternal survival was 279 (75.8%) and fetal survival was 168 (76%). The most common maternal complications included moderate bleeding 114 (31.0%), severe bleeding requiring surgical intervention 47 (12.8%) and vascular complications 14 (3.8%). The most commonly reported fetal complications include preterm delivery in 94 (42.5%) and NICU admission in 62 (28.1%).

Conclusions: ECLS in the peripartum period demonstrates value and reasonable safety in this population and should be considered in cases of refractory cardiopulmonary failure. Although results may be limited by publication bias, the current literature favors the implementation of ECLS in pregnant patients with severe morbidity.

Survival Characteristics of Prolonged Pediatric ECMO: ELSO Registry Review

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Abstract

Background: Little data is available for outcome with prolonged ECMO in children. The longest run in pediatric respiratory ECMO prior to 2000 was 62d, but over the last decade, there are reports of longer ECMO runs with survival and pulmonary recovery (>129d).

Methods: With acknowledgement to ELSO, all pediatric patients in the registry (1989-2017) 1-18yrs, on ECMO for pulmonary support for >14d were analyzed to identify characteristics related to survival.

Results: 24.8% of 5158 children were supported ≥14d. Average age=7.83yrs. Average weight=31.9kg. Survival=45.8%. 1989-2007 vs 2008-2017 were compared with significant differences: age, weight, race, time on, time from intubation to ECMO and pre-ECMO ventilation. Survivors vs non-survivors (2008-2017), demonstrated younger age (average 8.2vs9.2yrs), shorter duration on (median 20.4vs25.5d) and shorter duration intubation to ECMO (median 71vs77h). The entire cohort survival via mode was 48.8%VV vs 41.9%VA. Between 2-5wks support survival decreased significantly-66to36%; while >6wks survival=30-36%. Viral and unspecified pneumonia, and chemical pneumonitis/aspiration pneumonia had significantly higher survival rates.

Discussion: ECMO support at >6wks has a survival ~30-35% without discontinuation related to ECMO complications. Prolonged support is reasonable even in extreme long runs when other organ function preserved. DLV catheters make VV ECMO first consideration. Current ELSO registry data is insufficient to capture patient specific patient characteristics of survival. In addition decision to lung transplant and/or discontinuation of support is also unclear. Patient tailored management strategies to reduce organ failure, patient deconditioning and lung injury likely influence survival and require more indepth study. Thanks to ELSO.
Histopathology and Clinical Characteristics of Brain Injury in Adult Decedents after ECMO

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Abstract

Introduction: Brain pathology can significantly affect ECMO patients, but histologic phenotypes have not been well described. In this study, we explore autopsies and clinical data of adult ECMO recipients for patterns of micro- and macroscopic injury.

Methods: A retrospective chart review was conducted of adult decedents who had received any ECMO modality during the admission immediately preceding death at three US hospitals. All decedents underwent brain autopsy and specimens were reviewed by local neuropathologists. Clinical data including demographics, ECMO characteristics, lab values, and neuroimaging were analyzed for correlation with histopathologic patterns of injury.

Results: Forty-three decedents were included in the study who underwent ECMO for ARDS (33%), cardiogenic shock (33%), and cardiac arrest (34%). Subjects underwent ECMO for 330 ± 467 hours. Eighty-one percent of patients had abnormal pathology, which were most commonly perivascular microhemorrhage (37%), macrovascular hemorrhage (35%), acute infarction (30%), and hypoxic-ischemic injury (28%). Thirty-five percent (9/26) of patients had pathology on brain imaging (23 CT, 3 MRI). Patients with hypoxic-ischemic injury did not have significantly different PaCO2 or PaO2 values during ECMO compared to those without, but did have higher SOFA scores on admission. The peak PaCO2 during ECMO in patients with acute infarctions were lower than those without (49 vs. 67 mmHg, p=0.02). Patients with perivascular microhemorrhage had lower pre-ECMO hemoglobin (8.5 vs. 10.9 mg/dL, p=0.008).

Conclusion: Various forms of histopathologic brain injury exist in ECMO patients that can be missed by neuroimaging. Further study to define microscopic brain injury in ECMO patients should be conducted.

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Abstract

Background: In neonates, pulmonary hypoplasia (PH) can be associated with high mortality despite conventional medical therapy and ECMO. The purpose of this review is to provide ECMO outcome data for medical personnel who counsel families of patients with PH, often secondary to renal abnormalities. We report the diagnoses and outcomes associated with PH in neonates who were treated with ECMO over the past 35 years.

Methods: Retrospective review of the ELSO database of neonates treated with ECMO between 1981 and 2016 with a primary or secondary diagnosis of PH. Mortality trends over time were analyzed by decade. Fisher’s exact test and Cochran-Armitage Trend test were used to test for statistical significance.

Results: Of 1385 patients included for analyses, survival to discharge was 34%. Patients with congenital diaphragmatic hernia (CDH) had higher mortality than patients with PH secondary to renal dysplasia (p<0.001). For all groups combined, mortality decreased over time (p<0.001). Survival at discharge increased over time for CDH patients (p<0.001) but decreased for patients with PH secondary to renal dysplasia (p=0.012).

Conclusions: Overall, survival of neonates with PH treated with ECMO has decreased over the past 35 years. However, survival to discharge of neonates with PH secondary to renal dysplasia has decreased. The apparent rise in mortality of patients in the latter group could be due to improvements in non-ECMO medical support resulting in more critically-ill infants being treated with ECMO and/or more selective criteria regarding who should be offered ECMO.

Comparison of Outcomes in Central versus Peripheral Veno-arterial Extracorporeal Membrane Oxygenation Cannulation as a Bridge to Cardiac Transplant: An Analysis of the ELSO Registry

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Abstract

Veno-arterial Extracorporeal Membrane Oxygenation (VA-ECMO) continues to be a frequently utilized therapy to maintain organ perfusion in patients listed for cardiac transplant. This study uses the ELSO registry to compare the outcomes of central versus peripheral cannulated patients receiving VA-ECMO as a bridge to cardiac transplantation.

We queried the ELSO registry for all pre-transplant VA-ECMO patients 40 years of age or less from 2011-2017. Outcomes of interest included ECMO duration, ‘ECMO success’ defined as decannulation with expected recovery, hospital mortality, and transplant rates. Patients were assigned an acuity score based on reported pre-ECLS support. Further analysis was performed using a matched 1:1 set of central and peripheral cannulated patients based on age group, diagnosis, and total acuity score.

From 646 patients, 169 central and 344 peripheral cannulated patients were analyzed. Comparison of the central versus peripheral cannulation groups revealed median ECMO duration of 160 hours vs 162 hours, and ECMO success of 75.1% vs 78.8% respectively. 132 patients in each group were then matched which revealed median ECMO durations of 156 hours vs 191 hours, ECMO success of 74.4% vs 75.9%, and transplant rates of 19.6% vs 16.5% respectively, with none being statistically significant.

Hospital death rates between the two groups were statistically significant at 47.9% vs 36.4%. This difference disappears after matching, 47.3% vs 40.6%, with p-values of 0.01 and 0.27 respectively.

This study suggests that centrally cannulated VA-ECMO patients awaiting cardiac transplantation with similar clinical acuity are not at an increased risk of mortality compared to peripheral cannulation.
Association of Nutritional Adequacy and Extracorporeal Membrane Oxygenation Survival

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Abstract

Background: The nutritional adequacy required to influence clinical outcomes is unknown for patients undergoing extracorporeal membrane oxygenation (ECMO), with current recommendations cascaded from the critically ill population. Hence, we sought to explore if a minimum threshold of nutritional adequacy exists that suggests a relationship between nutritional adequacy and clinical outcomes for patients undergoing veno-venous ECMO (VV-ECMO).

Methods: We retrospectively collected data on consecutive VV-ECMO patients at our center from October 2012-September 2018. Nutritional adequacy was calculated for the duration of ECMO therapy. We utilized logistic regression and an optimization criterion of the minimum distance to point (0,1) on the receiver operating characteristic curve to identify an optimal threshold of nutritional adequacy to predict ECMO survival outcomes. To account for confounding, we adjusted for age, gender and APACHE III.

Results: Of 153 subjects, 113 (73.9%) survived ECMO. The nutritional adequacy with the highest discriminatory power for death on ECMO was 58%, which yielded a negative predictive value of 81.4%, positive predictive value of 41.2%, and prognostic accuracy of 68%. Even after adjustment, achieving ≥58% nutritional adequacy was associated with a 65% decreased odds of death on ECMO (odds ratio=0.35, 95% confidence interval: 0.16-0.77, p=0.0088).

Conclusion: Achieving nutritional adequacy ≥58% of prescribed nutrition was protective against death on VV-ECMO. This is lower than the 80% threshold observed amongst the overall critically ill population. Nutritional adequacy is of significant interest during ECMO therapy and further research to understand its relationship with clinical outcomes is essential to standardize guidelines for nutrition delivery during ECMO.
Elimination of the Venous Reservoir in a Pediatric Centrifugal ECMO Circuit

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Abstract

The use of a venous reservoir or bladder has been established as necessary and prudent for the use of roller head pumps in ECMO patients. In September 2013, we began using the Sorin Revolution Centrifugal pump in our pediatric (> 6kg) patient populations. The bladder remained in line as it provided additional safety as an air trap. Over the next several years we noted a new circuit component failure – a clotted cone. Between September 2013 and September 2017, there were 159 centrifugal circuits used on 132 patients with an 8% incidence of cones clotting. After a specific incident where a cone was changed out, the patient returned to bypass, and immediately the new cone clotted off, we decided that a practice change was needed. In several circuits, there were clots documented in the bladder, either as fibrin streaking or dark clots. After reviewing other center’s incidence of clotting and the low frequency of use of a bladder in centrifugal circuits, we decided to remove the bladder from our centrifugal circuits.

Since September 2017, we have had 50 patients on the new configuration with zero incidence of cone clotting. This was a successful change and has resulted in an improvement in patient care outcomes with the reduced potential for off-bypass time and potential for associated increased morbidity and mortality.

Predictors of cerebral volumes after ECMO treatment – a pilot study.

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Abstract

Acute cardiac failure requiring treatment with extracorporeal membrane oxygenation (ECMO) during intensive care is associated with multiple risk factors for structural brain injuries in long-term survivors. In this pilot study, volumetric brain segmentation was performed automatically by FreeSurfer using 3 Tesla T1-weighted MRI images from eight ECMO survivors (4 males, mean age 56 years) and 15 healthy, matched controls (4 males, mean age 48 years). The patients were treated with peripheral venoarterial ECMO at the University Hospital of North Norway (years 2013-15) for acute coronary syndromes complicated by cardiogenic shock and/or cardiac arrest. None had neurological complications registered during ECMO treatment, and were community dwelling when volunteering for this study in May 2017.

Compared to controls, ECMO survivors had significantly smaller total gray matter cerebral volumes, cortex volumes and subcortical gray matter volumes when controlling for age and total intracranial volume (eTIV) (All F’s > 5.5, all p’s < .031). There were non-significant group differences in total white and subcortical white matter volumes and hippocampal volumes. Duration of ECMO (median 9 days) was not significantly associated with cerebral volumes. Value of PaO2 (hypoxemia) prior to ECMO initiation was significantly associated with lower cortex volume, adjusted for eTIV and age in the ECMO group (B = .11, t = 2.8, p = .032). Future studies should identify significant brain alterations, its determinants and strive to correlate post-ECMO MRI markers with clinical outcomes important for long-term functioning among survivors.
2019 ELSO CONFERENCE ABSTRACTS

36 What are the causes of red cell loss during ECLS?
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Abstract
Most pediatric ECLS patients show a decline in hematocrit and require multiple RBC transfusions. To better understand RBC loss during ECLS, this study estimated RBC loss rates due to diastolic phlebotomy, bleeding, intravascular hemolysis, and extravascular hemolysis (damaged red cell removal by liver and spleen). Overall 93 ECLS runs were evaluated (age 1d-20y, 33VV, 60VA). Total RBC loss in mL RBC lost per liter of patient+circuit volume/hour was calculated from changes in hematocrit and transfused RBCs. RBC loss was calculated for patients with and without bleeding. RBC loss due to hemolysis was estimated from plasma hemoglobin and free hemoglobin half-life (~2 hours). Average RBC loss on ECLS was 2.7±2.9 mL/L/h, 19-fold higher than normal. High RBC loss (6.4±4.3 mL/L/h) had worse survival (48%) than low RBC loss (0.6±0.3 mL/L/h, survival 88%). RBC loss was 2-fold higher in patients with bleeding (3.6±3.6 mL/L/h) versus without (1.6±0.7 mL/L/h). In non-bleeding patients, intravascular hemolysis was 22% of total RBC loss and diagnostic phlebotomy 23%, suggesting that ~55% of RBC loss was due to extravascular hemolysis. RBC microvesicle generation, a measure of RBC injury/activation, was increased 7-11 fold during ECLS, indicating that sublethal RBC damage during ECLS may stimulate extravascular hemolysis. In non-bleeding ECLS patients, damaged RBC removal by extravascular hemolysis accounts for half of RBC loss with intravascular hemolysis and phlebotomy making up the remainder. Bleeding on ECLS “doubled the overall rate of RBC loss.

42 Brain Injuries and Neurodevelopmental Outcomes in Pediatric Extracorporeal Membrane Oxygenation
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Abstract
Background: Reported incidence of intracranial injuries in patients treated with Extracorporeal Membrane Oxygenation (ECMO) ranges from 15% to 35%. With increasing use of ECMO, understanding such injuries is important. The goal of this project is to describe ECMO-associated intracranial injuries and related neurodevelopmental outcomes.

Methods: We identified 189 patients managed with ECMO between 2010 and 2017 in the Pediatric ICU at Children’s Medical Center Dallas. 132 patients underwent routine post-ECMO MRI or CT imaging of the brain, as per our institutional protocol. Images were scored by a blinded neuroradiologist. 128 survivors were approached for neurodevelopmental surveys. The Pediatric Overall Performance Category Scale (POPC) and Pediatric Cerebral Performance Category Scale (PCPC) were administered in person or over the phone to a total of 104 patients; 80% of those had imaging.

Results:
14% of images reviewed had no injury. 40%, 18%, 20%, and 8% showed mild, moderate, severe, and extensive injury. 35% of injuries were hemorrhagic, 42% were ischemic, and 23% were mixed in nature. On the PCPC, 59% of respondents had normal scores; 12.5%, 17%, and 11.5% had mild, moderate, or severe disability. On the POPC, 30% of respondents had good function; 38.5%, 18%, and 13.5% had mild, moderate, or severe disability. In survivors, a correlation exists between worse injury and worse neurodevelopmental scores. Ischemic injury correlated with worse neurodevelopmental outcome.

Conclusion:
Routine post-ECMO head imaging is important for continued understanding of neurological injuries. Post-ECMO neurodevelopmental-screening should be standard practice to identify opportunities for early intervention and improve long-term outcomes.
A Leap Towards the Next Generation of Cannulation Simulators
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2hamad medical corporation, Doha, Qatar

Abstract
In extracorporeal membrane oxygenation (ECMO), cannulation is a very critical operation that requires maximum training. Therefore, one educational method is simulation-based training (SBT), allowing repetitive practice without risk and assimilation of knowledge. When the ECMO program commenced at Hamad Medical Corporation (HMC) in 2014, the team was constituted from professionals trained abroad, but due to Qatar’s 2030 vision of a more sustainable future, HMC collaborated with Qatar University to develop a local training solution with unrivaled capabilities. The current prototype of the simulator includes anatomically accurate cannulation access points as they include superficial arteries and correct blood vessel alignment, procedural emergencies of internal and external bleeding, and accurate simulation of arterial and venous simulated blood flows and pressures. The arterial flow is pulsatile and the venous flow is laminar. The simulator facilitates SBT for all ECMO modes: Venous-Arterial (VA), Veno-Venous (VV), VVA, and VAV. Further work complements the idea of interactivity with the learner as it adds a tablet application that allows the instructor to monitor the amount of bleeding that is happening, the possibility of internal bleeding specifically at the renal vein as it is in the cannula’s path and allows the instructor to trigger procedural emergencies which include seizure and tachycardia which causes the heart rhythm and oxygenation level to change based on the instructor’s request. In addition, more sensors are being added to assess learners’ skills more accurately. As discussed, the future work will be a game-changer for the future of cannulation simulators.

Rescue Extracorporeal Membrane Oxygenation (ECMO) for Acute Multi-Organ Failure in a Patient with Newly Diagnosed Acute Myeloid Leukemia
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Abstract
Case Presentation: 4 months old male with history of poor weight gain and laryngotracheomalacia presented with 1 day of difficulty breathing as well as fever. Patient was diagnosed with acute myeloid leukemia with hyperleukocytosis and admitted to PICU. Initial vitals: HR 153/min, RR 42/min, Saturation 98% on room air. Initial Labs: WBC 186, Hb 6.4, Platelets 15 with BUN 32, Creatinine 1.3, Uric acid 13.8. Imaging showed right upper pneumonia and hepatosplenomegaly. After initiation of chemotherapy, he was intubated with worsening respiratory difficulty, renal failure and fluid overload. Due to worsening acute respiratory distress syndrome (ARDS), he was placed on high frequency oscillator. ECMO was promptly established using veno-venous method with dialysis on hospital day-3. Patient was successfully weaned off ECMO on hospital day-6 and was off ventilator and dialysis by hospital day-14. Patient got discharged home on hospital day-30.

Discussion: Occurrence of ARDS in patients with hematologic malignancies is associated with significant morbidity and mortality. In patients with leukemia, leukemic cell pulmonary infiltration and respiratory failure remains major cause of death. This case was further complicated by kidney failure and fluid overload, needing escalation of mechanical ventilator support. There have been sporadic reports of ECMO use in hematologic malignancy with ARDS and/or septic shock with overall poor outcomes. Our patient with AML, acute respiratory and renal failure, fluid overload had a positive outcome on VV-ECMO. To our knowledge, this is the first case of AML in a young infant with multi-organ failure with a favorable outcome on VV-ECMO.
Improving the Efficiency of eCPR: Iterative Refinement of the Deployment Through Simulation, and Multi-Media Peer Review

Abiodun Orija1, Josh Caballero1, Erin August2, Martinus Dyrud3, Moses Washington4, Shelly Miller5, Joaquin Crespo1, Lance Cohen1, Enrique Gongora2, I-wen Wang3; 1Memorial Cardiovascular Institute, Memorial Regional Hospital, Hollywood, USA; 2University Hospital, University of Alabama, Birmingham, USA

Abstract

Performing eCPR is often a chaotic endeavour. Our early experience with eCPR demonstrated the need for better organisation and process. To this end we implemented a 3-pronged strategy:

1. Ongoing re-organization of eCPR supplies into a mobile unit with requisite equipment stored in numerical sequence of deployment
2. Implementation of monthly, recorded E-CPR drills involving CVICU, OR and ED staff
3. Video guided peer review and feedback

The initial step of organizational improvement entailed systematic compartmentalisation of necessary ECMO supplies into a mobile cart. Subsequent key step is organisation of supplies into numerical sequenced bins for logical deployment. Ongoing evaluations streamline the cart contents. The eCPR drills consisted of team members with assigned roles and made use of a ACLS mannequin modified with tubing and ballistic gel to simulate tissue and vasculature. Each drill session was recorded with the use portable and in-room eICU cameras. Following each session, the recorded videos are reviewed with all members of the ECMO service with minutes taken for specific process improvement. Recorded materials are stored and readily available for education and review.

We have performed 27 eCPR at our facility of which 15 were after the initiation of the above strategies. Subjective feedback from the team members show an increased level of confidence in their abilities to effectively perform eCPR. In the most recent 2 consecutive drills, the start of vascular access to ECMO support was decrease from 23 minutes to 20 minutes, well below the initial set of goal 30 minutes.

Supporting a Single Lung; First Successful VV ECMO Support for ARDS in A Patient with Remote History of Pneumonectomy

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Abstract

While VV-ECMO has been described in the peri-operative setting of post-pneumonectomy patients, there are no reported cases of successful VV-ECMO rescue of ARDS in a patient with remote pneumonectomy. A 60 year-old male with history of right pneumonectomy six years ago for complications following repair of Bochdalek diaphragmatic hernia presented to our satellite hospital’s emergency department with 3 days of progressive dyspnea and occasional cough. He was evaluated in rapid succession by emergency room then critical care physicians for hypoxemia. He progressed to intubation within 3 hours of arrival. Despite maximal ventilator support, he remained profoundly hypoxic. He was cannulated urgently at 9 hours following presentation and placed on VV ECMO with a 21Fr right internal jugular venous cannula and 23/25Fr right femoral venous cannula. He was then transferred on ECMO to the main hospital for further management. He was extubated on ECMO Day 3 and began ambulation on bicaval VV-ECMO. He was allowed to develop permissive hypercapnia (PCO2 55-60, normal pH) in order to generate autonomic respiratory drive. He was then decannulated at bedside on Day 9 of ECMO support and discharged from the hospital on 3 weeks later without oxygen. No cause of ARDS was found.

There are no case reports of successful VV-ECMO support in patients with pneumonectomy in remote past. Given the lack of pulmonary reserve, ARDS in this patient population progress devastatingly fast, requiring rapid clinical decision and implementation of VV-ECMO to achieve successful outcomes.
Beyond Frontiers: Prolonged Veno Venous Extracorporeal Life Support (VV ECMO) in Sever ARDS as a Bridge to Native Lung Recovery, Feasibility and Outcome.


Abstract

Objectives: ECMO frontiers remain for long time a standard care for infants and children since 1990 and for adults since 2009, the major changes in the technology occurred in 2008 with entire ECMO systems, give a chance to push this frontiers to new ECMO frontiers (ECPR, ECMO and transplant ....ect. Dr.Bartlett has insight of ECMO future next ten years, a significant fraction of patients will be on ECMO for a month or more awaiting lung recovery, we consider it beyond ECMO frontiers. we will try to answer question of feasibility and efficacy of prolonged ECMO, highlighting the emerging concept of possible late lung recovery.

Material and Method: Single center, retrospective review of patients with prolonged ECMO for 21 days or more (pECMO) and short term ECMO runs for less than 21 days (sECMO) between January 2018 to June 2019. outcome, demographic, pre ECMO patients condition, comorbidity and other ECMO indices were assessed.

Results: 43 patients identified, 23 patients for (sECMO) and 20 for (pECMO), 6 patients excluded still on pECMO, no significant difference between survival in both groups for hospital discharge however, survival was favour sECMO group, 19 patients in sECMO group discharged out of hospital (83%) and 10 patients in pECMO group (70%).

Conclusion: prolonged ECMO is feasible with favourable outcome providing expert ECMO management in high volume centers, previous concept to quit ECMO and futility based on ECMO days with definition of irreversible lung injury should be revised, more studies required to properly evaluate prolonged ECMO and futility.

Evaluation of centrifugal blood pumps in terms of hemodynamic performance using simulated neonatal and pediatric ECMO circuits

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Abstract

The objective of this translational study was to evaluate the PediMag, CentriMag, and RotaFlow centrifugal pumps in terms of hemodynamic performance using simulated neonatal and pediatric ECMO circuits with different sizes of arterial and venous cannulae. Cost of disposable pump heads was another important variable. The experimental circuit was composed of one of the centrifugal pump heads, a polymethylpentene membrane oxygenator, neonatal and pediatric arterial/venous cannulae, and 1/4-inch ID tubing. Circuits were primed with lactated Ringer’s solution and packed human red blood cells (hematocrit 35%). Trials were conducted at 36°C using the three pump heads and different cannulae (arterial/venous cannulae: 8 Fr/18 Fr, 10 Fr/20 Fr, and 12 Fr/22 Fr) at various flow rates (200–2400 mL/min, 200 mL/min increments) and rotational speeds. The RotaFlow pump had a higher pressure head and flow range compared with the PediMag and CentriMag pumps at the same rotational speed and identical experimental settings (P < 0.001). The arterial cannula had the highest pressure drop and hemodynamic energy loss in the circuit when compared to the oxygenator and arterial tubing. The RotaFlow centrifugal pump had a significantly better hemodynamic performance when compared to the PediMag and CentriMag pumps at identical experimental conditions in simulated neonatal and pediatric ECMO settings. In addition, the cost of the RotaFlow pump head ($400) is 20 to 30-fold less than the other centrifugal pumps [CentriMag ($12 000) or PediMag ($8000)] that were evaluated in this translational study.
Impact of cannula size and line length on venous line pressure in pediatric VA-/VV-ECLS circuits.

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Abstract
The objective of this study was to do an in vitro evaluation of venous line pressure using different venous line lengths and venous cannula sizes in pediatric venoarterial extracorporeal life support (VA-ECLS) and venovenous ECLS (VV-ECLS) circuits.

The pediatric VA-ECLS circuit consisted of a Xenios i-cor diagonal pump, a Maquet Quadrox-i pediatric oxygenator, a Medtronic Biomedicus arterial cannula, a Biomedicus venous cannula, and 1/4″ ID arterial and venous tubing. The pediatric VV-ECLS circuit was similar, except it included a Maquet Avalon ELITE bi-caval dual lumen cannula. Circuits were primed with lactated Ringer’s solution and packed red blood cells (hematocrit 40%). Trials were conducted at various flow rates (VA-ECLS: 250-1250 mL/min, VV-ECLS: 250-2000 mL/min) using different venous tubing lengths (2, 4, and 6 feet) and cannula sizes (VA-ECLS: A8Fr/V10Fr, A10Fr/V12Fr and A12Fr/V14Fr, VV-ECLS: 13Fr, 16Fr, 19Fr, 20Fr and 23Fr) at 36°C. Real-time pressure and flow data were recorded for analysis.

The use of a small-caliber venous cannula significantly increased the venous line pressure in the 2 pediatric circuits (P < 0.01). Shorter venous tubing lengths significantly reduced the venous line pressure at high flow rates (P < 0.01). The inflow side of Avalon dual lumen cannula had a significantly higher pressure drop than the outflow side (p < 0.001). Medtronic femoral arterial cannulas had lower pressure drops and hemodynamic energy losses at high flow rates when compared with the Maquet cannulae (p<0.01).

The results for this study provided valuable hemodynamic characteristics of all evaluated adult cannulas with human blood in order to guide ECLS cannula selection in clinical practice.
Impact of Different Perfusion Modalities on Coronary and Carotid Blood Flow Velocities for Partial Support in an Adult ECLS Swine Model
Akif Undar, Shigang Wang, Sunil Patel, Jenelle Izer, J. Brian Clark, Allen Kunselman, Ronald Wilson; Penn State College of Medicine, Penn State Health Children’s Hospital, Hershey, Hershey, PA, USA

Abstract
The objective of this study was to compare the effects of nonpulsatile and ECG-synchronized pulsatile extracorporeal life support on coronary and carotid blood flow velocities using transthoracic echocardiography and vascular ultrasound, respectively.

Nine adult swine were randomly separated into nonpulsatile (NP, n=5) and pulsatile (P, N=4) groups and placed on ECLS for 24 h using an i-cor-ECLS system. Noninvasive transthoracic images of the left and right coronary artery and the left carotid artery were acquired at the pre-ECLS (baseline), 30 min, 3-, 6-, 9-, 12-, and 24 h on-ECLS stages.

The mean diastolic velocity of the left and right coronary arteries in the NP group significantly decreased after 24 h on ECLS compared to the baseline and 30 min ECLS stages (P<0.05). There was no statistical difference in the mean diastolic velocity of the coronary arteries in the P group at 30 min, 3-, 6-, 9-, 12-, and 24 h on-ECLS compared to baseline. The P group showed a smaller decrease in the mean diastolic velocity of coronary arteries between the 30-min ECLS and 3-, 6-, 9-, 13-, 24-h ECLS stages compared to the NP group. The diastolic velocity of the left carotid artery in the NP group significantly decreased during 24-h ECLS compared to the P group (P<0.05). The flow rate of perfusion pumps was only 2.6 L/min for “partial” support.

An ECG-synchronized pulsatile ECLS system with partial support appeared to maintain coronary and carotid artery diastolic velocities better than conventional nonpulsatile ECLS. Further investigation of the perfusion modes during ECLS is warranted.

Effects of Pulsatile Control Algorithms for Diagonal Pump on Hemodynamic Performance in simulated pediatric and adult ECLS systems
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Abstract
The objective of this study is to compare hemodynamic performances under different pulsatile control algorithms between Medos DeltaStream DP3 and i-cor diagonal pumps in simulated pediatric and adult ECLS systems.

The experimental circuit consisted of parallel combined pediatric and adult ECLS circuits using an i-cor-pump head and either an i-cor console or Medos console, a Medos Hilite 2400LT oxygenator for the pediatric ECLS circuit, and a Medos Hilite 7000LT oxygenator for the adult ECLS circuit. The circuit was primed with lactated Ringer’s solution and human packed red blood cells (hematocrit 40%). Trials were conducted at various flow rates (pediatric circuit: 0.5 and 1 L/min; adult circuit: 2 and 4 L/min) under nonpulsatile and pulsatile modes (pulsatile amplitude: 1000–5000rpm [1000 rpm increments] for i-cor pump, 500–2500rpm [500 rpm increments] for Medos-DP3 pump) at 36°C.

Under pulsatile mode, energy equivalent pressures were always greater than mean pressures for the two systems. Total hemodynamic energy and surplus hemodynamic energy levels delivered to the patient increased with increasing pulsatile amplitude and decreased with increasing flow rate. The i-cor pump outperformed at low flow rates, but the Medos pump performed superiorly at high flow rates. There was no significant difference between two pumps in percentage of energy loss.

Pulsatile control algorithms of Medos and i-cor consoles had great effects on pulsatility. Although high pulsatile amplitudes delivered higher levels of hemodynamic energy to the patient, the high rotational speeds increased the risk of hemolysis. Further optimized pulsatile control algorithms are needed.
Impact of perfusion modalities on hemolysis during 12h-ECLS: A Pilot Study
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Abstract
The objective of this pilot study was to determine plasma free hemoglobin (pfHb), and lactate dehydrogenase (LDH) levels under non-pulsatile and pulsatile modes using the two pump systems in simulated-adult-ECLS-circuits. Eight ECLS circuits were divided into four groups: Medos-DP3 under nonpulsatile mode at flow rate 4 L/min (DP3-NP-4L, n=2), Medos-DP3 under pulsatile mode with pulsatile amplitude 1500rpm at 4 L/min (DP3-P-4L, n=2), Medos DP3 under pulsatile mode with pulsatile amplitude 1500rpm at 3 L/min (DP3-P-3L, n=2), i-cor pump under pulsatile mode with pulsatile amplitude 3500rpm at 2.5 L/min (i-corP-2.5L, n=2). All trials were conducted for 12h at a blood temperature of 36°C for the Medos circuit and room temperature for the i-cor circuit as the i-cor system lacks an integrated heat exchanger for the ILA membrane ventilator using fresh human blood. Blood samples were collected after priming and after every 3h for 12h.

The pfHb levels in all groups increased at the end of 12h-ECLS. The Medos pulsatile group at 4 L/min had maximum pfHb value, and the nonpulsatile group had minimum pfHb value at 12h-ECLS. The i-cor pulsatile group at 2.5 L/min had a lower pfHb value compared to the Medos-DP3 pulsatile group at 3 L/min. LDH levels had similar trends as pfHb levels in the Medos nonpulsatile and pulsatile groups. The 12h-LDH level in the i-cor pulsatile group was lower than the other three groups.

High flow rates with high rotational speeds, especially under pulsatile mode, may lead to more hemolysis.

Hemolysis Influence on Iron Dynamics During Pediatric Extracorporeal Life Support (ECLS): An Observational Study
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Abstract
Increased ferritin levels have been found in pediatric ECLS patients. Elevated ferritin may represent iron overload which can be toxic to solid organs. Diagnosis of iron overload is challenging as serum markers are elevated in the setting of acute inflammation. Recognizing the source and the degree of iron overload is important in that it may influence management during ECLS and may need to be addressed therapeutically.

This ongoing pilot study aims to describe dynamic changes in iron in pediatric patients during ECLS. We hypothesize that hemolysis correlates with iron changes during ECLS.

Ferritin and plasma free hemoglobin were the primary biomarkers evaluated. To understand the role of ferritin as an acute phase reactant, serum iron, TIBC, zinc protoporphyrin/heme ratio, LDH and haptoglobin were also evaluated. All variables were serially measured and prospectively collected.

We describe 6 cases of pediatric ECLS respiratory support of varying indication, age, and duration. Case descriptions including pre-ECLS acuity, cumulative transfusion, and circuit event history were compared to the changes in obtained biomarkers. All patients had an abnormally elevated ferritin throughout the duration of ECLS and after decannulation. Severe hemolysis was observed in 3 patients, appearing to correlate with acute elevations in serum iron but not with acute changes in ferritin. These patients also had the highest ferritin after decannulation, the longest duration of ECLS and cumulative transfusions above 100mL/kg.

Based on early observations, pediatric patients may be exposed to toxic levels of iron during ECLS. Further investigation is warranted regarding toxicity and organ deposition.
Pediatric arterial femoral cannulations for extracorporeal membrane oxygenation: Does size really matter?
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Abstract

Background
No studies exist comparing various femoral artery cannula sizes in children on ECMO. We hypothesize that smaller arterial cannulas can provide adequate flow in children while decreasing vascular complications.

Methods
A retrospective review of the ELSO database was performed from 2012-2017. Children undergoing femoral VA ECMO between ages 5 and 18 and weighing greater than 20kg were included. Patients were classified into 4 arterial cannula groups: 14-15Fr, 16-17Fr, 18-19Fr and 20-24Fr. Comparison of flow, bleeding complications, limb ischemia, and death were compared by cannula size. Multivariate logistic regression was performed for cannula size on outcomes.

Results
A total of 570 patients were included with 31.0% 14-15Fr cannulas, 32.6% 16-17Fr, 21.6% 18-19Fr, and 14.7% 20-24Fr. The 14-15Fr cannulas were associated with younger age and smaller weight (p<0.01). There was no difference in hours on ECMO, use of distal reperfusion, or percutaneous placement. The median flow for 14-15Fr was 62.5 cc/kg/min with no statistically significant difference found in other sizes (p=0.27). Complications occurred in 248 (43.5%), with 165 (28.9%) bleeding, 46 (8.1%) limb ischemia, and death were compared by cannula size. Multivariate logistic regression was performed for cannula size on outcomes.

Conclusion
Review of the ELSO database demonstrates that the use of smaller arterial cannulas regardless of age or size provides similar hemodynamic support with fewer overall complications.

Central Venoarterial Extracorporeal Life Support in Pediatric Refractory Septic Shock: A Single Center Experience
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Abstract

Objectives: Central venoarterial (VA)ECMO has been adopted by some institutions to support pediatric patients with refractory septic shock. The rationale is that central cannulation (CC) offers the potential advantage of significantly higher flows and oxygen delivery than peripheral cannulation (PC). We adopted this practice in 2011, and present our experience and outcomes with CC for pediatric septic shock and to compare these with PC.

Design: Retrospective case series.

Setting: Pediatric and cardiac ICUs in an academic pediatric hospital.

Methods: All patients 0-18 years old meeting criteria of refractory septic shock and placed on VA ECMO between 2011-2018. We collected demographics, clinical and ECMO variables, survival to decannulation and discharge, and change in functional status score (FSS).

Results: Thirteen children with septic shock were placed on VA ECMO; 8 centrally, 5 peripherally. Survival to decannulation was 75% and 40% for CC and PC respectively (p=0.29) and survival to discharge was 62.5% and 40% (p=0.59) Median ICU length of stay in survivors was 17 days (19 CC vs 17 PC, p=0.88), with a median ECMO duration of 148.1 hours (149.9 CC vs 77.8 CC, p=0.27). The median initial flow was 107.7 ml/kg/min (131 CC vs 86.3 PC, p=0.12). While the PC had higher baseline FSS pre-ECMO, all survivors had a mean increase in FSS at hospital discharge.

Conclusion: While ECMO for pediatric refractory septic shock remains controversial, a central approach to VA ECMO cannulation is feasible and has potential for good outcomes.
Veno-Venous Extracorporeal Life Support for the Successful Treatment of Severe Acute Respiratory Syndrome from E-Cigarette Use

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Abstract

The use of e-cigarettes is increasing across the United States, specifically among young adults. Despite public opinion that such products are generally safe, there is significant concern that e-cigarettes could be equally harmful to the lungs as smoking tobacco. The pathologic effects of e-cigarette use remains unclear. A single previous case report illustrates how residual chemical injury from e-cigarette usage can cause respiratory failure; however, the exact pathology hypothesized to result from e-cigarettes is not known.

We present two cases successfully using veno-venous extracorporeal life support (ECLS) in the treatment of presumed e-cigarette induced respiratory failure. A 42 year-old female and a 56 year-old male, both with a recent past medical history of non-specific respiratory symptoms, independently presented to the emergency department for ongoing dyspnea despite receiving outpatient antibiotic treatment for presumed community acquired pneumonia. Both patients underwent extensive in-hospital workup to rule-out infectious causes. Broncho-alveolar lavage revealed lymphocytosis and diffusive alveolar disease with no specific etiology. Upon hospital admission, both patients progressively developed severe acute respiratory distress syndrome and refractory hypoxemia requiring venous-venous extracorporeal membranous oxygenation (ECMO). Due to the idiopathic nature of both patients’ respiratory failure, we presume that their respiratory symptoms were likely due to recent recreational e-cigarette usage, which was confirmed with the patients’ family. Both patients were successfully weaned and decannulated from ECLS.

