Single Center Experience of Early Graft Failure in Pediatric Heart Transplantation Managed With ECMO

Peta MA Alexander, Asha G Nair, Leslie B Smoot, Daniel Wigmore, Erica McDavitt, Heather J Bastardi, Francis Fynn-Thompson, Ravi R Thiagarajan  
Boston Children’s Hospital, Boston, MA, USA  

BACKGROUND: Primary graft failure is the leading early cause of death after heart transplantation. ECMO is established therapy for low cardiac output in pediatric patients, but the role of ECMO is less well defined after heart transplantation (HT). We sought to characterize outcomes for these children.  

METHODS: Retrospective review of HT patients in our pediatric referral hospital between 1995 and 2015. Inclusion criteria were all patients cannulated to ECMO within the first 7 days after HT. Demographics and risk factors were compared between survivors and non-survivors. Standard statistical methods were applied.  

RESULTS: There were 246 HT performed in the study period. Congenital heart disease (CHD) and cardiomyopathy (CM) patients were evenly represented (119, 48% vs 115, 47%). ECMO was instituted within 7 days of transplant for 28 patients (11%), 18 (64%) of whom survived to hospital discharge. CHD was the most common indication for HT in those managed with early ECMO (18, 64% vs 10, 36% CM). Median time to ECMO was 1 day (range 0-2 days), with 11 patients (61%) cannulated to ECMO from cardio-pulmonary bypass in the operating room. Survival to hospital discharge did not differ according to patient factors such as age, weight, gender, pre-transplant diagnosis, liver or renal function, panel reactive antibody level or pre-transplant pulmonary vascular resistance assessed at cardiac catherization. Transplant factors such as donor:recipient weight ratio and organ ischemic time were not associated with survival, nor was indication for ECMO. Patients cannulated to ECMO in the operating room were less likely to survive to hospital discharge (4 of 11, 36%, p=0.02). Four patients treated with early ECMO received another ECMO run (4/28, 14%) at median time 55 days after decannulation (range 18 to 635 days).  

CONCLUSION: ECMO can be effectively used to rescue patients with early graft dysfunction after HT. It is associated with early mortality, with only two thirds of supported patients surviving to hospital discharge. Cannulation to ECMO directly from cardio-pulmonary bypass in the operating room may represent severe early graft failure and these patients were less likely to survive to hospital discharge in our population.  

Contact:  
Dr Peta Alexander  
Department of Cardiology  
Boston Children’s Hospital  
300 Longwood Avenue  
Boston MA USA 02215  
+1 617 415 3856  
peta.alexander@cardio.chboston.org
Trends in Outcomes and Cost Savings as a Result of Implementing an ECLS Fellowship Program
AF Linden, M Rojnica, RA Rose, N Bagrodia, AM Defnet, S Collins, JJ Kandel

The University of Chicago Medicine, Comer Children’s Hospital; The University of Chicago Medicine, Department of Surgery, Chicago, IL

Objectives
The implementation of an ECLS fellowship at a major tertiary care children’s hospital that continuously manages ECLS patients at the bedside and drives toward clinical management milestones was initiated in July 2014. The effects of this new clinical management infrastructure were analyzed in order to assess the clinical and financial viability of such a program.

Methods
Retrospective clinical and cost data of ECLS patients at the University of Chicago Comer Children’s Hospital were compared pre- and post-fellowship initiation. The target clinical outcomes endpoint was duration of days on ECLS per diagnostic category. The four diagnostic categories were: neonatal respiratory failure, pediatric respiratory failure, congenital diaphragmatic hernia (CDH) and sepsis. Direct cost of each subsequent day on ECLS was calculated using charge codes per patient applied to relevant cost centers.

Results
There were 22 patients over three years that were compared to 15 patients over 2 years when examining the relationship between pre- and post-ECLS fellowship initiation. Pre-fellowship, the largest category of patients managed on ECLS were those with neonatal respiratory failure (n=14). The remainder of patients had a CDH (n=6) or sepsis (n=2). Post-fellowship, diagnostic breakout was more varied (neonatal respiratory failure, n=6; pediatric respiratory failure, n=3; CDH, n=4; sepsis, n=2). Mean days on ECLS pre-fellowship initiation were 22 as compared to 15 days post-fellowship initiation. At a mean direct cost of $1,637 per subsequent day after ECLS initiation, $11,459 in cost savings was achieved per ECLS run by the decrease in pump days after fellowship creation.

Conclusion
Implementation of an ECLS fellowship can result in fewer days on pump due to more continuous management of this cost-intensive intervention. The subsequent cost savings associated with this clinical improvement is significant and justifies the cost of the training fellowship.

Contact:
Allison F. Linden, MD, MPH
University of Chicago Medicine, Comer Children’s Hospital
5841 S. Maryland Ave, Rm A-426, MC 4062
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AF Linden, M Rojnica, RA Rose, N Bagrodia, AM Defnet, S Collins, JJ Kandel

The University of Chicago Medicine, Comer Children’s Hospital; The University of Chicago Medicine, Department of Surgery, Chicago, IL

Objectives
An ECLS fellowship, structured to provide continuous active management of ECLS patients with specific management milestones, was implemented at a major tertiary care children’s in July 2014. The effects of this new clinical management infrastructure were analyzed in order to assess the clinical outcomes and financial impact of such a program.

Methods
Retrospective clinical and cost data of ECLS patients at The University of Chicago Comer Children’s Hospital were compared pre- and post-fellowship initiation, separated by diagnostic category: neonatal respiratory failure, pediatric respiratory failure, congenital diaphragmatic hernia (CDH) and sepsis. The target clinical outcomes endpoint was duration of days on ECLS per diagnostic category. Financial impact was assessed by quantifying the direct cost of each subsequent day on ECLS. This was calculated using expenses in cost centers that provide and charge for ECLS patient care, allocated by charge code per patient.

Results
22 patients over three years (pre-ECLS fellowship) were compared to 15 patients over 2 years (post-ECLS fellowship initiation). Pre-fellowship, the largest category of patients managed on ECLS were those with neonatal respiratory failure (n=14). The remainder of patients were diagnosed with CDH (n=6) or sepsis (n=2). Post-fellowship, diagnostic breakout was more varied (neonatal respiratory failure, n=6; pediatric respiratory failure, n=3; CDH, n=4; sepsis, n=2). Mean days on ECLS pre-fellowship initiation were 22, versus 15 days post-fellowship initiation. At a mean direct cost of $1,637 per subsequent day after ECLS initiation, $11,459 in cost savings was achieved per ECLS run, based on the decrease in ECLS days after fellowship creation.

Conclusion
Implementation of an ECLS fellowship can result in fewer days requiring ECLS support. We hypothesize that these shorter support times derive from more continuous active management of neonatal and pediatric patients requiring ECLS support, allowed by the focused management delivered by a dedicated fellow. The subsequent cost savings associated with this clinical improvement is significant, and in our institution more than compensates for the cost of the training fellowship.

Contact:
Allison F. Linden, MD, MPH
University of Chicago Medicine, Comer Children’s Hospital
Characteristics and Outcomes among patients with Alveolar Hemorrhage after initiation of Extracorporeal Membrane Oxygenation for Refractory Hypoxemia

Jessica Mullins MD, Manish Mohanka MD, Vaidehi Kaza MD, Srinivas Bollineni MD, Fernando Torres MD, Amit Banga MD. Lung Transplant Program at the University of Texas Southwestern Medical Center, Dallas TX

Introduction
Extracorporeal Membrane Oxygenation (ECMO) is known to be associated with several complications. However, pulmonary effects of ECMO have not received much attention. Herein, we report a series of four patients who developed alveolar hemorrhage (AH) in the absence of systemic coagulopathy after initiation of ECMO for refractory hypoxemia due to different etiologies.

Methods
We reviewed the institutional ECMO database. All patients with advanced lung disease who needed veno-venous (VV) or veno-arterial (VA) ECMO support from January 2013 through July 2015 were reviewed (n=37). Among these, 25 patients (67.6%) were placed on ECMO as bridge to lung transplantation (LT) whereas the rest were supported as bridge to recovery. Diagnosis of AH was based upon the finding of progressively bloody return on broncho-alveolar lavage (overall incidence 4/37, 10.8%). All patients were intubated and had no evidence of AH prior to ECMO initiation. Charts were reviewed for patient demographics, clinical, laboratory and imaging variables before and after initiation of ECMO, daily P/F ratios, and development of organ dysfunction.

Results
Mean age was 60 years (range 51-69 years) and majority were white (n=2) and females (n=3). Two patients had acute exacerbation of interstitial lung disease and were bridged to LT (incidence among bridge to LT: 8%) and the other two patients had refractory hypoxemia secondary to ARDS (incidence of AH among bridge to recovery: 16.7%). Only one patient had co-morbid pulmonary hypertension with right ventricle dysfunction and was supported with veno-arterial ECMO whereas the rest were on veno-venous ECMO. None of the patients had evidence of non-pulmonary organ dysfunction. AH was noted early after ECMO initiation (between 24 to 72 hours for all patients). Presentation was with worsening oxygenation and radiological infiltrates, and bloody return on endotracheal tube suctioning. Three patients had profound hypoxemia despite maximal support on ventilator and ECMO with PF ratio <50 necessitating use of rescue therapies including inhaled nitric oxide and/or paralytics. Three patients needed transfusions after ECMO initiation. There was no evidence of systemic coagulopathy/bleeding from other sites, and given the precarious clinical status, two of the three patients with refractory hypoxemia were treated with methylprednisone 7.5 mg/kg/day for three days with improvement in infiltrates and oxygenation in one patient. Progressive organ dysfunction lead to withdrawal of care among the other two patients. One of the survivors who underwent LT, had evidence of bilateral hemorrhagic foci throughout on gross appearance of the explants and extensive organizing diffuse alveolar damage on histology.

Conclusions
Spontaneous AH can develop among patients initiated on ECMO. It seems to occur in the early period after ECMO initiation and has a typical presentation. Whereas AH may occur as a result of coagulopathy related to hematologic organ dysfunction and/or use of systemic anticoagulation, a favorable response to corticosteroid may support an inflammatory etiology possibly resulting from a large proportion of cardiac output passing through the ECMO circuit prompting leukocyte activation and cytokine release.

Contact
Amit Banga MD, FCCP
Assistant Professor of Medicine, Lung Transplant Program
Division of Pulmonary & Critical Care Medicine
UT Southwestern Medical Center
5939 Harry Hines Blvd. Suite 603
Dallas, TX 75235-8550. Phone: 214-645-5989 Fax: 214-645-6272
amit.banga@utsouthwestern.edu
ECMO: Truly a Team Approach!

Aditya Bansal M.D.¹, Vincent Adolph M.D.¹, Armin Schubert M.D.², Eugene Parrino M.D.¹ and the ECMO Team
¹ Section of Cardiothoracic Surgery. Ochsner Clinic Foundation and The University of Queensland School of Medicine.
² Department of Anesthesia. Ochsner Clinic Foundation and The University of Queensland School of Medicine.