Argatroban use for clot resolution in a pediatric patient with massive pulmonary embolism requiring VA ECMO

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Abstract

A 3.5 year old female with a large head and neck lymphangioma, necessitating tracheostomy placement at one week of age, underwent a debulking procedure at an outside hospital. On post-operative day #2, she experienced a massive pulmonary embolism (PE) which resulted in cardiac arrest. She was resuscitated and was transported to our facility for ECMO evaluation due to persistently unstable hemodynamics. She was placed on VA ECMO via central cannulation as her large lymphangioma obscured neck vasculature. After several days on ECMO, left ventricular function had returned to normal but the patient continued to have severely depressed right ventricular function. In addition, she developed refractory thrombocytopenia and subtherapeutic anticoagulation on heparin infusion. Due to concerns for heparin induced thrombocytopenia and clot propagation on heparin infusion, the patient was transitioned to argatroban. Within 6 hours the patient had met appropriate anticoagulation parameters. The next day the patient had improved right ventricular function via echo and on ECMO day 14, 48 hours after argatroban was initiated, she was successfully decannulated. The patient made a full physical and neurologic recovery and was discharged on subcutaneous fondaparinux therapy. Massive pulmonary embolism in pediatric patients is rare, and our patient’s marked improvement shortly after initiating a direct thrombin inhibitor (DTI) raises equipoise in the treatment of such. In addition, as DTIs are emerging as a potential initial anticoagulation strategy for ECMO patients, further studies should be done to determine if they should be considered first-line anticoagulants in the setting of massive PE.
Predictors of Neurologic Recovery in Patients who undergo Extracorporeal Membrane Oxygenation for Refractory Cardiac Arrest
Andrea Axtell, Masaki Funamoto, Alex Legassey, Philicia Moonsamy, Kenneth Shelton, David D’Alessandro, Mauricio Villavicencio, Thoralf Sundt, Gaston Cudemus; Massachusetts General Hospital, Boston, USA

Abstract
Objective: The use of Extracorporeal Membrane Oxygenation as a rescue strategy during cardiopulmonary resuscitation (ECPR) is increasingly being used for non-responders to conventional CPR. To identify patients most likely to benefit from ECPR, we investigated predictors of hospital discharge with good neurologic function.

Methods: A retrospective cohort analysis was performed on adult patients who underwent ECPR between 01/2009-01/2019. Baseline characteristics and post-ECMO outcomes were compared between patients who had good versus poor neurologic function at discharge. Good neurologic function was defined as a cerebral performance category (CPC) 1-2, whereas poor neurologic function was defined as a CPC 3-5.

Results: Of 54 patients who underwent ECPR, 13 (24%) were discharged with good neurologic function and 41 (76%) had poor neurologic function (n=38 in-hospital deaths; n=3 discharged with severe disability.) Survivors with good neurologic function were younger (41 vs 61 years, p=0.03), more likely to arrest due to pulmonary embolism (46% vs 10%, p=0.01), and more likely to receive concurrent impella placement while on ECMO (38% vs 12%, p=0.03.) Young age was the most important predictor of good neurologic function (OR 0.92 [0.87-0.97], p=0.004) with a threshold for improved survival around 60 years. For all patients, survival to discharge was 30%; however, among survivors with good neurologic function, five-year survival was 100%.

Conclusion: ECPR is associated with high rates of neurologic morbidity and mortality. However, in select patients, it may be an acceptable option with favorable long-term survival. Additional studies are indicated to further define appropriate selection criteria for ECPR implementation.

Blood Flow Rate Influences Cell-based Coagulopathy During Simulated Neonatal Extracorporeal Circulation.
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Abstract
Thrombosis formation is common during neonatal extracorporeal life support (ECLS). ECLS role in generating pro-thrombotic platelets, leukocytes, and micron-sized extracellular vesicles (EVs) is not well understood. The cell-based model of coagulation proposes that expression of cellular receptors for coagulation proteins regulates thrombin generation. Our objective was to test the effect of blood flow rate on the generation of prothrombotic cells and EVs in a simulated neonatal ECLS circuit using heparinized human whole blood. Samples were collected over six hours from a roller pump circuit circulating at either the minimum, nominal, or maximum FDA approved blood flow (0.3, 0.5, or 0.7 L/min). Thromboelastography (TEG), STA®-Procoag-PPL, and calibrated automated thrombogram were used to assess coagulopathy. Expression of phosphatidylserine and tissue factor on platelets, leukocytes, and EV were measured with high-resolution flow cytometry. Despite heparinization, occlusive thrombosis halted flow in two out of five circuits at 0.3 L/min and three out of five circuits at 0.7 L/min. None of the five circuits at 0.5 L/min exhibited occlusive thrombus formation in two out of five circuits at 0.3 L/min and three out of five circuits at 0.7 L/min. None of the five circuits at 0.5 L/min exhibited occlusive thrombosis. Expression of phosphatidylserine (PS)-positive platelets and EVs increased at all flow rates more than blood under static conditions (p<0.0002). Tissue factor (TF)-positive leukocytes and EVs increased in simulated ECLS only at the minimum and maximum flow (p<0.0001). Tissue factor pathway inhibitor (TFPI), at fifty times more than the concentration in healthy adults, failed to suppress clot time at a minimum and maximum flow. Interventions to decrease ECLS generated tissue factor may be an effective approach to decrease clot formation in ECLS circuits.
Inadvertent IVC Filter Removal During ECMO Decannulation: A Case Report
Andrew Vasylyuk, Narra Reddy, Kathleen Swartz, Mario Villalba, Jimmi Mangla, Anthony Iacco, Felicia Ivascu, Beaumont, Royal Oak, USA

Abstract
The patient is a 57 year old woman who had a prior history of stroke, atrial fibrillation, prior DVTs and known patent foramen ovale with a history of a retrievable IVC filter placed four months prior to presentation. She was placed on veno-venous ECMO (VV) for ARDS secondary to multifocal Pseudomonas aeruginosa pneumonia. She was cannulated via a right internal jugular 31 French Avalon dual-lumen cannula (Getinge AB, Gothenburg, Sweden). She spent a total of 78 days on ECMO. Her ECMO course was complicated by numerous pneumothoraces requiring tube thoracostomies, one of which resulted in a massive left hemothorax requiring bedside thoracotomy and ligation of a lacerated intercostal artery on ECMO day 18. She was on multiple courses of broad spectrum antibiotics for multiple drug resistant isolates of Pseudomonas aeruginosa from her blood and sputum. A cannula infection was suspected when she developed a high grade Pseudomonas bacteremia which would not clear with antibiotics, and she was therefore decannulated urgently on ECMO day 78. During decannulation it was noted that her IVC filter had lodged into one of the inferior drainage holes of the cannula and came out intact with the cannula tip. There were no identifiable complications at her cannula site or elsewhere related to this. She was subsequently weaned from mechanical ventilation 25 days after decannulation. She was evaluated by her cardiologist and we elected not to replace her IVC filter. She was discharged to an LTACH on hospital day 125.

TBX4 Mutation in Neonate with Idiopathic Pulmonary Hypertension Requiring ECMO
Annie Chi, Rekha Hamilton, Chanda Simpson, Jill Pittman, Cook Children’s Medical Center, Fort Worth, USA

Abstract
Term infant delivered via C/S with respiratory distress at birth. Placed on CPAP in the delivery room requiring 100% FiO2. Infant intubated and placed on mechanical ventilation and surfactant given. ECHO soon after birth showed normal cardiac anatomy, supra-systemic pulmonary pressures. iNO 20ppm started with improvement in saturations. However FiO2 remained >80% and follow-up ECHO showed continued suprasystemic pulmonary pressures while on iNO. Milrinone and IV sildenafil started for additional pulmonary vasodilatation. Infant improved gradually over several days and FiO2 weaned to <50%. On DOL #12 infant with worsen oxygenation and ventilation despite HFOV and maximal medical management with antibiotics, and she was therefore decannulated urgently on ECMO day 78. During decannulation it was noted that her IVC filter had lodged into one of the inferior drainage holes of the cannula and came out intact with the cannula tip. There were no identifiable complications at her cannula site or elsewhere related to this. She was subsequently weaned from mechanical ventilation 25 days after decannulation. She was evaluated by her cardiologist and we elected not to replace her IVC filter. She was discharged to an LTACH on hospital day 125.

Evaluation of Thrombocytopenia in patients receiving Continuous Renal Replacement therapy (CRRT) on Extracorporeal Membrane Oxygenation (ECMO): A pilot study
Archana V.Dhar MD, Stacey Scott CPNP; Kimberly Sautlers CPNP; Xilong Li; Beverly Huet; Lakshmi Raman MD; Archana Dhar; UT Southwestern, Dallas, USA

Abstract
Background: Thrombocytopenia is a well-known complication of CRRT. However, in ECMO patients, does the modality of ECMO chosen impact thrombocytopenia and the need for platelet transfusions?
Hypothesis: Patients on ECMO while undergoing SCUF (Slow Continuous Ultrafiltration) will have less thrombocytopenia and less need for platelet transfusions than those undergoing CVVH (Continuous Veno Venous Hemofiltration).
Methods: We reviewed patients <15 kg on ECMO, who required either SCUF or CVVH. Utilizing retrospective chart review, we analyzed parameters including renal indices, fluid balance, platelet counts and heparin usage in these patients. Our objective was to evaluate the degree of thrombocytopenia and the need for platelet transfusions in these patients.
Results: Between 2013 and 2018, 134 children <15 kg were placed on ECMO. Of these, 20 patients underwent SCUF and 36 patients underwent CVVH. Thrombocytopenia was more pronounced in the CVVH group (mean: 70,000) vs. the SCUF group. p <0.07. The CVVH cohort required more platelet transfusions (26 ml/kg) vs. the SCUF cohort (9ml/kg), p <0.001. We also noted a higher plasma free value in the CRRT (p <0.05), indicative of increased incidence of hemolysis in this cohort.
Conclusion: Our pilot study indicates that SCUF is safer than CVVH in patients <15 kg on ECMO with less evidence of thrombocytopenia, need for platelet transfusions and hemolysis. However, further multi-center studies are needed to confirm these findings.

A National Survey of Extracorporeal Membrane Oxygenation Proceduralist Specialty Background
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Abstract
Extracorporeal Membrane Oxygenation (ECMO) cannulation was historically performed only by cardiothoracic (CT) surgeons. With growing use, ECMO teams are becoming interdisciplinary, with cannulations being performed by individuals with different training experience. Little is known of the training backgrounds of those performing ECMO cannulations. To obtain this data, a survey was distributed to US adult ECMO programs. A 15 question survey was electronically distributed to all programs in the United States via email and newsletter. Incomplete responses were excluded if <25% complete. Duplicate data was reconciled and merged. Programs were analyzed if their staff performed any adult ECMO service. Pediatric only programs were excluded. Descriptive statistics were run on available data. 88 unique entries met inclusion criteria. The majority of programs self-identified as academic centers (55%) in urban settings (73%). Institutions reported that the training background of cannulating physicians included CT surgeons and other specialties including renal indices, fluid balance, platelet counts and heparin usage in these patients. Our objective was to evaluate the degree of thrombocytopenia and the need for platelet transfusions in these patients.
Results: Between 2013 and 2018, 134 children <15 kg were placed on ECMO. Of these, 20 patients underwent SCUF and 36 patients underwent CVVH. Thrombocytopenia was more pronounced in the CVVH group (mean: 70,000) vs. the SCUF group. p <0.07. The CVVH cohort required more platelet transfusions (26 ml/kg) vs. the SCUF cohort (9ml/kg), p <0.001. We also noted a higher plasma free value in the CRRT (p <0.03), indicative of increased incidence of hemolysis in this cohort.
Conclusion: Our pilot study indicates that SCUF is safer than CVVH in patients <15 kg on ECMO with less evidence of thrombocytopenia, need for platelet transfusions and hemolysis. However, further multi-center studies are needed to confirm these findings.
Implementation and evaluation of an extracorporeal membrane oxygenation curriculum for ECMO-naive critical care nurses

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Abstract

Background: Despite the growing use of extracorporeal membrane oxygenation (ECMO) into intensive care units (ICU), there are no standardized ECMO training pathways for ICU nurses naive to ECMO.

Objectives: To execute and evaluate an ECMO curriculum for ICU nurses that may be reproducible across institutions.

Methods: An ECMO curriculum was designed for ICU nurses consisting of a basic safety course and an advanced user course. Each course incorporated didactic and simulation components, written knowledge examinations, and electronic modules. Overall and ICU group differences in pre- and post-course scores were analyzed using Student’s t-tests or nonparametric equality-of-medians tests. Differences in post-course scores across ICU groups were examined using multiple linear regression.

Results: ICU nurses naive to ECMO (n=301) participated in the basic safety course from a variety of ICUs; 107 nurses also participated in the advanced user course. Written knowledge examination scores improved from pre-course to post-course in both courses for overall cohorts (p<0.001 in all analyses). The median (IQR) individual pre-course to post-course score improvements for the basic safety course and advanced user course were 23.15% (15.4-38.5%) and 8.4% (0-16.7%) respectively. Post-course written knowledge examination scores differed only among the neurovascular ICU when compared to the medical ICU/cardiovascular ICU group (percent score difference: -3.0, 95% CI -5.3 to -0.77 p=0.01) for the basic safety course.

Conclusions: Implementation of an ECMO curriculum for a high volume of critical care nurses is feasible, effective, and may be reproducible across ICUs and institutions.

Revision of ECMO management strategies in patients with carnitidine cycle disorders

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Abstract

Methods

Revision of ECMO management strategies in patients with metabolic disorders such as carnitidine cycle disorders such as carnitidine palmityltransferase type 2 deficiency (CPT2D). Carnitidine palmityltransferase type 2 deficiency is a fatty acid oxidation disorder. Some of these disorders present in infancy. However, others can present later in life and present with attacks of rhabdomyolysis. Dietary management in these patients with longchain fatty acid oxidation disorders is crucial and can be treated with diet rich in carbohydrates and low in longchain fats. We present a 34 year old patient with hx of carnitidine palmityltransferase type 2 deficiency who presented with cardiac arrest/rhabdomyolysis and acute respiratory failure as well as acute kidney injury and adenovirus pneumonia. Patient had to be placed on veno-venous ECMO support as well as CRRT. Sedation was challenging in this patient due to inability to use propofol which is not recommended in patients with carnitidine deficiency syndromes.

Results

Carnitine deficiency is a rare metabolic myopathy. We present a 34 year old patient with hx of carnitidine palmitoyltransferase type 2 deficiency who presented with cardiac arrest/rhabdomyolysis, acute respiratory failure, AKI, adenovirus pneumonia. Patient had to be placed on veno-venous ECMO and CRRT. Sedation was challenging in this patient due to inability to use propofol which is not recommended in patients with carnitidine deficiency syndromes.

Conclusion

This is a rare case review of patient with carnitidine cycle disorder which was carnitidine palmitoyltransferase type 2 deficiency (CPT2D).
Use of the Extrauterine Environment for Neonatal Development (EXTEND) to Support Severe Diaphragmatic Hernia via the Umbilical Artery and Umbilical Vein

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Abstract

Introduction: The Extrauterine Environment for Neonatal Development (EXTEND) system was developed to physiologically support the extreme premature infant. We sought to demonstrate its applicability as an ex vivo platform for the support of the congenital diaphragmatic hernia infant, a common congenital anomaly that affects 1 in 2000 infants.

Methods: Diaphragmatic hernias (DH) were surgically created in fetal sheep at gestational age 70-76 days. Fetuses were cesarean delivered at ~120 days gestational age, cannulated via the umbilical vein and arteries, and placed in the Extrauterine Environment for Neonatal Development (EXTEND). There were two experimental groups supported by EXTEND: a DH group (n=5), and a Normal group: age-matched controls without DH (n=11). All groups were supported on the EXTEND system for 1-28 days (average = 15.0 days). All fetuses were then delivered and ventilated. A full necropsy was then performed, with perfusion fixation of the lungs via the pulmonary artery. Lung volume was determined by water displacement technique.

Results: Normal animals and DH animals had similar oxygenator circuit flow (Figure 1), shunt fraction (Figure 2), and heart rate while in the EXTEND system. However, once delivered from the EXTEND system, separate from the ECMO circuit, and placed on a conventional ventilator, the DH animals did significantly worse than normal animals, with lower tidal volumes, minute ventilation, and maximum PO2.

Conclusion: This study suggests fetuses with congenital diaphragmatic hernias can be safely and effectively supported on pumpless ECMO via the umbilical artery and vein in the EXTEND system.
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Fulminant eosinophilic myocarditis with a concomitant pheochromocytoma
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Abstract
A 33-year-old female presented with dyspnea on exertion, cold and mottled extremities, requiring intubation for acute hypoxia. Echocardiogram demonstrated an ejection fraction of 15% with global hypokinesis. Cardiac catheterization was unremarkable except for a cardiac index of 1.8 L/min/m². Myocardial biopsy demonstrated fulminant eosinophilic myocarditis; high dose steroids were started. She developed progressive hypotension and multiorgan failure with a rise in her creatinine and liver function tests. A CT scan looking for infection showed a retroperitoneal mass that did not appear malignant. The decision was made to initiate peripheral veno-arterial ECMO. Arterial access was obtained via a femoral artery cut down was performed with an end to side chimney graft that was tunneled, percutaneous femoral venous access was used for the inflow cannula. Her hemodynamics stabilized and after 2 days, she was extubated while on ECMO flows of 3-4 L/min. Over the next 4 days her creatinine and LFTs peaked before normalizing. Bedside ramp study with TTE showed recovery of left ventricular function with an ejection fraction of 50%. Given her improved ejection fraction she was decannulated on hospital day 5. Laboratory work up for the retroperitoneal mass demonstrated elevated plasma and urine metanephrines consistent with a pheochromocytoma. To our knowledge the association between eosinophilic myocarditis and pheochromocytoma has only been described in a post-mortem case series from the 1960s. While using ECMO for cardiogenic shock from fulminant myocarditis is not common; this case highlights its use for awake patients and the need for a comprehensive diagnostic work up.

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Lymphopenia during and after neonatal extracorporeal membrane oxygenation and its impact on survival
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Abstract
Background: Infections during ECMO are a common complication impacting mortality and occurring despite prophylactic antibiotics. While leukopenia during ECMO was studied during the 1980s and 1990s, we hypothesized that modern technology may alter the immunological response to ECMO.

Methods: In this exploratory single-center, retrospective study, we analyzed white blood cell (WBC) counts from birth until 72hrs after ECMO discontinuation. Neonates with congenital diaphragmatic hernias undergoing veno-arterial ECMO initiated within 24hrs of birth were included. Neonates with an infection or immunodeficiency were excluded.

Results: A total of 58 neonates (n=29 males) from 2006-2018 were included. At birth, 97% were within or above normal reference range (NRR) for WBCs. After 24hrs of ECMO, decreases were observed for all indices (p<0.01): 49% below neutrophil NRR and 95% below lymphocyte NRR. On day 3, 91% were neutropenic and 83% lymphopenic. By day 7, neutrophils recovered (98% within NRR), however, lymphopenia persisted with 81% below NRR at two weeks. No survival-to-discharge (0% vs. 50%) was observed in those with profound lymphopenia (≤0.5 10^3 cells/µL) on day 14. In patients who developed profound lymphopenia at any point during ECMO, survival-to-discharge was significantly lower (23.8% vs. 52.4%, p=0.03). At 48-72hrs post-decannulation, neutrophils significantly increased (+5.58 10^3 cells/µL, p<0.001). However, lymphocytes did not increase (+0.11 10^3 cells/µL, p=0.255), with 72% remaining lymphopenic.

Conclusions: Lymphopenia persists throughout ECMO and immediate post-ECMO period. This quantitative immunoparalysis may increase the risk for infection, particularly if ECMO duration is prolonged. The impact of severe lymphopenia on morbidity and mortality should be further investigated.
Outcomes of ECMO in Patients with Primary Immunodeficiency: An Analysis of the Extracorporeal Life Support Organization (ELSO) Registry
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Abstract
Background: Primary immunodeficiency (PID) places patients at risk for severe infections that may lead to refractory cardiopulmonary failure requiring ECMO support. This study aimed to analyze the clinical outcomes of patients with a PID who underwent ECMO for any indication.

Methods: All patients in the ELSO registry (1989-2018) with a PID as classified by the International Union of Immunological Societies were included. Complication and survival rates were compared to non-PID patients.

Results: A total of 325 patients (97 neonates, 205 children, 23 adults) with a PID were identified. The sample size increased from 12 in 1990s to 215 in 2010s, but with no significant change in survival-to-discharge (STD) (p=0.499). STD in neonates receiving pulmonary support was 38% vs. 73% for PID vs. non-PID patients (p=0.02). STD in children receiving pulmonary support was 45% vs. 58% in PID vs. non-PID patients (p=0.02). There were no significant differences in the rate of infectious complications in PID vs. non-PID patients for any age or support type (all p-values>0.05). In neonatal and pediatric pulmonary groups, cardiac (63% and 56%, respectively) and renal complications (37.5% and 52.1%, respectively) rates were elevated as compared to observations in non-PID patients. Metabolic complications were also high in the pediatric pulmonary group (32%).

Conclusions: ECMO can be effectively utilized in patients with a PID. However, STD for neonatal and pediatric patients with PID requiring ECMO for respiratory failure are significantly worse. Further analysis is required to identify factors predictive of mortality in PID neonates and children receiving pulmonary support.

Extremely Basic Arrhythmia Management
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Abstract
Alkalosis has traditionally been thought to be protective against ventricular arrhythmias; however, complications of extreme alkalosis can include vasoconstriction, decreased coronary perfusion, and arrhythmogenicity. We present an interesting case of refractory ventricular fibrillation in the setting of profound mixed alkalosis in a spontaneously breathing patient supported on VA ECMO.

A 46 year-old female was admitted to our ICU after urgent cannulation for VA ECMO following an inferior STEMI and subsequent cardiogenic shock. On ECMO day 5, she suddenly developed persistent ventricular fibrillation. With full mechanical support, she remained completely asymptomatic and hemodynamically stable, but as she was a bridge to recovery patient, we were compelled to aggressively treat her arrhythmia. Despite multiple pharmacologic and electrical cardioversion attempts, she remained in persistent VF for 90 consecutive minutes.

Stat ABG showed an extreme alkalosis with a pH of 7.69. A decision was made to intubate and mechanically ventilate the patient to reduce catecholamine burden and correct alkalosis. Immediately following induction and intubation, another shock was delivered, which instantly terminated the arrhythmia.

The data on extreme alkalosis remains scarce, but one study puts the mortality of patients with a pH over 7.65 at 80%. While these extreme values are not often seen, the increased use of ECMO in spontaneously breathing patients with concomitant diuresis may make severe alkalosis more common. Possible complications should be recognized and early preventive treatments should be considered.
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Supporting Families and Staff after ECMO through Shared Experiences
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Abstract
Since March 2015, our Pediatric ECMO team has cared for 31 patients. Of these, 16 patients are still living today (53%). Patient & family support are necessary during ECMO, as well as post-ECMO and hospital discharge. Recent studies show that not only patients who required ECMO fulfill post-traumatic stress disorder diagnostic criteria, but also their close relatives are at risk to develop PTSD. Minimal peer to peer resources exist in the community for these patients and families. We found this to be a gap in ECMO care and an area of opportunity for us to provide additional support to this patient population. Our team explored options for engaging and decided to host our first Pediatric ECMO Reunion. The reunion included both patients & families and multidisciplinary staff members who cared for our prior ECMO patients. This venue provided an opportunity for sharing patient stories, for ECMO providers to reconnect with survivors and staff to experience the positive outcomes from their work. This allowed for a first step for families to understand their experience and help decrease burnout in providers and staff. We provided families the option to stay in touch with the ECMO Program through different family work groups. We also interviewed families and distributed surveys for direct feedback on their experience working with our team while their child was on ECMO. Next steps include creating an ECMO Family Work Group by partnering with families to develop new ways to support future ECMO families and improve the ECMO family experience.

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Minimizing ECMO Mobilization Time for Beside ECMO Cannulations by Maximizing Multidisciplinary Team Efficiency
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Abstract
The majority of neonatal and pediatric patients require emergent cannulations at the bedside in the intensive care unit (ICU). To accomplish a bedside cannulation, multidisciplinary teams need to work together and perform tasks that may be different from the usual practices in the ICU. The complexity of the many tasks that need to be completed can lead to significant delay if not well choreographed. Our project goal was to streamline the pre-cannulation process to decrease the time from ECMO mobilization to procedure start. The initiative was implemented in September 2016. Interventions included formalization of ECMO Program policies & procedures and multidisciplinary education, as well as implementation of formal patient case reviews & quality assurance meetings. Our team collaborated with ancillary departments to ensure timeliness and efficiency with orders & processes related to ECMO initiation. We also created a detailed pre-cannulation checklist which defines each team members’ role and their responsibilities in the pre-cannulation process. The checklist is reviewed prior to the procedure time out as a final check to ensure all required tasks are completed. Upon retrospective chart review, the pre- & post-initiative data revealed a 54% decrease in time from ECMO mobilization to cannulation procedure start. The post-initiative average time of 65 minutes showed successful improvement from the pre-initiative average time of 136 minutes. We concluded that a structured process for pre-cannulation preparedness, role definition, multidisciplinary education, and team debriefs maximize efficiency in team readiness for a bedside ECMO cannulation procedure.
Where to Start? A Single Center Retrospective Analysis of Early Liberation from Mechanical Ventilation in VV ECMO Patients with Acute Respiratory Failure
Ingrid Gunther, Bridget Toy, Anthony Andriotis, Jacklyn Hagedorn, Tracey Morgensen, Daniel Smith, Lisa Staccone, Deane Smith, Anthony Lubinsky; NYU Langone Health, New York, USA

Abstract
Intro: The optimal strategy for weaning of respiratory support during lung recovery of patients requiring VV ECMO for acute respiratory failure is unknown. We hypothesized that earlier liberation from the ventilator in these patients may correlate with improved outcomes.

Methods: We retrospectively reviewed all VV ECMO patients at our center from November 2015 to May 2019. Patients who were on VV ECMO as bridge to transplant or for isolated intraoperative indications were excluded. The final study population included 18 patients; 6 were liberated from mechanical ventilation prior to ECMO decannulation and 12 were decannulated from ECMO, but remained mechanically ventilated. Demographics and outcomes were compared between the two groups.

Results: Patients liberated from the ventilator prior to ECMO were treated for asthma, pneumonia and vasculitis (33% each) versus predominantly pneumonia (58%), had a lower rate of pre-existing lung disease (17% vs 33%), and lower APACHE II scores (median of 21 vs 24). These patients had longer duration of ECMO (220 vs 205 hours), less ventilator days (5 vs 20.5 days), higher average Richmond Agitation Scores (-1 vs -3), fewer days until they were able to get out of bed (4.5 vs 15 days), shorter ICU stays (16 vs 29 days), and were more likely to survive to hospital discharge (100% vs 67%).

Conclusion: Early ventilator liberation of patients on VV ECMO was associated with improved outcomes. Our study is limited by small sample size, retrospective design, and potential for confounding due to baseline differences between groups.

Creating a Cohort of Nursing Experts to Assist in Emergent Bedside Cannulations
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Abstract
INTRO: Our Adult ECMO Program cannulates most of our patients in the operating room (OR). However, in the past year, our bedside cannulation volume increased from 13 to 27 across six inpatient units. Because we expect cannulations outside of the OR to increase, the Adult Langone Emergency Response Team (ALERT) nurses were identified as the ideal providers to assist in bedside cannulations.

METHODS: Our ECMO Team developed a cannulation program to meet the educational needs of the 20 ALERT nurses. The ECMO Directors and Coordinator held a two hour didactic course, reviewing cannulation procedures, ECMO configurations and nursing roles in a bedside cannulation. We distributed pre & post self-assessments to evaluate the nurses’ confidence levels. The ECMO Team then invited ALERT nurses to observe planned cannulations, providing an ideal setting for learning and reflection of the cannulation process. ALERT nurses identified areas for improvement that could aid in emergent initiation of ECMO outside of the OR. The program concluded with a one hour simulation session that provided an opportunity for both teams to clarify expectations of future cannulations.

RESULTS: Using the Wilcoxon Signed-rank test, we found a statistically significant improvement in pre & post self-assessment scores (p-value <0.001). Direct feedback from ALERT nurses included further clarification for ECMO team activation process, terminology of surgical supplies and additional resources needed to support a bedside cannulation. The program allowed for both teams to strengthen their collaboration that will ultimately result in improved workflow, communication and patient outcomes.
Venovenous ECMO: Successful use in a postpartum patient with ARDS. First case of Mobile ECMO at our center.

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Abstract

Introduction: Veno venous ECMO (VV-ECMO) is potentially indicated in patients with severe ARDS that continue with respiratory failure despite the use of prone positioning, neuromuscular blockers and PEEP optimization.

There are few cases reported using VV-ECMO during pregnancy and immediately after delivery and most had poor results. There is not enough information about the risks associated with ECMO in the postpartum period; nonetheless, ECMO can be used safely. Mobile VV-ECMO is a safe option when it is done by an experienced center.

Objective: To describe a successful case of Mobile VV-ECMO in a patient with ARDS during postpartum period.

Results: A 30-year-old patient at 34.5 weeks’ gestation is admitted in an obstetric hospital due to ARDS secondary to influenza virus pneumonia, presenting fetal distress, thus terminating her pregnancy by cesarean. Respiratory failure continues after 72 hours despite optimal medical support. The patient is presented to our service with PaO2 / FIO2 ratio <80 for 6 hours; so VV-ECMO is placed cannulating right jugular and femoral veins for extraction and left femoral vein for return. The patient is transferred to our center via land to finish antiviral and antibiotic treatment. Respiratory status improves and pneumonia resolves, removing ECMO 9 days later. The patient is discharged after 23 days.

Conclusion: The use of VV-ECMO in the postpartum period is safe when installed and managed by an experienced team.

Quality Assessment of ECMO Programs with a Focus on Mortality

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Abstract

Introduction: Evaluating the quality of an ECMO program is a key task for leaders. Mortality is a key driver of this evaluation. Currently available methodology utilizes risk-stratification to generate expected mortality rates which are then compared to actual outcomes. Performance is typically reported as observed to expected (O:E) ratios. Understanding the elements of the risk-stratification models and using multiple instruments can help provide a more accurate assessment of program quality.

Methods: We reviewed mortality data from January 1, 2018 to December 31, 2018. A total of 82 patients were evaluated using the ELSO Arbormetrix quality reporting platform, the Premier CareScience tool, and the 3M APR DRG model.

Results: Discussion: Evaluation of the data demonstrates a lack of correlation between each of the platforms. The ELSO quality platform uses risk-adjustment models which have been validated in ECMO populations. The CareScience model focuses on factors present on admission; ECMO has a significant impact on expected mortality only if the patient is placed on ECMO in the first 24 hours. The 3M model uses events occurring throughout the hospitalization. Understanding the important differences between the risk models is important for those involved in the assessment of quality in ECMO programs.
Parallel oxygenators for hypoxemia in an overweight patient on venovenous ECMO
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Abstract
Purpose
In patients on venovenous (VV) extracorporeal membrane oxygenation (ECMO) with extremely high cardiac output like obesity or sepsis, refractory hypoxemia is a challenging clinical problem sometimes. For the purpose of supporting more overall surface area of oxygenator, a second oxygenator was used in parallel to achieve adequate oxygenation in the same ECMO flow and negative pressure.

Method
A 64-year-old man whose height was 5 feet and 6 inches and weight was 250lbs developed severe hypoxemia due to acute respiratory distress syndrome as a complication of influenza. He was placed on VV ECMO with standard technique. ECMO flows achieved maximal 6.5 L/min because his body surface area was 2.30 m$^2$. The patient’s condition deteriorated with an arterial partial pressure of oxygen as low as 40 mmHg over the next 2 days. A second ECMO oxygenator was placed in parallel with the first one.

Result
The arterial partial pressure of oxygen was increased from 47.1 mmHg to 103 mmHg and carbon dioxide was from 35.8 reduced to 32.2 mmHg within 2 hours. This increase in oxygenation allowed the fraction of inspired oxygen on the ventilator to be weaned from 100% to 30% within 6 hours. The ECMO was taken off 10 days after the second oxygenator placed.

Conclusion
ECMO for obesity patients with high cardiac output can be challenging to manage with ECMO, particularly in progressive sepsis. This study demonstrates that parallel oxygenators in VV ECMO can be successfully used to treat refractory hypoxemia in a patient with acute pulmonary failure.
Reduced low-flow time in out-of-hospital CPR using a special eCPR - ambulance
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Abstract
Background: eCPR is a new and innovative option for patients suffering from acute cardiac arrest, frequently performed in-hospital with consecutive long CPR duration. A special eCPR - ambulance for the initiation of extracorporeal circulation on scene during out of hospital cardiac arrest (OHCA) was implemented in 2018/09. We evaluated time to on pump in all patients with OHCA within the last 10 month at our center in comparison to OHCA and in hospital eCPR.

Methods: The use of a special eCPR - ambulance equipped with extracorporeal membrane oxygenation technology was established during daytime (8 am to 4 pm). The eCPR team consists of an interdisciplinary team (cardiac surgeon, cardiologist, perfusionist). We report the prospective registry data of all patients treated with eCPR on scene between 2018/9 and 2019/6 compared to a retrospective set of OHCA patients (n=134) received in-hospital eCPR between 2010/10 and 2016/05.

Results: As our previous experiences in an in-hospital setting indicates, that low-flow time correlates directly with survival and is an independent predictor of mortality. In the pilot phase, the eCPR - ambulance was dispatched by a total of 45 alarms. 10 patients (mean age 56.5 ± 15.6 years) underwent eCPR and were included in our analysis. By establishing eCPR in the preclinical setting CPR duration was shortened from 72.2±28 minutes to 47±16.3 minutes.

Conclusions: Time to full support is an important and alterable predictor of patient survival in eCPR. Using an eCPR - ambulance, low - flow time may be reduced by a mean of 25 minutes.

Heparin vs. Bivalirudin for Systemic Anticoagulation in Pediatric Extracorporeal Membrane Oxygenation: A Single Center Retrospective Analysis
Claudine Brown, Sarah Scott, Maria Escober, Ripal Patel, Adrian Holloway, Courtney Foster; University Of Maryland Medical Center, Baltimore, USA

Abstract
Systemic anticoagulation while on extracorporeal membrane oxygenation (ECMO) is widely considered the standard of care in the pediatric population. Unfractionated heparin has long been considered the anticoagulant of choice. In recent years other agents like direct thrombin inhibitors are being used as alternatives to heparin. Bivalirudin’s use for this purpose has been mainly anecdotal due to the lack of pediatric specific data regarding the efficacy of the drug and a lack of standardized dosing and protocols.

This retrospective study seeks to determine whether bivalirudin offers similar clinical benefits to Heparin and if there are any distinct clinical benefits related to its use. Primary endpoints include: thrombotic events at any point during the entire ECMO run, survival to de-cannulation and 30 day mortality. Secondary outcomes assessed include vascular complications, bleeding and neurologic events. Data collected between July 2016 and July 2019 yielded 26 cases of ECMO (19 V-A ECMO, 7 V-V ECMO). Of these cases, 8 were anticoagulated with bivalirudin and 18 were heparinized. Of all patients, 12 were male and 14 were female. The median age was 16 months. The median duration on ECMO support was 6 days.

Further data analysis is currently ongoing which will include a propensity analysis and fisher exact tests. This study is the first of its kind in pediatrics and we hypothesize that there are no statistically significant differences in outcomes between the bivalirudin and the heparin group. We hope to use our study results as validation of a bivalirudin anticoagulation for pediatric ECMO use.
Neonatal Ventilator Management on ECMO: The Rest of the Story
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Abstract
Introduction: Significant practice variation exists in ventilator management strategies during ECMO for neonatal respiratory failure. While published experience recommends maintaining open lungs, evolving practices suggest lower rest settings, allowing for de-recruitment. We sought to understand ventilator management practices among experienced neonatal ECMO centers. This is the first step toward a larger goal of identifying optimal strategies and recommendations for best practices.

Methods: We conducted a REDCap™ survey of 33 neonatal ECMO centers participating in the Children’s Hospital Neonatal Consortium. Survey links were emailed to the lead representative for each participating center. One reminder email was sent to centers who had not responded within 2 weeks. Results are summarized by descriptive analysis.

Results: 20 centers (61%) responded, representing a cumulative volume of well over 100 neonates/year. 65% of responding centers follow a protocol for initial rest settings. Most centers (90%) primarily rest on Pressure Control (SIMV or AC). The most common initial PEEP is 9-10 (40%); PIP is 16-20 (55%); Rate is 10-15 (60%). Eleven (55%) centers do not accept complete atelectasis on CXR, while 20% “expect and accept complete white-out.” 45% “sometimes” use iNO during ECMO. 50% of centers “commonly” utilize bronchoscopy for recruitment.

Conclusions: Wide variation exists in neonatal ventilator management strategies during ECMO for respiratory failure. Areas which may benefit most from investigation and discussion include the degree of acceptable lung de-recruitment, the use of nitric oxide during ECMO, and when and how aggressively to encourage re-recruitment, including the optimal use of bronchoscopy.

Extracorporeal Membrane Oxygenation Circuitry Impact on Cefepime
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Abstract
Extracorporeal membrane oxygenation (ECMO) is known to alter drug pharmacokinetics (PK). The PK changes can result from drug binding to the oxygenator, alterations in clearance, and drug adsorption or sequestration, but the published literature is with old equipment and oxygenators. There is limited data regarding the impact of the Polymethylpentene (PMP) oxygenators on drug changes in ECMO circuits. The purpose of this study was to determine the impact of the Quadrox-i adult PMP oxygenators on the PK of cefepime (FEP) in contemporary ECMO circuits.

A 3/8-in. closed loop ECMO circuit was prepared with Quadrox-i adult oxygenator (Getinge). The circuit was primed with (whole blood), tromethamine, heparin, calcium gluconate and pH was balanced to 7.35-7.45. The closed-loop design was established by connecting the ends of the arterial and venous cannulae to a reservoir bag, allowing continuous flow of the priming fluid within the circuit. FEP was added to the continuously flowing circuits and levels were obtained pre-and post-oxygenator at the following time intervals; 5 mins, 1, 2, 3, 4, 5, 6 and 24 hrs. FEP control was maintained in a glass vial and samples obtained at the same time periods.