Background:
Extracorporeal Membrane Oxygenation (ECMO) is a therapeutic option increasingly used in the management of patients with cardiorespiratory failure that is refractory to maximal conventional treatment. This support may facilitate therapeutic intervention, bridge to recovery, bridge to a long-term support device, heart or lung transplantation, or bridge to palliation.

Methods:
We reviewed single institution data (Ochsner Main Campus) for adult patients treated with ECMO (VA or VA ECMO) from 1995 to 2015.

Results:
Data was obtained from the ELSO registry

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of Patients</td>
<td>14</td>
<td>10</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Successful Wean</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Percentage Wean</td>
<td>0%</td>
<td>40%</td>
<td>33.33%</td>
<td>72.73%</td>
</tr>
</tbody>
</table>

Due to lack of any integrated approach, missing clinical practice guidelines and lack of point person poor outcomes were seen. However with multidisciplinary selection process, proper patient selection and adherence to protocols have led to improvement in survival and patient safety. Challenges included lack of infrastructure for proper training and education for ECMO providers and absence of ECMO manager. This is now being overcome by onsite didactic and hands on training sessions for the respiratory therapist, enabling them to become ECMO specialist and a recruitment of a full time ECMO along with significant involvement of the perfusion services. Clinical practice guidelines and protocols have been prepared to enable safe utilization of these resource intensive therapies.

Conclusions:
Even with low annual volume of ECMO patients, an integrated team approach under a central leadership can lead to better utilization of services and with improved patient outcomes. This is something that we owe to our patients and also in the current era of outcome and value based reimbursement this would significantly impact the future care and our ability to be competitive with the other health institutions.

Contact Info: Aditya Bansal M.D., 1514 Jefferson Highway. New Orleans. LA.
Email: adbansal@ochsner.org, Cell: 504-258-7113
Impact of hemodialysis on mortality rate in children with extracorporeal membrane oxygenation: an analysis of KID database

Himani Pulivarthi, MD¹, Fernando Beltramo, MD²; Balagangadhar R. Totapally, MD²,³

¹Medical Graduate, Mamata Medical College, India
²Division of Critical Care Medicine ³Nicklaus Children’s Hospital, Miami, FL,
³ Herbert Wertheim College of Medicine, Florida International University, Miami, FL 33199

BACKGROUND: Acute kidney injury (AKI) and fluid overload is common among children on Extra Corporeal Membrane Oxygenation (ECMO) support. Ongoing systemic inflammation, hypercoagulable state and hemoglobinuria results in AKI. High volume of distribution and need for frequent blood product transfusion during ECMO therapy causes significant fluid overload.

OBJECTIVE: The objective of this study was to evaluate the effect of the use of dialysis on mortality rate in children receiving ECMO therapy.

DESIGN/METHODS: A retrospective analysis of the Healthcare Cost and Utilization Project 2012 Kids’ Inpatient Database was performed. The database was filtered using ICD-9 procedure code for extracorporeal membrane oxygenation (ECMO) support (39.65 and 39.66), hemodialysis (39.95). Sample weighting was employed to produce national estimates. Chi-square test, student t-test and binary regression analyses were performed using SPSS to analyze the data.

RESULTS: A total of 2111 children, including neonates who received ECMO therapy during 2012 with an overall mortality rate of 40.5%. Hemodialysis was done in 161 (7.6%). The mortality was significantly higher in children receiving hemodialysis (56.5% vs 39.2%) and cardiac surgery (46.2% vs 38.2%). Hemodialysis is associated with increased mortality in neonates (51.6% vs. 38.7%; p<0.05) and children (59% vs. 39.7%; p<0.05) but not in infants (60.8% vs. 40% p>0.05) or in cardiac surgical patients (54.8% vs 45.7%; OR 1.4, CI: 0.7-3.0).

CONCLUSIONS: This study provides an estimate of overall mortality rate in pediatric patients on ECMO and those who required renal support. The mortality rate was higher in patients with concurrent ECMO and hemodialysis compared to ECMO alone, especially in the neonatal age group and children.

Contact Author:
Fernando Beltramo MD
Division of Critical Care Medicine
Nicklaus Children’s Hospital, Miami Fl 33155
305-662-2639
fernando.beltramo@mch.com
Mortality of Neonates Undergoing Cardiac Surgery Requiring ECMO: An Analysis of Kids’ Inpatient Database.
Neha Vazzalwar\(^1\); Fernando Beltramo, MD\(^2\); Balagangadhar Totapally, MD\(^2\)
\(^1\)Glenbrooknorth High School, Northbrook, IL; \(^2\)Nicklaus Children’s Hospital, Miami, FL.

**Introduction:** Outcomes of neonates requiring cardiac surgery with subsequent need for ECMO vary with underlying diagnosis and surgical procedure. The purpose of this study was to evaluate the mortality rates of neonates who underwent cardiac surgery for common major cardiac lesions requiring ECMO during 2012 using the Kids' Inpatient Database (KID).

**Methods:** A retrospective analysis of the Healthcare Cost and Utilization Project 2012 KID was performed. The database was filtered using admission age < 30 days and various procedure codes for cardiac surgery. Individual cardiac lesions (TGA, HLHS, TA, TOF, Coarctation, and TAPVR) were identified using their diagnosis codes. Patients requiring extracorporeal membrane oxygenation (ICD 9 procedure code 39.65) were identified and compared with those did not require ECMO. Sample weighting was employed to produce national estimates. Chi-square test and appropriate non-parametric tests performed by SPSS-17 were used to analyze the data.

**Results:** The mortality rates for different cardiac lesions, with and without the need for ECMO are as follows:

<table>
<thead>
<tr>
<th>Lesion</th>
<th>TGA</th>
<th>HLHS</th>
<th>TA</th>
<th>TOF</th>
<th>Coarctation</th>
<th>TAPVR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>1148</td>
<td>675</td>
<td>242</td>
<td>293</td>
<td>1525</td>
<td>332</td>
</tr>
<tr>
<td>Needing ECMO</td>
<td>8.4%</td>
<td>18.1%</td>
<td>7%</td>
<td>7.2%</td>
<td>5.2%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Mortality- overall</td>
<td>8.4%</td>
<td>18.4%</td>
<td>5.8%</td>
<td>5.5%</td>
<td>6.4%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Mortality- with ECMO</td>
<td>51.5%</td>
<td>55.7%</td>
<td>41.2%</td>
<td>38.1%</td>
<td>53.2%</td>
<td>57.1%</td>
</tr>
<tr>
<td>Mortality- without ECMO</td>
<td>4.5%</td>
<td>10.1%</td>
<td>3.1%</td>
<td>2.9%</td>
<td>3.8%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Odds Ratio for mortality with ECMO (95% CI)</td>
<td>22.7 (13.9-37.2)</td>
<td>11.2 (7.1-17.6)</td>
<td>21.8 (6.4-74.2)</td>
<td>20.3 (6.6-62.7)</td>
<td>28.7 (11.7-48.2)</td>
<td>28.4 (12.4-64.9)</td>
</tr>
</tbody>
</table>

TGA: transposition of great arteries, HLHS: hypoplastic left heart syndrome; TA: truncus arteriosus; TOF: Tetralogy of Fallot; TAPVR: total anomalous pulmonary venous return

**Conclusions:** This study provides a national estimate of the need for ECMO and mortality after neonatal repair of specific cardiac conditions. Hypoplastic Left Heart Syndrome had the highest overall mortality and the need for ECMO with corrective surgery. In each of the cardiac lesion the need for ECMO increased the mortality by a factor of 5 to 10.

**Contact Author:**
Fernando Beltramo MD
Division of Critical Care Medicine
Nicklaus Children’s Hospital, Miami Fl 33155
305-662-2639; fernando.beltramo@mch.com
A safe neonatal ECMO circuit was designed with the intent of easy access, minimal modifications to manufacturer product, the ability to quickly blood prime, and highly mobile to support intra- and inter-hospital transport as well as ambulatory ECMO. Over the course of nearly a decade, ECMO technology has seen rapid advancement. The introduction of polymethylpentene (PMP) oxygenators as well as improved characteristics of centrifugal pumps and stable cannulation strategies has led to improved circuit longevity. The release of the Maquet CardioHelp system has provided a platform to monitor the ECMO patient without external transducers or saturation/hematocrit monitors, has servoregulation capabilities for enhanced safety, and a small footprint allowing for easy mobility. However, a pediatric CardioHelp disposable is not on the market in the United States. Therefore CardioHelp utilization with disposable alteration for neonatal and pediatric use was investigated. The CardioHelp HLS 7.0 disposable was altered by removing the 3/8” arterial-venous loop and priming mechanism. The CardioHelp HLS 7.0 was gravity primed utilizing the provided priming bag. The arterial line is clamped approximately ten inches from oxygenator outlet, cut away from the priming bag, and a custom manufactured (LivaNova) ¼” loop with a one-way manifold and AV bridge is added to the CardioHelp disposable via bonded 3/8” x ¾” reducing connectors. The loop is gravity primed and a wet connection is made to the CardioHelp disposable on the venous line approximately five inches from the pump inlet. The manifold flows from post-membrane port to the luered 3/8”x1/4” connector on the venous line. Distal to that connection on the ¾” venous line is a ¼”x ¼” luered connector in which a 1/8” stopcock bridge connects to the 3/8” x ¼” reducing connector on the arterial line. The remainder of de-airing is accomplished by gravity purging the manifold and bridge ports. To ensure adequate de-airing of the membrane, per manufacturer instructions, the RPMs are set to 3000 for two minutes and 4000 for one minute with the oxygenator venting cap open and the priming bag open in all directions for volume and pressure relief.

Blood priming of the system occurs by placing a clamp between the manifold return and the venous limb of the stopcock bridge, with a waste bag attached to the venous side of the stopcock bridge. Blood is spiked by the priming line attached to manifold and displaces crystalloid into the waste bag. The approximately 450ml prime volume requires one unit of RBCs, 60ml of FFP, heparinization with 100 international units of heparin, NaHCO3 for buffering, and CaGlu. After adequate blood priming, the priming and waste bags are removed and replaced with non-vented caps, the tubing clamp removed from venous line, and circuit allowed to recirculate at 1LPM until the surgeon is prepared for initiation of extracorporeal support. The stopcock bridge remains closed and clear primed. Blood priming the circuit can be accomplished in less than thirty seconds. The neonatal/pediatric CardioHelp ECMO circuit was tested under appropriate conditions in vitro and found to be adequate for support of patients up to 20kg at a flow rate of 100ml/kg/min. Blood prime was reduced from two units of RBCs and 120ml FFP to 1 unit of RBCs and 60ml FFP, essentially a 50% reduction is red cell exposures for the initiation of ECMO from the previous institutional circuit. Circuit maintenance has decreased with the removal of external pressure transducers, however does require saline flushing of the stopcock bridge and movement of the venous bubble sensor once per shift to reduce fibrin and thrombus formation. Routine blood draws from the ECMO circuit were discontinued, as was ACT monitoring. All negative pressure access points of the circuit were eliminated with the exception of the manifold line and the AV bridge. The manifold allows for drug infusion access without placing excessive negative pressure on infusion pumps, renal replacement, plasmapheresis, and rapid volume resuscitation. Venous and arterial bubble monitoring is utilized, with the pump set to stop when arterial emboli detected. Due to the perceived increase in safety of this circuit design with the CardioHelp console, staffing requirements were reduced from 1:1 to 1:4 ECMO Specialist to patient coverage dependent on patient acuity. Full conversion of the neonatal/pediatric ECMO fleet to the CardioHelp console and this circuit design for patients less than 20kg occurred in September of 2013. To date with over 40 patients supported, no user errors have been reported with this system at our institution. In early 2016, programmatic change to the CardioHelp HLS 5.0 for neonatal/pediatric circuit reduced the prime of this system by another 30ml (420ml). Our experience demonstrates the CardioHelp device can be safely utilized to support neonatal and small pediatric ECMO patients.