FEP loss was first noted at 6 hours with significant loss at 24 hours (~45%). FEP control showed no loss suggesting the FEP loss was not due to self-degradation at room temperature. Additional in vivo studies are needed to determine dosing regimen alterations for FEP with an ECMO circuit.
Oxygenator Impact on Voriconazole in Extracorporeal Membrane Oxygenation Circuits

Daniel Marino1, Amit Misra1,2, Jillian Deacon1, Wayne Moore3, Nadji Gilliam1, Tracy Low1, Adela Enache4, Arun Chopra3,5,6, Jeffrey Cies1,2; 1St. Christopher’s Hospital for Children, Philadelphia, USA. 2Drexel University College of Medicine, Philadelphia, USA. 3The Center for Pediatric Pharmacotherapy LLC, Pottstown, USA. 4Atlantic Diagnostic Laboratories LLC, Bensalem, USA. 5NYU Langone Medical Center, New York, USA. 6NYU School of Medicine, New York, USA

Abstract
Extracorporeal membrane oxygenation (ECMO) is known to alter drug pharmacokinetics (PK). The PK changes can result from drug binding to the oxygenator, alterations in clearance, and drug adsorption or sequestration, but the published literature is with old equipment and oxygenators. There is limited data regarding the impact of the oxygenator on drug changes in ECMO circuits in comparison to the other components of the ECMO circuit. The purpose of this study was to determine the impact of the Quadrox-i adult oxygenators on the PK of voriconazole (VOR) in contemporary ECMO circuits.

A 3/8-in. closed loop ECMO circuit was prepared with Quadrox-i adult oxygenator (Getinge) and one circuit without an oxygenator in series. The circuits were primed with (whole blood), tromethamine, heparin, calcium gluconate and pH was balanced to 7.35-7.45. VOR was added to the continuously flowing circuits and levels were obtained pre-and post-oxygenator or 2 samples from circuit without oxygenator at the following time intervals; 5 mins, 1, 2, 3, 4, 5, 6 and 24 hrs. VOR control was maintained in a glass vial and samples obtained at the same time periods.

There was significant VOR loss in the 3/8-inch circuit with an oxygenator and no apparent VOR loss in the 3/8-inch circuit without an oxygenator. The drug loss started by 2 hours (~20%) and continued over 24-hours (~40%). VOR control showed no loss suggesting the VOR loss was not due to self-degradation. Additional studies are needed to determine dosing regimen alterations for VOR with an ECMO circuit.

Membrane-Less Blood Gas Exchange Device

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Abstract
Study: Current blood oxygenators use microporous hollow fiber membranes, in a flow regime associated with turbulent flow, high-pressure gradients and thus resulting in damage to blood components especially problematic during long-term support.

Herein, we describe a novel gas exchange (NGE) device consisting of multiple ‘virtual-wall’ blood channels, characterized by enhanced gas diffusion and laminar flow at a significantly reduced pressure drop [First described by O2Cure in 2013, US 9138522B2].

Methods: The NGE is composed of gas exchange units, each consisting of a “forest” of superhydrophobic 10-30 nm vertically aligned carbon nanotubes (VACNT) spaced 100-300 nm apart, with 50–100 micron “clearings” that form ‘virtual’ blood flow channels. Gas molecules fill the spaces between the VACNT enabling direct blood-gas contact and highly efficient diffusion. Furthermore, the sparse VACNT significantly reduce blood flow friction, pressure drop and thus damage to blood.

Results: Bench experiments were performed with water and bovine blood. Oxygen transfer rate (OTR) per channel was 31.25 nl O2/min. The OTR of device having channel density of 28,000 channels/cm2 and with blood-gas contact area of 0.18 m2 (device size < 0.1 L) was 50 ml O2/min/L (flow rate 0.5 L/min, dP 6 mmHg). NGE performed well clinically in minipigs in ECMO and CPB configurations (device size < 1L).

Conclusions: VACNT-based NGE introduce a novel concept of efficient blood-gas exchange characterized by practically frictionless flow driven by low dP. It is expected to induce reduced damage to blood, making it suitable for long term support during cardiac and respiratory failure.
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VAV ECMO for Severe Calcium Channel Blocker Overdose
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Abstract
Purpose:
To present the challenges in managing patients with severe CCB poisoning and to describe the use of VAV ECMO as a rescue therapy.

Description:
This poster reviews the use of ECMO in the management of severe CCB poisoning. It will explore the role of traditional therapies including calcium, glucagon, gut-decontamination and vasoactive support. It will describe our experience with managing two patients who developed severe cardiovascular failure and severe hypoxemia after consuming a large doses of CCB. We opted to treat both with VAV ECMO. They had normal LV systolic function at the time of their admission. This case series highlights the complications of conventional therapies which resulted in severe respiratory failure. We will also describe non-conventional therapies we used in these patients including High Insulin Euglycemia Therapy (HIET), and Total Plasma Exchange (TPE).

Evaluation/Outcome:
ECMO is supportive therapy. There is no clarity about the ECMO modality to be used in patients on very high doses of vasoactive support who have a preserved LV systolic function and the use of circulatory support in these cases is controversial. In both these instances, we used hybrid modes which supported both respiratory function and cardiovascular function initially. Both patients were treated with TPE and Gut Decontamination and could be weaned off extra-corporeal circulatory support first and then respiratory support. And both patients survived without significant impairment.

Conclusion:
VAV ECMO supported both circulatory and respiratory dysfunction and an earlier institution of ECMO in severe CCB poisoning may be supported by our experience.

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Quality Improvement: ECMO Specialist Driven Cannula Stabilization Bundle to Prevent Decannulation
Daphne Hardison, Michael West, Brian Bridges, Melissa Danko; Monroe Carell Jr Children’s Hospital at Vanderbilt, Nashville, USA

Abstract
Introduction: Unplanned decannulation or displacement can lead to massive transfusions, fluid overload, longer run times, or death. Cannula problems are defined as reposition or exchange for misplacement, dislodgement, or mechanical failure. Our center reported cannula problems in neonates at 14% and pediatrics at 19%. We started using Kamishibai cards (K-cards) to decrease cannula migration, prevent dislodgement and unplanned decannulation. K-cards are tools used in daily rounding to provide just in time data and help improve quality of care utilizing bundles to promote evidence-based practices.

Methods: The components of the cannula stabilization bundle included ensuring the cannula is secured to patient, the ECMO tubing is secured to bed, no weight is on ECMO tubing, reviewing of cannula position on X-ray during handover, skin protectant in place, and documentation of ECMO cannula placement. A review of all ECMO runs during the last fiscal year were completed with audits completed each shift to identify utilization of the cannula stabilization bundle.

Results: Of the 54 runs completed during the study period, the median age for neonates 2 days (0 to 28), the median weight 3.4 kilograms (2.5 to 4.3) while the pediatric median age was 42 months (1 to 114 months). There were 45 neck and 9 open chest cannulations. Cannula dislodgement, looking at days from cannula malposition increased and are currently at 224 days since last malposition. For the study period (September 2018 to June 2019), 54 ECMO runs and 215 audits were completed. Bundle compliance increased from 11 percent to 71 percent in this time period.

Conclusions: In conclusion, ECMO cannula stabilization bundle implementation with standardized expectations for cannula and tubing management led to improved cannula stabilization and less risk to patients. ECMO Specialist education has driven our team to improve their observation of cannula position and better manage patient mobility. Continued audits and development of standardized bundles will help to reduce cannula dislodgement and serious safety events in the ECMO patient population.
A rare genetic diagnosis supported with Extracorporeal Membrane Oxygenation

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Abstract

Wolf-Hirschhorn Syndrome (WHS) is a rare genetic diagnosis caused by partial deletion of the short arm of chromosome 4. The syndrome is characterized by marked growth deficiency, distinct craniofacial features, cardiac anomalies and intellectual disabilities. Additional features may include renal anomalies and congenital diaphragmatic hernia (CDH). We present a neonatal patient with WHS and CDH supported with veno-arterial (VA) ECMO. There is a paucity of information regarding use of ECMO in WHS patients. Our patient was prenatally diagnosed with WHS and CDH supported with veno-arterial ECMO. There is a paucity of information regarding use of ECMO in WHS patients. The underlying genetic diagnosis potentially indicated a higher risk for renal morbidities associated with ECMO in WHS patients. The baby initially maintained acceptable ventilation and oxygenation. Echocardiogram revealed supra-systemic pulmonary pressures. Renal ultrasound was normal and head ultrasound (HUS) showed a grade 1 intraventricular hemorrhage. The baby was transitioned to VA ECMO for labile oxygenation. Urine output declined, renal insufficiency progressed with electrolyte disturbances and hypertension was noted. Repeat renal ultrasound revealed increased echogenicity, decreased corticomedullary differentiation and under-perfusion. Repeat HUS showed extensive hypoxic-ischemic changes. Life-sustaining measures were discontinued and the patient expired. While genetics counseled that ECMO should not be withheld due to the underlying genetic diagnosis, this case highlights the potential added risk for renal morbidities associated with ECMO in WHS patients. The underlying genetic diagnosis potentially indicated a higher risk for intrinsic renal disease potentiated by non-pulsatile ECMO flow in this newborn with WHS.
Safety and Effectiveness of Bivalirudin for VA ECMO in the Pediatric Cardiac ICU
Desiree Machado, Joseph Philip, Christopher Campbell, Brian Kelly, Timothy Bantle, Dalia Lopez-Colon, Giri Kaliki, Mohammad Ebraheem, Kevin Sullivan, Giles Peek, Mark Bleiweis; University of Florida, Gainesville, USA

Abstract
Background: bivalirudin is safe in pediatric ventricular assist devices (VAD) and is now the most commonly used agent. As bivalirudin is not reliant on antithrombin III, it makes a logical replacement for heparin in children whose hemostatic systems are developing. We present our experience using bivalirudin for VA ECMO in pediatric cardiac patients.

Methods: retrospective study, from January 2016 to July 2019.

Results: 19 patients (age range 7 days – 17 years) received VA ECMO and bivalirudin during a median length of 166 hours (one patient excluded due to support over 6189 hours). Median (range) doses were: 0.1mg/kg/h (0.01-0.2) initially with a median maximum of 0.54mg/kg/h (0.05-2). Once aPTT at goal (excluding initial titration) the median percentage of aPTT values within desired and below goal was 73.95% and 18.5% respectively. There were 3 circuit exchanges in 3 patients (circuit related coagulopathy, circuit clotting and circuit electively replaced after reoperation). There were 14 procedures performed in 11 patients, one patient received thrombolysis twice while on ECMO, and 7 patients were bridged to surgery (3 patients were bridged to cardiac surgery and 4 patients were bridged to VAD). Although bivalirudin was not held in any case, 2 patients required surgical intervention for bleeding. There were no thrombotic complications. There were 6 deaths, none related to anticoagulation.

Conclusion: bivalirudin is a safe and effective replacement for heparin as primary anticoagulation during VA for children supported in a dedicated pediatric cardiac ICU. Non-inferiority and cost studies are needed comparing to traditional methods of anticoagulation.

Ambulatory Veno-Arterial Extracorporeal Membrane Oxygenation in Pediatric and Adult Patients awaiting heart transplantation: The Mayo Clinic Experience
Devon Aganga1, Charlotte Van Dorn1, Joseph Dearani1, Sameh Said2, Errin Kalvelage1, Angeleah Rhymer1, Gregory Schears1, Jonathan Johnson2; 1Mayo Clinic, Rochester, USA. 2University of Minnesota, Minneapolis, USA

Abstract
Patients supported to heart transplant using veno-arterial extracorporeal membrane oxygenation (VA-ECMO) historically have inferior post-transplant outcomes compared to those supported by ventricular assist devices (VAD). Patients are frequently kept sedated and mechanically ventilated, making pre-heart transplant rehabilitation difficult compared to VAD patients. In this case series, we describe our experience rehabilitating pediatric and adult patients awaiting heart transplantation on central VA-ECMO.

We performed a single center, retrospective chart review of our institutional ECMO database and identified cases from 1/1/2012 to 6/30/2019. We included patients supported with central VA-ECMO for >14 days awaiting heart transplantation that had undergone sternal closure, extubation and rehabilitation.

We report 16 ambulatory VA-ECMO patients awaiting transplantation who were able to undergo rehabilitation. The median age was 5 years (range 1.7 – 19.1). Primary diagnoses included cardiomyopathy (5), complex congenital heart disease (4), myocarditis (2), transplant graft failure (1), prolonged QT syndrome (1), and cor pulmonale (3). Median ECMO duration was 114.3 days (range 69.6 – 165.9). Median time to extubation was 27 days (range 8 - 37). Median time to first ambulation was 28 days (range 14 – 50). Of the 16 patients, 8 (50%) underwent heart transplantation on ECMO, 3 recovered and were decannulated, and 1 transitioned to an LVAD as destination therapy. Twelve (75%) patients were alive at 90 days from decannulation, of whom 11 survived to hospital discharge. Ambulatory central VA-ECMO in awake, extubated patients participating in rehabilitation is feasible and allows for extended duration of support whilst maintaining transplant candidacy.
The use of inhaled Epoprostenol in conjunction with Extracorporeal Membrane Oxygenation increases the risk of Diffuse Alveolar Hemorrhage in patients diagnosed with Pulmonary Hypertension

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Abstract
DAH is a challenge when the patient is cannulated on ECLS and ventilation strategies such as lung rest are used that ultimately increase PVR. We posed the question if there was any direct correlation to the use of inhaled Epoprostenol and DAH in our ECLS population and looked for alternative therapies and evaluating effectiveness of the inhaled medication.

We retrospectively evaluated 86 patients in 2018 and separated those patients with DAH. We then tracked the use of inhaled Epoprostenol, reason for ECLS Cannulation, underlying diagnosis, mechanical ventilation strategy, and if agents such as trade amid was used.

18 of the 86 patients were on inhaled Epoprostenol. 8 of the 18 patients experienced DAH. Of the 8 patients, 1 patient was ventilated by traditional LPV as defined as VT 4-6ml/kg/IBW; 6 patients were ventilated via lung rest (<4ml/kg/IBW to maintain Pplat<25cmH20); 1 patient experienced unintentional large VT ventilation (>8ml). 4 patients received TXA (inhaled); 1 patient received oral TXA, and 3 patients did not receive TX at all. Of the patient preset with DAH while on ECLS and being administered inhaled Epoprostenol, 4 patients had an underlying diagnosis of Pulmonary Hypertension.

There was a direct correlation between the use of inhaled Epoprostenol and DAH in the defined patient group. As lung rest was the most used method of ventilation, future initiation of inhaled agents has been evaluated to prove ineffective. The potential risks associated with lung rest is to be further evaluated in patient on ECLS receiving inhaled Epoprostenol.

Successful Decannulation from Extracorporeal Life Support in Pediatric Patients is associated with elevated C3 and C3a within Tracheal Aspirates: A Pilot Study

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Abstract
Introduction: The ELSO registry International summary reported 1,145 neonatal and pediatric respiratory ECLS runs in 2018 with an average run time of 239 hours. To help with resource utilization, we aimed to identify biomarkers within baseline tracheal aspirates (TA) that can predict successful decannulation, defined as improvement in underlying condition with expected survival.

Methods: We prospectively enrolled pediatric patients requiring ECLS for respiratory indications. IRB approval and informed consent were obtained. TA that were obtained prior to/near ECLS initiation were included for analysis. The primary outcome was the association between TA inflammatory biomarkers with time to successful decannulation. Analyses were conducted in R v3.5.0.

Results: We analyzed TA samples from 14 ECLS patients. Patients with higher C3 and C3a within their baseline samples were associated with a greater probability of earlier successful decannulation compared to patients with lower levels (p=0.029 and p=0.029, respectively). Additionally, 5 of 14 patients enrolled had an infectious indication for requiring ECLS; total protein, interferon (IFN)-α, IFN-γ, interleukin (IL)-6, IL-10, IL-18 and IL-33 levels were all significantly higher (p<0.05) and IL-23 was significantly lower in these patients (p=0.004). However, these cytokine levels did not correlate with chances of successful decannulation.

Conclusions: Our results suggested an early higher level of complement activation may be a useful prognostic indicator for successful decannulation from ECLS for resource planning. This pilot study is the first to identify a possible association with TA and successful decannulation. Further studies should be conducted to further evaluate this association.
Extracorporeal Cardiopulmonary Resuscitation in a 36-Year-Old Man with Viral Myocarditis Who Survived Prolonged Cardiac Arrest and Bedside Decompressive Laparotomy Neurologically Intact

Dr. Elizabeth Powell, Dr. Gretchen Lemmink, Dr. Joshua Trester, Dr. Kari Gorder, Dr. Louis Louis; University of Cincinnati, Cincinnati, USA

Abstract

Introduction:
We report a case of prolonged cardiac arrest in a patient with viral myocarditis who was subsequently cannulated for Veno-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO). The patient developed bowel ischemia and abdominal compartment syndrome on ECMO and required a bedside decompressive laparotomy and hemicolecotomy.

Case:
A 36-year-old man with refractory pulseless ventricular tachycardia following a viral syndrome was transferred to the cardiovascular intensive care unit, where he then required VA-ECMO in an emergent fashion at the bedside. The patient was in cardiac arrest for 105 minutes before being cannulated for VA-ECMO. He required inotropic support and temporary transvenous pacing. Subsequently, on ECMO day three, the patient developed abdominal compartment syndrome requiring bedside decompressive laparotomy with temporary abdominal closure and end ileostomy. The patient had other sequela of ischemia to the right hand and bilateral lower extremities requiring bilateral below-knee amputations. He had no native cardiac activity for approximately one week, but then developed native cardiac function with an ejection fraction of 50%. After decannulation, the patient was discharged to a rehabilitation facility neurologically intact.

Conclusions:
Patients who receive high quality CPR and have a witnessed arrest with reversible cause can be considered for extracorporeal cardiopulmonary resuscitation (eCPR) even with a prolonged low flow state. Early recognition of abdominal compartment syndrome with rapid intervention also led to patient survival in this case. Though prolonged cardiac arrest and bowel ischemia requiring emergent laparotomy are independently associated with poor survival, we present a case of a patient who survived to discharge neurologically intact.

Successful Utilization of a Critical Care Fellow-Led ECMO Transport Team in Critically Ill Patient with Refractory Cardiogenic Shock

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Abstract

Introduction:
Increased utilization of extracorporeal membrane oxygenation (ECMO) has resulted in increased referral of critically-ill patients to ECMO centers. Interfacility transportation can be complex clinically and logistically, providing excellent opportunities for critical care medicine (CCM) trainees. We present a case of interfacility transportation of a critically-ill patient with life-threatening cardiogenic shock (CS) whose care was coordinated and stabilized at the referring facility by a critical care fellow under telemedicine supervision.

Case:
A 71-year-old male presented with inferior ST elevation myocardial infarction and bradycardia, underwent percutaneous coronary intervention with two drug eluding stents (DES) and a temporary transvenous pacemaker. Subsequently, he suffered a 6-minute asystolic arrest with failure of pacer capture, had restenosis requiring two more DES. Initiation of milrinone, insertion of a left sided Impella (Abiomed, Danvers, MA) and call to our center for transfer. Upon arrival by our ECMO transport team, the patient had evidence of ongoing pulmonary edema, hypoxia, and biventricular failure. The ECMO transport team, led by our CCM fellow, coordinated the initiation of nitric oxide and up-titration of inotrope with significant improvement and stabilization, allowing for successful transport without cardiac ECMO. With ongoing refractory CS, patient was cannulated for VA-ECMO on day 2, decannulated ECMO day 4, and ultimately discharged home.

Conclusion:
This case demonstrates the successful utilization of a CCM fellow-led ECMO transport team. Few adult CCM fellowship programs utilize trainees in this role. The addition of a CCM fellow supervised via telemedicine to an ECMO transport team adds to critical care educational experience.
Aibek Mirrakhimov1, Todd Dettmer1, Sundeep Guliani2, Isaac Tawil1, Erik Kraai2; 1University of New Mexico, Albuquerque, USA. 2University of New Mexico, Albuquerque, Uruguay

Abstract

Introduction:
Veno-arterial ECMO is increasingly used to support critically ill patients with cardiopulmonary failure [1]. These patients often undergo diagnostic imaging of the cardiovascular system. Several cases of misinterpretation of aortic pathology due to radiographic artifact have been described in peripheral ECMO [2]. We present 2 patients on VA ECMO who had similar CT findings of aortic dissection in the absence of genuine pathology.

Case series:
Patient 1: A 63-year-old male was placed on VA ECMO for massive pulmonary embolism and refractory shock. CT demonstrated abnormal opacification of the abdominal aorta concerning for dissection with flaps in renal and superior mesenteric arteries (Image 1). Patient was managed expectantly as CT findings were attributed to heterogeneous contrast opacification due to mixing of ECMO flow with native cardiac output. The patient underwent serial CT scans with and without ECMO, subsequently excluding aortic dissection.

Patient 2: A 68-year-old male suffered cardiac arrest and received VA ECMO. CT demonstrated filling defects within the thoracic aorta, interpreted as possible dissection (Image 2). He was managed conservatively as findings were attributable to dual circulations and heterogeneous contrast delivery.

Discussion:
VA ECMO is increasingly used in patients with cardiogenic shock. Healthcare providers should be aware that ECMO support, coupled with varying native cardiac output can demonstrate aortic dissection-like findings on CT. While these cases demonstrated artifact, peripheral VA ECMO patients are at risk for aortic injury due to cannulation or the primary pathology. Efforts to exclude aortic pathology must be sought through repeat and multi-modality imaging.

A Patient with Congenital Thrombotic Thrombocytopenic Purpura and Transfusion Associated Lung Injury Successfully Supported on ECMO

Erika Bernardo, Ryan Coleman, Amir Navaei, Amanda Grimes, Adam Vogel, Corey Chartan; Baylor College of Medicine, Houston, USA

Abstract

Congenital thrombotic thrombocytopenic purpura (TTP) is a rare and life-threatening disease characterized by recurrent episodes of thrombocytopenia, microangiopathic hemolytic anemia, and diffuse microvascular thrombosis, leading to ischemic changes in major organs. Treatment of TTP involves frequent transfusions of fresh frozen plasma (FFP). One rare but fatal complication of blood product transfusions is transfusion-associated lung injury (TRALI); presenting with sudden onset hypoxic respiratory failure within 6 hours of transfusion.

We present a 5-year-old female with congenital TTP who was successfully supported on ECMO for respiratory failure after a TRALI. This patient originally presented in acute hemolytic crisis with admission to the floor. Over a 24-hour period, she was transfused 45ml/kg of FFP. On the following morning, she developed respiratory failure requiring intubation. She received 170 ml (10/kg) RBCs. The following day she suddenly developed severe hypoxemia followed by hypotension refractory to high ventilator settings, HFOV and inhaled NO. CT scan was negative for PE but showed pulmonary edema. After multidisciplinary discussions, she was cannulated onto veno-venous ECMO using a dual lumen cannula. She was successfully supported with an 88-hour run on ECMO, anticoagulated with a heparin infusion, with ranges 20-26u/kg/hr, maintaining anti-Xa levels within goal of 0.3-0.5u/mL. Plasma free hemoglobin levels were 50-130mg/dL throughout the run, however, circuit nor cone changes were required. The patient did not experience a bleeding nor thrombotic event during her ECMO run. She was transfused 30ml/kg RBCs but did not need other blood products during ECMO. She was decannulated and discharged home 7 days later.

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ECMO Bleeding Complications: A Single Center’s Experience With Different Anticoagulation Methods

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Abstract

Extracorporeal membrane oxygenation (ECMO) often requires anticoagulation due to foreign circuitry. Unfortunately, bleeding complications contribute to many adverse outcomes. Although no standardized approach in anticoagulating ECMO patients seems to exist, multiple small studies favored bivalirudin over heparin. The objective of this study was to report bleeding outcomes among those anticoagulated with heparin, bivalirudin, or both at a rural tertiary care center.

This retrospective record review included patients supported with ECMO from January 2015 to June 2018 who were 18 years of age or older. Patients were excluded if they received no anticoagulation. Modes of ECMO evaluated included venovenous and venoarterial. Primary outcome was experiencing a bleeding complication that altered the patient’s care plan. Secondary data points analyzed included demographics, characteristics of bleeding complications, time on ECMO (TOE), transfusion products, type of anticoagulation, lab monitoring, time in therapeutic range, and mortality.

We identified 93 patients supported with ECMO. After exclusion criteria, the total cohort equaled 89 (4 excluded for no anticoagulation). Bivalirudin alone accounted for 10 patients, with a mean (S.D.) TOE of 10.8 days (7.65), heparin; 59 patients, TOE 4.2 days (4.5), and both heparin and bivalirudin; 20 patients, TOE 7.38 days (3.97). Overall bleeding complications were reported in 70% of patients on bivalirudin, 53% of the heparin group, and 65% in patients who received both. After statistical analysis, there were no differences in overall bleeding complications between above stated approaches to anticoagulation (X2 (3, N = 89) = 1.690, p = 0.430).
HIV Patient with PJP Pneumonia: Difficulty weaning from VV ECMO
Evan Gajkowski, Arvind Kalyan Sundaram, Jeremy Patterson, Jason Stamm, Yatin Mehta, Mary Reed; Geisinger Medical Center, Danville, USA

Abstract
Case presentation: A 45-year-old female was admitted to an outside hospital with fever and dyspnea. She was initially managed with antibiotics for community acquired pneumonia based on bilateral infiltrates seen on chest X-ray. Her symptoms continued to progress and a diagnostic bronchoscopy was performed, revealing the diagnosis of PJP. A subsequent HIV test was positive. Despite treatment with trimethoprim-sulfamethoxazole and prednisone the patient had progressive respiratory deterioration and met criteria for acute respiratory distress syndrome (ARDS). She required intubation and mechanical ventilator support and was treated with low tidal volume ventilation and paralysis. While she was initially maintained with prone ventilation and started on anti-retroviral therapy (ART) she progressed over several days to severe ARDS with both hypoxia and hypercarbia. Due to her young age and presence of single organ dysfunction she was cannulated for VV ECMO and her ventilator adjusted to protective, ultra-low tidal volume settings. Her hospital course was complicated by secondary pseudomonas ventilator associated pneumonia. After VV ECMO support for 15 days, appropriate therapy for HIV and PJP, patient continued to have significant hypercarbia and dead space ventilation which made support via conventional ventilation and weaning from ECMO difficult. After failing several weaning trials due to increased minute ventilation, her sweep gas was slowly decreased to generate a compensatory respiratory acidosis, which after 24 days allowed her to liberate from VV ECMO to conventional ventilator support. She subsequently had improvement in her lung function and was ultimately discharged to an acute rehabilitation facility without requiring ventilator support.

Nitric Acid Inhalation Causing Severe ARDS Requiring ECMO Support
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Abstract
Inspiration of nitric acid fumes results in intense parenchymal inflammatory reaction which can progress to fatal pulmonary injury. We present a rare case of nitric acid inhalation injury resulting in severe Acute Respiratory Distress Syndrome (ARDS) requiring ECMO support. A 49-year-old male with no significant past medical history presented with dyspnea and cough that developed immediately after inhaling nitric acid fumes at work. Initial chest X-ray showed diffuse, multifocal opacities. Within six hours of presentation, he developed hemoptysis, labored breathing, and worsening oxygenation requiring invasive mechanical ventilation. His PaO2/FiO2 ratio was 59 mmHg on 100% oxygen and chest X-ray showed almost complete opacification of both lungs. Despite lung protective ventilation, sedation, pharmacologic paralysis, epoprostenol, and methylprednisolone his oxygenation did not improve. He also developed shock state requiring four pressors. The patient was placed on VV ECMO and transferred to our facility. On arrival, his lung compliance was 4.6 mL/cmH2O and he was placed on rest ventilator settings with TV of 2 mL/Kg of IBW. He was treated with Methylprednisolone 60 mg q8h and acetylcysteine nebs q4h. Bronchoscopy showed only thin yellow secretions. By ECMO day 6 his oxygenation had improved, and his lung compliance was in low 40s. That same day he passed an ECMO wean and was decannulated. Acetylcysteine nebs were stopped, and patient was switched from methylprednisolone to prednisone with plan for slow tapering over the next four weeks. Patient was extubated on day 9, liberated from supplemental oxygen, and discharged home after 14 days of hospitalization.
Pulmonary histopathologic changes in autopsy after Extracorporeal Membrane Oxygenation treatment

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Abstract

BACKGROUND: The effect of ECMO therapy and pulmonary consequences of its use are still unknown. Only limited information is available regarding the histopathologic changes and its potential influence on the outcome of treatment.

METHODS: We retrospectively studied histopathologic findings in autopsy lungs of 53 patients who died during treatment with venovenous (VV) and arteriovenous (VA) ECMO from 2015 to July 2019. Medical and histopathology records were reviewed.

RESULTS: Thirty-three patients were treated with VA-ECMO (22 men; median age 52.78 ±12.99 yo.) and ten patients (15 men; 48.72±16.73 yo.) with VV-ECMO. Congestive heart failure was the main indication for VA-ECMO treatment (43% cases), whereas pneumonia was the main reason for VV-ECMO (44% cases). From the VA-ECMO group, 25 patients died, of whom 19 (76%) underwent section. The most common histopathological pulmonary findings in the VA-ECMO group were haemorrhagic pulmonary infarcts (32%), and pulmonary haemorrhage (32%). Other, less frequent histopathological findings are diffuse alveolar damage (DAD), interstitial oedema (5.1%) fibrosis of interlobular partitions (5.1%), pneumonia (5%), lung abscesses (5.14%). No significant changes were found in 5.14% of patients. From the VV ECMO group, 13 patients died, the autopsy was performed in 10 patients (77%). Histological examination showed pneumonia (40%), diffuse alveolar damage (30%), abscesses (15%) and haemorrhagic infarcts (15%).

CONCLUSIONS: Obtained histopathological results show severe lung injury associated with underlying disease. However, some may be associated with VV and another with VA ECMO. Our research allows a better understanding of ECMO-related lung changes and will help to prevent it.

Assessment of patients after long term ECMO treatment – preliminary results

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Abstract

INTRODUCTION

Extra Corporeal Membrane Oxygenation (ECMO) is a last line treatment for patients with most severe respiratory and/or cardiac failure, unfortunately little is known about further prognosis of ECMO survivals.

METHODS

To assess the health status of veno-venous ECMO survivals: spirometry, bodypelemysography, diffusing capacity for carbon monoxide (DLCO), high-resolution computed tomography (HRCT), bronchofiberoscopy with bronchoalveolar lavage (BAL-BF) and 6-minute walk test (6MWT) were performed after 90 -360 days from ICU discharge.

RESULTS

Three male patients, two 26 and one 59 years old, treated with VV ECMO for at least 16 days [16-36] because of severe pneumonia with respiratory failure (APACHE II-26-6) and mean PaO₂/FiO₂ 52.2 were included. The 26 yo patients were symptomless, the 59 yo reported dyspnea and walked (414[ m]), whereas younger patients (591 and 580 [m]) in the 6MWT. In all cases HRCT revealed residual alveolar ground glass opacities with focal scaring. Pulmonary function revealed no bronchial obstruction (FEV1/FVC<0.7), however FEV₁ was borderline (71.6-81 [%N]), and the dyspneic subject presented flow-volume curve flattening which suggested upper-airway narrowing, confirmed as tracheal stenosis. The total lung capacity (TLC) was borderline (69-98 [%N]), and DLCO slightly impaired 60 [%N]. BAL excluded bronchial colonization, however in younger patients’ total cell count showed mildly increased cellularity with increased lymphocytes (20-53.3 (N-11.8 ± 1.1 [%])).

CONCLUSION

Even asymptomatic ECMO survivals should probably be re-assessed after ICU treatment. Our research allows a better understanding whether observed findings are caused by post-ARDS lung healing, or caused by development of post-ECMO interstitial lung disease.
Neighborhood Median Income Does Not Affect Mortality Following Extracorporeal Life Support
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Abstract
Objective: Socio-economic status has been shown to influence outcomes in cardiothoracic surgery and critical care populations. This study examined if neighborhood-based median income (NMI) would affect outcomes of patients undergoing extracorporeal life support (ECLS).

Methods: Patients requiring ECLS at our academic center between January of 2013-January of 2019 were included in the study population. NMI was obtained utilizing the American Factfinder Database (U.S. Census Bureau) by patient zip code at time of admission. Patients were stratified into quartiles based on median income for further analysis. The primary outcome was longitudinal mortality stratified by NMI quartile. Secondary outcomes included the examination of the effects of insurance status on mortality, and outcomes further stratified by veno-venous (VV) vs. veno-arterial (VA) ECLS support.

Results: We identified 503 patients who underwent ECLS support at our institution with complete data available for analysis. There were no significant differences in mortality by NMI noted at the 30-day (p=0.08) or the 1-year (p=0.42) timepoints. Figure 1 shows no significant difference in 5-year longitudinal survival in ECLS patients when stratified by NMI (log rank p=0.208). Survival differences were noted between different modes of payers/insurers (p=0.03) at 30-days and 1 year, with self-pay and alternative/hybrid insurances having a higher mortality. When stratified by type of ECLS therapy (VA, VV, hybrids), there were no differences observed between NMI quartiles within each ECLS subtype.

Conclusions: NMI does not affect mortality following the use of ECLS therapy. Further research is warranted to determine socio-economic barriers to accessing ECLS therapy.

Successful removal of massive tracheobronchial clot during neonatal venoarterial ECMO by occlusive endotracheal suction catheter
Grace van Leeuwen Bichara, Anand Dhullipals, Mohammed Elkhwad, David Sigalet, Andrew Durward; Sidra Medicine, Doha, Qatar

Abstract
Introduction
Removal of obstructive blood clots from the central airways can be challenging and a variety of methods have been reported. There are isolated reports of these methods of patients on ECMO where procedural risk is magnified due to anticoagulation.

We report an endobronchial suction catheter technique to remove large tracheobronchial blood clot that had formed an airway cast in a neonate on venoarterial ECMO (VA-ECMO).

Case Report
A 2.7 kg term neonate, presenting right sided congenital diaphragm hernia with liver up and a large PDA, required emergency VA-ECMO for severe hypoxic and hypercarbic respiratory failure shortly after birth (pH <6.9, pCO2 90mmHg and preductal saturations <30%).

After 5 days of ECMO, there was no tidal volume and persistent opacification of both lungs. Flexible bronchoscopy revealed a large organized blood clot in the right main bronchus. Bronchoscopic fragmentation failed as the clot was extensive and adherent to major subsegmental bronchi in the shape of a cast. Within 48 hours, the clot extended into ETT. A near occlusive 10 FR catheter (outer diameter 3.3mm) was fed cautiously down the endotracheal tube (inner diameter 4mm) and then direct suction applied. Both the catheter and ETT were removed together in one motion, under suction, delivering a large intact organized thrombotic cast in the shape of the trachea bronchial tree.

Conclusion
We describe for the first time the successful removal of the tracheobronchial cast in a neonate on ECMO using a modified suction technique with an occlusive suction catheter via the endotracheal tube.
Neurological monitoring and seizures detection with continuous electroencephalography in Pediatric ECMO
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Abstract
Introduction
The clinical applications of continuous EEG (cEEG) in pediatric Extracorporeal Membrane Oxygenation Patients go far beyond the monitoring and detection of subclinical seizures. It should be interpreted as an early recognition tool in situations of impaired brain function. The physiological correlation between cEEG and regional cerebral blood flow allows it to be useful in identifying early changes in brain metabolism still in a reversible stage.

Methods
We collected data of all pediatric patients on ECMO between 2015 and mid 2018. A total of 27 patients were on ECMO and all of them had continuous electroencephalography monitoring during all the ECMO run, which was started within the initial 24 hours after cannulation.

Results
Four of these patients (14,8%) had electrographic seizures or were in status epilepticus, and all of them died.

Neuroimaging studies were performed in 92,5% of patients: 26% had only ultrasound (US), and 66,7% had CT or MRI. Patients cannulated with an open fontanel were followed with daily ultrasound monitoring. Pathological findings in neuroimaging were more common in our series when compared with literature data.

Neurodevelopmental outcomes in post-ECMO patients are been evaluated, and two patients presented Epilepsy.

Conclusion
Including, cEEG may serve a vital role in multimodality monitoring for early recognition of neurological complications from brain injuries that may not be noticed clinically, which is paramount to early intervention. Our analysis reinforces these concepts, since we can consider continuous EEG as a possible prognostic predictor, and its abnormalities are directly associated with an unfavourable outcome.

Bivalirudin use in the setting of Therapeutic plasma exchange in ECMO patients
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Abstract
Therapeutic plasma exchange (TPE) is a process by which whole blood is removed and separated into its components: red blood cells, white blood cells, platelets and plasma. TPE is used for the treatment of conditions in which a pathogenic substance or component in the blood is causing morbidity.

Extracorporeal life support (ECLS) or extracorporeal membrane oxygenation (ECMO) is used to provide cardiopulmonary support to patients. The choice of anticoagulation for patients on ECLS is predominantly between a direct thrombin inhibitor (DTI), and heparin "TPE does result in removal of anticoagulation medications (Kaplan, 2016). The procedure results in approximately 60-70% removal of Heparin. The amount of Bivalirudin removed during plasmapheresis is not well known and coagulation labs should be followed closely." We hypothesized better anticoagulation management for the Bivalirudin patients.

The objective of this study was to describe our experiences using a DTI as anticoagulation for ECLS while simultaneously undergoing TPE, during the period of October 2017 through April 2018. One case had no anticoagulation administered during TPE runs while the remaining two cases utilized Bivalirudin. Activated partial thromboplastin time (aPTT) was collected prior to and at the completion of each TPE run. The patient who had no anticoagulation had a pre-run average aPTT of 50 and a post-run average of 85. The two patients on Bivalirudin had a pre-run aPTT average of 43 and a post-run average of 78. There were no documented thrombotic or hemorrhagic complications during or immediately following TPE in any of the patients.
COMPARISON OF THE ADJUNCTIVE USE OF KETAMINE VERSUS STANDARD OF CARE IN SEDATION AND ANALGESIC MANAGEMENT IN PATIENTS RECEIVING VENO-VENOUS EXTRACORPOREAL MEMBRANE OXYGENATION (VV ECMO)
Honey Patel, Christine Parker, Omar Hernandez, Gary Schwartz, Dan Meyer, Kristen Tesson, Nathan Vaughan; Baylor University Medical Center, Dallas, USA. Abstract
Background: Patients on veno-venous extracorporeal membrane oxygenation (VV ECMO) can be challenging to sedate due to variances in pharmacologic agent properties and the ECMO circuit. Ketamine antagonizes the N-methyl-D-aspartate (NMDA) receptor blocking glutamate as well as an agonist of nociceptive opioid receptors to provide sedation and analgesia. It may be preferable over other sedatives due to its lack of respiratory depression and its ability to induce bronchodilation. Hence, we evaluated the adjunctive use of ketamine versus standard of care in sedation and analgesia management in patients receiving VV ECMO.
Methods: We reviewed charts of consecutive adult patients who received a ketamine infusion for ≥24 hours during VV ECMO at our center from January 2012 to June 2018 and propensity-matched patients who did not receive a ketamine infusion. We compared the proportion of sedation, analgesic, and vasopressor requirements within the first 24 hours, as well as survival rates between groups using Chi-Square and Fisher’s Exact tests.
Results: A total of 88 patients were included in analyses. Patients who received ketamine were significantly younger and had less comorbidities than patients who did not receive ketamine. Ketamine recipients required propofol, fentanyl, norepinephrine, and epinephrine at significantly lower rates than those who did not receive ketamine; however, they required more midazolam and hydromorphone. Neither intensive care unit nor in-hospital survival rates differed between the groups (59% vs. 64%, p=0.8269; 41% vs. 36%, p=0.6615)
Conclusion: Ketamine appears to have comparable safety to standard of care and is associated with differential sedation and analgesic requirements.