Contact: Desiree Bonadonna, ECMO Manager, 2301 Erwin Rd. Durham, NC 27710; 919.323.7266; desiree.bonadonna@duke.edu
Veno-Venous ECMO Support in a Patient with Acute Respiratory Distress Syndrome from \textit{Plasmodium Falciparum} Malaria

Lindsey Kreisher, BA, RRT, Desiree Bonadonna, MPS, CCP, LP, Mani Daneshmand, MD, John Davies, MA, RRT, Neil MacIntyre, MD, Craig R Rackley, MD
Duke University Medical Center
Durham, NC

\textbf{BACKGROUND} Malaria is one of the most significant imported tropical diseases that may require ICU level care, and is responsible for more than one million deaths each year globally. \textit{Plasmodium falciparum} is the organism responsible for the majority of these deaths. The acute respiratory distress syndrome (ARDS) occurs in approximately 31\% of malaria cases in the ICU. Many of the complications from malaria can contribute to ARDS including sequestration of parasitized RBCs in the pulmonary vasculature, aspiration pneumonia, fluid overload and Gram-negative bacteremia. We present a case of a 48 year old woman who presented with septic shock and hemolytic anemia following recent travel to Ghana. She was ultimately found to have \textit{Plasmodium falciparum} malaria with a high parasite burden and developed severe ARDS, which was successfully supported with veno-venous extracorporeal life support.

\textbf{CASE REPORT} A 48 year old woman presented with fever, watery, non-bloody diarrhea, and lightheadedness 4 days after returning from Ghana. She has no significant past medical or surgical history. She is a non-smoker, and does not use drugs or alcohol. She lives in the United States, and travelled to Ghana for 14 days. On presentation she was found to be febrile, hypotensive, tachycardic and confused. Her initial chest x-ray showed mild patchy bilateral opacities, and her initial laboratory analysis was notable for severe pancytopenia and mild lactic acidosis. She was admitted for further work-up. She was treated with vancomycin and piperacillin/tazobactam along with quinidine given high suspicion for malaria. She was found to have \textit{Plasmodium falciparum} malaria, and her blood smear revealed a parasitemia burden of 11.2\%. She had a prolonged QTc on quinidine and was switched to artemether and lumefantrine. On hospital day 3, her parasite burden was 0\%, but her respiratory status continued to worsen. She developed frank respiratory failure requiring mechanical ventilation for ARDS. Ultimately, her severe hypoxemic respiratory failure continued to worsen despite the use of high frequency oscillatory ventilation and 100\% FiO$_2$. On ventilator day 14, her arterial blood gas on maximum settings was pH 7.48, pCO$_2$ 35, PaO$_2$ 50, and HCO$_3$ 27. The decision was then made to transition the patient veno-venous extracorporeal membrane oxygenation (ECMO) support and the patient was cannulated with a 27 french Avalon double lumen catheter in the right internal jugular vein. She was placed on a conventional ventilator after initiation of ECMO to provide pressure assist control ventilation with an inspiratory pressure of 18 cm H$_2$O and a positive end expiratory pressure (PEEP) of 16 cm H$_2$O with a respiratory rate of 20 and 60\% FiO$_2$. The patient had the following arterial blood gas of pH 7.38, pCO$_2$ 38, PaO$_2$ 78, and HCO$_3$ 25 on these settings, and was able to be further weaned with a plateau pressure less than 30 cm H$_2$O. The patient developed acute kidney injury and ultimately initiated on continuous renal replacement therapy. On the fourth day of ECMO support the patient received a tracheostomy. On day six of ECMO support, the patient was breathing spontaneously and able to be weaned down to pressure support ventilation with an inspiratory pressure of 10 cm H$_2$O, a PEEP of 14 cm H$_2$O, and 40\% FiO$_2$. The decision was made to turn off the sweep gas for a trial off of veno-venous ECMO support. The patient passed the sweep trial and was decannulated after 6 days of ECMO support. Three days after coming off of ECMO support the patient performed her first tracheostomy collar trial on 40\% FiO$_2$ by cool aerosol mask and was completely liberated from the ventilator 4 days later. The patient’s renal function recovered and she no longer required renal replacement therapy. She continued to work with physical and occupational therapy and was able to have her tracheostomy removed and was breathing room air on hospital day 38. On day 47 the patient was discharged home with home health physical therapy. 

\textbf{DISCUSSION} Respiratory distress is a common manifestation in severe malaria. There can be many causes of respiratory distress in these patients including anemia, acidosis, pneumonia, pulmonary edema and acute respiratory distress syndrome. Acute respiratory distress syndrome may manifest several days after the patient has been treated with antimalarial drug treatment. We present a case of severe, refractory hypoxemic respiratory failure in which the use of veno-venous ECMO allowed the patient to be ventilated using a lung protective ventilation strategy and to ultimately recover from severe ARDS.

Contact: Desiree Bonadonna, ECMO Manager, 2301 Erwin Rd. Durham, NC 27710; 919.323.7266; desiree.bonadonna@duke.edu
Title: Potential Impact of ECMO on Pediatric Cardiac Surgery Mortality: Assessment and Metrics

Susan L. Bratton, MD, MPH, University of Utah School of Medicine, Department of Pediatrics, Division of Pediatric Critical Care Medicine; Titus T. Chan, MD, MS, MPP, University of Washington School of Medicine, Department of Pediatrics, Division of Pediatric Critical Care Medicine; Cindy Barrett, MD, MPH, University of Colorado School of Medicine, Department of Pediatrics, Division of Pediatric Cardiology; Jacob Wilkes, BS, Intermountain Medical Center, Quality and Informatics; Ravi R Thiagarajan, MBBS, MPH, Department of Pediatrics, Harvard Medical School, Department of Cardiology, Boston Children’s Hospital

Background: Extracorporeal membrane oxygenation (ECMO) is commonly used in a small fraction of pediatric cardiac surgical patients. We evaluated the potential impact of ECMO on surgical mortality as well as variation in ECMO use across centers.

Methods and Results: The Pediatric Health Information System was used to identify 127,189 pediatric cardiac surgical patients from 45 hospitals, of whom 3724 (2.9%) received ECMO. Median surgical mortality rate was 3.5% while the median ECMO mortality rate was 46%. Assuming that all ECMO treated patients would otherwise expire, median surgical mortality decreased almost a third (29%) with ECMO survival.

ECMO use was highly variable but generally increased with surgical volume and increased with complexity of surgical procedures. Medium and larger surgical volume programs had significantly greater rates of cardiac ECMO use and greater ECMO survival compared to the smallest centers. ECMO metrics indexed to surgical volume enabled comparisons across programs. The median rate of ECMO use among cardiac surgical patients was 2.85% (Interquartile ranges (IQR): 1.34-3.62%); and without ECMO, median surgical mortality would increase to 5.16% (IQR: 4.28-6.56%) assuming 100% mortality without the rescue support. Among patients who died, 36.7% were supported with ECMO (median, (IQR: 19.17 - 47.73%)). The median ECMO Free Surgical Survival Rate was 94.95% (IQR: 93.42 - 95.65%).

Conclusions: ECMO use by pediatric cardiac centers varied substantially. ECMO appears to decrease cardiac surgical mortality; however, optimum use remains unclear. ECMO metrics indexed to cardiac surgery cases provide a greater understanding of ECMO utilization, efficacy and provide potential for benchmarking.

Susan L Bratton 295 Chipeta Way PO Box 581289, Salt Lake City, UT 801-587-7560, Susan.Bratton@hsc.utah.edu
Predicting Survival in Neonates with Congenital Diaphragmatic Hernia (CDH) requiring ECMO

Yigit S. Guner, Danh V. Nguyen, Lishi Zhang, Yanjun Chen, Matthew T. Harting, Peter Rycus, Matteo Di Nardo, Thomas Brogan, John Cleary, Peter Yu

Objective: There have been significant advances in ICU management of infants with CDH, however there remain no systematic tools to predict and understand mortality risk of a given patient prior to ECMO initiation or during an ECMO course. ECMO specific risk prediction tools for CDH are needed to improve and evaluate the appropriateness and quality of ongoing care.

Methods: The latest ELSO (Extracorporeal Life Support Organization) registry data (2000-2016) was used to develop pre-ECMO and on-ECMO mortality prediction scores for CDH. Prediction models were developed using multivariable logistic regression models with backward selection based on the Akaike information criterion (AIC). The cohort was randomly divided into a two-thirds set for model development and a one-third set for validation. Model predictive discrimination was assessed using the C-statistic (equivalent to the area under the Receiver Operating Characteristic curve). We used the bootstrap method to assess model overfitting and calibration using the development dataset. Observed mortalities for the pre- and on-ECMO were further examined by five clinical risk groups defined by percentiles of the risk score (lowest 5%, 5-25%, 25-75%, 75-95% and highest 5%).

Results: We identified 4,374 neonates with CDH with an overall mortality of 52%. The dataset was split into training (n=2,952) and validation (n=1,422) sets. Predictive discrimination (C-statistic) for pre-ECMO mortality model was C = 0.65 (95% CI: 0.62-0.68) on the validation data. Within the highest risk group, based on the pre-ECMO risk score, mortality was with 84% (150 neonates) and 76% (62 neonates), in the training and validation datasets, respectively. The pre-ECMO risk score included Pre-ECMO ventilator settings, pH, prior DH repair, critical congenital heart disease, perinatal infection, and demographics. For the on-ECMO model, mortality prediction improved substantially: C = 0.74 (95% CI: 0.71-0.76) with the addition of on-ECMO associated complications and comorbidities. Within the highest risk group, defined by the on-ECMO risk score, mortality was 92% (160 neonates) and 88% (59 neonates) in the testing and validation datasets, respectively. Hosmer-Lemeshow goodness-of-fit tests indicated that both pre-ECMO ($\chi^2 = 10.4, p = 0.24$) and on-ECMO ($\chi^2 = 9.3, p = 0.31$) models were adequate.