Risk factors for agitation and delirium in postcardiotomy patients with ECMO support
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Abstract
Background: The prevalence of agitation and delirium in postcardiotomy patients supported with extracorporeal membrane oxygenation (ECMO) is still unclear. This study aimed to evaluate the incidence of agitation and delirium in postcardiotomy patients during the ECMO support, to identify the risk factors for its development, and to assess its associations with the outcomes.
Methods: This historical, single-center, observational study was conducted at Beijing Anzhen Hospital, Capital Medical University. Data were extracted from the prospective institutional registry database of ECMO patients. Univariate and multivariate logistic regression analyses were performed to predict risk factors.
Results: A total of 170 consecutive adult patients underwent ECMO in our hospital from January 2016 to December 2017. Nighty-four patients were included in the final analysis. The incidence of agitation and delirium was 35%. Agitation and delirium usually occurred within the first three days of ECMO. Multivariable analysis showed that history of stroke (odds ratio [OR], 5.517; 95% confidence interval [CI]: 1.360–22.377; p=0.017), carotid plaque (OR, 4.27; 95% CI: 1.12–16.27; p=0.034), and low mean arterial pressure (MAP) before ECMO initiation (OR, 0.97, 95% CI: 0.94–0.99, p=0.045) were independent risk factors for agitation and delirium during ECMO support.
Conclusions: Our results suggested that paying more attention to patients with history of stroke, carotid plaque and low MAP before ECMO initiation may ameliorate or prevent agitation and optimize the medical care of these patients.
Impact of Neonatal Abstinence Syndrome on Neonates Requiring ECMO Therapy
Hubert Ballard,1 Aric Shadler,2 Karen Garlitz,3 Deb Grider,1 Colby Walters,1 Mina Hanna,3 Prasad Bhandary,1 John Bauer,1 Peter Giannone,1 Philip Bernard1; 1University of Kentucky, Kentucky Children’s Hospital, Division of Neonatology, Department of Pediatrics, Lexington, USA. 2University of Kentucky, Kentucky Children’s Hospital, Lexington, USA

Abstract
Background: Neonates who have in utero drug exposure has become more common, and they frequently develop neonatal abstinence syndrome (NAS) requiring postnatal treatment. Since NAS has become more common it is seen in neonates who are critically ill and require ECMO. The impact of NAS on neonates requiring ECMO is unknown.

Methods: We performed a review of all neonates placed on ECMO from January 2013-January 2019. The control group (C) was neonates without in utero drug exposure vs. the NAS group (NAS-ECMO) which were exposed to narcotics in utero and required treatment for NAS postnatally. Data were analyzed for birth weight, gestational age, complications during ECMO therapy, survival to discharge, sedation requirements including number of medications (adjuvant therapies), and length of stay (LOS).

Results: 51 patients (C = 38, NAS-ECMO = 13) were placed on ECMO during this time period. Birth weight was lower in NAS-ECMO (2.792 ± 554 grams) vs. control (3.269 kg ± 641 grams) (p = 0.02). Gestational age, survival to discharge, and complications during ECMO were similar between groups. LOS was longer in NAS-ECMO vs. controls (45 days vs. 38 days, p = 0.05). The NAS-ECMO group also required more adjuvants to maintain sedation compared to controls (2.64 vs. 1.26, p = 0.02).

Conclusion: Neonates placed on ECMO with NAS have increased LOS and require more sedatives during ECMO. This suggests these patients are more difficult to manage during ECMO and may benefit from different sedation approaches.

Prediction of Survival with Pre-ECMO Lactate Level in VA ECMO with Cardiogenic Shock
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Abstract
Background: The effectiveness of extracorporeal membrane oxygenation (ECMO) for patients with cardiogenic shock is well-established, and lactate is well known as the biochemical biomarker of end organ perfusion. We evaluate the efficacy of pre-ECMO lactate level for prediction of survival in patients with cardiogenic shock.

Methods: We respectively reviewed the medical records of patients who underwent ECMO for cardiogenic shock between January 2015 and December 2017. Seventy nine adult patients underwent the venoarterial ECMO for cardiogenic shock. These patients were divided into survivor and nonsurvivor groups, based on survival to hospital discharge. The patient characteristics in pre-ECMO condition were compared between 2 groups.

Results: Mean age was 60.9 ± 14.8 years and 29 (36.2%) patients were female. The overall survival rate to hospital discharge was 46.8% (n=37). In multivariate analysis, independent predictors of mortality were the pre-ECMO lactate level (OR, 1.1703; 95% CI, 1.0521-1.3017; p = 0.0038). The optimal cut-off value for pre-ECMO lactate was 9.2 (AUC 0.696, p=0.0015). Kaplan-Meier survival curves showed that the cumulative survival rate at hospital discharge was significantly higher among patients with pre-ECMO lactate of 9.2 or less compared with patients greater than 9.2 (65.1% versus 28.1%; p=0.0007).

Conclusions: The pre-ECMO lactate may be an predictor of outcomes with the use of ECMO in adult cardiogenic shock. However it is still difficult to predict survival with only pre-ECMO lactate levels and to determine whether to apply the ECMO for adult cardiogenic shock. Further research on how to predict reversibility more accurately is essential.
Prevalence of Dyphasia in EMCO Patients: A Single Center Experience
Abiodun Orija, Erin August, Shannon Bryant, Lance Cohen, I-wen Wang; Memorial Healthcare System, Hollywood, FL, USA

Abstract
Introduction: Dysphagia in ECMO patients has not be described in in the literature. We reviewed of our past 100 ECMO patients to establish prevalence of motor and pharyngeal dyphagia.

Method: Single-center retrospective analysis of all ECMO cases from February 2014 to July 2019. All studies by speech pathologists were reviewed. Patient demographics, mode and duration of ECMO, cannulation sites, and cannula sizes were abstracted. Dyphagia was rated mild, moderate and severe by speech pathologists.

Results: From February 2014 to July 2019, 100 cases of ECMO was performed at our institution: 55 were VA-ECMO and 45 were VV-ECMO. Mean age of all patients was 50.2 years. Ratio of male to female = 70:30. Mean hours of ECMO support were xxx. VA cannulation was via either central or femoral access. VV ECMO cannulation were more varied: dual lumen cannula, bicaval, bifemoral, and central.

12 patients did not have speech evaluation and 6 additional patients were not extubated. Of the cases evaluated by speech therapists, only 10 did not have dysphagia. Of the remaining, the majority had mild or moderate motor/pharyngeal dysfunction. Only 3 cases of severe dysphagia required speech therapy. All three cases were VV ECMO with 3-5 days of ECMO support with dual lumen (2) and bifemoral (1) cannulation.

Conclusions: The prevalence of dysphagia in ECMO support is 88% with most having mild to moderate motor/pharyngeal dysfunction. Only 3 (4%) required ongoing speech therapy. This observation represents likely the severity of illness in combination with duration of ECMO and ventilator support.

Causes and timing of death in patients supported with VV ECMO - What can we learn?
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Abstract
Introduction: We evaluated causes and timing of in-hospital mortality in patients on VV ECMO.

Methods: All patients, excluding trauma and bridge to lung transplant, admitted 8/2014-6/2019 to a specialty ICU for VV ECMO were reviewed. Data was collected and analyzed with parametric and non-parametric statistics as indicated.

Results: 222 patients were reviewed. In hospital mortality was 24.8% (n=55). Non-survivor’s median age was 53 [38,59] years, pre-ECMO pH 7.15 [7.04,7.24], P/F 70 [59,91], RESP score 1[-1,3] and SOFA score 13 [10,15]. Median time on ECMO for non-survivors was 270 [107,613] hours with median hospital length of stay of 19 [6,32] days.

46/55 patients died on VV ECMO prior to lung recovery. Median time on ECMO was 261 hours [81,613]. Causes of death (COD) included: 26 removal of life sustaining therapy (LST) in setting of MSOF; 8 cardiac arrest (7 in the setting of MSOF); 7 had removal of LST due to overall poor prognosis; 3 by neurological criteria; 1 of acute hemorrhage. 9/55 died, median 9 days [6,11], after decannulation. COD included: 3 cardiac arrest; 2 removal of LST due to MSOF; 3 removal of LST due to poor prognosis; 1 acute hemorrhage.

Non-survivors were older, had higher pre-ECMO SOFA and lactate and lower pH and RESP scores compared to survivors. (p< 0.05)

Conclusion: Most non-survivors die prior to decannulation from VV ECMO. The most common causes of death is removal of LST in the setting of MSOF. Non-survivors are older and have worse predictive mortality scores than survivors.
Infectious etiologies of respiratory failure and survival outcomes in VV-ECMO
Marianne Wallis1, Jay Menaker2,3, Katherine Kelley3, Michael Mazzeffi2, Kristopher Deatrick2, David Kaczorowski1, Ronson Madathil2, Ronald Rubinstein2, Thomas Scalea2,3, Samuel Galvagno2,3; 1University of Maryland Medical Center, Baltimore, USA. 2University of Maryland School of Medicine, Baltimore, USA. 3R Adams Cowley Shock Trauma Center, Baltimore, USA

Abstract
Introduction: We assessed outcomes based on infectious indications for VV ECMO.

Methods: A review of patients, excluding bridge to lung transplant and trauma patients, admitted to an ICU for VV ECMO between 8/2014 and 3/2019 was performed. Those with a viral or bacterial pneumonia were identified. A multivariate Cox regression model was applied assessing factors for survival associated with infectious etiologies for VV-ECMO. Recursive partitioning and classification and regression tree (CART) analyses were used to assess attributable mortality.

Results: 90 patients, with median age of 41 years, SOFA score of 10, RESP score of 3 and P/F ratio of 65 were cannulated for respiratory infections – 44 viral, 46 bacterial. Survival to hospital discharge was 80% and 65%, respectively (P = .18). The most common viral etiology was influenza A (n=27, 61%), while S. pneumonia and MRSA accounted for most bacterial pneumonias (each with n=10, 22%). All decannulated viral pneumonia patients survived to hospital discharge. 4 with bacterial pneumonia died within 30-days post decannulation prior to discharge.

CART analysis demonstrated that 30-day post-cannulation mortality increases with SOFA score >13 and age >53 years. Of patients with those characteristics, 30-day post-cannulation mortality was 50% with bacterial and 56% with viral pneumonia.

Conclusion: There is no difference in survival to hospital discharge based on infectious indications for VV ECMO. Most patients who are decannulated survive to hospital discharge. Severity of illness and age play a role in survival to 30-day post VV ECMO cannulation.

Tracheostomy in patients on venovenous extracorporeal membrane oxygenation: Is it safe?
Katherine Kelley1, Samuel Galvagno2,3, Marianne Wallis1, Michael Mazzeffi2, David Kaczorowski2, Kristopher Deatrick2, Ronson Madathil2, Ronald Tesoriero3,4, James O’Connor2,1, Thomas Scalea2,3, Jay Menaker2,1; 1R Adams Cowley Shock Trauma Center, Baltimore, USA. 2University of Maryland School of Medicine, Baltimore, USA. 3University of Maryland Medical Center, Baltimore, USA

Abstract
Background The purpose of this study is to evaluate the technique and complication rate of tracheostomy in patients on VV-ECMO.

Methods: All patients, excluding bridge to lung transplant and those with traumatic tracheal injuries as indication for ECMO, admitted 11/2015-01/2019 to a dedicated multi-disciplinary ICU for VV-ECMO patients were reviewed. Data were collected retrospectively and analyzed with appropriate parametric and nonparametric statistics as indicated. Bleeding complications within 48 hours of tracheostomy were defined as major for those requiring transfusion of ≥2 units PRBC or unplanned operative hemorrhage control; all other bleeding was considered minor.

Results: 96 patients underwent tracheostomy while on VV-ECMO. Percutaneous tracheostomy was performed in 51 (24%) patients, open tracheostomy in 24 (11.5%) and hybrid procedures in 21 (10%). 28/96 (29%) patients had post procedure bleeding complications. Bleeding was from the tracheostomy site in 13 patients, the airway in 13 patients and both in 2 patients. 6 patients had major tracheostomy site bleeding, 1 requiring operative intervention and 2 cryotherapy by bronchoscopy. 7 patients had minor tracheostomy site bleeding only, 10 minor airway bleeding only and 2 had minor bleeding at both sites. Minor bleeding control included local packing, holding of anticoagulation or transfusion of 1 unit of PRBC. Bleeding complications were more common following percutaneous tracheostomy (37%, p=0.032).

Conclusions: Bleeding following tracheostomy in VV-ECMO is common with higher bleeding rates observed for those done percutaneously. Most complications were minor. Tracheostomy in patients on VV-ECMO appears safe.
Outcomes and Predictors of Mortality in Non-Cardiac Pediatric Patients on Venoarterial Extracorporeal Membrane Oxygenation after Left Atrial Decompression: A Single-Center Experience
Ahmad Hamed, Jeff Hong, Ravi Vamsee, Neel Shah, Surendranath Veeram Reddy, Cindy Bowens, Lakshmi Raman; UT Southwestern Medical Center, Dallas, USA

Abstract
Background: One recognized complication of VA-ECMO is development and worsening of left-sided heart congestion. At our institution, this issue is addressed via percutaneous left atrial (LA) decompression.

Methods: We reviewed patients from our pediatric intensive care unit (PICU) on VA-ECMO who received LA decompression. Utilizing retrospective chart review, we analyzed the following pre- and post-decompression parameters: laboratory findings, ventilatory support, vasoactive-inotropic scores (VIS), ECMO circuit measurements, echocardiography results, and cardiac catheterization hemodynamics. Our objectives were to describe outcomes and identify predictors of mortality in this population.

Results: Between 2009 and 2019, 27 patients at our PICU met inclusion criteria. There were no procedural complications related to LA decompression. Overall survival to discharge was 63%. Immediately after LA decompression, 67% of patients experienced a decrease in lactate; VIS decreased in 44% of patients (VIS remained stable in 52% of patients); ECMO venous pressures decreased in 78% of patients; and where data was available, LA pressure decreased in 67% of patients. Lower pH, higher lactate, and higher PaCO2 were associated with increased mortality (P-value < 0.05). While not statistically significant, lower PaO2 and higher VIS trended towards increased mortality. There was no association between ECMO circuit measurements and mortality.

Conclusion: LA decompression for patients on VA-ECMO at our institution was a safe procedure that led to overall improvement in lactate, VIS, venous pressures, and LA pressures. Predictors of mortality included lower pH, higher lactate, and higher PaCO2. Our population had a similar survival rate compared to what is currently reported in the literature.

Novel use of Protek Duo cannula for left ventricular decompression in an adult patient with post-infarction LV pseudoanerysm and cardiogenic shock.
Jeffrey Yourshaw, Daniel Steinberg, Sanford Zeigler; Medical University of South Carolina, Charleston, USA

Abstract
Left ventricular (LV) pseudoanerysm is a rare complication following myocardial infarction. A 54-year-old man presented in transfer to our medical center for treatment of enlarging post-infarction LV pseudoanerysm of the inferior wall, and subsequent cardiogenic shock. On presentation the patient was suffering from confusion, hypotension, tachycardia, oliguric renal failure, and congestive hepatopathy. In the catheterization lab, a transesophageal echocardiogram was performed showing compression of the right atrium and right ventricle by the large LV pseudoanerysm. Right heart catheterization showed elevated filling pressures and low cardiac output. Given the clinical situation and anatomic complexity, a novel solution was sought to treat cardiogenic shock. A 31-French Protek Duo cannula (TandemLife) was placed via the right internal jugular vein with inflow at the superior vena cava/right atrial junction and main pulmonary artery. A 19-French arterial cannula was placed via the left femoral artery with outflow in the descending aorta. The cannulas were then connected in a VVA configuration to a CentriMag (Abbott Inc.) acting as a pulmonary artery and right atrial vent, and effectively decompressing the left ventricle. Over the next 3 days there was rapid improvement in renal and hepatic function. On day 4, surgical repair of the pseudoanerysm was performed with bovine pericardium. VVA ECMO was successfully discontinued during the operative case. Following surgery the patient had an uneventful 10-day hospital course, and was discharged in improved condition to inpatient rehabilitation.
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**Educating the ECLS Specialist**
Jennifer Jones; The Children’s Hospital, Oklahoma City, USA

**Abstract**
In 2014 The Children’s Hospital in Oklahoma did not have the nursing staff to accommodate the need of our cardiac program, so to bridge the gap most of the patients that ended up on ECLS support we had to use a contract company to staff. We had to change these practices for proper patient care and for a revenue standpoint. Hospital leadership came together to form a plan on how to properly educate the Specialist and how to staff our own ECMO clients. We decided to take all 30 specialist back for a 4 day 8 hour classes, it was done over two separate courses. We used the recommended topics from ELSO and divide it up among everyone then we had multiple services from pediatric and adult services come and speak. We started with didactic, then in the afternoon would go to the simulation lab to run patient scenarios. We had them divide into three separate groups an adult and pediatric simulation room, after each simulation we would debrief each scenario. In the third Simulation room the perfusionist went over transports and component changes ECT. The staffing model currently consist of the Specialist signing up one day each week on the ECMO schedule and that does apply towards their full time requirements this currently covers two patients concurrently. Mandatory requirements are they must sit 12 hours every 12 weeks to keep their pump hours current and to attend quarterly drills that consist of wet drills and simulations.

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**Cadaver Cannulation**
Jennifer Jones, Klayton Buckley; OU Medicine, Oklahoma City, USA

**Abstract**
The Children’s Hospital ay OU Med is looking to explore different avenues to provide physician's training in ECLS cannulation. We have learned that different techniques for cadaver preservation exist, one is salt water embalming. This body preservation makes the body more pliable, soft and exhibit more of a natural existence. To date, the willed body program here at OU Med has been able to develop perfusion techniques to provide flow in peripheral limbs for trauma simulations. We hope to develop perfusion techniques that provide systemic perfusion to provide a realistic ECMO cannulation simulation with ECHO guidance, and/or fluoroscopy guidance for training techniques. While this process has never been done before here at OU Med, we are currently awaiting for approval from the Oklahoma State Anatomical Board. The objectives are to allow the surgeons to gain hands on experience with cannulating human cadavers in a realistic clinical situation, using current imaging techniques. We currently provide care to 50 patients annually (pediatric and adult), with 75% of those patients centrally cannulated by the cardiothoracic surgeons. The trauma and general surgeons do not get the opportunities to cannulate as often, due to lack of patients opportunities and the recent development of the adult program in October 2018. We have theorized several different ways to evacuate clots, and the ability to provide systemic circulation. Once our protocols are approved by the State Board, we hope to have the ability to provide cannulation techniques for both veno-arterial, and veno-veno support.
The Use of Extracorporeal Life Support in Children with Autoimmune Disorders: A Review of a Multicenter Database
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Abstract
Background: Current literature on the use of ECLS in children with autoimmune disorders is limited. The objective of this study is to describe the practice and outcomes of the use of ECLS in this population.

Methods: Retrospective cohort study utilizing the Extracorporeal Life Support Organization (ELSO) registry. Children less than 18 years of age with ICD-9 and ICD-10 codes for autoimmune disorders from 1989 through 2018 were included.

Results: During the study period, 207 patients with a diagnosis of an autoimmune disorder required ECLS and 104 patients (50.2%) survived to discharge. The median patient age was 115 months (IQR: 31-185 months). Most patients (n = 131, 63%) received ECMO for respiratory support with 53% survival, 44 (21%) received cardiac support with 55% survival, and 32 (15%) received ECPR with 34% survival. Survival rates by support type did not differ significantly (p= 0.15). The median duration of mechanical ventilation prior to cannulation was 22 hours (IQR: 6-75 hours). The median duration of ECMO exposure was 157 hours (IQR: 99-284 hours). The largest difference in survival rate was seen in patients with juvenile idiopathic arthritis. The use of corticosteroids was a significant pre-ECMO risk factor for mortality. Non-survivors were more likely to require renal replacement therapy and had a higher rate of infections and neurologic complications.

Conclusions: Patients with autoimmune disorders have similar survival compared to the overall pediatric ECMO population. To our knowledge, this is the first description of the use of ECLS in pediatric patients with autoimmune disorders.

VA-ECLS Mobility to improve post-surgical outcomes
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Abstract
Purpose: To have a safe and feasible way to mobilize VA-ECLS patients who are femorally cannulated while waiting to bridge to transplant or durable device
Background: The UWMC ECLS program has been growing rapidly and there has been a call for figuring out the most safe and feasible way to mobilize this population to improve post-surgery outcomes.
Methods: At UWMC a team of therapists on the CTICU along with nursing and physicians created safe parameters for VA ECLS mobility based on other facility programs and studies. The protocol was implemented with the use of the Vital-Go Total Lift bed. We first simulated this intervention and then implemented it with patients as they required increased cardiac support in the form of VA-ECLS.

Outcomes: To date the bed has been used and protocol has been implemented on 5 patients requiring VA-ECLS. We have seen patients mobilize quicker post-op than historically seen with this population, and less deconditioning from prolonged bedrest. This has also helped support patients being more awake, off ventilatory support and participate in therapy on the days leading up to surgery. Along with participating in therapy the patients have been able to be more involved in their plan of care and complex decision making process that is often involved in this high level of care.

Conclusions: This has so-far been an objectively and subjectively successful protocol that is still in the beginning stages of its implementation. We are looking forward to more concrete information to study and develop as we continue to grow.
SUCCESSFUL FEMORO-FEMORAL VENO-ARTERIAL ECMO SUPPORT OF A PATIENT WITH SEVERE AORTIC AND MITRAL VALVULAR REGURGITATION

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Abstract
Introduction:
Veno-arterial ECMO is contraindicated in the setting of severe aortic regurgitation (AR) largely due to progressive distention and overload of the left ventricle (LV) from retrograde flow. There are several case reports in which patients with mild to moderate AR were successfully managed with VA ECMO and surgical LV venting. We describe a patient with severe aortic and mitral regurgitation (MR) who was successfully maintained on VA ECMO without a surgical LV vent.

Case:
A 37-year-old man presented with progressive hypoxia. Radiographic studies revealed diffuse pulmonary edema. Despite maximal ventilatory support, hypoxia progressed until he suffered a PEA cardiac arrest. At that time percutaneous femoro-femoral VA ECPR was successfully initiated. Norepinephrine was started for blood pressure support and was weaned off within 24 hours of cannulation. A subsequent echocardiogram demonstrated normal biventricular function and large vegetations on the aortic, mitral, and tricuspid valves with torrential AR, severe MR, and moderate tricuspid insufficiency as well as an aorto-left atrial fistulous tract. After 4 days of VA ECLS, the patient’s multi-organ failure improved, and he underwent aortic valve replacement, mitral valvuloplasty, tricuspid valve debridement, ligation of the aorto-LA fistula, and ECMO decannulation. He was discharged on hospital day 28 to acute inpatient rehab.

This case suggests that select patients with severe AR may be successfully supported with VA ECMO if adequate intrinsic LV venting is present.

Near-Infrared Spectroscopy Monitoring for Lower Extremity Ischemia may be Beneficial in Femoral V-A ECMO Patients with Distal Perfusion Catheters

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Abstract
Introduction:
Previous studies have described Near-Infrared Spectroscopy (NIRS) for identification of lower extremity (LE) ischemia in femorally cannulated V-A ECMO (Vf-A ECMO) patients. The device (SenSmart® Model X-100; Nonin Inc. Plymouth, MN) measures regional tissue oxygenation (rSO₂). No standard cutoff values are available to suggest when intervention is required. The previous studies report ischemic complications at a maximum difference between legs (rSO₂Δ) >43 and lowest rSO₂ on either leg (rSO₂ nadir) <23.

Methods:
After obtaining IRB approval, a single institution retrospective chart review was performed for all Vf-A ECMO patients with LE NIRS. Institutional policy requires LE NIRS and routine placement of distal perfusion catheters (DPC) for all Vf-A ECMO patients. Data were analyzed to determine if monitoring was useful in patients with and without DPCs and to find ideal alarm values for rSO₂Δ and nadir.

Results:
23 patients met inclusion criteria, 7 had clinically confirmed LE ischemia. 17 patients had a prophylactic DPC, 3 had a DPC placed for LE ischemia, 3 did not require DPC placement. Ideal sensitivity and specificity were calculated for rSO₂Δ values >15, 100% and 87.5% and for nadir rSO₂ <35, 71.43% and 100% respectively.

Conclusion:
NIRS may be beneficial for the identification of LE ischemia in Vf-A ECMO patients. The nadir and rSO₂Δ thresholds for intervention appear to be more subtle than previously suggested. Continued monitoring is required despite DPC placement.
Pressures and flows through dialysis catheteresis using a centrifugal ECMO pump with a Maquet Quadrox iD oxygenator in an ECMO circuit primed with human blood.

Jose Luis Olarte¹, Jill Marie Pittman²; "Cook Children's Hospital, Fort Worth, USA. ¹Cook children's Hospital, Fort Worth, USA

Abstract

Introduction: Dialysis catheters (larger than 11.5 Fr) can potentially be employed for VV ECMO support, extracorporeal CO2 removal (ECCO2r) or lung augmentation therapy. The safety of these catheters for short term renal replacement therapy use (7–14 days) has already been established.

Methods: A laboratory in vitro study, which was cleared by the IRB. We utilized an expired, unused, blood primed, ¼ inch circuit with a centrifugal pump with a pediatric oxygenator. The circuit was warmed to 37°C. The resulting hemoglobin level was 10g/dL. We tested an 11.5 Fr/12cm and a 13.5Fr/16cm dialysis catheters. Luer-lock adapters were added to the arterial and venous limbs of the ECMO circuit to connect to the catheter. We increased the revolutions per minute (RPM) in increments of 200, from 2000 to 3800. Arterial limb flow, bladder pressure and post-oxygenator pressure were recorded. The system resistance was calculated.

Results: The flow of the 13.5 Fr catheter ranged from 0.31 to 0.57L/min with trans-pump pressures ranging from 62 to 213 mmHg (Figure 1). The estimated resistance ranged from 626 to 830 kPa/m³ sec⁻¹. The 11.5 Fr catheter’s flow ranged from 0.11 to 0.31L/min with trans-pump pressures ranging from 64 to 220 mmHg (figure 1). The estimated resistance ranged from 1292 to 1576 kPa/m³ sec⁻¹.

Bottom Line: A 13.5 Fr catheter allowed flows of 0.4 to 0.5L with RPMs ranging 3000-3500. The resistance of the 11.5 Fr was double compared to the 13.5 Fr. The safety of dialysis catheters to deliver ECMO has not been widely tested.

Repositioning Bi-Caval Dual Lumen Venovenous ECMO Cannulas (Avalon) in Pediatric Patients

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Abstract

Introduction: During Venovenous ECMO, Avalon cannula displacement to the hepatic veins or right atrium is a common occurrence. Cardiac perforations have been reported. Others have reported techniques in the catheterization lab to reposition these cannulas. We present a bedside technique to attempt cannula repositioning.

Technique: With ECHO guidance (Figure 1), one operator manipulates the cannula, a second operator flexes the patient’s neck and shoulders to align the right atrium (RA) with inferior vena cava (IVC).

Methods: Retrospective chart review of all patients in whom Avalon cannula was used from 2009 to 2019.

Results: Thirty-two children were cannulated with Avalon cannulas. Twenty-six patients (84%) were cannulated percutaneously and 8 (16%) with open surgical technique. Four patients (12%) experienced cannula displacement after the initial cannulation. Repositioning at the bedside was successful in all 4 patients. Two patients had the cannula tip migrate to the hepatic veins and in the other 2 patients, into the right atrium. In one neonate, who had open surgical cannulation, required a prolonged surgical approach to liberate the cannula for reposition. The other 3 patients who were cannulated percutaneously, repositioning was less laborious by only removing skin sutures. One infant had a Broviac inserted in the SVC along with the Avalon cannula and during repositioning the neonate developed a pericardial effusion.

Bottom Line: Alignment of the RA and IVC by flexing the neck and shoulders facilitated repositioning of Avalon cannulas at the bedside. Percutaneous insertion of the Avalon cannulas made later reposition less difficult. Preparation for pericardiocentesis is advised.
Post-Intensive Care Syndrome (PICS) in Prolonged Extracorporeal Life Support (ECLS)
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Abstract

Background
Extracorporeal Life Support (ECLS) survivors are at significant risk of the health challenges from Post Intensive Care Syndrome (PICS) which describes the long-term cognitive, functional, and behavioral/mood impairments due to critical illness. The Health Aging Brain Center Monitor (HABC-M) is a validated tool for assessing symptoms of PICS. Since 2009, >300 adults received ECLS at our institution, of which 26 were on circuit >30 days. To our knowledge, this is the largest cohort of such patients.

Objective
To better understand the long term impact of PICS in prolonged ECLS (>30 days).

Methods
26 patients received ECLS for >30 days at our institution from 2009-2019. A physician trained to administer the HABC-M contacted patients. 27 questions were administered based on recollection in the prior 2 weeks, yielding scores in cognitive, functional, and behavioral/mood subscales. Scores for each question ranged from 0 to 3, with higher scores indicating more severe dysfunction.

Results
Of 26 patients, 11 were scored. 10 were deceased and the rest had moved and follow-up plans are in place. The average HABC-M score for respondents was 9.09.

Discussion
Our hypothesis was that PICS is more severe in those with prolonged ECLS, which our preliminary results seemed to refute. Our patients’ average HABC-M score of 9.09 was lower than average for ICU patients (16.3) in the general population (8.3). Data collection for the remaining patients is underway. We hope to use this data to monitor long-term implications of ECLS and improve post-ECLS care.

Safety and Efficacy of Bivalirudin for Systemic Anticoagulation in Veno-venous Extracorporeal Membrane Oxygenation
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Abstract

Background
Although unfractionated heparin (UFH) is the most commonly utilized anticoagulant in patients requiring extracorporeal membrane oxygenation (ECMO), our institution utilizes bivalirudin. Although the UFH versus bivalirudin comparisons exist, none to our knowledge involve the veno-venous ECMO population. The aim of this case series was to provide insight into the manageability and clinical outcomes of bivalirudin based ECMO. We also sought to determine modifiable factors associated with clinical outcomes.

Methods
The primary outcome of this study was the percent of time in the target anticoagulation range. Secondary outcomes included major bleeding, clinical thrombosis, and receipt of blood products. The anticoagulation target was set by the treating team to a low intensity (aPTT of 40 to 60 seconds) or high intensity (60 to 80 seconds) target.

Results
68 patients were included with 90% treated with veno-venous ECMO. The median duration on ECMO was 11.9 days. The average time in the therapeutic range was 73.4% ± 15.0%. Major bleeding and clinical thrombosis occurred in 43% and 21% of patients, respectively. Longer duration ECMO was associated with more major bleeding and clinical thrombosis. Continuous renal replacement therapy (CRRT) was associated with a higher receipt of blood products.

Conclusions
Bivalirudin may be an acceptable alternative anticoagulant in patients requiring ECMO but prospective randomized studies are needed to establish its role in this patient population. The percent in the target anticoagulation range and incidence of major bleeding and clinical thrombosis found in this study with bivalirudin are similar to studies in which UFH was used.
Early and mid-term outcomes after veno-arterial extracorporeal membrane oxygenation with compact portable circulatory support device: a single-center experience

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Abstract

Objective: To evaluate early and mid-term outcomes after circulatory support using CardioHelp® (Maquet Cardiopulmonary, Germany) device.

Methods: Single center, retrospective study using Cardiohelp® for VA-ECMO between 2012 and 2019, in adult patients admitted for cardiogenic shock necessitating temporary assist device, as a bridge therapy. We excluded veno-venous-ECMO. Primary endpoint was mid-term survival after VA-ECMO. Secondary endpoints were safety and security of this device in early in-hospital period.

Results: One hundred and thirty three (133) patients benefited from a Cardiohelp® assist device for cardiogenic shock, among them 100/133 (75.2%) were peripheral ECMO. Mean age was 53.8±14.2 years with 30 patients older than 65 years. Forty-seven patients (40.9%) had a LVEF lower than 20%. Forty-four patients (33.1%) had a preimplantation cardiac arrest. VA-ECMO was implanted as a bridge to recovery in 102/133 (76.7%), to transplant in 9/133 (6.8%) and to revascularization in 11/133 (8.1%). Eleven patients (8.3%) were implanted as a bridge to decision. Postcardiotomy shock was the most frequent etiology for VA-ECMO (31%), followed by post transplantation graft failure (14%). No membrane thrombosis or device related complications were observed. In-hospital mortality was 65/133 (48.9%). Fourteen patients (10.5%) had a fasciotomy for lower limb ischemia and 50/133 (37.6%) were reoperated for bleeding. Survival at 1 and 3 years was respectively 91.8 and 89.5% for discharged patients.

Conclusion: Cardiohelp® device is a safe and secure compact portable device for short bridge therapy.

Early and midterm outcomes of post-cardiotomy extracorporeal membrane oxygenation in cardiogenic shock

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Abstract

Objective: Post-cardiotomy extracorporeal membrane oxygenation (PC-ECMO) support is associated with high early mortality. However, the patients who benefit from PC-ECMO and longitudinal outcomes are unknown. Herein, we compared early outcomes and midterm survival of PC-ECMO among patients after cardiac transplantation (CT) and other heart surgery (OHS).

Methods: Between 2009 and 2018, 82 consecutive patients underwent PC-ECMO for persistent cardiogenic shock at our institution, following cardiac transplantation (n=27) or OHS (n=55). Patients who needed ECMO for respiratory support were excluded. All preoperative and early postoperative data were prospectively collected in our cardiac surgery database. Survival follow-up was accomplished using the provincial vital registry.

Results: In CT group, patients were significantly younger (49±15.4 vs. 57.7±11.6 years, \(p=0.01\)), with less acute myocardial infarction (11.1% vs. 49.1%, \(p<0.001\)) and less preoperative hypertension (29.6% vs. 69.1%, \(p=0.0009\)) compared to OHS. Central cannulation for ECMO was more often used in OHS patients (63.6% vs. 33.3%, \(p=0.02\)) and patients were more frequently assisted with preoperative intra-aortic balloon pump (32.7% vs. 3.1%, \(p=0.004\)) compared to CT. In-hospital mortality was similar (48.2% vs. 63.6%, \(p=0.23\)) for CT and OHS groups, respectively. Midterm survival up to 3 years, was significantly higher in CT group (57.7% vs. 32.7%, \(p=0.02\)).

Conclusion: Post-cardiotomy ECMO for persistent cardiogenic shock remains with high early mortality. Among survivors, mid-term mortality is significantly better among post cardiac transplantation-ECMO patients compared to other surgeries. These results should be taken into consideration for patient selection and optimized outcomes following post-cardiotomy ECMO.
Successful use of VA ECMO for one year as a bridge to heart transplant in a child
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Abstract
Successful use of prolonged VV ECMO for respiratory failure is well known, but long term VA ECMO support is less common. A 14 year old boy was referred for consideration of Ventricular Assist Device (VAD) and heart transplantation. 4 months previously he had undergone 4th time redo sternotomy for mitral valve replacement. He failed to wean from cardiopulmonary bypass and was transitioned to VA ECMO with tunneled transthoracic cannula (right atrium, left ventricle and aorta). He developed sternal wound breakdown with multiple abscess formation which precluded VAD use. His course was complicated by frailty, renal failure, recurrent gastro-intestinal (GI) bleeding and non-infectious diarrhea. Upper and lower GI biopsies demonstrated ischemic injury prompting increased ECMO flow, the GI bleed improved allowing enteral nutrition. At ECMO month 8, Candida parapsilosis was detected in blood and circuit cultures, with candiduria which was treated with Amphotericin-B, 5-Flucytosine and bladder irrigation. His renal failure did not recover. Extensive rehabilitation, optimal nutrition, liberation from sedation, extubation, protocolized wound care and physiotherapy whilst supported with VA ECMO with tunneled transthoracic cannula (right atrium, left ventricle and aorta). He developed sternal wound breakdown with multiple abscess formation which precluded VAD use. His course was complicated by frailty, renal failure, recurrent gastro-intestinal (GI) bleeding and non-infectious diarrhea. Upper and lower GI biopsies demonstrated ischemic injury prompting increased ECMO flow, the GI bleed improved allowing enteral nutrition. At ECMO month 8, Candida parapsilosis was detected in blood and circuit cultures, with candiduria which was treated with Amphotericin-B, 5-Flucytosine and bladder irrigation. His renal failure did not recover. Extensive rehabilitation, optimal nutrition, liberation from sedation, extubation, protocolized wound care and physiotherapy whilst supported with VA ECMO (Cardiohelp, Maquet) were central to his rehabilitation leading to resolution of infection, allowing candidacy for heart-kidney transplantation. After a year of support he underwent heart transplantation and decannulation from ECMO. Surgery was technically challenging due to dense vascular adhesions and collateral vessels. Kidney transplantation was abandoned due to difficulty with collateral bleeding. The sternal wound was treated primarily with wound vac, healing took several months. He is thriving 9 months post transplant albeit needing renal replacement therapy.

The impact of extracorporeal membrane oxygenation support on survival in pediatric patients in a pediatric cardiac ICU: review of our experience.
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Abstract
Introduction: Extracorporeal membrane oxygenation (ECMO) circulatory support is used after surgery or as a bridge to recovery or transplant. This is a retrospective single center study 11/2010-11/2017, to analyze our experience and to stratify the risk factors that are associated with mortality.