Conclusion: Prediction of outcomes based risk groups may help improve approaches for the treatment of CDH. Understanding of both the pre-ECMO and on-ECMO risk groups will aid ECMO teams to inform families of expected outcomes and allow for a patient-centered decision making process. The development and validation of risk groups can also aid in future comparison of different aspects of treatment in care of patients with CDH on ECMO.
Title: Patterns and Predictors of Resource Utilization in Neonates Receiving Extracorporeal Membrane Oxygenation in the State of California from 2006-2010

Authors: Gene Chen, BS², Ashley Song, MPH¹,², Ashwini Lakshmanan, MD, MPH¹,²,³, Philippe S. Friedlich, MD, MSEpi, MBA¹, and Rachel Chapman, MD¹

Affiliations:
¹Center for Fetal and Neonatal Medicine, USC Division of Neonatal Medicine, Children’s Hospital Los Angeles; Keck School of Medicine, University of Southern California, Los Angeles, CA, United States
²Department of Preventive Medicine, Keck School of Medicine, University of Southern California, Los Angeles, CA, United States
³Leonard D. Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles, CA, United States

Background: Extracorporeal membrane oxygenation (ECMO) is an important yet resource-intensive procedure with many indications, each with differing associated costs and outcomes. Objective: To identify factors influencing mortality, length of stay (LOS), and hospital charges (HC) amongst neonatal ECMO recipients and the disparities that exist within such factors.

Design/Methods: Data released by the California Office of Statewide Health Planning and Development (OSHPD) from the years 2006-2010 (birth cohort file) was studied. Neonates were classified as individuals ≤ 28 days old. ECMO use was identified using the ICD-9 code for ECMO, 39.65. The most common primary diagnoses were identified and were subsequently coded as individual categorical variables indicating presence of a particular diagnosis amongst all diagnosis codes. The most common primary diagnoses were persistent fetal circulation (PFC), meconium aspiration (MA), respiratory failure (RF), hypoplastic left heart syndrome (HLHS), and congenital diaphragmatic hernia (CDH). Bivariate tests were used to compare characteristics between survivors and non-survivors. Multivariate (MV) logistic regression was used to model predictors of mortality. MV regression analysis was used to model predictors of LOS and HC.

Results: 263 neonates were identified as having received ECMO from 2006-2010. Amongst those identified, the mortality rate was 35.36%. The logistic regression model for mortality found that after adjusting for LOS and the most common diagnoses, non-Hispanics had 1.5x lower odds of survival compared to Hispanics. Those with CDH had 3.07x higher odds of dying than those who didn’t, similarly, those with HLHS were at higher odds of dying (1.58x) than those who did not. Longer LOS was associated with survival. The model obtained from stepwise MV regression for LOS found that MediCal patients had significantly longer LOS (7.7 days, SE: 3.6, p=.039) compared to those on private insurance, after adjusting for other variables in the model. Blacks were found to have significantly longer LOS (15.0 days, SE: 7.2, p=.035) compared to whites. In the HC model, a one day increase in LOS was associated with a $14647 increase in HC (SE: $735, p<.001), while death was associated with a $205570 increase (SE: $68805, p=.003) in HC. Whites were found to have the highest charges out of all racial groups.

Conclusion: Neonatal ECMO recipients diagnosed with CDH and HLHS who received ECMO were less likely to survive compared to those diagnosed with MA, RF, or PFC. Longer length of stay and Hispanic ethnicity were found to be associated with better survival outcomes. Significant racial and ethnic disparities were found when comparing survival, LOS, and HC, warranting further investigation.
Preliminary Outcome of Novel Selective Hypothermic Therapy for Prolonged Extracorporeal Cardiopulmonary Resuscitation (SHOT-eCPR)- Cooling the brain much lower

Yih-Sharng Chen, Chih-Hsien Wang, Heng-Wen Chou, Nai-Hsin Chi, Shu-Chien Huang, Nai-Kuan Chou.
Cardiovascular Surgery, National Taiwan University Hospital, Taipei, Taiwan

Background.
Hypothermia is believed a neuroprotection treatment approach for cardiac arrest patients. Major obstacles in applying systemic hypothermia in cardiac arrest patients include the time required to achieve even modest cooling, the difficulty in maintaining target temperatures, and the potential hazards of systemic hypothermia on body functions.

Patients and methods.
We designed a novel protocol that a specific catheter (Twinflo®) (Fig 1) was inserted into right carotid artery after extracorporeal cardiopulmonary resuscitation (ECPR). The blood was drawn out from arch via Twinflo and cooled through the heat-exchanger setting 15°C, then reinfused into right carotid artery (Fig 2). The procedure could cool the nasal temperature to 25 ± 2°C in 15 minutes. The period was “deep” brain hypothermia was set 12 hours in the present design. In the meanwhile, the rectal temperature was maintained around 35 ± 2°C. We recruited the patients with informed consent undergoing ECPR in those undergoing massage without return of spontaneous circulation more than 10 minutes.

Results.
Five patients were recruited in the SHOT-eCPR study, age 45 ± 13 years old and ECPR duration 48 ± 6 min, 4 with out-of hospital cardiac arrest (OHCA) and 1 in-hospital cardiac arrest (IHCA). Four of them (80%) were successfully weaned off ECMO, and 3 of survivors (60%) fully recovered consciousness and discharged from hospital in a week. The ECPR without SHOT result in the same period was 45% (37/82) and favorable neurological outcome was 34% (28/82), which does not reach statistical difference.

Conclusions.
The present study demonstrated its safety and feasibility of SHOT in eCPR, and the further randomized trail could go further for the efficacy.
Contact to Yih-Sharng Chen, National Taiwan University Hospital, Taipei, Taiwan, email: yschen1234@gmail.com
Early Decompressive Laparotomy after Veno-Venous Extracorporeal Membrane Oxygenation for Abdominal Hypertension

Chetan Pasrija, MD¹, Michael Rouse, BS¹, Maxwell Raithel, BS¹, Raymond Rector, CCP², Michael A. Mazzefi, MD³, Si M. Pham, MD¹, Daniel Herr⁴, Bartley P. Griffith, MD¹, Zachary N. Kon, MD¹

¹University of Maryland School of Medicine, Division of Cardiac Surgery
²Perfusion Services, University of Maryland Medical Center
³Department of Anesthesiology, University of Maryland School of Medicine
⁴Shock Trauma Critical Care, University of Maryland School of Medicine

Introduction
Abdominal hypertension during veno-venous extracorporeal membrane oxygenation (VV-ECMO) support can lead to low flow secondary to high abdominal pressure resulting in inferior vena caval compression. While exploratory laparotomy during VV-ECMO support has been reported to be associated with exceedingly high mortality rates, we hypothesized that early laparotomy for abdominal decompression would result in increased ECMO flow, leading to improved oxygenation and improved outcomes.

Methods
All patients, at a single institution, undergoing a decompressive laparotomy for abdominal hypertension (2013-2016), while supported on VV-ECMO, were retrospectively reviewed. Abdominal hypertension was characterized as a bladder pressure >20 with abdominal distention on clinical exam and inadequate venous drainage to the ECMO circuit. The primary outcome was in-hospital mortality. Secondary outcomes were change in ECMO flow after decompressive laparotomy and duration on ECMO.

Results
11 patients were identified with a median age of 45 (IQR: 32-57) years. The etiology for ECMO cannulation was acute respiratory distress syndrome in 9 patients and intra-operative support during lung transplantation in 2 patients. The cannulation strategy was femoral venous drainage with internal jugular return in 64% (7/11) of patients, and femoral venous drainage with contralateral femoral venous return in 36% (4/11) of patients. The median bladder pressure pre-operatively was 27 (IQR: 24-29), and all patients had inadequate venous drainage leading to hypoxia. The etiology for abdominal hypertension included hypervolemia (45%), active bleeding (36%), and bowel ischemia (18%). The median time from cannulation to abdominal hypertension and expedient laparotomy was 40 (IQR: 3-122) hours. After laparotomy, median ECMO flow increased from 3.1 (IQR: 2.9-4.2) liters per minute (LPM) to 5.0 (4.7-5.7) LPM. The median ECMO duration was 14 (IQR: 9-16) days. Overall, in-hospital survival was 64%.

Conclusion
While previous reports have described prohibitive mortality rates for patients requiring a laparotomy on ECMO, this study demonstrates that an expedient decompressive laparotomy for abdominal hypertension can be done safely and effectively.

Corresponding Author: Chetan Pasrija, MD
110 S. Paca St, 7th floor. Baltimore, MD 21201
240.418.0678
cpasrija@gmail.com
A 29-week pregnant patient on veno-venous ECMO for ARDS secondary to H1N1 went into labor in the Surgical/Trauma ICU of UNC Health Care. The baby was delivered vaginally, and was extubated after 48 hours. The presentation will discuss the nursing management of the patient while in labor, immediately after childbirth, and postpartum care while remaining on ECMO. This includes the delicate balance of anticoagulation and hemorrhage control. This case marks the first known=documented successful vaginal delivery in a patient on ECMO to our knowledge.
Is stopping heparin safe in patients on Extracorporeal Membrane Oxygenation treatment?

Yoon Sang Chung, MD *, Dai Yun Cho, PhD *, Dong Suep Sohn, PhD *, Wang Soo Lee, PhD #, Hoyoun Won, MD #, Dong Hoon Lee, PhD ¶, Hyun Kang, PhD §, Joonhwa Hong, PhD *

Departments of *Thoracic and Cardiovascular Surgery, #Cardiology, ¶Emergency Medicine, and §Anesthesiology and Pain Medicine
Chung-Ang Univ. Hospital, Seoul, Korea

Abstract

Purpose: Anticoagulation during extracorporeal membrane oxygenation (ECMO) treatment is unavoidable. However, discontinuation of heparin infusion is necessary when challenges associated with the use of heparin, such as bleeding and thrombocytopenia, are encountered.

Methods: The medical records of 94 adult (age ≥ 18) patients treated with ECMO from January 2011 to March 2015 at Chung-Ang University Hospital, Seoul, Korea were reviewed.

Results: Among the 94 patients, 55 patients underwent ECMO treatment for 3 or more days. In 53% of these patients (n=29, group A), heparin was stopped for 3 or more days due to thrombocytopenic events (<50,000 cells/mm³), higher than target range (>230 sec) activated clotting time (ACT), bleeding complications or the need for other surgical procedures. In 44% of patients (n=24, group B), heparin was continuously infused during the entire ECMO process. The mean length of ECMO support after the initiation of heparin discontinuation in patients in group A was 10.2 (±14.7) days. There were no intracardiac, intravascular or intra-circuit thrombotic complications.
in group A. There was no difference in the ECMO weaning success rate (41% in group A vs. 54% in group B, 
\( p=0.35 \)).

**Conclusions:** Heparin discontinuation can be considered in select group of patients with coagulation abnormality 
and/or bleeding.

Key words: extracorporeal membrane oxygenation, heparin, oxygenator, thrombosis, hemorrhage, complications

**Contact Person**

Yoon Sang Chung, M.D.