Results
26 patients (2 patients required two ECMO run), 21 patients (80%) survived to discharge. There were 15 postcardiotomy patients, 9 myocardial failure patients and 2 patients with congenital heart disease, on ECMO prior to surgery. The median BSA and weight for our cohort were 0.24 m² and 4 Kg. 12/21 (57%) patients recovered, whereas 9/21 (42%) were bridged to Ventricular Assist Device (VAD). 8 of 9 patients with myocardial failure (88%) and 11 of 15 postcardiotomy patients (73%) survived. 3 of 4 non-survivors were postcardiotomy, two post Norwood Sano procedure and one with pulmonary atresia and intact ventricular septum post shunt placement. 4 of survivors and 3 of non-survivors had E-CPR with 57% survival. Univariate analysis indicated time to lactate clearance (Hours) was significantly longer among non-survivors 42 hours (range:9-52) and survivors 20 hours (6.5-49, p-Value 0.03). Also Renal failure requiring continuous renal replacement therapy was found in all the non survivors (4 of 4) and only 4 of 11 survivors (p=0.02). The mean Pediatric Cerebral Performance Score was 1.6 (normal to mild disability) over average 1.8-year follow up.

Conclusion
Acute kidney injury requiring RRT and time of lactate clearance were associated with higher mortality. ECMO duration, complexity of defect and ECPR did not impact outcomes.
Implementation of Weaning Guidelines Prevents Circuit Thrombosis and ensures adequate Anticoagulation of Patient and Circuit

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Abstract

There have been improvements made in circuitry and in ECLS management techniques that have led to more widespread use of Veno-Arterial extracorporeal membrane oxygenation (VA ECMO) for cardiac patients. However, there are not many circuitry techniques published from ELSO centers for the weaning process.

ELSO guidelines mention a retrograde technique when using a centrifugal pump which prevents stagnant flow patterns in the circuit that are seen when flows are lowered below 200 ml/min. This flow is the minimum flow stated in the manufacturer’s information for use on the pediatric Quadrox oxygenator. We have adopted the adult Quadrox on all our patients which presents challenges when weaning.

Our center chooses to use a clamp trial process that follows a weaning period at flows of 30-50 ml/kg/min for more than 4 hours which also makes it challenging for the specialist to keep suggested manufacturer recommended minimum flows, no less than 500 ml/min, through the adult Quadrox. To achieve this, there has to be a coordinated effort to ensure the circuit and the patient’s anticoagulation profile is safe and the patient’s hematocrit is optimized. One such technique to maintain a clot-free circuit is opening the bridge during the weaning. It has been essential for our multidisciplinary team to have guidelines during the clamp trial which recently have exceeded 6 hours during certain circumstances.

Our guidelines have proven to be effective for our center and we think that may be beneficial to share with our colleagues.

Distal Perfusion Catheters: How Much Flow is Enough?

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Abstract

Background: Distal perfusion catheters (DPCs) have become widely accepted as safe and effective in preventing lower limb ischemia in patients requiring femoral artery cannulation for extracorporeal membrane oxygenation (ECMO) support. Several studies have demonstrated the efficacy of DPCs, however the required flow to prevent limb ischemia is not known. This study aims to determine the flow rate needed to maintain limb viability.

Methods: A retrospective chart review was performed on patients who underwent VA ECMO with femoral artery cannulation and a DPC placement at a single academic institution between 2016 and 2019. A DPC was placed in all patients and flows were monitored with a flow probe to document the perfusion to the distal limb. Limb perfusion was also monitored noninvasively with tissue oximetry placed on the patients’ calves throughout duration of support.

Results: A total of 108 patients were placed on VA ECMO with femoral arterial cannulation and had DPC placement. Time on support was an average of 8 days and was associated with 4 occurrences of limb ischemia requiring intervention (3 fasciotomy, 1 thrombectomy). Average DPC flow was 0.21cc/min for all patients. Average flow in those patients with limb ischemia was 0.156cc/min.

Conclusion: Placement and monitoring of DPCs via flow probe with a target rate of 0.21 cc/min ensures adequate distal limb perfusion in patients with femoral artery ECMO cannulation. We recommend a minimum flow of at least 0.15cc/min as reduced flow rates may heighten risk of complications.
Weaning from venovenous extracorporeal membrane oxygenation and invasive mechanical ventilation: the EuroELSO 2019 survey

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Abstract
Introduction: The evidence in guiding the weaning processes from venovenous extracorporeal membrane oxygenation (VV ECMO) and invasive mechanical ventilation (IMV) is limited. The aim of this study was to understand strategies used in weaning from both, ECMO and IMV.

Methods: This online survey was conducted from 04/11/2019 to 05/31/2019 and distributed during the 8th EuroELSO Congress, via Extracorporeal life Support Organization (ELSO) Newsletter, and social media platforms. It consisted of 15 questions. One response per center was included. Participation was voluntary. In accordance with the General Data Protection Regulation no respondent data was stored.

Results: Of 253 responses, 67% were ELSO-member. Participants reported ECMO to be offered for both pulmonary and cardiac support in 88%. 47% of the centers treated only adults, and 32% all age-groups. 49% perform >30 ECMO runs/year. The majority (75%) claimed to extubate patients after decannulation and a fraction (12%) to have patients awake and not intubated during ECMO. In 58% of the centers, practice of discontinuing ECMO was reported to occur before weaning from IMV. 42% of responders aim to reduce sedation and mean IMV to spontaneous ventilation during ECMO. In 32% of centers, reducing sedation after commencement of ECMO was reported, with a goal of liberating from IMV prior to ECMO decannulation.

Conclusion: One out of three participants consider weaning off IMV before ECMO, demonstrating a growing perception about the practicality and feasibility of awake ECMO. The variation in the management strategies between centers may be influenced by case mix, experience and volume.

ECMO and Anaphylaxis

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Abstract
Anaphylaxis is often difficult to diagnose, and with cardiac collapse or refractory hypoxemia, can be fatal. There are case reports of pediatric patients with anaphylaxis being treated with extracorporeal support, but the literature is sparse regarding adult patients. Common triggers are food allergies and medications- specifically antibiotics and neuromuscular blockade agents used in anesthesia. We reviewed our institution’s ECMO cases, and found six cases with ECMO placed for emergently decompensating physiology that could be consistent with anaphylaxis.

Two cases involved known food allergens exposures: A 19 yr old woman who unwittingly ingested a cashew and a man with angioedema after shellfish exposure. Both had refractory hypoxemia after ventilator settings were maximized, had short runs of VV ECMO, and recovered fully. Four patients were emergently placed on VA ECMO after anesthesia induction. Two occurred at induction for coronary bypass surgery with 50% survival after VA ECMO. The underlying cardiac issues cannot be excluded as the underlying cause of the patients’ decompensations in these cases, and further confirmatory testing had not been done (eg, tryptase levels). One 47 yr old man arrested after anesthesia induction for rotator cuff surgery without any other identifiable contributing cause, and one coded after AV fistula revision and was found to have a tryptase level of 77. Both these patients made full recoveries.

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VA-ECMO In A Cardiac Arrest Patient After Accidental Treprostinil Disruption

Kari Gorder, Elizabeth Powell, Cassandra Bailey; University of Cincinnati, Cincinnati, USA

Abstract
Introduction: We report a case of a 50-year-old female with a history of pulmonary arterial hypertension on intravenous treprostinil (Remodulin®) infusion who presented with cardiac arrest after accidental disruption of her infusion catheter. She was subsequently cannulated for Veno-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO) and survived to discharge neurologically intact.

Case
A 50-year-old woman with a history of pulmonary arterial hypertension (PAH) presented to the emergency department with accidental disruption of her infusion catheter. She was initiated on inhaled nitric oxide but subsequently decompensated and experienced a cardiac arrest. After return of spontaneous circulation, she continued to have significant hemodynamic instability with evidence of right ventricular dysfunction and the decision was made to place the patient on VA-ECMO. Her intravenous treprostinil was restarted while on ECMO. She was decannulated on ECMO day nine and extubated the following day. She was discharged to a rehabilitation facility neurologically intact.

Discussion
Continuous infusions of pulmonary vasodilator agents such as treprostinil are an increasingly common treatment modality for patients with severe PAH, and disruptions in medication administration can lead to respiratory failure, hemodynamic instability, acute-on-chronic right heart failure and even death. VA-ECMO was used in this case as a bridge to reintitiation of vasodilator therapy and recovery of acute right heart failure in a patient with PAH who experienced cardiac arrest after treprostinil infusion disruption.
**A Novel Daily Bleeding Scale to Characterize Bleeding Severity in Pediatric ECMO**

Katherine Doane, Prashant Bharadwaj, James Yellin, Arun Saini, Ping Zhang, Meera Chitlur

**Abstract**

Introduction: Bleeding events frequently occur in pediatric ECMO patients. The magnitude and impact of bleeding events of varying severity are unknown. We developed and utilized a novel daily bleeding scale (graded 0 to 4 with increasing severity) to determine overall bleeding burden, timing of grade 3 or 4 bleeding events, and risk factors for bleeding events. Methods: Multicenter retrospective cohort study of pediatric ECMO patients, excluding post-cardiac surgery and neonatal patients, at 10 centers utilizing Pediatric ECMO Outcomes Registry (PEDECOR) database from Dec 2013-Feb 2019. Results: A total of 283 pediatric ECMO patients with median age 1.3 years (IQR 0.1, 9.0) and median ECMO duration of 5 days (IQR 3.0, 9.5) were included. Approximately 75% of patients had at least one bleeding event with the following distribution of maximum severity during ECMO course: 27.2%, 26.1%, 15.9%, and 5.7% (grade 1-4 respectively). Based on Kaplan-Meier estimation, 11% (CI 8-15%) of patients are likely to experience a grade 3 or 4 bleeding event by ECMO day 2, 20% (CI 15-26%) at 7 days, and 31% (CI 23-41%) at 14 days. Age (adjusted effect ratio [aHR] 1.07 for each 1-year increase, CI 1.04-1.10, p<0.001) and veno-arterial (VA) ECMO (adjusted aHR 1.95, CI 1.50-2.53, p<0.001) were associated with grade 3 or 4 bleeding events. Conclusion: Bleeding events are common among pediatric ECMO patients. Nearly one-fourth of these events are severe and likely to occur within the first 2 weeks of ECMO. Increasing age and VA ECMO are associated with earlier severe bleeding events.

**Factor XII Deficiency in ECMO Patients**

Katherine Regling, Sarah Ramiz, Meera Chitlur

**Abstract**

Extracorporeal membrane oxygenation (ECMO) for cardiopulmonary support of critically ill patients is used frequently in the pediatric and adult population. Bleeding and thrombosis are usually related to contact of blood and its cellular components with the non-biologic surface of the extracorporeal circuit. Increased contact activation causes platelet activation, consumption of Factor XII, and formation of FXIIa-antithrombin complexes which may increase risk for thrombosis. Factor XII deficiency is not associated with bleeding, but results in a significant prolongation of conventional coagulation assays. Therefore, aPTT and Activated Clotting time (ACT) become unreliable, and it becomes difficult to dissec heparin versus coagulation factor effect on the R-time on thromboelastography (TEG). Here, we present 3 patients with prolonged aPTT prior to or at the start of ECMO. Mixing studies were completed on 2 out of 3 patients and were negative for a lupus anticoagulant; prompting evaluation for factor deficiencies. All 3 patients had Factor XII levels <40% on initial testing, were negative for a lupus anticoagulant; prompting evaluation for factor deficiencies. We recommend attempting to correct factor deficiency with FFP to potentially decrease risk of thrombotic complications, and choosing an alternative laboratory monitoring assay for heparin, such as Anti-Xa levels, which may more accurately correspond to the anticoagulation status in this population.

**Next Generation ECMO Oxygenator With Integrated Monitoring**

Kathryn Osterholzer, Chris Pollt, Patrick Weerwind, Scott Merz

**Abstract**

OBJECTIVE: A novel membrane oxygenator module with integrated monitoring was developed for ECMO. Currently, there is no commercially made membrane oxygenator specifically developed for long term use. METHODS: The design focused on optimizing the transverse flow path through the heat exchange and gas exchange fibers to improve longevity and performance. The device uses a circular blood flow cross-section and proprietary inlet to minimize shear and stasis while retaining a low pressure-drop. Integrated sensors display fluid path pressure, temperature, and oxygen saturation. The surface is bonded with a non-leaching biocompatible surface, Balance™ Biosurface. The device development also included complex in vitro performance testing to verify function, and a chronic 96-hour GLP in vivo study in an ovine model to confirm the performance and safety of the device. RESULTS: Gas and heat transfer testing were conducted per ISO 7199:2016 using bovine blood products to simulate a 14-day use. The device met all critical performance targets. In vitro durability studies were conducted after 30 days of simulated prime in a buffered saline solution and 14 days of simulated use, and confirmed product integrity of the blood path, water path, gas path, and surface coating. The in vivo study demonstrated clinical functionality of the oxygenator for the study period. There were no clots in any location in any test device, and all animals survived with no side effects. CONCLUSIONS: A next generation ECMO oxygenator with integrated monitoring has been developed with optimized features to support the long term ECMO patients.

**Myocardial Stun in the Congenital Diaphragmatic Hernia Population**

Katie Brandewie, Foong-Yen Lim, Russel Hirsch, Wonshill Koh, Reanna Smith, Jonathan Byrnes

**Abstract**

Congenital diaphragmatic hernia (CDH) results from failed diaphragmatic development followed by lung hypoplasia, causing some CDH patients to require extracorporeal membrane oxygenation (ECMO) for stabilization. Myocardial stun is a decrease in left ventricular contractility and occurs when at-risk myocardium receives the acute afterload from the ECMO circuit flow. We aimed to investigate CDH patients at our institution, the echocardiographic findings immediately after (and, when available, before) ECMO cannulation, risk factors for myocardial stun, and associated morbidity. We studied CDH patients from 01/2011-12/2017 who required ECMO. Myocardial stun occurred in 39.6% (21/53) of patients, two-thirds (14/21) of whom had resolved their dysfunction by 12 hours. Only 3 of the 21 had persistent left ventricular dysfunction beyond 24 hours with 2 of these 3 having persistent dysfunction due to aortic arch hypoperfusion. No risk factors for myocardial stun were statistically significant other than 5 minute Apgar score (p < 0.01) and age at cannulation (p < 0.01). Despite mounting evidence for early left heart decompression after ECMO cannulation in other populations, our data does not suggest that this is necessarily indicated in the CDH population. Myocardial stun after ECMO cannulation in neonates with CDH is a frequent, under-recognized, and typically self-resolving complication. Most patients have benign course if arch is not obstructed by thrombus or anatomical obstruction.
A CASE OF MUCORMYCOSIS IN A NEONATAL ECMO PATIENT
Kaylee Struewing, Brian Moore, Lames Hamoodi, Morgan McCoy, John Bauer, Peter Giannone, Hubert Ballard; University Of Kentucky, Lexington, USA

Abstract
Outline of the Case
Our 34-week infant was born by precipitous SVD at OSH with prenatal concern of limited prenatal care, and intrauterine drug exposure. APGARS were 6/7/5/9 with significant respiratory distress requiring intubation and prostaglandins prior to transport. The initial NICU course was significant for meconium peritonitis and septic shock. By DOL 22, development of MRSA necrotizing pneumonia and pulmonary hypertension led to VA ECMO. On ECMO Day 5, a RUQ lucency appeared that required antimicrobial coverage for potential pneumoperitoneum and fungal infection. On ECMO Day 17, clinical deterioration with increased coagulopathy, worsening respiratory status during ECMO, and worsening perfusion and worsening limb ischemic changes led to withdrawal of care. Autopsy and histopathologic examination revealed hepatic mucormycosis.

Discussion:
Mucormycosis is a rare but fatal fungal infection in neonates. It has various manifestations affecting respiratory, nervous, and gastrointestinal systems. Gastrointestinal manifestations are the most common in neonates. Risk factors for mucormycosis include prematurity, low birth weight, poor nutrition, diarrhea, hyperglycemia, corticosteroid use, antibiotic administration, surgery, eneral tube placement and intubation. Our patient had many risk factors including prematurity, prolonged antibiotics, poor nutrition, breaks in skin barrier, nasogastric tube and endotracheal tube placement. Similar in presentation to NEC, there are no classic radiographic findings associated with gastrointestinal mucormycosis. Often postmortem, GMS Nitrate stain highlights its branching morphology. Amphotericin B remains the recommended treatment of mucormycosis with surgical debridement as indicated. Unfortunately, even with such management, the mortality for mucormycosis, especially gastrointestinal, remains high at 80%.

Successful Use of VA-ECMO in a Neonate with Multi-Enzyme Urea Cycle Defect
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Abstract
Background
Since the deployment of neonatal ECMO for respiratory failure, the use of ECMO in this population has diversified. This case report illustrates a subpopulation where neonatal ECMO could improve survival and neurodevelopmental outcomes. We present a term female with multi-enzyme urea cycle defect (UCD) who developed severe hyperammonemia refractory to medical management and was placed on VA-ECMO-driven continuous veno-venous hemodiafiltration (CVVHDF) with rapid decline in ammonia levels.

Case presentation
Female infant presented with respiratory distress and poor feeding at 6 hours of life followed by seizure activity, lethargy and progressive hyperammonemia with peak levels >2000 mmol/L. Hyperammonemia was refractory to ammonia scavengers, hemodialysis (HD) for 4 hours and CVVHDF for 12 hours. HD/CVVHDF were limited by flow rates, hemolysis and hemodynamic instability requiring pressors. Commencement of VA ECMO-driven CVVHDF resulted in rapid decline of ammonia 5 hours post-initiation and normalization in 10 hours. The run was complicated by systemic vasodilation and hypotension from intravenous arginine and nitrogen scavengers resulting in prolonged use of pressors and conversion to oral nitrogen scavengers to mitigate these effects. Genetic testing confirmed carbamoyl phosphate synthetase 1(CPS1) and partial N-Acetylglutamate synthetase (NAGS) deficiencies. She was discharged home on maintenance ammonia scavenger regimen and low protein diet via gastrostomy tube.

Conclusion
This case demonstrates the successful use of ECMO-driven CVVHDF to rapidly reduce ammonia levels in UCD. Early consideration and initiation of ECMO in this subpopulation is critical to reducing neurologic morbidity and mortality from severe hyperammonemia.
Changing Mobility Culture in the ECMO Patient Population
Kelly Madigan, Heidi Dalton; Inova Fairfax Medical Center, Falls Church, USA

Abstract
Background: Our center has expanded its ECMO program from less than 20 patients per year to over 100 in the last three years. This includes VV and VA support, as well as bridge to transplant. Previously, cannulation sites and functional level were found to be barriers to traditional mobility techniques with these critically ill patients.

Methods/Results: Efforts to maximize early mobility and improve overall functional outcomes in patients cannulated for ECMO, both femoral and double lumen IJ sites, were improved by:
1. Establishing a weekly multidisciplinary meeting with clinicians, bedside caregivers, and PT and OT personnel to discuss care plans for each ECMO patient and promote early referral to PT and OT
2. Contracting with Kreg Therapeutics for specialty beds to allow for verticalization and improved chair positioning, transition from supine to sitting to standing, and help enhance mobility and maintain muscle strength
3. Creation of protocols for training, competency checks, and education for mobilization and ambulation of patients
4. Sharing of successful ambulation stories with staff and leadership
5. Maintaining consistent care after decannulation to maximize rehabilitation potential

These efforts have resulted in extubated ECMO patients walking the halls, increased discharge directly to home, and improved team dynamics. We have also established a family liaison team led by a past-ECMO patient and family member to provide ongoing in-hospital support to ECMO patients and their families. Post-hospital support continues in an adult ECMO clinic to assess clinical, neuropsychological and mental health status after discharge.

TECMO: Tracheostomy while on ExtraCorporal Membrane Oxygenation: A comparison study between percutaneous and open procedure
Ismael Salas de Armas, Kha Dinh, Pushan Jani, Reshma Hussain, Kritti Mittal, Lisa Janowiak, Bindu Akkanti, Manish Patel, Mehmet Akay, Rahat Hussain, Jayeshkumar Patel, Keshava Rajagopal, Chandi Patel, Biswaji Kar, Igor Gregoric; UTHealth, The University of Texas Health Science Center at Houston, Houston, USA

Abstract
While the ideal timing of a tracheostomy for critically ill patients remains controversial, transitioning from an endotracheal tube has beneficial implications. Concerns arise for patients under extracorporeal membrane oxygenation (ECMO) support. This subgroup possesses perioperative challenges—hemodynamic and respiratory compromises, multiorgan dysfunction, and hyper/hypocoagulable states. Studies have described the two tracheostomy approaches separately; however, to our knowledge, a comparison between percutaneous and surgical tracheostomy in patients on ECMO has not been reported. This study aims to demonstrate any differences in major bleeding or other tracheostomy-associated complications with the two methods while on ECMO.

In a single center, retrospective cohort study, we reviewed our medical records of all patients who received tracheostomy while on ECMO from July of 2013 to May of 2019. The primary endpoint was major bleeding requiring surgical intervention or blood transfusions. Secondary endpoints were tracheal/esophageal injury, pneumothorax/pneumomediastinum, ECMO complication, intraprocedural mortality, and survival to discharge.

Twenty-seven ECMO patients were reviewed, 16 patients (59%) on the percutaneous arm and 11 patients on the open arm. The mean ECMO days prior to tracheostomy was 12.1 vs 18.2, respectively. Major bleeding in either group was not statistically significant (percutaneous 7 (44%) vs open 3 (27%) – P value 0.45). Other than a dislodgement of an ECMO cannula in the open approach, there were no other incidences for the secondary endpoints.

Both percutaneous and open tracheostomy in patients on ECMO requires a multidisciplinary approach to minimize adverse effects. Major bleeding can occur in both groups but was not statistically significant.
Plasma Biomarkers of Cardiac Dysfunction in Pediatric Patients Supported on Extracorporeal Membrane Oxygenation (ECMO)
Kristen Coletti MD, Megan Griffiths MD, Melanie Nies MD, Stephanie Brandal BS, Jun Yang PhD, Allen D. Everett MD, Melania M. Bembea MD, PhD; Johns Hopkins University, Baltimore, USA

Abstract

Introduction: Plasma markers of cardiac dysfunction are noninvasive, rapid measures shown to correlate with echocardiogram and cardiac catheterization findings. They may be valuable during ECMO where assessment of cardiac function is challenging. We explored whether cardiac dilatation (NT-proBNP, ST2), fibrosis (galectin-3), and anti-angiogenesis (endostatin) biomarker concentrations change with clinical improvement on ECMO.

Methods: This was an IRB-approved pilot study of 20 children <18y on ECMO at an academic center between 07/2010–06/2015. Plasma samples and echocardiogram data were collected at cannulation and decannulation.

Results: Sixty-eight percent of patients exhibited cardiac dysfunction at cannulation vs 17% at decannulation. ST2 decreased from cannulation to decannulation, median 325.8ng/mL (interquartile range [IQR], 127.7-602.6) vs 205.8ng/mL (IQR, 46.8-297.6), p=0.02. Galectin-3 and NT-proBNP also decreased but were not significant (NS). Endostatin increased from cannulation to decannulation, 41.9ng/mL (IQR, 27.0-65.4) vs 85.1ng/mL (IQR, 53.6-104.6), p=0.001. Among the neonatal ECMO subgroup (n=11) with congenital diaphragmatic hernia or persistent pulmonary hypertension of the newborn, endostatin increased from cannulation to decannulation, 37.3ng/mL (IQR, 28.7-63.4) vs 90.6ng/mL (IQR, 79.6-129.6), p=0.0007. Galectin-3 increased, while ST2 and NT-proBNP decreased (NS). Among the pediatric ECMO subgroup (n=9) with cardiogenic or septic shock, ST2 decreased from cannulation to decannulation, 592.2ng/mL (IQR, 323.4-798.8) vs 293.0ng/mL (IQR, 164.3-523.2), p=0.03. Galectin3 and NT-proBNP decreased, while endostatin increased (NS).

Conclusion: Biomarkers of cardiac dysfunction, especially ST2, are elevated in cardiopulmonary failure on ECMO and decrease with ability to decannulate from ECMO. Endostatin increases and may be protective. These biomarkers have potential application for monitoring recovery and timing of decannulation.

Systemic Inflammatory Response Syndrome after Decannulation from the ECMO Circuit: A Retrospective Cohort Study
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Abstract

Introduction: A phenomenon that has been frequently observed but not well described in the literature is the development of systemic inflammatory response syndrome (SIRS) associated with ECMO decannulation and separation from the ECMO circuit. It is often difficult to determine if the SIRS response is due to an infection or if it is due to an inflammatory response related to the removal of ECMO.

Methods: We retrospectively reviewed the charts of 72 consecutive ECMO patients from February 2017 to May 2019 and identified patients that developed SIRS in the post-decannulation period. SIRS was defined as having 2 of 3 criteria: fever >38.3, leukocytosis >12,000/dl and escalation of vasopressors compared to pre-decannulation baseline.

Results: Of the 72 patients placed on ECMO, 46 survived to decannulation, of which 26 (57%) developed SIRS phenomenon in the immediate post-decannulation period. A total of 20 (77%) of the post-decannulation SIRS cohort were treated with antibiotics during their ECMO course, of which 14 had positive cultures during their ECMO course and an additional 6 had negative cultures but were treated with antibiotics due to suspected infection (from clinical history or concerning imaging). Of the 6 (23%) remaining SIRS patients who were not treated with antibiotics during their ECMO course, 3 developed positive cultures post-decannulation, and 3 remained culture negative throughout their stay.

Conclusions: Post-decannulation SIRS is a common clinical entity that occurs with and without evidence of infection. The cause of post-decannulation SIRS is unclear and further studies are needed to better understand this phenomenon.
USE OF BIVALIRUDIN IN PEDIATRIC PATIENTS ON ECMO
Kriti Puri, Ryan Coleman, Timothy Humlicek, Lisa Hensch, Shiu-Ki Rocky Hui, Jun Teruya, Amanda Ruth; Texas Children’s Hospital, Houston, USA

Abstract

INTRODUCTION: Data are scarce regarding bivalirudin anticoagulation in pediatric patients on extracorporeal membrane oxygenation (ECMO) support.

METHODS: Single center retrospective cohort study of all patients aged <18 years who received bivalirudin anticoagulation during ECMO from 08/2017 to 08/2018. Demographics, clinical variables, and details of bivalirudin therapy were analyzed.

RESULTS: Bivalirudin was initiated in 10 patients on ECMO (6 VA, 4 VV) during the study period – 4/10 male, 4/10 non-Hispanic White, median age 0.6 yr (IQR 0.3 - 1.1 yr). Indications for bivalirudin included: high clot burden on heparin (6/10), sub-therapeutic heparin levels despite high doses (3/10), and history of heparin-induced thrombocytopenia (1/10). Seven patients survived to decannulation – 2/3 non-survivors had withdrawal of life-sustaining therapies. Median duration of ECMO was 10d (IQR 6-24d). Bleeding complications included 1 subarachnoid hemorrhage, 1 gastrointestinal hemorrhage, 2 pulmonary hemorrhage, and 6 cannula site bleeds. Three patients had major clotting complications. Median number of circuit changes per ECMO day on bivalirudin was 0.06 (IQR 0 to 0.13). Median length of bivalirudin run was 6.5d (IQR 4-12d). Median initiating dose was 0.19mg/kg/hr (IQR 0.15–0.25mg/kg/hr). Median target activated partial thromboplastin time with heparzyme was 60–80sec. Median time to reach target was 1d (IQR 0.8-2.3d). Median therapeutic dose was 0.39mg/kg/hr (IQR 0.33–0.61mg/kg/hr). Median transfusion volumes while on bivalirudin were – RBC 9.1ml/kg/day (IQR 5.5-21.9ml/kg/day), FFP 2.7ml/kg/day (IQR 1.2-4.3ml/kg/day), platelets 8.0ml/kg/day (IQR 5.5-16.3ml/kg/day).

CONCLUSIONS: Bivalirudin is an alternative for rescue anticoagulation for pediatric patients on ECMO if heparin is ineffective or contraindicated. Further safety and efficacy of this therapy should be evaluated.

Use of laryngeal mask airway as a bridge to extracorporeal membrane oxygenation in a 2 m/o neonate with undiagnosed critical airway long-segment tracheal stenosis
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Abstract

We describe a 37 week gestation African American male infant admitted to the neonatal intensive care unit with prenatal diagnosis of trisomy 21 and balanced AV canal. The infant required high-flow nasal cannula for respiratory insufficiency; etiology was deemed to be secondary to pulmonary over circulation. In anticipation of discharge home, the infant underwent gastrostomy tube surgery and was intubated for the first time in the OR by anesthesia. Radiograph for endotracheal tube placement was not obtained in the OR; chest x-ray on admission to the NICU revealed the endotracheal tube malpositioned above the thoracic inlet. Infant was expectedly extubated post-operatively; however, upon extubation, he developed significant respiratory distress unresponsive to racemic epinephrine and dexamethasone administration. Despite the emergent need for a stable airway with new onset post-operative respiratory distress, this infant was unable to be reintubated beyond the level of the vocal folds. Decision was made to insert a laryngeal mask airway (LMA) and obtain stat airway CT, which revealed a diagnosis of long-segment tracheal stenosis. This report highlights the first known pediatric case involving use of LMA as a bridge to veno-arterial extracorporeal membrane oxygenation (VA-ECMO) in a patient diagnosed with a critical airway malformation in the context of unrepaired congenital heart disease and trisomy 21. This account also brings awareness to congenital tracheal stenosis as a rare differential diagnosis in the evaluation of a formerly asymptomatic infant with post-extubation respiratory distress of unclear etiology.
Utilization of ECMO in a patient with cardiac failure due to propionic acidemia metabolic crisis
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Abstract
Propionic acidemia (PA) is an inborn error of amino acid metabolism that results in anion gap acidosis and hyperammonemia. Children usually present in the neonatal period with severe encephalopathy from hyperammonemia requiring dialysis. There are several reports of the use of ECMO to facilitate dialysis in this population. Here we present a case of a 22 month old male with a history of PA admitted for an acute metabolic crisis, unresponsiveness, respiratory distress, hyperammonemia, and shock. Despite fluid resuscitation, the patient developed refractory shock despite high-dose vasoactive infusions. Echocardiogram demonstrated severe biventricular dysfunction. He was placed on extracorporeal membrane oxygenation (ECMO) for cardiac support along with continuous renal replacement therapy (CRRT) to treat the hyperammonemia and metabolic acidosis. He rapidly (<36 hours) improved with near-normal cardiac function on repeat echocardiogram, preceded by resolution of the acidosis and hyperammonemia. He was decannulated after 4 days. Despite the severity of his illness he did not have any evidence of metabolic or ischemic stroke on MRI. He was extubated and discharged from the ICU. Propionic acidemia is caused by deficiency in propionyl-CoA carboxylase. The increased levels of propionic acidemia leads to anion gap acidosis and hyperammonemia. Patients with PA are known to be at risk of sudden cardiac deterioration during metabolic crises and respond to supportive care and removal of the toxic substances. The utilization of ECMO in these patients should be considered as this patient had rapid improvement in cardiac function after resolution of metabolic derangement and had a good neurologic outcome.

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Hyperbilirubinemia may decrease sensitivity of Plasma Free Hb (PFHB) as a marker of Intravascular Hemolysis- Can lead to Misdagnosis!!
Lovesh Arora, Jennifer Crumley, Kristina Rudolph, Elizabeth Moore; University of Iowa Hospitals & Clinics, Iowa city, USA

Abstract
Bilirubin interferes with the same wavelength absorption as PFHB on spectrophotometric analysis. This similarity makes evaluating for hemolysis challenging in patients with hyperbilirubinemia. We present the case of an 83 year-old male who was admitted to CVICU following Bentall procedure with Veno-Arterial (VA) ECMO (Getinge Cardiohelp system), due to right ventricular failure. Within 24 hours of ECMO, our patient developed a rapidly rising PFHB, greater than 300 mg/dL. However, this occurred in the setting of hyperbilirubinemia. Clinical markers in favor of true intravascular hemolysis were- 1) elevated PFHB 2) dark colored urine but very low urine output d/t renal failure 3) elevated indirect bilirubin. Clinical markers not in favor of true intravascular hemolysis were- 1) Stable Hb and serum potassium 3) clear effluent on CRRT machine 4) no evident clots on ECMO circuit 5) no problems with oxygenation on ECMO 6) Therapeutic PTT and TEGs 7) majority was conjugated hyperbilirubinemia. The question before us, should we exchange the circuit or wait in the absence of true signs of intravascular hemolysis? Ultimately, despite all other indicators of hemolysis being negative, decision was made to replace the ECMO circuit on day 3 of support. Subsequently, less than 24 hours post circuit exchange, PFHB values were: 184 and 148 followed by a value < 50 mg/dL 72 hours post circuit replacement. Some institutions are measuring Plasma Free OXY-Hemoglobin, based on the concept of different wavelength absorption and minimal interference of bilirubin. ECMO managing staff should consider this fact while reviewing PFHB levels.
Successful management of severe abnormal uterine bleeding in a 12-year-old patient supported with extracorporeal membrane oxygenation as a bridge to cardiac and double lung transplant for treatment of right ventricular failure and cardiogenic shock in the setting of pulmonary hypertension

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Abstract

Objective
The aim of this case report is to present the management of severe abnormal uterine bleeding during ECMO course.

Case presentation
A 12-year-old female patient presented to the ED with progressive shortness of breath was discovered to have severe pulmonary hypertension on echocardiogram and confirmed on cardiac catheterization. After cardiac catheterization patient developed acute decompensation, requiring escalation of vasoactives and ultimately VA ECMO cannulation for severe heart failure and she was listed for heart and lung transplant. Following her ECMO course, she developed massive uterine bleeding during her menses requiring multiple blood transfusions. Her abnormal uterine bleeding was refractory to different treatments including Depo-Provera, tranexamic acid infusions, high dose of oral contraceptives and IV estrogens as directed by OB-GYN. Ultimately she was scheduled for a dilation and curettage with tamponade of her uterus with Foley catheter, which was removed 2 days later. Her bleeding resolved after the D&C and was continue on oral contraceptives. ECMO support continued as a bridge to cardiac and double lung transplant.

Discussion
Bleeding complications remains as a major source of morbidity and mortality in the ECMO supported patient. Uterine bleeding is not a common complication but must be considered as ECLS therapy is being used more frequently in women of childbearing age. In this case successful control of bleeding and survival was attributed to the use of a surgical approach to resolve the bleeding by a multidisciplinary team.
ECMO complications: are we doing & training right?
Marta Velia Antonini1, Susan Aouamria1, Francesca Guidetti1, Alessandro Monesi1, Carlo Coniglio1, Sandra Rossi2; 1Intensive Care Unit, 1st Department of Anesthesia and Intensive Care, University Hospital of Parma, Parma, Italy. 2Student, BS in Cardiocirculatory Physiopathology and Cardiovascular Perfusion Techniques, University of Modena and Reggio Emilia, Modena, Italy. 3Intensive Care Unit, Emergency Department, Maggiore Hospital, Bologna, Italy. 4Intensive Care Unit, Emergency Department and HEMS, Maggiore Hospital, Bologna, Italy

Abstract

Introduction
ECMO remains a high-risk endeavour with patients at risk of various mechanical or system-related complications. Prompt and proper management of these potentially life-threatening scenarios is essential in preventing or reducing related morbidity, improving outcomes and reducing mortality; however, is not well described and related literature is scarce.

Methods
We distributed a 21 question survey to an international and multi-disciplinary panel of ECMO experts with the goal of assessing level of agreement with statements related to the management of six ECMO complications. Level of agreement was scored on a five-point Likert scale. Second, the experts prioritized selected interventions focused on detecting and addressing ECMO complications.

Results
A total of 14 surveys were completed by clinicians, nurses, perfusionists, and respiratory therapists from 11 different countries. Most respondents worked in high volume ELSO centers (n=13). An extremely variable bedside care to the patient/circuit was reported, in terms of ratio and roles of the involved providers. All respondents were deeply ECMO and ECMO education/training experienced, most actively involved in ELSO or ELSO Chapters activities (n=13), in ECMOed, the ELSO ECMO education taskforce, (n=7). In figure 1, overview on the replies/comments provided, and detailed considerations over the approach suggested by respondents to face:

- circuit air embolism;
- accidental decannulation;
- accidental disruption;
- drainage insufficiency;
- membrane lung failure;
- and return obstruction.

Conclusions
Our findings highlight some consensus but also discordant practices related to ECMO circuit emergencies troubleshooting. Guidelines are needed to define protocols to be taught, adopted and applied in these critical care settings.
Evaluation of Extended-Interval Aminoglycoside Regimens in Neonatal Patients on Extracorporeal Membrane Oxygenation

Martha McBride1, Greg Gusimano2, Sadie Stone1, Azhar Baghal1, Paul MacLennan3, Kim Benner1,2,3; 1Children’s of Alabama, Birmingham, USA. 2University of Alabama at Birmingham, Birmingham, USA. 3Sanford University McWhorter School of Pharmacy, Birmingham, USA.

Abstract

Purpose: Extracorporeal membrane oxygenation (ECMO) can alter the pharmacokinetics of aminoglycosides. Neonatal patients on ECMO may require higher doses at longer intervals to reach desired serum peak concentrations. This study evaluates the effectiveness of a gentamicin regimen of 3.5 mg/kg/per dose every 36 hours in this population.

Methods: This case-control study was a retrospective chart review from 2013-2017 of neonatal inpatients aged 0 to 6 months receiving gentamicin while on ECMO. Data collected included demographic information, gentamicin serum concentrations (peak and/or trough), and number of gentamicin doses given prior to collecting levels. Primary endpoint was whether or not the desired serum peak concentration was achieved using dosing regimen of 3.5 mg/kg/dose every 36 hours.

Results: Of the total patients evaluated, 79 patients met the inclusion criteria for final analysis. 15 patients (18.9 percent) achieved peak concentrations within the goal range of 7 to 9 mcg/mL (7.6 plus or minus 0.5 mcg/mL), and 64 patients demonstrated peak concentrations outside the goal range (5.7 plus or minus 1.1 mcg/mL) (p <0.0001).

Conclusion: A dosing regimen of 3.5 mg/kg/dose every 36 hours resulted in a majority of total patients achieving desired peak concentrations. Patients with peak concentrations below the goal range may benefit from a higher dose at the same interval to achieve a peak concentration between 7 and 9 mcg/mL. A future study would need to be conducted to determine the effectiveness of higher doses to achieve goal peak concentrations.