Chung-Ang University Hospital

102, Heukseok-ro, Dongjak-gu, Seoul, Korea 156-755

+82-10-6287-5150

yoonc@hotmail.com
Improving Communication Among Extracorporeal Life Support Providers Using a Daily Goal Sheet

Katherine C. Clement, MD1; Renee Bush, RN BSN CCRN2; Pamela Choquette RN2; Sarah Hassing RN BSN CCRN2; Sarah Peters RN2; LaTony Webber, BSRT RRT-NPS2.

1Department of Pediatrics, University of North Carolina School of Medicine
2University of North Carolina Health Care, UNC Medical Center

Introduction: With as many as seven providers invested in daily care of Extracorporeal Life Support (ECLS) patients, clear and consistent communication is paramount for quality patient care. Electronic Health Records claim to improve efficiency and productivity; however, the implementation of a new computer order entry system in our institution lacked a standard place to document daily goals, titration parameters, and lab schedules, which led to confusion, dissatisfaction, and distrust among ECLS team members.

Methods: Using Lean Six Sigma methodology through an institutional Purple Belt training course, a multidisciplinary team worked to create a standardized method of communication. The end product was an ECLS daily goal sheet that provided a common place to document the daily lab schedule, titration goals, and overall daily care plan.

Results: Prior to intervention, 71.67% of survey respondents felt there was a problem with communication of daily goals to ECLS team members, and 96.67% felt that knowing daily goals was “very important”. After three months of implementation of an ECLS daily goal sheet, 96% of survey respondents felt the goal sheet was a useful tool for communication, and 82% felt it improved communication among ECLS team members.

Conclusion: Use of an ECLS daily goal sheet improves communication and satisfaction among caregivers of ECLS patients.

Contact person:

Katherine C. Clement, MD
University of North Carolina at Chapel Hill
417 MacNider, CB#7221
333 S. Columbia Street
Chapel Hill, NC 27599
Phone: 919-966-7495
Email: katherine_clement@med.unc.edu
Awake extracorporeal membrane oxygenation (ECMO) in conscious, extubated patients has been used successfully in adults, primarily as a bridge to lung or heart-lung transplantation and recovery from refractory cardiogenic shock. More recently, there have been reports of successful use of awake ECMO in the pediatric population as a bridge to lung or heart-lung transplantation, or in recovery from respiratory failure or refractory cardiogenic shock. The practice of awake ECMO in neonatal patients has been reported only as an exceptional measure in unusual cases, and traditional management of these patients still includes mechanical ventilator support and liberal use of sedatives and analgesics. Disadvantages and risks of continued intubation include ongoing ventilator induced lung injury, ventilator associated pneumonia, iatrogenic medication dependence with progressive dose escalation, neuromuscular deconditioning, delayed oral feeding skills, and impaired familial bonding. We present a series of neonatal respiratory failure patients who were extubated while on ECMO and managed without invasive ventilation.

Patient 1 was a 2973 g term infant on VA ECMO for pulmonary hypertension, meconium aspiration syndrome, and sepsis; he was electively extubated on ECMO day 6 secondary to development of pneumothorax, which persisted despite low rest ventilator settings. The air leak resolved without requiring thoracostomy tube placement. The patient was decannulated on ECMO day 9 and discharged home 6 days after decannulation.

Patient 2 was a 3200 gm, 4 week old term infant on VV ECMO secondary to RSV bronchiolitis and Haemophilus influenza pneumonia; she was extubated on ECMO day 4 to allow for decreased sedation needs and improved pulmonary toilet. This patient was decannulated on ECMO day 13 and was discharged to the referring institution 2 days later for ongoing recovery.

Patient 3 was a 2910 gm term infant with congenital diaphragmatic hernia, severe pulmonary hypoplasia and pulmonary hypertension who was placed on VV ECMO on day of life 7 and extubated on ECMO day 8 to decrease sedation needs and facilitate effective pulmonary toilet. He was successfully decannulated on ECMO day 16, but ultimately expired due to complications from his underlying diagnoses.

Patient 4 was a 2950 gm term infant treated with VA ECMO for pulmonary hypertension, meconium aspiration, and bilateral pneumothoraces that did not resolve despite multiple thoracostomy tubes. He was extubated on ECMO day 2 secondary to persistent air leak despite low rest ventilator settings. The pneumothoraces resolved, and the patient was decannulated on ECMO day 6. All patients were maintained on minimal analgesia, were awake, and were orally fed on ECMO when appropriate.

Awake neonatal ECMO, whether VV or VA, appears safe and effective and may offer significant advantages over traditional management in certain clinical scenarios. Further investigation is warranted.

Corresponding Author
Joanna Costa, MD
Division of Neonatology, Department of Pediatrics
Nemours / Alfred I. duPont Hospital for Children
1600 Rockland Road
Wilmington, DE 19803
Telephone: 302-651-4984 Email: Joanna.Costa@nemours.org
Clinical changes in practice for refractory cardiac failure patients supported with VA ECMO

Merna Cucanic, Jayne Sheldrake and Dr Vincent Pellegrino
The Alfred Hospital, Melbourne, Australia

Introduction: VA ECMO therapy for refractory cardiac failure has traditionally been utilized as a short term support. This therapy aims to successfully wean patients from extra corporeal life support (ECLS) over a period of days. Patients were commonly sedated and intubated for safety. VA ECMO is now being used to support increasingly complex cardiac failure patients, including as a bridge to longer-term support using a VAD. The technical and clinical care of these patients has needed to evolve whilst decisions of long term management are sought. This patient group often requires a longer ECMO run.

A relatively challenging and promising strategy is to initiate and provide ECMO support whilst patients remain awake. Benefits of awake ECMO have been described in recent literature and suggest ECMO therapy facilitates physical therapy, prevents deconditioning, and optimizes patient outcomes. Sonett & Bacchatta(2012). Awake ECMO therapy requires less sedation and carries less sedation related complications. Brodie (2014)

This new approach resulted in an increased challenge for the bedside nurse caring for the patient. The nurse is the primary care service provider for the awake patient by the bedside, as the unit manages the ECMO service using the single caregiver model.

We examined all patients initiated on VA ECMO with refractory cardiac failure admitted to The Alfred Hospital in the period of 2012-2016 in order to describe the changes in clinical practice that have occurred. We excluded cases of VA ECMO commenced for refractory cardiac arrest (ECMO-CPR) as very few of these patients ever meet the requirement for awake ECMO.

Results: Since 2012 one third of our patients have benefited from this change in practice. In 2012 there were 37 (49%) of our total VA ECMO patients managed awake and extubated. 49(33%) in 2013 were awake and extubated, 35 (49%) in 2014, 49 (27%) in 2015 and to date in 2016 there are 18(56%). The majority of these patients had an initial percutaneous femoral-femoral configuration with a distal perfusion cannula. Awake patients receiving prolonged support have recently been reconfigured during their ECMO run to subclavian artery return to facilitate long-term care.

Conclusion: Benefits from patient involvement during awake ECMO support for patients with refractory cardiac failure are clear compared to being sedated and intubated. Empowering patients to be actively involved in decision-making, their long term goals and end of life care is extremely important. Active physiotherapy such as the use of the recumbent bike, tilt table and early ambulation also provides daily patient goals and an opportunity to directly participate in care, improve tolerance of position restrictions and may optimise the muscle mass and maintain patient physical condition. Hodgson 2012 however challenges to meeting the needs of patients with refractory cardiac failure include loss of respiratory support from IPPV, ICU delirium, managing extended position restrictions and cannula site bleeding secondary to movement. A change in configuration from our unit’s current femoral-femoral approach for some patients whilst minimising these complications may also aid longer-term support. Assessment and decision-making for long term feasible outcomes can be then completed in a more considered timeframe.

The additional patient care needs as a result of this change in practice has fallen to the bedside nurse. This change in practice required a huge cultural shift in both bedside management for the nurse’s holistic approach to ECMO safety, whilst enabling patient empowerment, involvement and ensuring the patient are instrumental their treatment goals.

Merna Cucanic, M.cucanic@alfred.org.au, The Alfred Hospital, Melbourne, Australia
FIXED WING ECLS TRANSPORT OF > 50 PEDIATRIC PATIENTS IN WESTERN CANADA

Granoski, D., Garcia Guerra, G., Duncan, S., Lequier, L.
Stollery Children’s Hospital, Edmonton, Alberta, Canada

INTRODUCTION
Stollery Children’s Hospital in Edmonton, Alberta receives patients who require cardiac surgery, solid organ transplantation, and Extracorporeal Life Support (ECLS) from pediatric centers throughout Western Canada. An ECLS transport service was developed in 2005 to retrieve patients who were too unstable for transport without ECLS.

OBJECTIVE / METHODS
Experience and challenges of developing an ECLS transport service are described. Factors evaluated include: number of patients transported and outcome, equipment used, distance travelled, team composition, cannulation approach, length of transports, complications that occurred during transport, and protocols established as a result.

RESULTS
54 pediatric patients have been transported to Edmonton on ECLS, by the Stollery Children’s Hospital PICU ECLS transport team. Pediatric size ranged from 2–70 kg (median weight 11 kg). Method of cannulation included 42 VA, 8 VV and 4 VV-VA ECLS. 47 patients were cannulated by referral center surgeons, while 7 patients were cannulated by a surgeon from Edmonton who accompanied the transport team.

Distances patients were transported ranged from 300km (186.4 miles) to 1350km (839 Miles), with an average distance of 606 km (382 miles). All pediatric patients were transported by fixed wing aircraft. Time from initial referral call for ECLS to arrival of the transport team at the referral center ranged from 2.75 – 42.3 hours (average 6.36 hrs, median time 5 hrs).

A custom ECLS transport system was designed on a Lifeport AeroSled II® to fit on a standard Lifeport base. Initial custom modifications done to our transport sled were approved for fixed wing flight from Transport Canada with a supplemental type certificate.

Our standard ECLS transport configuration includes: the Jostra Rotaflow® centrifugal pump/console, a Gaymar® blanket heater modified for use with the Quadrox-D/iD oxygenator, a custom built oxygenator holder and centrifugal pump bracket, and a Medtronic DLP® pressure display monitor. This configuration was used to transport 50 of 54 patients.

Standard ECLS transport team composition included: an ECLS trained pediatric intensivist or fellow, a PICU transport RN and RRT (often ECLS cross-trained), a senior ECLS specialist, and sometimes a surgeon.

42 of 54 patients survived to hospital discharge (78%). Complications during transport included: console battery or mechanical failures (12), circuit disruption with air entrainment (1), hypothermia < 34°C (15), hypocarbia pCO2 < 30 (11), significant bleeding during transport (2), and sweep gas delivery disruptions (2). Initial program challenges were improved with equipment standardization, protocol development, and collaboration with referral centers.