ECCO R AS A BRIDGE TO LUNG TRANSPLANTATION IN A PEDIATRIC PATIENT

Matthew Deitemeyer1, Victoria Duffy2, Ashley Hodge2, Patrick McConnell2,1; 1Nationwide Children’s Hospital, Columbus, USA. 2The Ohio State University, Columbus, USA

Abstract

CASE OUTLINE: A seven month old presented with increased work of breathing, non-productive cough, poor oral intake and a saturation of 90%. He was found to have pulmonary hypertension with moderate right ventricle dysfunction. After a cardiac MRI, percutaneous coronary intervention (PCI) was performed and a stent was inserted in the main pulmonary artery and were started on DAPT. Demographics, procedural characteristics, antithrombotics, coagulation parameters, and ELSO defined hemorrhagic complications were collected. Differences in patient/treatment characteristics and outcomes were compared between patients who experienced a hemorrhagic complication vs. those who did not.

Conclusions: ECCO R proved to be a safe, effective and feasible option for this pediatric patient as a bridge to lung transplantation. The use of ECCO R provided temporary support which facilitated weaning from invasive ventilation, allowed for physical rehabilitation and the ability for the patient to interact with family and caregivers while awaiting lung transplantation.

Utility of Screening Head Ultrasound in Children on ECMO

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Abstract

Introduction: Published recommendations endorse daily head ultrasound (HUS) to monitor for neurological complications for the first 3-7 days on ECMO and less frequently thereafter. The aim of this study was to assess the utility of routine screening HUS in infants on ECMO in the current era.

Methods: We included all patients treated with ECMO at Riley Hospital for Children and had a HUS performed from 2015-2018. Results: There were 122 ECMO runs among 117 children. Average age at ECMO initiation was 7 days (IQR 2 days, 2 months). The population included 56.5% cardiac, 36.9% neonatal and 6.6% pediatric. Survival to discharge was 68.9%. There were 419 HUS performed averaging 3.4 HUS per patient and a range of 1 to 10 studies per individual. There were 36 patients with abnormal findings. The majority required no change in care; ventriculomegaly or increased extra-axial fluid (n=15), structural abnormality (n=6) and periventricular leukomalacia (n=3). There were 12 patients with stroke, 8 hemorrhagic and 4 ischemic. Among those, 7 were identified on the initial HUS. The other 5 were identified after a previous negative HUS, but 4 had clinical events concerning for new neurological injuries, such as seizure.

Conclusions: Most abnormalities on HUS are incidental findings requiring no intervention. The vast majority of clinically important findings on HUS were on the initial HUS or after clinical events that were concerning for new neurological injury. Routine screening HUS, after an initial negative, are not warranted unless there is a clinical indication.

Hemorrhagic Complications During Venoarterial Extracorporeal Membrane Oxygenation in Patients on Dual Antiplatelet Therapy after Percutaneous Coronary Intervention

Matthew Lillyblad1, Anna Alcorn1, Kelly Tointon1, Ivan Chavez1,2, Katarzyna Hryniewicz1,2; 1Abbott Northwestern Hospital, Minneapolis, USA. 2Minneapolis Heart Institute, Minneapolis, USA.

Abstract

Introduction

VA-ECMO support is rapidly expanding in patients with cardiogenic shock complicating acute coronary syndromes treated with PCI. Hemorrhage is among the most common complications associated with VA ECMO but little is known regarding incidence and risk factors for hemorrhagic complications in patients necessitating DAPT during VA-ECMO.

Methods

We retrospectively reviewed adult patients admitted from 2009-2019 who were supported with VA-ECMO and underwent PCI with stent placement and were started on DAPT. Demographics, procedural characteristics, antithrombotics, coagulation parameters, and ELSO defined hemorrhagic complications were collected. Differences in patient/treatment characteristics and outcomes were compared between patients who experienced a hemorrhagic complication vs. those who did not.

Results

60 patients met inclusion criteria for our analysis. Overall 27% of patients (n = 16) experienced an ELSO defined hemorrhagic complication while supported by VA ECMO. Patients who had a hemorrhagic complication were younger (58 vs. 63 years, p = 0.05), female (44% vs. 11%, p = 0.01), required longer ECMO support (173 vs. 87 hours, p = 0.01), and had a lower nadir platelet count (65 vs. 80 x10^9/cu-mm, p = 0.01). There was a trend toward higher peak INR (1.9 vs. 1.5, p = 0.5) in patients who bled as well. Ticagrelor treated patients did not experience more hemorrhagic complications than clopidogrel (9 vs. 7, p = 0.77).

Conclusion

ELSO defined hemorrhagic complications were common in patients supported by VA-ECMO after PCI who require DAPT. Risk factors for bleeding include younger age, female gender, duration of support, and thrombocytopenia.
Utilizing a Multi-Disciplinary Approach to Evaluate Advanced Heart Failure Mechanical Circulatory Support in an Academic Medical Center
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Abstract
Purpose: To streamline patient evaluation for cardiogenic shock and implement appropriate MCS therapies within a timely fashion.

Background: Traditionally, upon initial contact, multiple teams discordantly strategized patient trajectory for cardiogenic shock. This discoordination of care delayed appropriate and timely treatment. A multidisciplinary process, the ‘Heart Shock Team’, was established to assess cardiogenic shock patients prior to admission, upon arrival to the ED, and during subsequent procedures, to ensure appropriate advanced heart failure therapy treatment.

Methods: In 2017, a team of stakeholders developed a Cardiogenic Shock algorithm for process standardization. Communication processes were implemented to provide early communication regarding patient status, vitals, ETA, and role checklists.

Evaluation: Of the 67 patients screened, 56 patients were admitted for advanced heart failure management. Of those patients, 16 received medical management, 1 escalated to IABP, 4 escalated to Impella CP, 7 escalated to an Impella 5.0, and 10 to VA ECMO.

Two (2) patients required increased mechanical support within 24 hours due to insufficient initial support. Escalation included either ECMO or Impella 5.0. All other patients were adequately supported by devices or medical management as initially determined by the team. In instances where insufficient support occurred, the protocol was not followed.

Survival to discharge rate for admitted patients was 69%.

Conclusions: The ‘Heart Shock’ protocol has successfully reduced decision-making variability in treatment. The process clearly shows improved interdisciplinary communication and rapid escalation of care for these patients. Limitations of this analysis include exclusion of Impella placements not activated by this process.

Veno-arterial Extracorporeal Membrane Oxygenation (VA ECMO) Support in Adult Patients with Refractory Septic Shock
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Abstract
Background: Several case reports and series describing the use of VA-ECMO for refractory septic shock have produced mixed outcomes. The Extracorporeal Life Support Organization (ELSO) endorses an individualized approach to the application of ECMO support for refractory septic shock. The use of VA-ECMO for refractory septic shock in adults remains challenging with lack of data to guide patient selection and provide counseling about expected outcomes. The purpose of this single-center, retrospective cohort study is to describe the outcomes and characteristics of adults supported with VA-ECMO for refractory septic shock.

Methods: Patients admitted to a tertiary care hospital from 2011 to 2018 with a primary diagnosis of sepsis and placed on VA ECMO due to refractory shock were included in a retrospective cohort study. Data was analyzed using descriptive statistics.

Results: Twenty patients met inclusion criteria, median age was 53.5 (31.2-71.2) years. Median SOFA score in the 24 hours prior to cannulation was 18 (11-21). Sixteen patients (80%) survived to arterial decannulation. Fourteen (70%) survived to hospital discharge with median CPC score of 1 (1-3). Seventeen (85%) of patients had new cardiac dysfunction and thirteen (65%) had a left ventricular ejection fraction of ≤ 20%. Median duration of VA-ECMO support was 104.9 (31.0-272.2) hours. Nine patients (45%) had ECMO related complications; one (5%) contributed to death.

Conclusion: Survival to hospital discharge was approximately 60% higher than predicted by illness severity score in this cohort treated with VA ECMO for refractory septic shock with good neurologic outcome.
**2019 ELSO CONFERENCE ABSTRACTS**

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**V-V ECMO support during clinical trial use of Brincidofovir for Disseminated Adenovirus**

**Mazen Odish**, Scott Chicotka, Cassia Yi, Travis Pollema, Robert Owens; **University of California, San Diego, San Diego, USA**

**Abstract**

A 44-year-old man with fulminant multiple sclerosis for which he was immunosuppressed with high dose steroids, rituximab, and more recently, ocrelizumab and plasmapheresis presented to the ED with fevers, pharyngitis, dyspnea, myalgias, and diarrhea. A viral respiratory PCR panel was positive for adenovirus, and he was diagnosed with disseminated disease due to severe hypoxia and acute renal failure. His disseminated adenovirus was initially treated with intravenous immunoglobulin (IVIG). Due to hypoxic respiratory failure he was intubated. Veno-venous extracorporeal membrane oxygenation (VV-ECMO) was initiated for severe ARDS on hospital day (HD) 8 despite treatment with low tidal volume ventilation (6cc/kg of ideal body weight), high PEEP (using esophageal balloon to estimate pleural pressure), proning, inhaled epoprostenol, and paralysis. After VV-ECMO was initiated, he was placed on very low tidal volume ventilation (<2 cc per kg of ideal body weight) with preserved moderate PEEP (~15-17 cmH\textsubscript{2}O). Neuromuscular blockade, epoprostenol, and proning were discontinued. Continuous renal replacement therapy (CRRT) was started for his acute renal failure with negative daily fluid goals. The patient was enrolled in a clinical trial of Brincidofovir for disseminated adenovirus (NCT02596997). After starting Brincidofovir, adenovirus viral levels substantially decreased and ARDS improved. He was decannulated from VV-ECMO after 48 hours. This case illustrates that ECMO can be used to support patients in clinical trials, such as brincidofovir for disseminated adenovirus.

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**The Ethics of ECMO support for an Undocumented Immigrant.**

**Mazen Odish**, Scott Chicotka, Cassia Yi, Christopher Tainter, Travis Pollema, Robert Owens; **University of California, San Diego, San Diego, USA**

**Abstract**

A young man aged ~20 years old was found down by United States Customs and Border Protection agents north of the Mexico-United States border. The patient was lethargic, moaning, soaked, and hypothermic. Upon Emergency Medical Services (EMS) arrival, he was pulseless and cardiopulmonary resuscitation (CPR) was performed for 60 minutes en route to the Emergency Department (ED), where core body temperature was 26° C. Return of spontaneous circulation occurred 45 minutes later after rewarming. He developed severe hypoxemia despite maximum ventilator support, and he was placed on veno-venous extracorporeal membrane oxygenation (VV-ECMO). Additionally, he required a fasciotomy for compartment syndrome and dialysis for acute renal failure. Oxygenation improved, and he was decannulated from VV-ECMO after 48 hours. He was discharged to border patrol custody after a 39 day hospitalization. During his stay, two board patrol agents were at bedside for 24 hours a day. His hospitalization cost approximately $600,000, paid for by the Immigration Health Services. VV-ECMO was placed prior to understanding his age (17 years-old), immigration and socioeconomic status. This case demonstrates 1) the use of ECMO in emergent situations when not all information is available, 2) the high cost for patients who require ECMO, which must be weighed against future quality of life and productivity and thus may be cost effective, and 3) that immigration policies have other public health and economic consequences.
Life-Saving ECLS in an Infant with Catastrophic Pulmonary Hemorrhage: A Case Report
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Abstract
Introduction: The use of ECLS for severe pulmonary hemorrhage is supported in pediatrics with an overall survival of 69% reported in the ELSO registry.

Case Presentation: A term thriving 6-week-old female presented to the emergency department with acute cough and mild hemoptysis. She initially had minimal respiratory distress but rapidly decompensated with complete respiratory and cardiovascular collapse secondary to frank severe pulmonary hemorrhage, hypoxic respiratory failure, tension pneumothorax and severe biventricular dysfunction. She was urgently cannulated to V-A ECMO due to impending cardiorespiratory arrest. Despite systemic anticoagulation with target ACTs of 180-200, the precipitating pulmonary hemorrhage resolved quickly. Cardiac function normalized. An extensive diagnostic work up including: infectious and vasculitic profiles, full exome gene sequencing, bronchoscopy, and a CT chest yielded no diagnostic results. Over her uncomplicated 72 hour ECLS run her lung compliance progressively improved and she was successfully decannulated. She was extubated to room air 2 days later and discharged home the following week. Her diagnosis remains elusive.

Discussion: Whilst relatively small pediatric cohorts make it challenging to further stratify mortality risk based on underlying disease process, it is realistic to presume that, as in our case, the majority of cases would be undifferentiated upon initial presentation. This infant was rescued from certain demise due to prompt initiation of VA-ECMO and was discharged home with no residual sequelae.

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Figure 1.
Presentation

Figure 2.
Pre-Cannulation

Figure 3.
Post-Cannulation

Figure 4.
Post-Decannulation
Longitudinal follow up post ECMO: Functional, Psychiatric and Cognitive Outcomes
Mehul Desai, Mitch Psotka, Anika Raja, Patrick Moran, Erik Osborn, Heidi Dalton, Charles Murphy, Lauren Cooper, Chris King; INOVA Fairfax Medical Center, Fairfax, USA

Abstract
Introduction: Extracorporeal membrane oxygenation (ECMO) allows for rescue of patients with severe cardiac and respiratory failure. Survivors are at risk for a number of complications, such as critical illness polyneuropathy and myopathy, post-traumatic stress disorder, and cognitive impairment. Minimal research has been performed to assess the long-term effects of ECMO.

Method: We established a dual-purpose follow-up clinic to ensure that ECMO survivors were receiving optimal medical care following discharge. Attendees were offered enrollment in a longitudinal research study to assess quality of life and functional/cognitive recovery. Information from standard of care testing, including echocardiography, pulmonary function testing, six-minute walk test, and chest imaging was collected. Patients who provided consent for the study were also administered the following surveys at approximately 1, 6- and 12-months post-discharge: HRQOL testing with SF-36, Hospital Anxiety and Depression scale, Primary Care PTSD survey, Lawton-Brody instrumental activities of daily living (IADL) survey and the Montreal cognitive assessment. Patients unable to attend ECMO clinic may be administered the 1, 6- and 12-month surveys by phone.

Results: At abstract preparation, 12 patients had enrolled in the study (8 VA, 3 VV, and 1 VAV). 1 patient expired after discharge, 1 was lost to follow-up and 1 patient withdrew consent. 17 additional patients were screened but not enrolled (11 in-hospital death, 4 refused consent, 2 cognitive impairment precluding survey completion). Data collection is ongoing.

Discussion: Data analysis should provide useful data on long-term outcomes. A multi-center database utilizing a similar design could increase the yield of this project.

An evaluation of flow characteristics of Dual Lumen Cannulas: Real life application
Mehul Desai, Julie Jordan, Heidi Dalton, Erik Osborn, Liam Ryan, Ramesh Singh; INOVA Fairfax Medical Center, Fairfax, USA

Abstract
Introduction: Dual lumen cannulas (DLC) have garnered interest especially in the pulmonary transplant population due to their ability to allow easier ambulation than dual site cannulation. The Avalon Elite bicaval cannula is one of the most frequently used cannulas, although multiple other cannulas have now entered the market. We sought to compare the flow characteristics of the Avalon Elite and Crescent cannulas.

Method: At our institution, placement of a DLC is done under direct fluoroscopic guidance of the wire and cannula. The position of the return jet is then confirmed by transesophageal echocardiography to ensure minimal recirculation. We reviewed flow data on 6 Crescent and 6 Avalon cannulas. Size of the cannula was selected by the surgeon based on the needs of the patient and anatomical limitations. Flow and RPM data was collected from both 27 Fr and 31 Fr Avalon cannulas as well as 30 Fr and 32 Fr Crescent Cannulas.

Results: The data was graphed on a scatter plot with a general trend to higher flows at lower RPM’s noted with the crescent cannula.

Discussion: Our data suggests that the Medtronic Crescent cannula allows for lower RPM with higher flows. This may have clinical implications, as excessively high negative venous pressures can result in hemolysis, increased shear stress with resultant platelet activation and interruptions in flow.
CRITICAL BLEEDING IN THE NEONATAL POSTOPERATIVE ECMO PATIENT: A CASE REPORT
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Abstract
INTRODUCTION: 3 Kg, 36 6/7 baby born C-section, unknown right CDH. VA ECMO at 6 hours of life at OSH for worsening PPHN and hypoxemia. Transferred after two failed attempts of weaning ECMO on DOL 17. On arrival CT angiography showed right lung hypoplasia, liver in chest, hepatic veins drain to right atrium, and interrupted IVC. Surgical repair of RCDH performed while on ECMO on DOL 24 without complications (50 mL EBL).

DISCUSSION:
MEDICATIONS: Dexmedetomidine, Morphine, Epinephrine, Alprostadil, Flolan, Heparin, Hydrocortisone, Sildenafil, Amicar, Cefazolin, Kcentra. Three critical bleeds postoperatively, resulting in instability and prolonged ECMO course. First bleed, intrathoracic POD 1-4 (2,000 mL blood loss). Second, intra-abdominal POD 5-9 (718 mL blood loss). Third, pericardial POD 11 (141 mL blood loss). All bleeds managed with massive transfusion, bleeding/anticoagulation protocols, and Kcentra/Amicar infusions. Patient was successfully weaned off VA ECMO support and decannulated on POD 14. The patient spent a total 835 hours on ECMO support. A ¼ inch CardioHelp circuit with an open bridge shunt was used to maintain an oxygenator flow of 0.5 LPM and a patient blood flow of 0.26-0.42 LPM (1855-2200 RPMs).

CONCLUSION: Postoperative bleeding in neonates can be successfully managed with a combination of standardized high risk bleeding protocol, aggressive thrombogenic therapy, and daily multidisciplinary rounds. Utilizing this approach we successfully provided ECMO support without heparin for periods of time concurrent with the use of Amicar and Kcentra infusions. Initial ECMO circuit ran for 534 hours before electively changing, with minor visible clotting noted.

It might be Zebras: Expecting the Unexpected in ECMO
Michael Gaber, Jordan Weingarten; Ascension Seton Medical Center, Austin, USA

Abstract
Background: Ideally patients are only placed on ECMO when they have a potentially reversible disease and lack major contraindications to treatment; benefit should outweigh risk. Meticulous pre-cannulation assessment can help with this risk stratification. Unfortunately, some patients decompensate too rapidly to allow much more than a cursory evaluation prior to cannulation. In this population, post-cannulation diligence looking for unusual comorbidities and unusual conditions is particularly important.

Cases: Within a one-month period our center cannulated 3 rapidly decompensating patients necessitating emergency VV ECMO support. Two of these patients were cannulated with little prior information and only short assessment periods possible prior to cannulation; the third was cannulated without a clear primary diagnosis despite workup. All patients were hypotensive and profoundly hypoxemic prior to cannulation; two were being hand-ventilated since standard mechanical ventilation could not maintain saturations in an acceptable range. All three had unusual and totally irreversible primary underlying conditions leading to respiratory failure that was not apparent prior to cannulation.

Conclusion: The standard patient who aspirated or has sepsis-mediated respiratory failure does not require ECMO support. It is likely that the sub-population of patients requiring ECMO has an increased incidence of unusual conditions leading to respiratory failure. In those patients whose cannulation was of necessity rushed due to rapid decompensation, it is particularly important to diligently search for underlying conditions predisposing the patient to a poor outcome. The adage “When you hear hoofbeats, think of horses, not zebras” is correct in most cases, but ECMO is not most cases.
Comparison of the Constrained Vortex Physics of Centrifugal Pumps Used for VV ECMO
Jennifer Carter, Dean Linder, Jr, Angela Abella, Michael Hines; Ochsner Health, New Orleans, LA, USA

Abstract
INTRODUCTION: Capabilities of centrifugal pumps depend on the principles of constrained vortex determined by the unique design of each device. Excessive RPM may lead to hemolysis which has been shown to increase morbidity and mortality in ECMO patients. We evaluate the constrained vortex “efficiency” of three devices.

METHODS: A bloodless in vitro centrifugal circuit model with a PMP membrane and 31Fr DL cannula was used to compare three centrifugal pumps: Thoratec CentriMag (CM), TandemLife (TL) and Sorin Revolution (SR). Flows were measured with the Transonic Flow Probe. Inlet, pre- and post-membrane pressures were recorded. Maximal flow, line pressure, and inlet negative pressures were measured to evaluate the pumps’ capabilities.

RESULTS: The SR generated a maximal flow of 7.37L/min (@3500RPM) compared to 6.96L/min (@5500RPM) for the CM, and 4.86L/min (@7500RPM) with the TL. Tests with other oxygenators and DL cannulas demonstrated similar relationships and nearly identical curves. The maximal positive pressure generated was higher in the SR (730mmHg @3500RPM), compared to the CM (689mmHg @5500RPM) or the TL (402mmHg @7500RPM). The SR also generated the lowest inlet pressure [-180mmHg @3500RPM, 12.58L/min], compared to the CM [-139mmHg @4800 RPM, 10.69 L/min] and the TL [-90mmHg @7500 RPM, 8.17 L/min].

DISCUSSION: The Sorin Revolution centrifugal pump demonstrated superior constrained vortex function over the CentriMag and TandemLife devices as evidenced by higher flows at lower RPMs, the ability to generate higher positive pressure and more negative inlet pressure. These factors help to provide maximal flow to VV ECMO patients.

Assessment of Resistance and Maximal Flows in Double Lumen Cannulas used for Veno-Venous ECMO
Jeffrey St. Romain, Dean Linder, Jr, Jennifer Carter, Angela Abella, Michael Hines; Ochsner Health, New Orleans, LA, USA

Abstract
INTRODUCTION: Double lumen (DL) cannulas allow single site access for adult Veno-venous ECMO, improving mobilization and reducing infection risk. There are currently four FDA approved DL cannulas for use in VV ECMO. While vendors have published flow data for their device, there has been no direct performance comparison of the four cannulas.

METHODS: Using a bloodless in vitro centrifugal circuit model with a Maquet PMP membrane, we compared flows through the available DL cannulas: Maquet Avalon Elite (31Fr); TandemLife Protek Duo (31Fr); MC3/Medtronic Crescent (30/32Fr); and Origin (28Fr). Flows were measured using the Transonic Flow Probe. Cannulas were suspended within a saline reservoir to allow free unobstructed flow at all ports. Tests were run with the Thoratec CentriMag (CM) and the Sorin Revolution (SR).

RESULTS: The highest flows (L/min) were observed in the 32Fr Crescent cannula (CM-9.44/SR-10.31), followed by the 30Fr Crescent (CM-7.35/SR-7.90), the 31Fr Avalon (CM-6.96/SR-7.37), the 31Fr Duo (CM-6.36/SR-6.88) and the 28Fr Origin (CM-5.51/SR-5.97).

CONCLUSION: Poiseuille’s Equation explains that flow is impacted by the resistance within the lumen which is directly proportional to length (L), and indirectly proportional to the radius to the fourth power (r^4), making cannula internal diameter (radius) extremely important. However internal design of the DL cannulas has additional impact on resistance. The observed flow characteristics were superior in the 32Fr Crescent cannula and the 30Fr Crescent also exhibited superior flows to the two other “larger” 31Fr cannulas, and the smaller 28Fr Origin cannula.
The use of extracorporeal membrane oxygenation in a neonate with cardiopulmonary failure due to hyperammonemia secondary to carbamoyl phosphate synthetase I deficiency

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Abstract
Introduction: Carbamoyl phosphate synthetase I (CPSI) is a mitochondrial enzyme necessary for metabolism of ammonia, and decreased activity causes severe hyperammonemia, coma, and death. This is the first case to describe the use of extracorporeal membrane oxygenation (ECMO) for cardiopulmonary failure in a neonate with CPSI deficiency.

Case: A 3-day old male presented with lethargy and poor feeding. He was tachycardic, cyanotic, mottled, and jaundiced. Blood and urine cultures were obtained and IV antibiotics were initiated. Laboratory evaluation revealed severe metabolic acidosis. He was admitted to the PICU and developed apnea requiring intubation. Echocardiogram (ECHO) showed severely depressed left ventricular function. Milrinone and epinephrine were initiated for inotropy. Despite maximal medical therapy, he progressed to decompensated shock and was cannulated for veno-arterial (VA) ECMO. Ammonia level returned at >1000 umol/L and an inborn error of metabolism was suspected. Hemodialysis was quickly initiated through the ECMO circuit. Sodium phenylacetate and sodium benzoate were given as ammonia scavengers. A repeat ECHO demonstrated normal cardiac function, ECMO flow was then weaned and clamped. He had normal oxygenation, ventilation, and cardiac function by ECHO during a trial off. He was decannulated on ECMO day 2.

Discussion: ECMO has been described for emergent high flow hemodialysis for hyperammonemia, this case describes the additional use of ECMO for cardiovascular support for neonates with inborn errors of metabolism. ECMO provided a means of cardiopulmonary support as a bridge to diagnosis in a patient with a condition often fatal in the neonatal period.

Successful Extracorporeal Cardiopulmonary Resuscitation in a Pediatric Patient with Permanent Junctional Reciprocating Tachycardia

Mohammad Al-mousily, Minoo Kavarana, Lanier Jackson, Jason Buckley, John Costello, Monika Cardona, Laura Hollinger; Medical University of South Carolina, Charleston, USA

Abstract

Introduction: Permanent Junctional Reciprocating Tachycardia (PJRT) is a rare incessant tachyarrhythmia that can induce cardiomyopathy and cardiogenic shock in infants and children. Here we present successful extracorporeal cardiopulmonary resuscitation (eCPR) and rescue of a 3 year-old with PJRT and cardiac arrest.

Abstract: A 3-year old healthy girl with viral symptoms, severely depressed biventricular function, and PJRT transferred to our institution. She was initially interactive, but within 10 minutes became somnolent with bradycardic arrest. During CPR, the in-house daytime extracorporeal life support (ECLS) team was mobilized, and despite transient rescue, she arrested again 15 minutes later. Within 47 minutes of initial arrest, cannulation with a 14Fr right carotid Biomedicus and a 20Fr internal jugular Medtronic single-stage cannula was accomplished during active CPR, and 1950 cc/min of flow was established with a saline-primed Sorin Centrifugal pump with 3/8” circuitry. Interestingly, her rhythm was not amenable to electrophysiology mapping due to unique and complete PJRT rhythm suppression during anesthetic. Rhythm control was ultimately obtained with a complex regimen of pharmacotherapy (Flecainide, Nadolol and Amiodarone). After 8 days of ECLS, her cardiac function recovered and she was successfully decannulated. Despite high-resolution brain imaging with tiny bilateral foci of infarct, she had no neurological sequelae and she made a full cardiac, renal and neurological recovery.

Conclusion: Survival in the ELSO registry for pediatric eCPR patients during tachyarrhythmias is approximately 50%. Here we report successful eCPR with excellent neuroprotection and full recovery of a pediatric patient with a rare tachyarrhythmia causing reversible cardiomyopathy.
Safety First: The Utilization of a Safe Start Tool in a Diverse ECMO Center

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Abstract

Introduction: The provision of extracorporeal life support (ECLS) is a very complex, high-risk procedure utilized in the care of critically ill patients in cardiac, pulmonary, or cardiopulmonary failure. Careful, strategic coordination of all aspects of this therapeutic modality optimizes this life-saving therapy. Ensuring the highest level of safety is in place at all times greatly decreases the opportunity for errors leading to untoward outcomes. We report our center’s experience with the process of developing and utilizing a safe start tool when caring for an ECLS patient.

Experience: The provision of ECLS support across our academic medical center is by a single ECLS team & inclusive of patients residing within two different hospitals; a pediatric hospital & an adult hospital. Due to this immense diversity, members comprising our team must continually be ready to care for patients of any age /size & with an array of diagnoses. Training is comprehensive of three ECMO platforms and circuitry configurations are consistent to foster predictability. However, minor variances in safety preparations were identified, creating areas of vulnerability for the care giver. The Safe Start Tool was developed to foster consistency in safety practices when caring for an ECLS patient. The tool is broken down into critical aspects surrounding the plan of care (ECMO type /settings, emergency supplies, etc.). Discovered discrepancies are reconciled in real time.

Conclusion: The utilization of safety tools in the care of ECLS patients ensures consistency and fosters predictability of care for the critically ill patient requiring advanced support in unpredictable circumstances.

An Ethical ECLS Conundrum: How to Determine Next Steps

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Abstract

Introduction: ECMO support is a highly invasive, lifesaving therapy that must be carefully employed while giving consideration to a patient’s own desires. Here we report our center’s recent experience.

Experience: A 54-year-old male with a history of RCA stent (03/2019) presented to an outside hospital with chest tightness, dizziness, vomiting, and diarrhea. An echocardiogram revealed a left ventricular aneurysm and pericardial effusion. He underwent left heart catheterization showing a patent RCA stent and an enlarged ventricular aneurysm of the inferior wall. He was transferred to our center for further management of cardiogenic shock that necessitated VA ECMO via a RJ Protek Duo Cannula, 19Fr LFA, our center’s centrifugal pump, and oxygenator. The Protek Duo cannula was chosen to allow for maximum evacuation of blood from the heart through peripheral cannulation.

On Day 2 of his ECMO course, the family raised divided concerns regarding the patient’s wishes for this level of life sustaining support. Without known advanced directives, there was an ethical conundrum for the direction of his care. We remained on full ECMO support, stopped all sedation, and extubated the patient. Once the patient was oriented, we were able to speak with him regarding his medical condition and options which allowed him to make his own decision. The patient decided to proceed with the surgical repair of his LV aneurysm and was successfully decannulated from ECLS support at the completion of his procedure. Total ECMO support was 4 days.

Peak troponin may predict ability to wean off VA ECMO

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Abstract

Introduction: Venoarterial extracorporeal membrane oxygenation (VA ECMO) is becoming an accepted modality in the treatment of refractory cardiogenic shock (RCS) complicating acute myocardial infarction (AMI). RCS complicates AMI in 5-10% of cases and continues to be associated with high mortality. The optimal timing of separation from support may be difficult to determine, and therefore, it may be beneficial to use peak troponin as a predictor of weaning.

Methods: The present study is a retrospective medical record review of adult patients with RCS as complication of AMI supported with VA ECMO at our institution from January 1, 2010 to April 29, 2019. Results: A total of 61 patients met inclusion criteria: mean age was 62 years, 79% males, 66% presented with STEMI. Thirty nine patients were successfully weaned, one patient did not survive to discharge. Of the 22 that were unsuccessfully weaned, 6 were transitioned to LVAD. When comparing patients using troponin cutoff 400ng/mL, below cutoff was associated with a significantly higher ejection fraction (39% vs 23%, p = .02), ability to be weaned (p = .003), and survival to discharge (p = .04). With each 50ng/mL increase in troponin, likelihood of weaning decreases by 17%.

Conclusion: Peak troponin above 400ng/mL may be helpful in determining ability to wean from VA ECMO and possibly accelerate evaluation for advanced therapies such as durable LVAD or cardiac transplantation, which may translate into lower associated morbidity and mortality.
Massive Pulmonary Artery Bleeding Secondary to Angioinvasive Aspergillosis on Veno-venous Extracorporeal Membrane Oxygenation

Narra Reddy, Andrew Vasyluk, Kathleen Swartz, Jimmi Mangla, Felicia Ivascu, Anthony Iacco, Mario Villalba; William Beaumont Hospital, Royal Oak, USA

Abstract

This is a 40 year old female who presented with respiratory failure secondary to influenza A requiring veno-venous Extracorporeal Membrane Oxygenation (VV ECMO) support. Soon after cannulation, Aspergillus fumigatus was found in her respiratory cultures. She was initially treated with voriconazole and later transitioned to Amphotericin B. On ECMO day 31, the patient developed massive hemoptysis and was taken emergently to interventional radiology where she was found to have numerous pseudoaneurysms from all branches of her left upper lobe pulmonary artery which required extensive embolization. Despite intervention, she had persistent bleeding requiring further embolization of branches of the left upper lobe pulmonary artery one week later.

Four days later she again experienced massive hemorrhage into her airways and through her right chest tube. She underwent embolization of her right lower lobe pulmonary artery. She was kept off of systemic anticoagulation for several weeks after her initial bleeding episode secondary to persistent oozing from her airways and as such, she underwent three circuit changes for oxygenator exchange. Systemic anticoagulation was resumed after her airway oozing stopped. She later experienced a large intraparenchymal hemorrhage of her left occipital lobe rendering her blind. ECMO support was withdrawn on day 100 due to the significant deficits from her stroke and lack of improvement in her lung function.

This case report will add to the small body of literature on angioinvasive aspergillosis.

Outcomes associated with VV ECMO in the super morbidly obese (BMI>50) in a tertiary teaching medical facility

Omar Hernandez, Kaitlyn Lingle, Rachel Dahl, Dan Meyer, Gary Schwartz, Kara Monday, Nathan Vaughan; Baylor University Medical Center, Dallas, USA

Abstract

Background: Super morbid obesity (BMI greater than 50 kg/m²) presents a challenge in patients with respiratory failure. Decreased lung volumes, decreased chest wall compliance, and increased airway resistance make lung protective ventilation difficult therefore making ECLS an attractive alternative. However, the technical aspects of cannulation and management of this patient population have historically been considered a relative contraindication.

Methods: A retrospective review was performed for all patients placed on VV ECMO for respiratory failure from July 2012 to July 2019 at an urban tertiary care institution.

Results: Twenty patients of 283 had a BMI greater than 50 kg/m². Eighty percent (n=16) were weaned off ECMO and 70% (n=14) survived to discharge compared to the cohort with BMI less than 50 kg/m² in which 70% (n=183) were weaned from ECMO and 60% (n=157) survived to discharge. Average days on ECMO for super morbidly obese patients were 10.6 versus 8.6 for BMI less than 50 kg/m², average ICU LOS 23.6 days versus 19.2, and average hospital LOS 26.7 days versus 23.9, respectively. Although the ECMO days, ICU LOS, and hospital LOS are higher in the super morbidly obese, the survival to discharge is not significantly different than those with BMI less than 50 kg/m².

Conclusion: BMI greater than 50 kg/m² should not be considered an independent contraindication to VV ECMO for patients in severe respiratory failure.
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Association of Blood Product Utilization while on Veno-Venous Extracorporeal Membrane Oxygenation and Survival to Discharge
William Weber1, Kristen Tecson2, Pranav Kapoor3, Kara Monday4, Omar Hernandez1, Gary Schwartz1, Dan Meyer1, Nathan Vaughan1; 1Baylor University Medical Center, Dallas, USA.

Abstract
Background: Veno-venous extracorporeal membrane oxygenation (VV-ECMO) provides support for patients with refractory respiratory failure. Blood transfusion is an essential component of extracorporeal therapies. ELSO guidelines call for near normal hemoglobin values. We sought to show safety of lower target hemoglobin levels.

Methods: A retrospective review of consecutive VV-ECMO patients at a tertiary urban center from September 2012 to July 2018 was performed. Blood products were given at the discretion of the multidisciplinary care team without a strict protocol. We performed multivariable logistic regression to assess the association between utilization of packed red blood cells (RBC) and platelets, and survival at discharge while accounting for age, gender, APACHE III, and presence of acute respiratory distress syndrome (ARDS).

Results: Of 157 patients, 98 (62.4%) survived to discharge. Characteristics of survivors and non-survivors did not significantly differ, except in APACHE III score (higher among non-survivors) and ARDS rate (higher among survivors). RBC transfusion was rarely performed for hemoglobin of more than 9 gm/dL, and hemoglobin was generally maintained between 8 and 10 gm/dL. The odds of death prior to discharge did not differ based on units of RBC or platelets utilized (adjusted odds ratio RBC: 1.011, 95% confidence interval: 0.963-1.062, p = 0.6583; adjusted odds ratio platelets: 1.01, 95% confidence interval: 0.896-1.138, p = 0.8731).

Conclusion: Day 3 hemoglobin remained between 8.7 and 10.1 and was similar between survivors and non-survivors. Transfusion was not associated with mortality in this study. The only independent risk factor for in-hospital mortality was APACHE III.

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A Role for Inhaled TXA in ECMO patients: A Case Series of Massive Hemoptysis
Nicholas Villalobos, Gabriela Cabanilla, Paul Diehl, Shoza Ahmed; University of New Mexico, Albuquerque, USA

Abstract
Background: Inhaled tranexamic acid is being recognized as a management for hemoptysis. Recent literature has shown bleeding mitigation when used in less severe cases, but oftentimes in the intensive care setting dealing with V-V ECMO, we seek quick therapeutic options in complex situations. The following cases outline two patients with ARDS on V-V ECMO, and the use of 500mg of nebulized TXA three times daily, through the ETT for necrotizing pneumonia.

Case Report:
A 45 year old male with acute respiratory failure secondary to H1N1 / ARDS and cannulated with bi-femoral cannula for VV ECMO. Respiratory failure progressed and had complete white out bilaterally. He had multiple, serial bronchoscopies over several weeks, with hemorrhage. His circuit was reconfigured to bi-femoral drainage and a return cannula in the Right jugular vein. He went on to have a course of inhaled TXA and further bedside surgical interventions before decannulation.

Second case involved a 68 year old Gentleman that unfortunately had a prolonged hospitalization from a spinal fracture with concomitant ARDS with pseudomonas pneumonia that was placed on V-V ECMO and went on to have left lower lobe hemorrhage, requiring endobronchial balloon to tamponade bleeding with TXA adjunct therapy.

Discussion:
These cases outline complex situations in which patients on V-V ECMO are at the sharp end of their hospitalization, and may be invariably too unstable to endure interventional radiologic procedures. The option of nebulized TXA may provide both time and management of uncontrolled bleeding, keeping the ECMO circuit and physiologically intricate patient in mind.
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Would bleeding trauma patients benefit from extracorporeal support? A retrospective case review
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Abstract
Traumatic haemorrhage is one of the leading causes of death in injured patients. It is hypothesised that extracorporeal membrane oxygenation (ECMO) may improve outcomes. We wanted to explore the potential of the implementation of ECMO to change the outcomes of severely ill trauma patients in a major trauma centre (MTC) in London.

Method: This was a retrospective case review of patients who presented to a major trauma centre in London with severe traumatic haemorrhage and died. Data was collected over a 20-month period from January 2017 to August 2018 and included 169 Code Red patients who died; 151 who were admitted to the ICU and 18 from the emergency department or in the operating theatre. Each case was reviewed, and a potential role for ECMO was decided by two of the team. Patients who died from significant respiratory failure were considered candidates for venovenous support, while patients who died from uncontrollable haemorrhage were considered candidates for venoarterial support.

Results: There were 13 cases of traumatic haemorrhage which met criteria for ECMO- mechanisms included 8 penetrating trauma, 1 gunshot wound, 1 road traffic collision, 1 fall and 2 polytrauma. 1 case would have benefited from venovenous support whilst the rest would have required venoarterial support.

Conclusion: There are several patients presenting to a MTC that can benefit from ECMO. The number of cases identified would meet the minimum required number of ECMO runs per year identified by the Extracorporeal Life Support Organisation (ELSO) for a hospital to become an accredited centre.

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A Case Series of Accidental Hypothermia with Cardiac Arrest in a Subtropical Environment Treated with Venorarterial ECMO
William Weber, MD, Omar Hernandez, RN, Christopher McAfee, RN, Christopher Couch, MD, Nathan Vaughan, MD, Dan Meyer, MD, Gary Schwartz, MD; Baylor University Medical Center, Dallas, USA

Abstract
BACKGROUND: In cases of severe hypothermia, cardiovascular collapse due to lethal cardiac arrhythmias is common. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) provides a solution that is capable of supporting perfusion and rewarming. There are case studies from subfreezing temperatures that demonstrate high rates of survival in cases of hypothermic cardiac arrest.

PURPOSE: The authors aim to describe VA-ECMO use in hypothermia in a temperate climate.

METHODS: We performed a retrospective review of patients who underwent peripheral VA ECMO from July 2017 to April 2019 in a single tertiary care center.

RESULTS: We identified 5 patients with hypothermic cardiac arrest treated with VA-ECMO. Of these patients, 4/5 (80%) survived to hospital discharge. Two patients were in cardiac arrest when EMS arrived. Three patients arrested while in the ED, or under the care of EMS.

Of the survivors, 2/4 suffered from minor neurological complications (tremor, and neuropathy). 2/4 of the survivors were discharged with a diagnosis of dementia. These two patients had a history of cognitive problems, but their baseline status was unknown. All patients were discharged to rehab or long term acute care facility. The single mortality was evaluated for organ donation but was declined.

CONCLUSIONS: ECMO in hypothermic cardiac arrest provides a viable means of support, and rewarming. Previous case reports have been confined to alpine, arctic, or other extreme cold environments. This study showed a survival rate of 80%, slightly higher than previously reported. This demonstrates that selected patients may have a high survival even in more temperate climates.
Promoting Patient- and Family-Centered Care for Patients on Extracorporeal Membrane Oxygenation: A Nursing Led Comprehensive Care Team
Lexi Workman, Sarah Richards, Rachel Spak, J.W. Awari Hayanga, Paul McCarthy; West Virginia University Heart and Vascular Institute, Morgantown, USA

Abstract
BACKGROUND:
Multiple needs exist for both patients and family members supported with Extracorporeal membrane oxygenation (ECMO). Patient and family-centered care were patients and families partner in care, is a philosophy of our intensive care unit (ICU).

Our program cares primarily for patients with limited resources who have come from rural hospitals that are far from ours. In response to the growth of our program and the needs of our patients, several nurses took the initiative to develop a system to coordinate and improve the delivery of patient and family-centered care and to address clinical, spiritual, social, and financial needs.

METHODS:
This is a report on the development of a nursing-driven “comprehensive care team” and its impact. The concept for this team came in response to increased demand for specialized services.

All patients on ECMO get a consult from our comprehensive care team with nursing and other team members designing a customized comprehensive care plan.

RESULTS:
Since the implementation of this team there have been decreases in complications such as delirium and decubitus ulcers and improved outcomes. Consults for services such as music and pet therapy have increased and the team routinely coordinates birthday parties, holiday meals, and special visits. A recent survey reports universal support of the service and increased nursing satisfaction.

CONCLUSIONS:
The comprehensive care team has made an impact on our ECMO program. Nurses are empowered and important needs of patients and families are being addressed. The success of this program is now expanding to other patient populations.

A Case Report of Successful Revascularization of a Middle Cerebral Artery Occlusion in a Patient in Cardiogenic Shock on VA ECMO
Paul McCarthy¹, Vanessa Gouge², Christopher Bianco², Swarna Rajagopalan¹, Abdul Tarabishy³, Muhammad Salman³; ¹West Virginia University Heart and Vascular Institute, Morgantown, USA. ²West Virginia University Heart and Vascular Institute, Morgantown, USA. ³West Virginia University Heart and Vascular Institute, Morgantown, USA.

Abstract
BACKGROUND:
Neurologic complications such as stroke, hemorrhage and seizure not uncommon in patients on extracorporeal membrane oxygenation (ECMO) and negatively affect outcomes. The utilization of ECMO is increasing and prompt recognition of such complications is important.

Neurointerventional management of stroke and continues to advance with more patients being candidates for treatment. There is, however, little literature on patients on ECMO receiving neurointerventions for acute stroke.

METHODS:
This is a case of a 48-year-old male who presented in cardiogenic shock (ejection fraction 5%) due amphetamine abuse and arrhythmias. He was initially supported with VA ECMO and had an Impella ® placed to offload the left ventricle. He was anticoagulated with systemic heparin and was extubated on his third hospital day. After 4 days of support his heart began to recover removal of the Impella ® was planned. He suddenly developed right sided weakness and neglect. Neuroimaging revealed a left MCA occlusion. The Impella ® was removed and the sheath was used for access for thrombectomy.

RESULTS:
Thrombectomy was performed with successful revascularization. The patient returned the ICU with significant neurologic improvement. Over the next several days his cardiac function and neurologic exam improved. He was decannulated on hospital day 7 and eventually discharged home.

CONCLUSIONS:
Due to rapid recognition and diagnosis the patient this patient on VA ECMO underwent a successful neurointervention. Patients on ECMO are at risk of stroke and being on ECMO is not an absolute contraindication to neurointervention.
Venoarterial Extracorporeal Membrane Oxygenation and Therapeutic Plasma Exchange for Refractory Vasoplegia: A Case Report
Erica Gilles1, Krista Renner1, Courtney Bainbridge1, Steven Turley1, Ankit Ankit Sakhuja1, Christopher Cook1; 1West Virginia University Heart and Vascular Institute, Morgantown, USA. 2West Virginia University Heart and Vascular Institute, Morgantown, USA. 3West Virginia University Heart and Vascular Institute, Morgan, USA. 4West Virginia University Heart and Vascular Institute, Morgant, USA

Abstract
BACKGROUND:
Vasoplegia syndrome (VPS) is a syndrome of low systemic vascular resistance, resulting in reduced blood pressure with a normal or raised cardiac output. VPS occurs in post-cardiac bypass, trauma, burns and sepsis. The pathogenesis is not fully understood but involves endothelial secretions, vasoactive metabolites, and autacoids.
Therapeutic plasma exchange (TPE) non-selectively removes substances theorized to contribute to VPS. Reports suggest that TPE helps hemodynamics in VPS.

METHODS:
We report a case of a 24-year-old female with bacterial endocarditis affecting the mitral valve after surgical repair. While in the intensive care unit she required epinephrine, norepinephrine and vasopressin infusions to maintain marginal blood pressures. After ultrasound directed resuscitation her infusions increased and with phenylephrine, sodium thiosulfate and methylene blue added. She had acute kidney injury, shocked liver and lactic acidosis. Due to refractory VPS the decision was made to place her on VA ECMO for support and perform TPE as rescue therapy.
An exchange of 1.5 plasma volumes (half plasma and half albumin) was performed. Within hours, vasopressor requires were halved. The patient was making urine and had a normal lactate in the morning and was nearly off vasopressors. She continued to recover and was decannulated after a few days with the rest of her course being unremarkable.

CONCLUSIONS:
This patient with endocarditis and VPS was rescued with VA ECMO and TPE. VA ECMO can help support patients with VPS and TPE may be beneficial in selected patients. More studies are warranted.

Rapid expansion of an ECMO program facilitated by a comprehensive ECMO specialist training program
Rachel Sterling, RN, Bradford Anderson, RN, Rahbekah Tran, RN, Brandon Crist, RN, Jeffrey DellaVolpe, MD; Methodist Hospital, San Antonio, USA

Abstract
Background: From 2013 to 2019, the Methodist Hospital ECMO program expanded by 1300% and received patients from over 500 miles across Texas. Between 2013 and 2017, a total of 68 patients were placed on ECMO. In 2018, there were 77 patients and as of July 2019, the year-to-date total is 79 patients.
Methods: In order to accommodate this rapidly expanding ECMO population, a comprehensive ECMO specialist training program was created for nurses and respiratory therapists in the cardiovascular ICU. The specialist course consists of two days of didactic training and two days of wet lab training focused on familiarity with the circuit, potential complications, and troubleshooting. All specialists are required to pass a comprehensive written exam with an 80% or above. Specialists then complete 84 hours at bedside managing ECMO alongside a perfusionist. To complete the training, a final simulation exam is administered by a perfusionist. For continuing education, quarterly wet lab simulations, annual didactic review classes and at least two specialist shifts a quarter are required. Specialists are encouraged to participate in monthly ECMO committee meetings to review cases and quality indicators.
Results: Since the launch of the program in August 2018, 20 specialists have completed training and 31 are currently in training with projected completion date of September 2019. By the end of 2019, the projected number of specialists is 80.
Conclusions: By initiating a rigorous ECMO specialist training program, the Methodist Hospital ECMO program is able to exponentially grow while maintaining quality care and favorable ECMO outcomes.
Feasibility of a bedside decannulation protocol for VV and VA ECMO
Bradford Anderson, RN, Rachel Sterling, RN, Brandon Crist, RN, Jeffrey DellaVolpe, MD; Methodist Hospital, San Antonio, USA

Abstract

Background: Decannulation at bedside allows for discontinuation of ECMO while reducing the OR burden, and mitigating the risks of general anesthesia. However, there is little evidence describing the safety and feasibility of this practice.

Methods: A bedside protocol was implemented for removal of arterial and venous cannulas in the ICU setting. Bedside decannulation is performed by a specialized team consisting of an ECMO physician, perfusionist, ECMO specialist, and Cath Lab technician. Post-decannulation, daily surveillance of cannula sites is performed by a member of the ECMO team. Ultrasound of the groin is completed within three days and sutures are removed approximately 5-7 days post decannulation. Criteria for the protocol includes percutaneously placed cannulas and no known cannulation related complications. Patients were taken for surgical decannulation if they were centrally cannulated, cannulated with a surgical cut down, or if the arterial cannula was 19 French or larger.

Results: Approximately 95% (74 of 78) of ECMO patients met criteria for bedside decannulation protocol criterion and were decannulated at bedside. Approximately 26% (21 of 78) experienced post decannulation complications. Complications included pseudoaneurysm (3), arteriovenous fistula (1), bleeding (4), abscess (3), hematoma (5), occlusive thrombus (3) and deep vein thrombosis (2).

Conclusions: The implementation of a standardized bedside decannulation protocol has proven to be feasible and has the potential to decrease OR burden and anesthesia administration. More data are needed to identify which patients are prone to decannulation complications and to compare the rate of complications in surgical versus bedside decannulations.

Extra-Corporeal Membrane Oxygenation for Catheter Ablation in a post-cardiotomy patient with Electrical Storm.
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Abstract

Electrical storm (ES), characterized by multiple episodes of ventricular arrhythmias within a short time period, may require catheter ablation (CA). Patients with ES may have cardiovascular instability which becomes more unstable during CA. Extra-Corporeal Membrane Oxygenation (ECMO) during CA has been described in patients presenting with out of hospital cardiac arrest associated with ES. Postcardiotomy ECMO for CA has not been previously described.

A 50-year-old patient (with poor LV function EF<20% and renal failure) presented with ST-Elevation-Myocardial-Infarction (STEMI). Following elective insertion of intra-aortic balloon pump (IABP), he underwent emergency coronary artery grafting (CABG). He was weaned off bypass with enoximone and norepinephrine infusions but remained intubated and ventilated on intensive care. 10 days postoperatively, he developed ES with cardiac arrest requiring DC shock and CPR. There was no satisfactory response to maximal antiarrhythmic therapy and he had 29 ventricular fibrillation/tachycardia (VF/VT) episodes on one night, responding to external cardioversion. Therefore he was planned for CA. The transfer to the catheter laboratory table and supine position was associated with refractory pulmonary oedema, hypoxia and hypotension leading to abandonment of CA plan. Therefore, elective Veno-Arterial-ECMO was established the day before a second CA attempt, which was performed uneventfully. ECMO was weaned off on the next day. The patient remains in normal sinus rhythm and free of arrhythmias to date.

In conclusions, our case illustrates the possibilities of ECMO in the mechanical circulatory support to assist the VT/VF ablation in post cardiac surgery patient with persistent severely impaired LV function.
Evaluation of the Incidence of Thrombotic and Hemorrhagic Events in the Absence of Maintenance Anticoagulation on Extracorporeal Life Support (ECLS)

Christopher Barnes, DNP; Peter Barrett, MD, MS FACS; David A. Dean, MD; Rebecca Reedy, RN, BSN; Piedmont Atlanta Hospital, Atlanta, USA. Piedmont Heart Institute, Atlanta, USA

Abstract
When conventional therapies aimed at temporizing potentially reversible cardiopulmonary dysfunction fail to achieve desired outcomes, the use of extracorporeal life support (ECLS) may be indicated. The two most common complications of ECLS include hemorrhage and thrombosis, which can place these patients at risk for a myriad of other, longer lasting effects, including increased length of stay, increased healthcare costs, neurologic impairment, loss of limbs, and even death. A retrospective chart review was performed to compare the rate of thrombotic and hemorrhagic events in patients receiving ECLS who were and were not administered maintenance anticoagulation at a local, quaternary care medical center. The total sample size included 268 patients. The results of this project revealed more hemorrhagic events (n=173) than thrombotic events (n=56), independent of the use of maintenance anticoagulation. Membrane oxygenator (9%, n=15) and circuit thrombotic (3%, n=5) events were noted in higher incidence with patients who were on maintenance anticoagulation (n=166). Results demonstrate a statistically significant relationship (p<0.05) between the absence of maintenance anticoagulation (n=166). The remaining variables, ischemic bowel, gastrointestinal hemorrhage, cannula and surgical site hemorrhage, hemorrhagic cardiac tamponade, hemorrhagic stroke, and compartment syndrome, demonstrated a higher incidence than thrombotic events although p>0.05 for each value. Overall, more research into the optimal anticoagulation and management of this fine balance of prevention of hemorrhage and thrombosis is required.

Extracorporeal Membrane Oxygenation and Class III Obesity As a Traditional Contraindication: the Data Says Otherwise

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Abstract
Extracorporeal Membrane Oxygenation (ECMO) may be indicated for acute respiratory or cardiac dysfunction when conventional therapies fail. Traditionally, Class III obesity (body mass index > 40) has been considered a possible contraindication to ECMO therapy because of difficulty obtaining access and achieving therapeutic flow rates, among other reasons. In a retrospective study of 738 patients (n=738) at a single quaternary care center from January 2014 to May 2019, the relationship between BMI and ECMO run survival rate was analyzed. The population was divided into two groups: the first containing 678 patients with a BMI < 40 and the second including 59 patients with a BMI > 40. A total of 398 patients, regardless of BMI, survived to decannulation (53.9%). The subset of patients with a BMI < 40 observed a 53.02% survival rate compared to a 64.4% survival rate in patients with a BMI > 40. Chi-square independence analysis (p=0.092) indicates that survival to ECMO decannulation and BMI are independent of one another at a 95% confidence level (α=0.05). This study suggests that BMI alone is not an accurate predictor of outcomes and should not be the main determining factor when considering a patient for ECMO therapy.

Clinical Benefits of Cutting-Away ECMO Cannulas Prior to Decannulation

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Abstract
Introduction
Some ECMO practitioners prefer to come off ECMO by "cutting-away"; detaching the circuit and infusing low dose heparin into the cannulas with delayed decannulation. Clinical benefits may include decreased surgical bleeding due to time off systemic anticoagulation.

Methods
We performed a retrospective chart review of ECMO patients decannulated between 2017 and 2019. Patients were chosen for standard decannulation or cutting-away based on surgeon preference; some surgeons always cutting-away and others do not. Data collected included operative time, duration of time cannulas remained in place, hemoglobin change associated with decannulation, and complications. Statistical analysis was performed using two sample equal variance T-test and scatter plot with a trend line.

Results
Twenty-three ECMO runs were reviewed. Twelve were cut-away prior to decannulation. The average operative time for decannulation was unchanged between groups (44.4 vs 45 minutes, p=0.44). The average difference in hemoglobin after decannulation for cut-away patients and standard decannulation patients was -0.0545 and -0.975 (P<0.01). There was a trend towards less blood loss during decannulation in patients as time off ECMO increased (R²=0.329). There were no reported complications from the retained cannulas after cutting-away from ECMO.

Conclusions
The use of the cut-away technique decreases blood loss during decannulation without significantly changing the operative time. A trend shows that the longer a patient is off of ECMO, the less their hemoglobin will drop due to decannulation. This technique may mitigate the risk of continued unnecessary ECMO time while awaiting surgeon availability without incurring separate risk of morbidity or mortality.
Simulations for Aeromedical Transport and Remote Cannulation of ECMO Patients
Rebecca Rose, BA, RRT-NPS, William Cohen, Rebecca Williamson, BS, Justin Okray, PA-C, Viktoriya Kagan, APN, Colleen LaBuhn, APN, Pamela Combs, PhD, Karen Meehan, APN, Ryan Piech, CCP, Tae Song, MD; University of Chicago Medicine, Chicago, USA

Abstract
Background: Our institution developed an ECMO cannulation/transport program to rescue critically ill patients, too unstable to transport from community hospitals. ECMO cannulation and transport is a high stakes endeavor. To minimize errors, prepare for unexpected complications, and optimize communication between staff members, we instituted a simulation program for remote cannulation and aeromedical transport of patients supported on ECMO.

Methods:
Our simulation program aimed to improve team communication, adaptability, and readiness for complications and emergencies during outside cannulations. Scenarios begin with a call from the outside institution and end with an ICU hand-off at the home center. Special attention is given to advanced preparations for transport, potential cannulation complications, transfer from hospital beds to transport beds, and subsequent placement and flight in the helicopter. Simulations are also used to develop contingencies and plan future training exercises.

Results:
Following the establishment of an ECMO cannulation and transport simulation program, our center has safely cannulated and transported 23 patients over 27 months, with 17/23 on VV ECMO and 6/23 on VA ECMO. 57% of transported patients were discharged home and would likely have not survived otherwise, having failed all other conventional medical treatment.

Conclusion:
A successfully organized mobile ECMO team with well-rehearsed preparations, transport, and cannulation procedures can effectively support patients who have exhausted the medical capabilities of community institutions, with few complications. With this support, patients with a very poor prognosis can be given a significant chance of survival.

ECMO Aeromedical Transport in a Burn Patient
William Cohen, Rebecca Rose, BA, RRT-NPS, Rebecca Williamson, BS, Justin Okray, PA-C, Viktoriya Kagan, APN, Colleen LaBuhn, APN, Pamela Combs, PhD, Karen Meehan, APN, Ryan Piech, CCP, Tae Song, MD; University of Chicago Medicine, Chicago, USA

Abstract
Case Description: A 20-year-old male presented to an outside facility, intubated, with partial and full thickness chemical burns totaling 45% body coverage, in addition to inhalation injuries. The patient’s respiratory status worsened secondary to Acute Respiratory Distress Syndrome (ARDS.) Four days after initial presentation, the patient developed inadequate gas exchange despite maximal ventilatory support. Our ECMO transport team was contacted for evaluation.

Our team traveled to the institution by helicopter and initiated Venovenous (VV) ECMO via a 25Fr left femoral vein long multi-stage inflow cannula and 19Fr right femoral vein long single-stage outflow cannula due to the presence of severe neck burns. At our center, the patient received a tracheostomy 12 days after initial injury. The patient underwent multiple surgical procedures for debridement and allograft placement while on ECMO, and was weaned off VV ECMO following 23 days of support. His tracheostomy was decannulated after 53 days of use and he was discharged, on room air, to an acute-care rehabilitation facility 69 days after initial injury.

Discussion: ARDS is a common complication in burn patients who, in some cases, can be supported with ECMO. Burn related ECMO use is becoming increasingly utilized, however many community institutions lack the capabilities to initiate and maintain this treatment. This case demonstrates that ECMO cannulation and inter-facility transport of burn patients suffering from inhalation injuries can be an effective method to increase the likelihood of recovery.

The Use of Extracorporeal Life Support in an Infant with a Fatal Condition Mimicking Sepsis
Ritesh Korumilli, Omar Alibrahim; University of Buffalo, Buffalo, USA

Abstract
Case description: A full-term 4-month-old male presented to us with acute respiratory failure and shock with a history of URI and fever for 4 days prior. Patient was intubated and found to have profound anemia with Hb of 3.3 g/dL and a Hct of 11.2%, shock and refractory metabolic acidosis. Family history was significant for a male sibling who passed away after presenting similarly with shock and profound anemia at 18 days of age. In a few hours despite aggressive resuscitation including multiple transfusions, patient suffered asystolic cardiac arrests but ROSC was achieved, placed on VA ECMO and then CRRT was started for acute renal failure and hyperammonemia of 636 mcemol/L. Abdominal ultrasound revealed thrombosis of the portal and splenic vein. The neurological exam within 48 hours showed fixed and dilated pupils. Blood tests were suggestive of suspected familial form of HLH including the presence of ferritin >40000 ng/mL, AST/ALT of 7920/4322 u/L, severe coagulopathy with a fibrinogen of 64mg/dL and splenic and portal vein thrombosis, severe anemia and refractory septic shock-like picture. In view of his grave prognosis and poor neurologic activity, all support was withdrawn. Autopsy and further testing were not performed due to family refusal.

Conclusion: To our knowledge, this is the first case with suspected familial HLH presenting with profound anemia and shock needing ECMO support. Further research to identify eligible patients who may benefit from ECMO early in the course as a bridge to diagnosis/ transplant is needed.
41 Therapeutic plasma exchange for neonatal septic shock
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Abstract
Objective: To examine the use of therapeutic plasma exchange (TPE) as adjunctive therapy in neonatal septic shock.
Results: We identified three neonates with septic shock that received TPE. Two neonates had adenovirus sepsis, one had group B streptococcus sepsis. All neonates were on extracorporeal life support (ECLS) when TPE was started. The median duration of TPE was 6 days (IQR 3, 15), with a median of 4 cycles (IQR 3, 5). Lactate levels decreased significantly after TPE (median before 5.4 mmol/L (IQR 2.4, 16.1) vs. after 1.2 mmol/L (IQR 1.0 - 5.8); P < 0.001). Platelet levels did not change (median before 73,000 /mm3 (IQR 49,000 - 100,000) vs. after 80,000 /mm3 (IQR 62,000 - 108,000); P = 0.2). Organ failure indices improved after TPE in two of the three neonates. Hypocalcemia was seen in all cases despite prophylactic calcium infusions. One neonate died, and two survived to ICU discharge.
Conclusion: TPE can safely be performed in neonates with septic shock. TPE may have a role as an adjunctive therapy in neonates with septic shock requiring ECLS.

49 DECREASING INCIDENCE OF AKI BY ACCOUNTING INSENSIBLE LOSSES IN PEDIATRIC PATIENTS ON ECMO
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Abstract
INTRODUCTION: Acute kidney injury is a common complication in patients treated with ECMO. The progression of AKI is independently associated with an increase in mortality. Pediatric patients on ECMO experience additional fluid loss from the artificial membrane that needs to be accounted for in the calculation of their daily fluid balance. We sought to test the hypothesis that recognizing and accounting for insensible losses in our daily fluid management would decrease the incidence of AKI.
METHODS: A retrospective cohort study was conducted at a university affiliated children’s hospital PICU comparing the incidence of AKI before and after the implementation of accounting insensible losses. This study included patients 0-18 years of age who required ECMO support from May 2010 - April 2019.
RESULTS: Since instituting the practice of accounting for insensible losses during ECMO, 22 patients were placed on ECMO in the ICU. These patients were compared to 22 patients prior to our change in practice. The total incidence of AKI in our intervention group was 40% (9/22), compared with 50% (11/22) in our control group. However, post-decanulation assessments among survivors showed a 10.5% (2/19) incidence of AKI in our intervention group and 47% (8/17) in our control group (p-value=0.016).
CONCLUSIONS: There is a high incidence of AKI in pediatric patients requiring ECMO, and accounting for insensible fluid loss from the artificial membrane has shown a decrease in the incidence of AKI post-decanulation. We acknowledge that this study is limited by our single center retrospective analysis and the smaller sample size.

213 Factors Associated with Acute Kidney Injury in Children Supported with Extracorporeal Membrane Oxygenation
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Abstract
Rationale: Extracorporeal membrane oxygenation (ECMO) is used for respiratory, cardiac failure and ECPR in children but is complicated by Acute Kidney Injury. Objectives: (1) To measure the incidence of AKI during ECMO support; (2) to identify factors associated with this complication; and (3) to determine the impact of these complications on patient outcome.
Methods: This was a retrospective cohort study in pediatric and neonatal intensive care units in a University affiliated Children’s Hospital, carried out from March 2010 to June 2019. Measurements and Main Results: ECMO support was required on 71 consecutive patients under 18 years of age. Demographics, diagnosis, ECMO mode, pump type, creatinine clearance, NIRS, fluid balance, pRIFLE criteria and outcome were recorded. Overall Survival was 62%. AKI occurred in 51% and was independently associated with higher daily risk of mortality. Pump type, mode of ECMO, low NIRS was not associated with AKI. Length of ECMO duration (RR= 1.742, p value=0.0276) was predictive of subsequent development of AKI.
Conclusions: The incidence of Acute Kidney Injury is high during ECMO support. Length of ECMO support is a major contributor to renal injury during ECMO. Strategies to reduce the daily risk of AKI such as accounting for insensible losses, may be appropriate subjects of future trials to improve outcomes of children requiring this supportive therapy. We acknowledge that this study is limited by our single center retrospective analysis and the sample size.

80 The use of effective mobile veno-veno ECMO in a patient with Leri-Weill Dyschondrosteosis mesomelic dwarfism.
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Abstract
The use of mobile veno-venous extracorporeal membrane oxygenation (ECMO) is an established support strategy for refractory hypoxemia due to acute respiratory distress syndrome. We report, to the best of our knowledge, the use of effective mobile veno-veno ECMO in a patient with Leri-Weill Dyschondrosteosis mesomelic dwarfism. A 56-year-old woman with Leri-Weill Dyschondrosteosis mesomelic dwarfism (127 cm, 36 kg) was referred for mobile ECMO after worsening gas exchange with refractory hypoxemia and respiratory acidosis due to pneumonia. Peripheral bi-femoral veno-venous ECMO was initiated with a 23Fr Medtronic BioMedicus drainage cannula and a 19Fr Medtronic BioMedicus return cannula on a Cardiohelp HLS Advance 5.0L. Once ECLS was in situ, the patient stabilised and her ventilation reduced to standard rest settings. The patient was transferred to the retrieval centre, by road, on mobile ECMO with no adverse events. A CTPA showed dense consolidation within all lung lobes with very limited normal lung parenchyma. She was treated with antimicrobials and required continuous renal replacement therapy for anuric renal failure. The patient was weaned and decannulated from ECMO after 17 days of support once her chest X-rays and arterial blood gases analysis showed improvement. The use of peripheral VV ECMO is a safe and effective strategy for the treatment of ARDS in this cohort of patients. Although standard protocols can be observed, special consideration should be made to appropriate cannulation and circuit choice due to body habitus.
High fidelity in-situ simulation for teaching crisis resource management in ECMO crisis situations
Rosie Smith, Rosie Cervera-Jackson, Amy Chan-Dominy, Jolana Sykorova, Maurizio Passariello, Stephane Ledot; The Royal Brompton, London, United Kingdom

Abstract
Background: The development of Crisis Resource Management (CRM) skills, including communication strategies, leadership and resource utilisation is increasingly recognised as important for healthcare professionals (HCPs) caring for complex patients, such as those receiving ECMO. Simulation facilitates practice of emergency procedures, guidelines and CRM skills in a safe, interprofessional environment.

Method: We report our experience of inter-professional high fidelity in-situ simulation training on CRM using ECMO scenarios and equipment.

Results: Simulation training sessions followed protocols established by our hospital’s Simulated interPRofessional Team Training (SPRinT) program. Simulations took place in clinical areas, such as the intensive care unit, using a Gaumard HAL® mannequin and our standard ECMO circuit on a Cardiohelp or Levitronix system. Simulation scenarios were derived from ‘real-life’ patient incidents, including anonymized clinical data, investigation results and imaging. Using equipment, layouts and scenarios familiar to participants enables immersion and facilitates learning. Participants acted as part of an inter-professional team during the session, and debriefing after the session was facilitated using the Advocacy-Inquiry method and ‘debriefing with good judgement’ principles. 34 feedback questionnaires from 5 simulation sessions reported positive experience, with an overall rating of 95% (level of agreement rating scale 0-100%). The average rating on the experience being realistic was 92%. 91% participants agreed with the statement that in-situ ECMO simulations may help provide safer patient care in the future.

Conclusion: High-fidelity in-situ simulation training can provide a realistic experience for training in practice of emergency procedures, guidelines and CRM skills for HCPs caring for patients on ECMO.

The Metabolic Demands of Extracorporeal Membrane Oxygenation in Older Infants and Children
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Abstract
Nutritional support for patients on Extracorporeal membrane oxygenation (ECMO) can be challenging, difficult to assess and can impact patient’s outcome. ECMO provides cardiorespiratory support and may alter metabolic demands. Infants and children on ECMO have the same caloric needs as healthy infants and children. Included were patients 30 days to 21 years requiring ECMO. Exclusion criteria; uncuffed endotracheal tube, active seizures, or a ketogenic diet. Determination of O2 consumption (VO2) and CO2 production (VCO2) Indirect calorimetry from oxygenator by obtaining blood gases pre- and post-oxygenator. O2 and CO2 content calculated using the 0149 Physiome model (Dash&Bassingthwaighte, 2015) O2 and CO2 content were multiplied by ECMO blood flow to obtain the VO2 and VCO2, respectively. Calculation of Resting Energy Expenditure (REE) VO2 and VCO2 from the mechanical ventilator and oxygenator were added and the Weir equation used to calculate REE in kcal/day: REE = (3.94 x VO2) + (1.11 x VCO2) x1440) Measurements were obtained during ECMO and after decannulation. Data were compared to the predicted REE of children using the Schofield equation: REE = 8.4 [weight (kg)] + [height (cm)] + 200 Demonstrated the ability to measure REE on infant and pediatric patients. Septic shock patients on ECMO were highly hypermetabolic. However, brain death demonstrated a lower than predicted REE. There is a general down sloping trend of REEs after decannulation. REE can be measured on infants and children on ECMO. REEs on septic shock patients on ECMO were highly hypermetabolic. However, brain death demonstrated a lower than predicted REE. There is a general down sloping trend of REEs after decannulation.
Impact of Protocolized Inhaled Prostacyclin Therapy on the Need for ECMO in Neonates >34 weeks Gestation with PPHN Unresponsive to iNO.

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Abstract

INTRODUCTION: ECMO is an important rescue therapy for persistent pulmonary hypertension of the newborn (PPHN), however outcomes vary widely with underlying diagnosis. Since the original trials demonstrating efficacy of both ECMO in treating PPHN, novel pulmonary vasodilators have become available, including inhaled prostacyclin analogs (iPCAs) iloprost (Ventavis™) Treprostinil (Tyvaso™). However, iPCAs are inadequately studied in the neonatal population.

METHODS: In 1/2015 we implemented a protocol for the management of PPHN (Figure 1), including an iPCA trial for those failing iNO. We performed a retrospective review of infants >34 weeks gestation with PPHN born from 1/2015 - 2/2018 who failed iNO, and were treated with an iPCA and/or ECMO. We excluded infants with congenital diaphragmatic hernia (CDH) and complex congenital heart disease (CHD).

RESULTS: Our study population included 17 infants with PPHN refractory to iNO. Overall survival was 72%. Three patients required ECMO without a trial of iPCA (pre-ECMO OI median 48, range 33-49). Fourteen patients escalated to iPCA therapy; 4 subsequently required ECMO (pre-iPCA median OI 51, range 20-74). Of the remaining 10 iPCA-treated patients, 4 died from HIE while 10 survived without progression to ECMO. In patients treated with iPCA who survived without ECMO, median pre-iPCA OI was 31 (range 25-75), and improved to 19 (range 10-30) on iPCA therapy.

CONCLUSIONS: In this select population with PPHN unresponsive iNO, patients with more moderate OIs responded to iPCA treatment and avoided ECMO. ECMO eligible patients who meet ECMO criteria should not have ECMO delayed for a trial of iPCA.

ECMO Utilization in Burn Patients with severe ARDS

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Abstract

Inhalation related pulmonary injury is a major contributor to morbidity and mortality in burn victims. Acute respiratory distress syndrome (ARDS) is a complication that affects approximately 40% of such patients and is associated with a high mortality rate. While extracorporeal membrane oxygenation (ECMO) for the treatment of ARDS in adults has shown promise, adults treated with ECMO following trauma or burns have a lower survival (33%) compared to those with other conditions. The indications, management, cannulation strategies, and weaning of ECMO in adult burns is less clear and largely confined to case reports. We retrospectively reviewed all patients who received their burn care at a single regional burn center between 2017 and 2019 and were treated with ECMO. Our primary endpoint was survival to discharge. We identified 6 patients with ARDS secondary to inhalational related injury who were placed onto ECMO during this 3-year period. Prior to the time of cannulation for ECMO, the average APACHE II score, SOFA score, and P/F ratio were 32.3, 10.7, and 58 respectively. 5 patients were placed on VV ECMO with 1 cannulated onto VA ECMO. Out of 6 patients reviewed, 4 were discharged from the hospital and 2 died. Of those who survived, the average duration of ECMO support was 515 hours. Mortality in burn patients with ARDS may be lower than previously reported if they are managed with ECMO. While further research on ECMO in patients is warranted, it is a viable option for supporting critically injured burn patients.

The Use of VA ECMO as a Bridge to Pediatric Heart-Lung Transplant: A Case Report

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Abstract

Objective: We report a case of severe primary pulmonary hypertension in a pediatric patient requiring 120 days of VA ECMO as a bridge to heart-lung transplant (HLT).

Methods: A 12 year old with no significant past medical history presented with worsening shortness of breath over 12 months. She presented with signs of heart failure, with chest xray showing cardiomegaly, and echocardiogram findings consistent with pulmonary hypertension. She was admitted to the PICU, developed cardiogenic shock which failed medical management, and required cannulation to VA ECMO with plans to bridge to transplant. The patient was listed status 1A for HLT shortly after cannulation.

Results: Within 2 days of cannulation she was extubated and within a week of cannulation she was standing and working with physical therapy for ambulation. She ate by mouth, with extra nutrition added with nighttime nasogastric feeds. She was on VA ECMO for 120 days prior to heart-lung transplantation.

Conclusion: This case demonstrates that VA ECMO can be used as a successful bridge to pediatric HLT. The current data on ECMO as a bridge to HLT is scarce, with pediatric data based only on case reports. Extrapolating from adult literature and on lung-only transplants, key factors to better 1-year survival include adequate nutrition, early extubation, and early ambulation. Contrary to previous data, VA ECMO should be considered as a therapeutic option to bridge pediatric patients to HLT.
Predictors of Seizures in Children on Extracorporeal Membrane Oxygenation
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Abstract
Objective: Children undergoing extracorporeal membrane oxygenation (ECMO) are at risk for seizures. Following implementation of standardized continuous electroencephalographic monitoring (CEEG) in 2013, we reported an 18% electrographic seizure incidence of which 83% were EEG-only and 61% were status epilepticus. Determination of risk factors for electrographic seizures will help target CEEG resources.

Methods: We performed a retrospective chart review of children (<18 years) who underwent CEEG for 48 hours following initiation of ECMO from July 2013 to June 2018 to identify seizure predictors.

Results: 352 children were supported with ECMO, and 310 (88.1%) underwent CEEG. 170 (54.8%) were male, the median age was 17 (Interquartile 2, 280) days, and median weight was 4.2 (3.1, 10) kg. The most common indications for ECMO were respiratory failure, cardiac failure and extracorporeal resuscitation (ECPR). Electrographic seizures occurred in 35 children (11.3%), with EEG-only seizures in 26 (74.3%) and status epilepticus in 16 (45.7%). Mortality was higher with (25 of 35, 71.4%) than without (96 of 275, 34.9%) seizures (p<0.0001). Univariable analyses identified the following predictors (Table): veno-arterial (VA) ECMO, chest cannulation, cardiac intensive unit location, inability to separate from cardiopulmonary bypass, ECPR, cardiac arrest, hypoxemic respiratory failure, persistent pulmonary hypertension of the newborn, and postoperative congenital heart disease. Notably there were no seizures with veno-venous (VV) ECMO.

Conclusion: Electrographic seizures occurred in 11% of children requiring ECMO. The majority of seizures were EEG-only, thereby requiring CEEG for identification. There were no seizures on VV-ECMO; therefore CEEG resources can be targeted to children on VA-ECMO.
Echocardiographic Diagnosis of Cardiac Tamponade In a Patient Requiring Veno-Arterial Extracorporeal Membrane Oxygenation
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Abstract
A 72 year old male underwent coronary artery bypass grafting was placed on VA ECMO due to inability to separate from cardiopulmonary bypass. On post-operative day 5, the patient’s hemodynamics deteriorated requiring increasing amounts of vasoactive medications and fluid administration. Despite no changes to the parameters to the ECMO circuit, it was noted that flows had decreased from 3.5 L/min to 1.6 L/min and venous drainage pressures had significantly increased as well suggesting a hypovolemic state. No changes in chest tube drainage was noted. Flows and venous pressures would transiently improve with fluid administration but would return to abnormal levels once fluid administration was stopped. Laboratories were significant for elevated lactic acid and low mixed venous oxygen. Echocardiography was performed to evaluate fluid status, cannula position, and cardiac function. A significant pericardial effusion causing tamponade was discovered using trans-esophageal echocardiography that was unable to be fully visualized with transthoracic echocardiography. Because of this finding, the patient was taken for emergent surgical exploration with correction bleeding from an anastomosis on the PDA. Over one liter of blood was removed from the pericardial space. Hemodynamics and ECMO flows normalized and vasoactive medications were weaned off. The patient went on to definitive LVAD placement due to severe heart failure. This case exemplifies the challenge of diagnosis of tamponade in patients on VA ECMO as the typical exam findings are not present. It also shows the importance that echocardiography plays in the management of patients on ECMO support.