CONCLUSIONS
Fixed wing transport of patients on ECLS can be done safely and successfully, over vast distances, with excellent survival outcomes. Important factors contributing to our ECLS transport program success include: ongoing experience, effective communication and collaboration with referral centers and EMS, development and implementation of standardized protocols and equipment, referral center surgical support for cannulation, and cross training our ECLS and transport teams.

Donald Granoski, RRT
Stollery Children’s Hospital
3A1.34 WMC, 8440-112 St. Edmonton AB, Canada T6G 2B7
don.granoski@albertahealthservices.ca
780-407-8136
Feedback Driven Education Improves ECMO Specialist Confidence and Competence


Introduction: Children’s Healthcare of Atlanta’s ECMO program began in 1991. Over the past 25 years, the type and number of patients we placed on ECMO has changed dramatically. Early years of our program saw primarily neonatal patients and averaged just over 30 cases per year. The past 10 years we have seen a majority of cardiac patients with an average caseload of 58 patients per year. Our team is comprised of a core team of 10 “primers” and RN/RRT “specialists” from each of our three critical care units. Our recertification policy for our ECMO specialists follows established ELSO guidelines and consists of an annual water drill, quarterly quizzes taken from our newsletter, and a minimum of 100 hours annually of bedside pump time.

Discussion: Historically, the annual water drill served our department well, as we only used a roller head pump system. In November 2013, we began using the Sorin Revolution Centrifugal pump system for our pediatric and cardiac patients while continuing to use the roller head system for our neonatal population. In 2014, we started using a simulation model training for the centrifugal pump in addition to the water drill for the roller head system. After the first round of simulation training, we noticed worsening performance during both simulations and water drills due to confusion between the two types of pump technology. We felt that our team would benefit from more frequent simulation and water drill training sessions. In September 2015, a survey was sent to each of our 48 ECMO specialists with a return rate of 88%. One of the questions asked them to choose a desired frequency of mandatory water drills and simulations. Of the choices given, the majority of specialists chose either quarterly or semiannual training. We also asked about the satisfaction with the job-related training that our department offered. Although the majority of the team was satisfied, (64%), a significant percentage were not (35%). A number of the comments received also expressed a desire for more hands on education. Using this feedback, we made the decision to increase the frequency of our training to every quarter; alternating between pump systems and between simulation and water drill. We also began providing increased bedside education using pole mounted mini circuits as well as bedside simulation training.

Results: Upon completion of two training sessions in six months, a follow up survey was sent to 43 ECMO specialists with a return rate of 81%. We asked the specialists to rate their level of confidence before and after their training sessions. Of the responses we received, 51% felt that they had increased confidence after completing their water drill. No one lost confidence. We also asked if they felt that they would be able to keep up with this training frequency with 91% supportive. A number of the comments also expressed appreciation for the increased training.

Conclusion: Scheduling the simulation/water drills sessions are difficult and require commitment from the core team as well as the bedside specialist. The early feedback we have received shows us that when the ECMO caregivers confidence level and skills improve, there is more of a commitment to the team and ultimately provides the best care for our patients. Maintaining competence on multiple pump systems is difficult. Evaluating current ECMO Team performance and surveying individual thoughts on requirements is an important aspect of developing an educational process for your team. Early feedback should be used to drive change. Our surveys have shown that Specialist confidence has increased with the additional training sessions. Future surveys should be used to evaluate current status as well as any changes so as to assure that the educational efforts are impactful and appropriate.

Joel Davis RRT-NPS, ECMO & Advanced Technologies Department, Children’s Healthcare of Atlanta at Egleston, 1405 Clifton Rd, NE, Atlanta, GA 30322
To Treat, or Not to Treat: Anti-thrombin III levels in Neonatal Respiratory ECMO

Salisbury, C, Davis, JC, Nix, C, Keene, S

Introduction: Heparin dosage rates for neonatal respiratory ECMO patients at our institution have increased by 43% in the past three years without a change in targeted ACTs. Knowing that neonates have lower intrinsic ATIII levels when compared to other populations, we sought to review our ATIII practices. Ideal ATIII levels for neonates on ECMO are unknown.

Methods: Neonatal ECMO patients from 2013-2016 at our institution were reviewed (n=44). These patients were supported by a ¼ inch Sorin S3 rollerhead pump with a better bladder, Maquet Pediatric Quadrox, and Medtronic arterial filter. The following lab values were evaluated: ATIII levels, ATIII dosages, Anti-Xa levels, fibrinogen levels and FFP usage. We also reviewed hematologic complications.

Results: Baseline ATIII levels on ECMO ranged from 21-59%, with an average of 38%. Of the 44 patients, 33 were given ATIII at some point during their ECMO course. Treatment practices were inconsistent. The lowest ATIII level left untreated was 24%, while the highest level treated was 74%. ATIII dosages also varied greatly, ranging from 52 to 579 units per dose. The average ATIII dose was 253. ATIII levels did not consistently affect Heparin drip rates, but did raise Anti Xa levels. Higher ATIII and Anti Xa levels did not significantly correlate with less clotting of the circuit, nor did they result in a significant increase in intracranial hemorrhage.

Discussion: It is unclear whether the routine use of ATIII is warranted in the neonatal ECMO population. The data suggests that increasing ATIII levels may increase AntiXa, but this does not result in consistently lower heparin needs. It is unclear if higher ATIII and Anti Xa levels result in less circuit/component clotting. There are no guidelines for dosage amounts outside of congenital antithrombin deficiency, and the current guidelines for dosing do not account for the ECMO circuit blood volume. In addition, ATIII is extremely costly, especially when compared with heparin. In this population, an average dose of ATIII cost $885.5.

Conclusion: Further study is needed to determine the value of treating ATIII levels in the neonatal ECMO populations. While increasing ATIII did increase Anti Xa levels, this did not correlate with longer circuit life or decreased Heparin dosages.
Feedback Driven Education Improves ECMO Specialist Confidence and Competence


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Discussion: Historically, the annual water drill served our department well, as we only used a roller head pump system. In November 2013, we began using the Sorin Revolution Centrifugal pump system for our pediatric and cardiac patients while continuing to use the roller head system for our neonatal population. In 2014, we started using a simulation model training for the centrifugal pump in addition to the water drill for the roller head system. After the first round of simulation training, we noticed worsening performance during both simulations and water drills due to confusion between the two types of pump technology. We felt that our team would benefit from more frequent simulation and water drill training sessions. In September 2015, a survey was sent to each of our 48 ECMO specialists with a return rate of 88%. One of the questions asked them to choose a desired frequency of mandatory water drills and simulations. Of the choices given, the majority of specialists chose either quarterly or semiannual training. We also asked about the satisfaction with the job-related training that our department offered. Although the majority of the team was satisfied, (64%), a significant percentage were not (35%). A number of the comments received also expressed a desire for more hands on education. Using this feedback, we made the decision to increase the frequency of our training to every quarter; alternating between pump systems and between simulation and water drill. We also began providing increased bedside education using pole mounted mini circuits as well as bedside simulation training.

Results: Upon completion of two training sessions in six months, a follow up survey was sent to 43 ECMO specialists with a return rate of 81%. We asked the specialists to rate their level of confidence before and after their training sessions. Of the responses we received, 51% felt that they had increased confidence after completing their water drill. No one lost confidence. We also asked if they felt that they would be able to keep up with this training frequency with 91% supportive. A number of the comments also expressed appreciation for the increased training.

Conclusion: Scheduling the simulation/water drills sessions are difficult and require commitment from the core team as well as the bedside specialist. The early feedback we have received shows us that when the ECMO caregivers confidence level and skills improve, there is more of a commitment to the team and ultimately provides the best care for our patients. Maintaining competence on multiple pump systems is difficult. Evaluating current ECMO Team performance and surveying individual thoughts on requirements is an important aspect of developing an educational process for your team. Early feedback should be used to drive change. Our surveys have shown that Specialist confidence has increased with the additional training sessions. Future surveys should be used to evaluate current status as well as any changes so as to assure that the educational efforts are impactful and appropriate.

Joel Davis RRT-NPS, joel.davis@choa.org, ECMO & Advanced Technologies Department, Children’s Healthcare of Atlanta at Egleston, 1405 Clifton Rd, NE, Atlanta, GA 30322
Cerebral Autoregulation During Pediatric Extracorporeal Membrane Oxygenation Therapy

a Department of Anesthesia and Critical Care Medicine, The Children's Hospital of Philadelphia, Philadelphia, PA USA 19104
b Division of Neurology, The Children's Hospital of Philadelphia, Philadelphia, PA USA 19104
c Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA USA 19104
d Department of Bioengineering, University of Pennsylvania, Philadelphia, PA USA 19104
e Department of Surgery, Hospital of the University of Pennsylvania, Philadelphia, PA USA 19104
f Department of Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA USA 30332

Background: More than 1500 children each year undergo Extracorporeal Membrane Oxygenation (ECMO) therapy for refractory cardiac and/or respiratory failure. Neurologic injury is a common and often devastating complication. The pathophysiology of neurologic injury acquired on ECMO is poorly understood but could potentially be secondary to profoundly disrupted neurovascular physiology. Cerebral autoregulation refers to the brain’s ability to maintain adequate perfusion, and consequently oxygenation, despite variations in systemic blood pressure. Impaired autoregulation can increase the brain’s vulnerability to variations in ECMO flows, thereby increasing the risks of ischemia at low flows and hyperemia/hemorrhage at high flows. Given the lack of adequate neurologic monitoring tools, ECMO flow rates are currently adjusted solely based on markers of global systemic perfusion.

Methods: We measured the cerebral blood flow (CBF) and oxygenation (ScO2) of children during the first 5 days following V-A ECMO initiation using diffuse optical and correlation spectroscopies. These tools allow rapid, quantitative and non-invasive measurements of tissue blood oxygenation, volume and blood flow and have been validated against a number of clinical techniques and animal models. We also evaluated cerebral autoregulation by measuring CBF and oxygenation during modifications of ECMO flow rates from baseline.

Results: We studied 10 children on V-A ECMO for a total of 17 measurements to date. Most common primary diagnosis was congenital diaphragmatic hernia (n = 4) and congenital heart disease (n = 4). Mean age was 21 days (median 2 days) at ECMO initiation. Overall mortality was 60%. Six patients died after compassionate ECMO withdrawal for refractory cardiac and/or respiratory failure (n=5) or for catastrophic neurologic injury (n=1). CBF of patients were measured at baseline ECMO flow (determined by clinical team) and during experimental modification of flows. CBF response to ECMO flows and systemic arterial blood pressure varied by patient and over time. We observe both regulated (constant) and passive (pressure dependent) cerebral blood flow responses to changes in mean systemic arterial blood pressure.

Conclusion: Diffuse optical spectroscopies measurements suggest the presence of altered cerebral autoregulation in some ECMO patients. Correlations with the incidence of neurologic injury and long term outcome are warranted. A better understanding of cerebral physiology on ECMO could eventually lead to the development of individualized ECMO management that could potentially limit the risk of neurologic injury.

Contact: Geneviève Du Pont-Thibodeau, The Children’s Hospital of Philadelphia, 3401 Civic Center blvd, Philadelphia, PA 19104, USA
genevievedpt@gmail.com
Sedation Practices of Neonates Receiving Extracorporeal Membrane Oxygenation

Christine D. Franciscovich, MSN, CRNP, NNP-BC, Heather M. Monk, PharmD, and Elizabeth Ely, RN, PhD
Children’s Hospital of Philadelphia

**Introduction:** Sedation practices vary considerably worldwide for Extracorporeal Membrane Oxygenation (ECMO) patients and universal guidelines do not exist for pharmacologic treatment. It is well described in the literature that sedation requirements for ECMO patients are significantly higher compared to those not on ECMO (Shekar, et al., 2012). There are limited studies that describe the type and doses of sedatives and analgesics used in neonates.

**Methods:** A two year retrospective chart review was performed of all ECMO patients in the Newborn/Infant Intensive Care Unit (N/IICU) at a quaternary pediatric institution from January 1, 2012 to January 1, 2014. Inclusion criteria included any patient on ECMO support in the N/IICU during the study period. Data collected from the patients’ medical records included demographic information such as gestational age, weight, diagnosis, type of sedation and analgesics utilized (continuous infusion, scheduled intermittent, and pro re nata [PRN]), pain scores recorded and daily dose of sedation therapies while on ECMO. All opioids were converted to intravenous morphine equivalents and all benzodiazepines were converted to intravenous midazolam equivalents. Patients were stratified into comparative groups with regards to ECMO run duration and indication (e.g. surgical versus non-surgical).

**Results:** Fifty-one neonates required ECMO support during the study period. The most commonly used continuous medication infusions (CMI) were morphine, midazolam, and hydromorphone. A ketamine infusion was utilized in 1 patient. The most commonly used PRN medications included morphine, midazolam, hydromorphone, lorazepam, diazepam, and pentobarbital. Fentanyl was prescribed less frequently for routine PRN use but was utilized for procedural pain management. There were 35 patients with an ECMO duration of 0-14 days versus 16 patients with an ECMO duration of ≥ 15 days. Twenty-six patients were cannulated for non-surgical indications versus 25 patients for surgical indications. The non-surgical patients had a mean ECMO duration of 8.4 days as compared to surgical patients with a mean ECMO duration of 15.1 days (p<0.001). The median morphine equivalent doses for non-surgical patients was 4.3 mg on day 1 of ECMO, 8.2 mg on day 7 and 11.4 mg on day 14. Surgical patients had a median morphine equivalent dose of 5.5 mg on day 1, 8.6 mg on day 7 and 12.8 mg by day 14. Similar patterns were seen with benzodiazepine equivalents for non-surgical and surgical patient groups with rising median doses over time and higher median doses in the surgical patients. Graphic analysis of medication administered by patient over time will also be provided. Pain scores did not correlate to medication administration.

**Conclusions:** Administration of sedation and analgesic medications to infants on ECMO included escalating doses over time. Pain scores did not accurately reflect the clinical need for sedation administration. Universal guidelines for pharmacologic interventions and a tool to assess analgesic and sedation needs for neonates on ECMO is critical. Work to develop such a pain and sedation algorithm for neonates on ECMO is underway.


Christine Franciscovich, MSN, CRNP, NNP-BC, 3401 Civic Center Boulevard, Philadelphia, PA 19104, 215-990-8170, franciscovichc@email.chop.edu
Fibrin formation, Hemolysis and Blood Product Usage on the CardioHelp ECMO circuit
Conall Francoeur, Christos Calaritis, Fiona Muttalib, and Samara Zavalkoff
Montreal Children’s Hospital, Division of Pediatric Critical Care

BACKGROUND: During extracorporeal membrane oxygenation (ECMO) support, there is ongoing need for platelet transfusion due to the adherence and aggregation of platelets to the artificial surface. There is also regular need for red blood cell transfusion related to patient factors, systemic anticoagulation and/or destruction of red cells through the circuit. This hemolysis may vary depending on circuit components and materials.

The recently released CardioHelp (Maquet) device combines ECMO components into a compact, portable machine. This technology differs in several ways from our previous technology, a Quadrox D oxygenator, Rotaflow centrifugal pump and modified bypass circuit with Carmeda coating. This circuit is designed specifically for ECMO, is coated completely in Bioline (vs. combination of Carmeda and Bioline), has fewer connectors, a modified oxygenator inlet and far fewer tubing size transition zones.

In 2016, the Montreal Children’s Hospital transitioned to the CardioHelp. Based on our early experience, we hypothesize that the CardioHelp system has led to reduced hemolysis, fibrin formation and consequently less red blood cell and platelet transfusions compared to our previous ECMO technology.

METHODS: We reviewed our institution’s early experience with Cardiohelp through a retrospective chart review. We evaluated hemolysis (measured by plasma free hemoglobin), fibrin formation (visual), platelet and packed red blood cell (PRBC) transfusion volumes. We compared this data in characteristic-matched cases that were treated with our previous ECMO system (non-CardioHelp). We attempted to match for age, indication (respiratory vs post-cardiotomy) and type of ECMO (veno-venous (VV) vs. veno-arterial (VA)) support. We collected data on potential confounders that impact thrombotic or bleeding potential, such as preexisting hematological disease, surgical intervention on ECMO and infection.

RESULTS: We reviewed six cases: three Cardiohelp and three supported with our prior technology. Each group consisted of 2 VV and 1 VA case. Our ECMO protocols, management and team remained stable throughout the study period. Transfusion thresholds, for all cases, were a hematocrit of 40% and platelets of 100,000. Cumulative pRBC volume transfused at 72h of ECMO was more than double in the non-CardioHelp group as compared to the CardioHelp group (25.08 vs. 65.18 ml/kg). The average platelet volume per kg per day needed in the first 72h of ECMO was significantly lower in the CardioHelp vs non-Cardiohelp group (2.22 vs 18.43, p = 0.0003). The mean plasma free hemoglobin levels at 72h were also significantly lower in the CardioHelp vs non-CardioHelp group (0.412 vs. 0.955, p = 0.0501). At 72h of ECMO, none (3/3) of the CardioHelp patients had fibrin visualized in their circuits whereas 2 of 3 patients with the old technology did. At 96h of ECMO, neither of the 2 CardioHelp patients still on ECMO had fibrin while the comparative 3 non-Cardiohelp patients all had fibrin.

CONCLUSION: Our early experience with CardioHelp demonstrates a significant reduction in hemolysis, fibrin formation and PRBC and platelet transfusions as compared to our previous ECMO system.
Optimizing contrast enhanced thoracoabdominal CT in patients during extracorporeal membrane oxygenation (ECMO)

M Lidegran ¹, L Gordon Murkes¹, J. Andersson Lindholm³, B Frenckner²,³

¹ Department of pediatric radiology, Astrid Lindgren Children’s Hospital, Karolinska University Hospital, Stockholm, Sweden.
² Department of pediatric surgery, Astrid Lindgren Children's Hospital, Karolinska University Hospital, Stockholm, Sweden.
³ ECMO centre, Karolinska University Hospital, Stockholm, Sweden.

Purpose: To prospectively evaluate the quality and value of contrast enhanced (CE) chest- and abdominal CT in patients during ECMO, using a protocol for contrast medium administration adapted to the type of ECMO circuit, cannulation sites and clinical question.

Methods & Materials: All CE thoraco-abdominal CT examinations performed in patients on ECMO during a 2 years study time were included. An updated protocol for i.v. contrast delivery was applied taking into account the type of ECMO circulation [veno-venous (VV) or veno-arterial (VA)], ECMO cannulation sites, preferred CT phase and the anatomy of interest. For each examination a study protocol was completed. The ECMO intensivist recorded clinical information and ECMO technique, the radiologist at the CT department added information on CT technique and contrast administration. The following day a senior radiologist graded the quality of the scan and evaluated any added information from CT and impact on the treatment, in consensus with the ECMO intensivist.

Results: During the study time 102 CE thoraco-abdominal CT examinations were performed in 68 different patients, while on ECMO. Mean age was 29 years (2 days-70 years). Sixty-six scans were performed during VA and 36 during VV ECMO. Thirty-six of the examinations included CTA of systemic arteries or pulmonary circulation. In a majority of examinations (n=75) CT contrast was delivered to the membrane oxygenator with preserved ECMO flow. A peripheral or central venous access was utilized 25 examinations, with reduced ECMO flow during contrast injection. In two patients contrast was injected to the perfusion catheter to the femoral artery for CTA of the leg arteries. Bolus tracking (BT) was used in all patients for timing of contrast material. In case of contrast delivery to the oxygenator, an estimated transit time through the ECMO circuit was used as guidance for start of BT, to reduce radiation dose. Mean scan quality was graded 4.4 on a five grade scale. One examination, an abdominal CTA during VA ECMO with femoral artery cannulation, was initially non-diagnostic after contrast injection via a central venous line and had to be rescanned with injection to the oxygenator. In 99 of the 102 examinations CT added new information and in 65 the CT findings affected the treatment.

Conclusions: High quality CE CT scans can reliably be performed in patients on ECMO by adapting contrast medium delivery to the type of ECMO circulation, cannulation sites and anatomy of interest. The CT examinations frequently add important information affecting the treatment.

Marika Gullberg Lidegran, MD PhD
Department of pediatric radiology, Astrid Lindgren Children’s Hospital, Karolinska University Hospital, SE 171 76 Stockholm, Sweden
marika.gullberg-lidegran@karolinska.se
Prone Positioning Transport to an Extracorporeal Membrane Oxygenation Facility: Safe and Effective

Daniel Gutteridge MD, Dennis Disney RRT, Chadi Hage MD, Thomas Wozniak MD, Tracie Layne RN, David Roe MD
Indiana University Health Methodist: Thoracic Transplant and ECMO

The use of extracorporeal membrane oxygenation (ECMO) has been utilized for decades but it was not until the 2009 H1N1 epidemic that it began to evolve into the mainstream as a rescue therapy in adults. While its use has expanded, due to the complexity, cost, and amount of resources required to maintain a program; it remains primarily restricted to large volume tertiary care centers. Acute respiratory distress syndrome (ARDS) patients referred for ECMO typically have failed conventional respiratory treatments and/or are undergoing ARDSnet ventilation and end rescue therapies, including prone ventilation. The critical, and often unstable, nature of patients with ARDS places them at high risk for transport to tertiary care centers. We intend to review our experience with transporting ARDS patients, via air and ground, in the prone position for ECMO therapy.

A retrospective chart review was performed of all patients transported from referring hospitals for ECMO therapy due to ARDS. We identified that 7 adult patients required transport to our facility in the prone position to maintain minimally safe oxygen saturations. Prior to transfer all patients had failed supination due to worsening of respiratory status. Patient demographics are noted in table 1. Rotary aircraft transported two patients, up to 130 miles, and 5 patients by ground transport, up to 27 miles. Patients remained on similar vent setting to the outside hospitals. During transport 4 patients required paralysis. No complications or adverse affects were reported. There were no endotracheal tube dislodgements, central or peripheral line removals, worsening of respiratory status resulting in cardiac arrest, pneumothorax, or deaths. All patients were safely transitioned to venous-venous ECMO therapy on arrival at Indiana University Health Methodist Hospital and 5 of 7 survived to discharge.