Teamwork: The Key to Successful Mobilization of Extracorporeal Device Patients
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Abstract
In a high acuity cardiovascular surgical intensive care unit (CVICU), mobilizing patients attached to mechanical devices, i.e. Extracorporeal Membranous Oxygenation (ECMO), Centrimag, and Intra-aortic Balloon Pump (IABP), presents challenges, as not all patients are ideally cannulated for ambulation. Utilizing established guidelines, protocols, and innovative therapies, (i.e. verticalization therapy, ergonomic bed bike use, and gaming), interdisciplinary mobility rounding, and individualized mobility plans have enabled our team to facilitate earlier mobilization of critically ill patients. This innovative approach has enabled us to transform the unit’s culture to support this initiative by involving all team members. It is now the expectation that all patients mobilize when defined hemodynamic goals are met. The patient’s mobilization team includes 1-2 bedside nurses, Perfusionist, Respiratory Therapist, and a Physical/Occupational Therapist to ambulate or engage in other therapies. It is imperative that each team member takes responsibility (access, ventilator, CRRT, intravenous, other LDAs) for the integrity of their respective lines while the patient participates in verticalization therapy or walking. It is equally paramount to involve family members by “normalizing” these patients so they gain the confidence to actively engage with the patient. Case studies will demonstrate how this multidisciplinary approach has allowed us to optimize treatments, maximizing therapy sessions with only one transient adverse outcome. Involving the patient and family during daily multidisciplinary rounds, allowing each team member to take ownership of their role, and establishing hemodynamic and pulmonary goals are integral for implementation of safe and effective early mobility.
Cognitive profile after ECMO-treatment - pilot study

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Abstract

Few data are available on the neurocognitive outcomes from survivors of acute coronary syndromes complicated by refractory cardiogenic shock or cardiac arrest, treated with extracorporeal membrane oxygenation (ECMO). The present pilot study was conducted to assess the clinical neurological and cognitive profile of long-term survivors.

Eight survivors (4 males, mean age 59), treated between 2013 and 2015 with peripheral venoarterial ECMO at the University Hospital of North Norway volunteered to undergo individual evaluation using the Modified Rankin Scale (MRS) and a 1 hour neuropsychological assessment battery (May 2017). Indications for ECMO initiation was cardiogenic shock (N = 7) and cardiac arrest (N=1). The median duration of ECMO treatment was 9 days. Five survivors had experienced cardiac arrest prior to ECMO treatment (time to return of spontaneous circulation; 16-90 minutes).

The MRS showed no disability in four and slight disability in three survivors. One survivor who had experienced a cerebral infarction prior to ECMO initiation had moderate disability. Cognitive test results ≤ -1.5 standard deviations from the normative mean was observed in the memory domain for 40%. Additional low scores on executive functioning tests was observed in two survivors. Tests for verbal comprehension, perceptual reasoning, attention, working memory, motor coordination and psychomotor speed were well within the normal age-range for all survivors.

Survivors of successful ECMO treatment for acute coronary syndromes seems to have some residual neurological and cognitive problems. Memory and executive functions appear to be most at risk.

ECMO in Pediatric Trauma - A Case Series

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Abstract

Purpose: Minimal patient level data exists on the use of ECMO in pediatric trauma patients. Historically, trauma was a relative contraindication due to hemorrhagic risks. We sought to review outcomes of pediatric trauma patients supported with ECMO in a single level one pediatric trauma center.

Methods: A retrospective review of the electronic health record was conducted from January 2016 to June 2019 to identify pediatric trauma patients (<18 years of age) who received ECMO during their trauma hospitalization.

Results: Six patients were identified. Five survived to discharge. Average patient age was 10.8 (STD 5.8) years. Admitting diagnoses included: gunshot wound, motor vehicle crash, pedestrian struck by tree, dog bite, flame burn with inhalation injury, and near drowning. Average post-trauma day to ECMO cannulation was 3.8 days. Indications included ARDS in four cases, ARDS with pneumonia and bronchopleural fistula, and flash pulmonary edema. Four patients were placed on veno-venous (VV) ECMO. Three were cannulated via double lumen VV, one was multi-site VV. Two patients were placed on veno-arterial ECMO. Three of the 6 patients required operative management of their injuries before ECMO cannulation. One of the 3 operative patients had significant bleeding from their traumatic injuries after ECMO cannulation. Two of the non-operative patients experienced hemorrhagic complications.

Conclusions: Pediatric trauma should not be viewed as a contraindication to the use of ECMO for patients with respiratory or cardiopulmonary failure. Hemorrhagic complications in operative and non-operative trauma must be considered but should not exclude patients from ECMO eligibility.
Understanding Risk Factors and Types of Acute Brain Injury in Adult ECMO: An Autopsy Study
Sung-Min Cho, Romergryko Geocadin, Giorgio Caturegli, Vanessa Chan, Bartholomew White, Bo Soo Kim, Marc Sussman, Chun Woo Choi, Glenn Whitman, Liam Chen; Johns Hopkins University School of Medicine, Baltimore, USA

Abstract
Objectives:
Current studies lack information on characteristics of acute brain injury (ABI) in patients with extracorporeal membrane oxygenation (ECMO). We sought to describe the characteristics of ABI in ECMO through neuropathologic assessment.

Methods:
We reviewed the ECMO patients who had undergone brain autopsy from January 2009 to December 2018.

Results:
Twenty-five patients (median age 53 years) had post mortem examination with brain autopsy. Twenty-two (88%) had venoarterial-ECMO (9 cardiac arrest; 13 cardiogenic shock) and 3 (12%) had venovenous-ECMO. The median ECMO support time was 96 hours. The most common ABI was hypoxic ischemic brain injury (HIBI) (44%), followed by intracranial hemorrhage (24%), and acute ischemic stroke (20%). Subarachnoid hemorrhage (20%) was the most common type of intracranial hemorrhage, followed by intracerebral hemorrhage (8%), and subdural hemorrhage (4%). Only 7 (28%) patients were without ABI after ECMO.

The risk factors for ABI included hypertension (11 vs. 1, p=0.046), and a higher day 1 lactate level (10.0 vs. 5.1, p=0.02). Patients with HIBI had more hypertension (8 vs. 4, p=0.047), a higher day 1 lactate level (12.6 vs. 5.8, p=0.02), and a lower pH level (7.09 vs. 7.24, p=0.027). ECMO duration, cannulation methods, persistent coma, antithrombotic therapy, renal and hepatic impairment were not risk factors of ABI.

Conclusions:
In the population who underwent post mortem neuropathologic evaluation, 72% of ECMO patients developed ABI. HIBI was the most common type of injury suggesting ~50% of patients sustained ABI prior to or peri-cannulation period as a consequence of cardiogenic shock and cardiac arrest.

Comparison of Brain Injury in VA- and VV-ECMO: A Propensity Score Matched Analysis
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Abstract
Background: Comparison of the prevalence and characteristics of brain injury between venoarterial (VA) and venovenous (VV)-ECMO is limited. We aimed to compare the prevalence brain injury in VA- and VV-ECMO.

Methods: We reviewed the Extracorporeal Life Support Organization registry from 2013-2017. A logistic regression analysis was used to evaluate the differences between VA- and VV-ECMO populations in association with brain injury while accounting for predictors. We used propensity scores to match VA- and VV-ECMO groups to determine the associated brain injury risk. Brain injury included ischemic infarct (IS), intracranial hemorrhage (ICH), and seizures.

Results: Of 19,721 patients (10,656 VA-ECMOs; 9065 VV-ECMOs), a total of 784 (7%) patients had brain injury (250 ICHs, 439 ISs, and 165 seizures) in the VA-ECMO group. For VV-ECMO, 533 (6%) sustained brain injury (320 ICHs, 144 ISs, and 117 seizures). In multivariate analysis, vasopressor/inotrope requirement, renal replacement, infection, ECMO circuit problems, disseminated intravascular coagulation, arrhythmia, myocardial stunning, and acute myocardial infarction were associated with brain injury in both groups. Overall, brain injury as well as IS was more common in the VA-ECMO group (aOR=1.67, p<0.001, and aOR=2.96, p<0.001, respectively). Frequency of ICH was similar between groups (aOR=1.05, p=0.84). When 1112 VA-ECMO patients were matched to 1013 VV-ECMO patients VA-ECMO still had a significantly higher rate of brain injury than the VV-ECMO group (aOR=1.48, p=0.03).

Conclusions: Acute brain injury as well as ischemic stroke was more common in patients with VA-ECMO compared to VV-ECMO. However, the rate of intracranial hemorrhage was similar.
Neuroimaging and Neurodevelopmental Outcomes in Neonates with Hypoxic Ischemic Encephalopathy (HIE) who received Extracorporeal Membrane Oxygenation (ECMO) and Controlled Hypothermia (CH)

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Abstract

Background:
Deployment of ECMO in neonates on CH can potentially worsen neurodevelopmental outcomes. Emerging ECMO literature suggests that current neuroimaging studies do not correlate with neurodevelopmental morbidity. Suitable predictors of outcomes in the combined CH/ECMO population are needed to guide clinical practice.

Methods:
Retrospective study of neonates with HIE who underwent CH/ECMO in our tertiary institution between 01/2011-05/2018. Available neuroimaging and developmental data were collected. MRIs were scored by a blinded pediatric radiologist.

Results:
Of twelve neonates, abnormal head ultrasound (HUS) and MRI findings were noted in 4 (33%) and 5 (42%), respectively. Seven neonates (58%) had any neurodevelopmental follow-up. Mean MRI score 2 (+/-2), mean developmental score at 15 months for gross motor (GM) 6/7, fine motor (FM) 3.75/4, expressive language 2/2 and receptive language at 18 months 1/1.

One patient with abnormal HUS and MRI with follow-up until 6 months displayed GM, FM delay and impaired functional status requiring gastrostomy (MRI score 6/8).

Two out of 6 patients (33%) with normal MRI and HUS had follow up. Both had mild GM delay at 6 months, however, one normalized by 18 months. MRI scores did not correlate with neurodevelopmental outcome at 15 months of age (p=0.28)

Conclusion:
Common neuroimaging techniques did not predict long term neurologic morbidity in this cohort of patients with HIE who received CH/ECMO. While larger studies are required to validate these findings, alternative and/or more comprehensive neuroimaging, such as EEG and NIRS, may be needed to better predict neurologic morbidity.

Bleeding Complications and MRI Findings among Neonates receiving Controlled Hypothermia (CH) and Extracorporeal Membrane Oxygenation (ECMO)

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Abstract

Background: The benefits of adding ECMO as a rescue therapy on asphyxiated neonates undergoing cooling remains unclear. The inherent risks of ECMO may outweigh any potential advantage in this population.

Methods: Retrospective cohort study comparing short-term outcomes and MRI findings of neonates who received both CH/ECMO vs CH or ECMO alone in a tertiary institution between 1/2011-5/2018. MRIs were scored by a blinded pediatric radiologist using Barkovich scoring system.

Results: Fifty-seven patients were included. Baseline characteristics between CH/ECMO (n=12), ECMO (n=20), and CH (n=25) were similar except for a higher initial oxygenation index in those requiring ECMO (OI mean; 20.52 (CH/ECMO) vs 27.1 (ECMO) vs 8.49 (CH), (p=0.001). Four patients (16%) in CH and 4 (20%) in ECMO suffered moderate to severe bleeding (intracranial or pulmonary hemorrhage) vs 5 (40%) in CH/ECMO (p=0.07). Mean MRI severity scores for CH/ECMO vs CH in T1 weighted image was 2.4 vs 3.9 (p=0.09), T2 weighted 1.1 vs 2.9 (p=0.1) and 0.22 vs 1.25 (p=0.28) in diffusion-weighted image. There were no differences in mortality or functional status at discharge among survivors.

Conclusion: Neonates requiring CH/ECMO had a trend for higher incidence of bleeding complications. Despite higher OIs in CH/ECMO group as a surrogate marker for hypoxic injury, mean MRI severity scores were not different in CH/ECMO vs CH alone. CH/ECMO can be safely deployed in HIE cases compounded by refractory PPHN with careful monitoring and aggressive management of coagulopathy to help mediate bleeding complications.
VAV ECMO: Still an option for North-South syndrome?
Karen Meehan, Michele Emory, Rebecca Rose, Vika Kagan, Justin Okray, Colleen LaBuhn, Pamela Combs, Ryan Piech, William Cohen, Rebecca Williamson, Tae Song; University of Chicago, Chicago, USA

Abstract
North-South syndrome (or upper body hypoxia) occurs in patients supported with peripheral VA ECMO, when cardiac function recovers but the lung function is inadequate. Conversion to VAV ECMO is an option used to address this problem, by adding a neck cannula, and pre-oxygenating the blood that bypasses the drainage cannula and circulates through the lungs and left heart, then is ejected.

A retrospective review was performed, of 121 patients that underwent peripheral VA ECMO cannulation, between Jan 2017 and Apr 2019 at an academic institution. Of these patients, 10 required conversion to VAV ECMO for North-South syndrome.

The patients were supported on VAV ECMO for an average of 5.3 days. 2 patients were decannulated, 4 were converted to VV ECMO, and 2 were converted to BiVAD support. 3 patients survived to decannulation, and 2 survived to discharge. 2 patients had an Impella in place at the time of VA ECMO cannulation.

North-South syndrome is becoming encountered more frequently in the clinical setting. Patients requiring VAV ECMO have a high rate of mortality. Early conversion to other temporary MCS options, including VV ECMO, BiVAD, and ambulatory VA ECMO, should be considered.

Extracorporeal Membrane Oxygenation Survival in Pediatric Recipients of Hematopoietic Stem Cell Transplantation
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Abstract
Background: Hematopoietic stem cell transplantation (HSCT) is used to treat a wide array of malignant and non-malignant pediatric diseases, with a high incidence of post-transplant intensive care and mechanical ventilation. Extracorporeal membrane oxygenation (ECMO) may be considered for patients not responding to conventional intensive care. However, HSCT may be an exclusionary criterion given historically poor outcomes. Given advancements in the delivery of ECMO and treatment of HSCT complications, an updated review of ECMO survival is warranted.

Methods: We conducted a retrospective review of Extracorporeal Life Support Organization Registry pediatric patients receiving ECMO between 1991 and 2017 with ICD-9/10 diagnosis of HSCT. Our primary outcome was survival to discharge. Bivariate analyses assessed association between survival and demographic, clinical and ECMO variables using Fischer’s exact, Pearson’s chi-square, and logistic regression. Statistical analyses were performed using JMP®.

Results: 81 patients met inclusion criteria. Overall survival to discharge was 17.8%. The survival trend significantly improved over time (p=0.02). Pre-ECMO support with epinephrine was associated with improved survival (p<0.01 OR 7.31 [1.75-30.57]). Patients with malignancy (solid tumor, leukemia, lymphoma) were less likely to survive to discharge (p=0.01, OR 0.10 [0.01-0.83]). Metabolic complications (glucose >240 mg/dL, pH<7.2, pH>7.6, hyperbilirubinemia) were associated with decreased survival (p=0.03, OR 0.19 [0.04-0.93]).

Conclusions: ECMO survival in HSCT patients is improving over time. Poor prognostic factors include underlying malignancy and metabolic complications. Our data supports the practice of temporary mechanical support in carefully selected patients if provider, center and family are in agreement regarding risks and benefits.
Utilization and Efficacy of Left Atrial Veno-Arterial Extracorporeal Membrane Oxygenation (LAVA-ECMO) as an Alternative Cannulation Technique: A Strategy Allowing for Conventional Hemodynamic and Respiratory Support as well as Ventricular and Pulmonary Unloading. 

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Abstract

Background: Veno-arterial Extracorporeal Membrane Oxygenation (VA-ECMO) in left ventricular (LV) dysfunction can lead to deleterious consequences of worsening LV distention and pulmonary edema. LV unloading is often achieved with an Impella device which is contraindicated in the setting of LV thrombus, critical aortic stenosis and high degrees of aortic regurgitation. Left Atrial Veno-arterial ECMO (LAVA-ECMO) is an option for hemodynamic support.

Methods: We describe an advanced technique of LAVA-ECMO requiring trans-septal placement of a venous femoral cannula to simultaneously drain both atria in a patient with an Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) 1 profile as a result of severe bicuspid aortic stenosis resulting in cardiogenic shock and respiratory failure as well as multiple system organ failure (MSOF).

Outcome: Our patient was treated with LAVA-ECMO for five days. He underwent trans-catheter aortic valve replacement post cannulation day 3 and full LAVA-ECMO support for five days. He had complete resolution of his MSOF. He was discharged home with a twelve day length of stay. There were no technical issues with the cannulas or the circuit throughout his cannulation. He tolerated the small residual atrial septal defect without issue.

Conclusion: LAVA-ECMO is a viable alternative to a traditional cannulation strategy in a patient with contraindications for standard ECMO insertion. LAVA-ECMO provides drainage of both the left and right atria via a single trans-septal cannula allowing for successful decompression of the right and left ventricle as well as decreasing pulmonary edema. It also provides full support for percutaneous aortic valve interventions.

Reduced mortality with bivalirudin-based versus conventional heparin-based anticoagulation for adult and pediatric patients supported on extracorporeal membrane oxygenation

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Abstract

Management of patients on extracorporeal membrane oxygenation (ECMO) necessitates systemic anticoagulation to avoid thromboembolic and hemorrhagic complications. The conventional approach relies on a continuous infusion of unfractionated heparin. However, this may not be the ideal agent in this setting because it requires antithrombin III to antagonize thrombin and it is ineffective in blocking clot-bound thrombin. Bivalirudin is a semi-synthetic bivalent inhibitor of both free and fibrin-bound thrombin that produces transient reversal of thrombin, with a short half-life of 25 minutes. Potential advantages over unfractionated heparin are inhibition of fibrin (clot)-bound thrombin, a more predictable anticoagulant response, and no effect on platelet factor 4. To better elucidate the clinical impact of a bivalirudin based anticoagulation strategy in adults and pediatrics, a retrospective case-controlled study was undertaken to compare key outcomes including mortality, thromboembolic complications, and use of allogeneic blood products.

A total of 42 adult and 14 pediatric patients treated with bivalirudin-based anticoagulation were compared to a matched control group of 296 adult and 96 pediatric patients who received heparin-based anticoagulation between January 1st, 2010 and May 3rd, 2018. The bivalirudin group was found to have an odds ratio (OR) for mortality of 0.44 (P < 0.02), increased ECMO-free days (OR 3.95, P < 0.05), and an increased hospital length of stay (OR 1.71, P < 0.01) with no difference in blood loss or transfusion volumes.

Bivalirudin based anticoagulation for adult and pediatric patients supported on ECMO was found to significantly reduce mortality compared to those managed with conventional heparin based therapy.
Continuous EEG monitoring for early detection of intracranial hemorrhage on ECMO: A Case Report
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Abstract
Introduction: Neurologic complications remain a significant cause of morbidity and mortality on ECMO, yet there is a lack of standardization of neuro-monitoring. Recent evidence suggests that seizures may be under-diagnosed in pediatric ECMO patients and continuous EEG monitoring (cEEG) provides real-time information on cerebral activities, which may allow early recognition of intracranial pathology.

Case: An 18-month-old female was admitted for acute respiratory distress syndrome after submersion injury. On day 7 of illness, she was placed on VV ECMO for refractory hypercarbia. She underwent cEEG monitoring per our new institutional ECMO neuromonitoring protocol. On ECMO day 4, a new electrographic seizure, not associated with any clinical changes, was reported. An emergent head CT showed a new 1.2 cm intraparenchymal hemorrhage in the posterior right cingulate gyrus. Anticoagulation goals were adjusted to target an unfractionated heparin level of 0.1-0.15, and aminocaproic acid infusion was started. ECMO circuit clot burden remained stable despite lower anticoagulation target. On ECMO day 21, a follow-up head CT showed a decrease in the hemorrhage size. The patient was successfully decannulated the following day and was discharged home after inpatient rehabilitation with good functional outcomes.

Discussion: cEEG may play an important role in the early detection of intracranial pathology, even prior to clinical changes being identified. Whether this technology can lead to improved neurological outcomes on ECMO through modifications in anticoagulation strategy to minimize bleeding complications and neurological injury need further study.

Novel Method for Biventricular Support with 2 TandemLife Protek Duo cannulas
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Abstract
The TandemLife Protek Duo (PD) is a dual lumen percutaneous cannula that can be used for RVAD support or VV ECMO. We present a novel minimally invasive method of providing biventricular support using 2 PD cannulas. The percutaneous RVAD was placed via the right internal jugular vein. The LVAD was placed via mini thoracotomy, through the left ventricular apex with the proximal port in the LV (as the inflow) and distal port in the aorta (as the outflow).

A retrospective chart review was completed at an urban academic center of patients placed on minimally invasive biventricular support using PD cannulas from 2018-2019. Five patients were placed on biventricular support with PD cannulas. All were male, median age was 53 years old. Etiology of shock was ischemic (100%) as all had underwent recent PCI or thrombectomy. Median time on support was 10.8 days. 4 patients were successfully decannulated, 2 patients survived to discharge, with 1 patient still in hospital. 1 patient suffered a non-debilitating stroke and no patient suffered bleeding requiring surgical intervention.

PD BiVAD is a novel method of providing reliable biventricular support. It allows for ambulation and minimizes the complications that can arise with central biventricular support.
A pragmatic extracorporeal membrane oxygenation training program for critical care clinicians
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Abstract
Background: Despite the rapid integration of extracorporeal membrane oxygenation (ECMO) into intensive care units over the past decade, there is a lack of established ECMO training programs for critical care clinicians. We developed pragmatic, multidisciplinary critical care ECMO courses with didactic and simulation-based content designed for rapid training of clinicians prior to expanded ECMO clinical practice.

Methods: We conducted a prospective cohort study of 97 critical care clinicians who underwent ECMO courses between October 2018 and January 2019 at a tertiary care academic medical center. We leveraged The Extracorporeal Life Support Organization’s training guidelines, current literature, and simulation-based training to produce 6-hour ECMO courses. We examined pre- and post-course written knowledge examinations to evaluate assimilation of knowledge and content delivery, and distributed an electronic evaluation at the completion of the course.

Results: Ninety-seven clinicians participated in the ECMO training courses. This included 49 (51%) physicians and 48 (49%) advanced practice nurses and physician’s assistants from the departments of medicine (n=29), surgery (n=42), and anesthesia (n=26). There was a significant difference between the pre-course and post-course examination score (median [IQR] 70% [60-80%] vs. 90% [80-90%] respectively, p<0.001). The median (IQR) individual gain from pre-course score to post-course score was 20% (10-30%).

Conclusions: This is the first study to demonstrate the feasibility of a rapid deployment of ECMO training for a variety of critical care providers within a hospital. Further work is necessary to determine the utility of different training methods across specialties in order to standardize ECMO training programs.

TECMO: Trauma ECMO using a Joint Activation and Management Team
William Hallinan, Smith Karen, Sunil Prasad MD, Mark Gestring; University of Rochester, Rochester, USA

Abstract
The utilization for extracorporeal life support in the setting of trauma is often inconsistent and centers have had reluctance to support trauma cases with anticoagulation in the setting of injury. This large Level 1 Trauma Center and Regional ECLS program have developed a Joint Inter Departmental approach to the recognition, activation, co-management and quality oversight of Trauma ECMO (TECMO) cases. Performance improvement processes identified potential Trauma patients that could have benefitted from earlier initiation of ECLS. Education and clinical practice guidelines were created to increase the awareness of ECLS with pre-hospital providers, emergency medicine and trauma team members. The trauma team developed joint evaluation and notification process with the ECLS surgical team. Revision of clinical management guidelines included anticoagulant (Heparin Sodium) free operating parameters and a 100% quality review of all cases were undertaken. TECMO patients were cared for in the Cardiovascular Intensive Care Unit setting with the ecmo specialist model with cardiac surgery oversight and the co-management of the trauma team.

The result of this endeavor highlights the challenges in this patient population. The indications for ECLS in the trauma include hypothermic circulatory collapse, cardiac contusion or structural injury, respiratory failure from parenchymal lung injury, right heart failure related to lung resection or pneumonectomy or inflammatory lung dysfunction. These patients often have concomitant injury patterns like traumatic brain injuries that need blood pressure control above the normal ECLS ranges. These patients also require staged surgical procedures that necessitates additional off unit travel to imaging or operative theatres.
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Transport Time Out: A novel patient hand-off process during interfacility ECMO Transports
William Hallinan, Karen Smith; University of Rochester, Rochester, USA

Abstract
Health care quality organizations like The Joint Commission have highlighted the transition of care period as a vulnerable time when the potential to do harm may occur through inadequate transfer of vital information. High quality hand offs are complex and difficult in the setting of critically ill patients. A busy academic ECLS transport team performing 66-88 circulatory assist transports annually developed an organized approach to safe patient hand-offs.

The ECLS transport time out process is a four step process that includes an activation checklist, an organized pre-brief, a transport time out and a patient family meeting. The activation checklist attempts to compile the most accurate patient information prior to team departure. The transport team pre-brief is a formal review off all information, team roles, equipment review and clinical care plan prior to departure with all team members. The transport time out occurs at the sending hospital away from the patient room with all peer care disciplines (surgery, ordering providers, anesthesia, nursing, respiratory, perfusion etc) and is conducted in a format where each specialty reports to the entire transport team as a whole unit. When possible, a separate family meeting occurs with the transport staff and available patient family to gain information, discuss patient wishes and educate family about the transport process.

This structured timeout for ECMO transport often identifies conflicting patient information and opportunities for better care delivery. The transport team will also perform a reverse huddle with the accepting staff at the regional ECMO center.

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Stop Moving! An analysis of cannula displacement
Witney Darmody Lett, Kim Estavillo, Dr. Ken Shaffer, Dr. Preston Lavinghousez; Dell Children’s Medical Center, Austin, USA

Abstract
From 2017-2019, Dell Children’s Medical Center has experienced an increasing number of ECMO cases. Increasing cannulations has resulted in a higher incidence of repeat surgical team interventions for post-initiation cannula repositioning.

The goal of this study is to reduce the frequency of cannula position revisions within the first 48 hours to less than 20% and improve outcomes by decreasing duration of ECMO in patients by optimizing cannula positioning as early as possible.

31 patients were cannulated from January, 2017- January, 2019 at Dell Children’s Medical Center. Quantitative data was collected and analyzed based on type of ECMO utilized, vessel location of cannula placement, method of verification for initial placement, the quantity of manipulations per patient, the time constant in which these manipulations occurred.

During the study period, 31 patients were placed on ECMO (11 on VV, 20 on VA). Of those 20 VA patients, 7 were cannulated via open chest with only one occurrence of cannula adjustment. 17 of the peripherally cannulated patients required cannula repositioning, 35% occurring during the first 24 hours. During initiation, echo was utilized a mere 45% when determining cannula position depth. There were 5 occurrences where cannula adjustment was strongly suggested, but not performed due to differing medical interpretations of correct position. Visual education aides have been developed as a quick reference at the bedside. A standardized tool is necessary to promote streamlined cannulation techniques. Education is needed for all cardiologists and sonographers to understand cannula placement and flow graphics via echo.

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Venoarterial extracorporeal membrane oxygenation for refractory cardiogenic shock in a hospital in China
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Abstract
Objective: Refractory cardiogenic shock (CS) is a clinical situation with unfavorable outcomes. The venoarterial extracorporeal membrane oxygenation (VA-ECMO) has been increasingly as a part of the treatment for refractory profound CS. We aim to characterize the experience with VA-ECMO support in patients with CS in our hospital.

Methods: All patients with refractory CS that underwent VA-ECMO support at our tertiary hospital between September 2015 and June 2019 were included in the study.

Results: VA-ECMO was used in 47 patients, with an average age of 52±17 years, of which seventeen (36.2%) were female. The main indication for VA-ECMO service was postcardiomyopathy shock (40.4%, N=19), followed by ischemic heart disease (23.4%, N=11) and acute fulminant myocarditis (17%, N=8). Prior to VA-ECMO implantation, cardiac arrest occurred in 8.5% (N=7) of patients, with a mean time to ROSC 5±42 of minutes. Additional devices implanted occurred in 49% (N=23), followed by IABP (30%, N=14). The most frequent awake ECMO cases were in 43% of acute fulminant myocarditis (N=7). One (2.1%) patient of VA-ECMO was converted to LVAD. Systemic anticoagulation was the major proportion (96%, N=45).

Limb ischemia occurred in 19% (N=9), of which 1 patient developed compartment syndrome. Massive cerebral infarction and left ventricular thrombus formation occurred in 2.1% of patients (N=1, respectively. Cannulation-associated haemorrhage occurred in 8.5% (N=4), and surgical haemorrhage in 8.5% (N=4). Pulmonary edema due to distension of the left ventricle occurred in 2.1% (N=1). Cannulation-associated blood infection occurred in 6% (N=3).

A total of 51 % (N=24) patients were weaned from VA-ECMO, 47% (N=22) patients discharged from the hospital with 43% (N=20) in good neurological condition. Mean ECMO support duration was 7±6.8 days.

Conclusion: CS is a clinical situation with very high mortality. The application of VA-ECMO was still challenging in CS. Comprehensive information on outcomes and complications is necessary to manage our learning curve and improve quality of care.
Intervention Revascularization Strategy for Acute Myocardial Infarction with Prolonged Cardiac Arrest Requiring Extracorporeal Membrane Oxygenation Support -- Arrest Shock in seconds, rescue in minutes, intervention decision making in quarters

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Abstract

Background: ECPR (extracorporeal cardiopulmonary resuscitation) was considered as adjuvant therapy for prolonged CPR with cardiac etiologies. The most common cause is acute myocardial infarction (AMI). Immediate revascularization of infarct-related vessels is effective in AMI patients with cardiogenic shock.

Aim: Whether complete revascularization (CR) or incomplete revascularization (IR) is associated with better outcomes for AMI patients with ECPR.

Methods and Results: Since 2006 to 2016, a total of 90 patients with AMI complicated with ECPR were included after excluding those with patent coronary angiography. Two groups, IR and CR, were categorized according to the revascularization completeness status in 3 coronary territories (32 IR and 58 CR patients). Hospital survival was marginally higher in the CR group (48.3%) than in the IR group (28.1%) (p = 0.064), and a favorable neurological outcome at hospital discharge was comparable between the CR (37.9%) and IR groups (21.9%) (p = 0.121). Propensity score- matched cohort study revealed comparable outcomes of hospital survival (29.4% and 29.4% for IR and CR) and favorable neurological outcome (23.5% and 17.6% for IR and CR). Multivariate logistic regression revealed that CR and IR were associated with comparable neurological outcome (odds ratio: 1.82, P=0.221).

Conclusion: For AMI complicated with ECPR, CR did not guarantee a better survival and neurological outcome. Whether culprit-lesion or complete revascularization is appropriate needs further study.

Evaluation of Solid Organ Involvement in Infant ECLS patients with Elevated iron Markers

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Abstract

Infants undergoing extracorporeal life support (ECLS) are at risk for elevations in serum ferritin and iron attributed to duration of ECLS and cumulative transfusion. Solid organ iron deposition related to iron overload, specifically the liver and brain, is associated with long-term clinical and neurodevelopmental implications. The role of ECLS on solid organ iron deposition is unknown.

Quantify and describe iron deposition in the brain and liver of post-ECLS infant patients using magnetic resonance imaging.

Three infants with persistently elevated serum ferritin and iron during ECLS underwent post-decannulation transverse signal decay rate R2(R2*) MR imaging to quantify iron deposition and distribution in the liver (R2-weighted Spin Echo Sequence, reporting R2 and LIC) and basal ganglia (R2-weighted Gradient Echo Sequence, reporting R2* and T2*).

All R2 (R=0.992) and R2* (R=0.962) values correlated with normal values of iron deposition per corrected age. Only one patient demonstrated an abnormal distribution of iron in the basal ganglia correlating with the identified areas of microfocal hemorrhage on primary scan. Brain iron (R2*) inversely correlated with the liver iron (R2), with correlation strengthening with chronological age.

Despite persisting elevated serum biomarkers, R2 (R2*) magnetic resonance imaging determined no evidence of abnormal iron deposition in the basal ganglia or liver. While this imaging may detect additional trace heavy metals, the strong paramagnetic effect of iron allows for reliable quantification. These findings warrant going forward with additional studies in ECLS patients to verify our preliminary observations.
Interprofessional ECMO TeleRounding: A Novel Approach to Neonatal ECMO Education
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Abstract
Background: Extracorporeal membrane oxygenation (ECMO) is a low frequency, yet high risk procedure with limited opportunities for provider education.

Objectives: To determine the strengths and barriers of teleconference ECMO rounds for provider education.

Methods: Providers could join ECMO rounds by teleconference. A HIPAA compliant teleconferencing software was utilized on an iPad with a wireless conference speaker. Participants received the rounding sheet, one-line synopsis with teleconference information via email. Participants could ask questions by chat box. Data was collected on ECMO issues discussed, number and participant role. ECMO telerounds experience follow up survey was sent.

Results: From March-April 2019, 14 ECMO patients and 98 ECMO days were teleconferenced from a Level IV NICU (Figure 1). Topics discussed are in Table 1. Providers were able to join ECMO rounds from home (13, 72%), from another hospital (8, 44%), from their office (6, 33%) and while commuting (5, 28%). Nearly all participants felt teleconferencing lowered barriers to attend ECMO rounds (17, 94%), gave the option to be engaged while virtually rounding (16, 89%) and felt their continuity of care was improved when between service and calls (14, 78%). The majority of participants rated teleconference ECMO rounds as good or very good (Figure 2). The top barriers to utilizing teleconferencing for ECMO rounds was inability to hear discussions well and inability to participate more actively in the discussion.

Conclusion: Teleconference ECMO rounds can improve participation and complement existing didactics, simulations, clinical care and inter-professional discussions to create a more complete model for ECMO education.
Variation in Peri-surgical Anti-coagulation Practices in Congenital Diaphragmatic Hernia Patients on Extracorporeal Membrane Oxygenation

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Abstract

Background: Heparin is the anti-coagulant of choice in neonatal extracorporeal membrane oxygenation (ECMO). Management of anti-coagulation for congenital diaphragmatic hernia (CDH) patients requiring surgery on ECMO is challenging, as a fine balance between post-op bleeding and ECMO circuit integrity has to be maintained.

Objective: To determine peri-surgical anti-coagulation practices in CDH patients on ECMO across Level IV neonatal intensive care units (NICUs). Management of anti-coagulation for congenital diaphragmatic hernia (CDH) patients requiring surgery on ECMO is challenging, as a fine balance between post-op bleeding and ECMO circuit integrity has to be maintained.

Methods: We conducted a survey of all participating hospitals of the Children’s Hospitals Neonatal Consortium (CHNC) which is a collaborative of 34 Children’s Hospitals with Level IV NICUs in the United States and Canada. Exploratory data analysis was conducted.

Results: There were 16 survey respondents. All centers use heparin as the primary anti-coagulant on ECMO. Aminocaproic acid is routinely used before CDH surgery on ECMO at 71% of centers. Loading dose was uniform at 100mg/kg, while maintenance dose varied from 20-35mg/kg/hour. Duration of aminocaproic acid use varied from 24-72 hours (Figure 1). Most centers (86%) adjust heparin in the peri-surgical period (Figure 2). Table 1. shows center practices for target values of anti-coagulation parameters following CDH surgery on ECMO. To minimize bleeding on ECMO following surgery, 79% centers target higher platelet count, 43% target higher fibrinogen level and 14% use paralysis.

Conclusion: Wide variation exists in peri-surgical anti-coagulation practices of CDH patients requiring ECMO. Further investigation regarding outcomes associated with specific anti-coagulation strategies including prevalence of post-op bleeding, circuit change frequency, surgical re-exploration for bleeding, duration of ECMO, hospital length of stay and mortality is needed.
Variation in Surgical Practices in Congenital Diaphragmatic Hernia Patients on Extracorporeal Membrane Oxygenation

Zeenia Billimoria1,2, Robert DiGeronimo1,2, Brian Gray3,4, Rachel Chapman1,4, Mark Weems5,6, Daniel Dirnberger9, John Daniel10,11, John Cleary12, Sarah Keene13,14, Theresa Grover15, Ruth Seabrook16,17, Tasnim Najafi16,17, Shannon Hamrick13,14, Kevin Sullivan13, Sarah Keene13,14, Theresa Grover15

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Abstract

Background: Neonates with severe congenital diaphragmatic hernia (CDH) occasionally require extracorporeal membrane oxygenation (ECMO) as a bridge to surgical repair. There is much debate on the ideal timing of repair for CDH patients needing ECMO with some data to support early repair in patients with severe markers.

Objective: To determine surgical practices in CDH patients on ECMO across Level IV neonatal intensive care units (NICUs).

Methods: We conducted a survey of all participating hospitals of the Children’s Hospitals Neonatal Consortium (CHNC) which is a collaborative of 34 Children’s Hospitals with Level IV NICUs in the United States and Canada. Exploratory data analysis was conducted.

Results: There were 16 survey respondents. Most centers (88%) repair CDH patients on ECMO. Timing of surgical repair on ECMO varied from 24 hours to 21 days (Figure 1). Centers in the “other” category based surgical repair on either pre-determined severity markers, repairing severe CDH patients within 48 hours, or duration on ECMO, repairing CDH patients unable to wean off ECMO within 14-21 days. Most centers (93%) perform surgery at bedside in the NICU. Fifty percent of centers always place a chest tube after surgical repair on ECMO. Abdominal mesh is used for closure in 64% of centers if primary abdominal closure is perceived to be tight (Figure 2).

Conclusion: Wide variation exists in timing of repair of CDH patients requiring ECMO. Further investigation of CDH severity markers and outcomes such as survival and ECMO duration is needed before practice standardization across centers can be recommended.
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