Mobile ECMO programs cover an expanding geographic area but are still lacking across most of the country. Our retrospective analysis demonstrates it is safe to transport critically ill patients in ARDS, in the prone position, to ECMO centers for more advanced care. In patients that ECMO would be a consideration; prone positioning should not be a contraindication for transport and evaluation to a tertiary care center.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>ARDS causative event</th>
<th>Vent days prior to transfer</th>
<th>ARDSnet Ventilation</th>
<th>8/F at Outside Hospital</th>
<th>Transport Distance (Miles)</th>
<th>Transport Type</th>
<th>Outcome</th>
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<td>Methylprednisolone</td>
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<td>Yes</td>
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<td>Streptococcus</td>
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<td>Ground</td>
<td>Discharged</td>
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<tr>
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<td>MISTA</td>
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<td>Yes</td>
<td>68</td>
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<tr>
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<td>PIP</td>
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<td>Yes</td>
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<td>Ground</td>
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<tr>
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<td>Viral Pneumonia</td>
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<td>51</td>
<td>4</td>
<td>Ground</td>
<td>Discharged</td>
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Table 1: Prone ECMO patient characteristics.
We present three cases of pediatric patients with thrombocytopenia associated multiple organ failure due to secondary hemophagocytic lymphohistiocytosis (HLH). All three patients had respiratory failure and acute kidney injury and were supported with venoarterial extracorporeal membrane oxygenation (VA ECMO) and continuous renal replacement therapy (CRRT). Two of the three cases were associated with documented viral infections, adenovirus and human metapneumovirus. No primary infectious source was isolated in one case. All three cases met clinical criteria for HLH. Genetic testing for HLH was pursued in three cases without identification of a mutation in an HLH gene in two cases. Genetic testing is still pending in one case. All three patients were treated with plasma exchange and IVIG, with one patient treated with dexamethasone and etoposide per the HLH-94 protocol. HLH treatment was not pursued in two patients given disseminated viral infection and disseminated multi-drug resistant pseudomonas infection, which precluded immunosuppressive therapy. No significant complications from ECMO support were experienced.

Contact:
Alice Walz, MD
alice.walz@vanderbilt.edu
Monroe Carell Jr. Children’s Hospital
Vanderbilt University Medical Center
5121 Doctors’ Office Tower
2200 Children’s Way
Nashville, TN  37232-9075
P: 615 936-1302
Right Internal Jugular Patency Post Percutaneous Cannulation with Avalon Bicaval Catheters using the “No Pressure” Technique

Caballero, Roberto, MD, MsMA; Herrera, Guillermo, MBA, RRT-NPS; Olarte, Jose, MD; Cook Children’s Medical Center, Fort Worth, Texas

Introduction: ECMO cannulation and decannulation has traditionally been implemented with the direct visualization or “cut-down” technique necessitating the tying off of the internal jugular vein. Non-incisional Seldinger technique at the bedside has been reported by Intensivists in their patients with fluoroscopy. We present our center’s experience with decannulation using the “no pressure” technique resulting in right internal jugular vein (RIJV) patency post decannulation.

Materials and Methods: Cook Children’s Medical Center is a 450-bed quaternary-care children’s hospital. Percutaneous cannulation guidelines and checklists for cannulation and decannulation were developed by a core team. Patients selected for VVDL ECMO were assessed for RIJV caliber and patency using Doppler ultrasound. Decannulation was done using the “no pressure” technique, which is skin closure at insertion site with absorbable suture. No pressure is applied during closure to venotomy site. The RIJV was assessed using Doppler ultrasound post ECMO. A retrospective record review was done of these patients from January 2008 through June 2016.

Results: Seventeen patients, who survived to hospital discharge, were cannulated percutaneously and decannulated using the “no pressure” technique for veno-venous dual lumen support. Percutaneous cannulation in itself had no complications. Of the 17 patients, 15 patients or 88% maintained a patent RIJV as documented by Doppler ultrasound. Ultrasound was done approximately 7-10 days post decannulation. A total of 25 patients were supported using VVDL cannulae during this time frame. Out of the 25 patients, 8 patients included the use of other catheters in conjunction with the Avalon and in most cases used other insertion techniques e.g. conversion to VVDL-A ECMO or VVDL-V. These patients were therefore excluded. The use of the Avalon alone was associated with 83% survival off ECMO and 67% survival to discharge. VVDL with the use any other adjunct catheter had a survival of 80% to come off ECMO and 52% survival to discharge.

Conclusions: VVDL ECMO cannulation and decannulation for pediatric patients can be accomplished at the bedside by Pediatric Intensivists. RIJV patency is largely preserved with the “no pressure” decannulation technique. Larger groups should be studied to further refine best practices and assess neurological outcomes.

Contact: Guillermo Herrera, MBA, RRT-NPS
Cook Children’s Health Care System
801 7th Ave, Fort Worth, TX 76104
325.829.6426
The Use of a Multi-Disciplinary Team to Improve and Reduce Pressure Injuries while on ECMO Support

Herrera, Guillermo, MBA, RRT-NPS; Caballero, Roberto, MD, MHA; Davis, Susan, MD; Gonzalez, Diana Cecilia, PT, DPT; Atkins, Courtney, OTR/L; Davis, Melodie, RN; Brookes, Traci, MSN, RN; Bina, Mary, RRT; Hines, Kim, RRT;
Cook Children’s Medical Center, Fort Worth, Texas USA

Introduction: Traditional movement on ECMO has been nonexistent or very minimal given the grave dangers of decannulation. With this minimal movement comes an increase in pressure injuries and a potential for longer ECMO runs. A multi-disciplinary team was created to reduce or prevent pressure injuries on ECMO.

Methods: A committee was created consisting of members from the CVICU and PICU. The committee consisted of the ECMO Medical Director, a CVICU Intensivist, a Nurse Manager, a Physical Therapist, an Occupational Therapist, the ECMO Manager, and the PICU Director. The committee conducted a nationwide survey of physical and occupational therapy while a patient is on ECMO support for pediatric patients. We compared the results with our current practice and created our goals. We also included lung transplant centers regardless of their more rigorous physical therapy demands. We reduced the use of the High Frequency Oscillator due to its very short and rigid circuit. We explored other modes of ventilation that would allow for “rest” settings but also prevent derecruitment. We created 3 tiers which would be part of ECMO daily orders and discussed the ability of the patient’s movement during rounds each day. The tiers would increase in the amount of movement going from 1-3. Tier 1 is defined as the most critical patients, who are likely sedated and/or debilitated enough that active movement/mobility is not plausible. Tier 2 patients will be defined as patients that can tolerate sedation weans in order to cognitively participate in sessions. Patients will be able to follow simple commands and/or able to maintain an awake status for the duration of treatment sessions. Tier 3 patients will be defined as patients that are doing well from a clinician’s standpoint with Tier 2 (vital signs stable, cognitive status improved, some strength to extremities) and can follow complex commands, as well as are cognitively aware enough to be able to express needs (fatigue, pain, etc.). Physical Therapy and Occupational Therapy along with Wound Care consults were made with every ECMO case increasing the awareness of the patient’s need for more mobility.

Results: Twenty six patients were supported with ECMO in 2015 through June 2016 in the CVICU and in the PICU. Fourteen patients were supported with ECMO before the implementation of our program with 7 patients having an initial pressure injury on ECMO or a pressure injury progressing to a higher staging level categorized by Physical Therapy. Twelve patients were supported after the implementation of our program with 1 patient having an initial pressure injury while on ECMO support and 0 patients progressing to a higher staging level categorized by Physical Therapy. An increase in movement of postural drainage, passive range of motion, and Q2 repositioning was also noted along with a culture change of movement on ECMO support.

Conclusion: A multi-disciplinary team is needed to improve pressure injuries while a patient is supported with ECMO. Any movement will require education and will require all disciplines of the ICU team. Large moves may require the need for simulations before attempting. A reduction of pressure injuries is possible but only with the aid of all ICU members.
EXTRACORPOREAL CIRCULATION DURING LUNG TRANSPLANTATION PROCEDURES: A META-ANALYSIS

Hoechter DJ¹, Shen YM², Günther S³, Schramm R³,⁴, von Dossow V¹

1) Dept. of Anesthesiology; 2) Institute of Medical Biometry and Epidemiology; 3) Clinic of Cardiac Surgery; 4) Transplantation Center
University Hospital, Ludwig-Maximilians-University (LMU), Munich, Germany

BACKGROUND:
Extracorporeal circulation is an inevitable tool in lung transplantation. Over the past years, an increasing number of centers changed their standard for intraoperative extracorporeal circulation from cardiopulmonary bypass (CPB) to extracorporeal membrane oxygenation (ECMO) – with differing results. This meta-analysis reviews the existing evidence.

METHODS:
An online literature research on Medline, Embase, and Pubmed has been performed. Two persons independently judged the papers found using the ACROBAT-NRSI tool of the Cochrane collaboration. Meta-analyses and meta-regressions were used to determine whether ECMO resulted in better outcomes versus CPB.

RESULTS:
Six papers were included in the analysis. All were considered to have serious bias due to heparinization co-intervention. Forest-plots showed the benefit of ECMO in blood transfusions (average mean difference: packed-red-blood-cells: -0.46 units[95% CI=-3.72, 2.80], fresh-frozen-plasma: -0.65 units[95% CI=-1.56, 0.25], platelets: -1.72 units[95% CI=-3.67, 0.23]). Duration of ventilator support with average mean difference of -2.86 days [95% CI=-11.43, 5.71] and ICU length of stay (LOS) with average mean difference of -4.79 days [95% CI=-8.17, -1.41] were shorter in ECMO patients. ECMO treatment tended to be superior regarding 3 month mortality (OR=0.46, 95% CI=0.21-1.02) and 1 year mortality (OR=0.65, 95% CI=0.37-1.13). However, only ICU LOS reached statistical significance. Meta-regression-analyses showed that heterogeneity across studies (sex, year that ECMO was implemented, underlying pathology) influenced differences.

CONCLUSION:
These data indicate a benefit of the intraoperative use of ECMO during lung transplantations regarding short-term outcome (ICU stay). The superiority of ECMO in lung transplantation patients remains to be determined in larger multi-center randomized trials.

Dominik J. Hoechter
Department of Anesthesiology, University of Munich (LMU)
Marchioninistr. 15 – 81377 Munich, GERMANY
Dominik.hoechter@med.uni-muenchen.de
+49 (0)1721765357
PREDICTING THE NECESSITY FOR EXTRACORPOREAL CIRCULATION DURING LUNG TRANSPLANTATION – A FEASIBILITY STUDY

Dominik J. Hoechter1, Ludwig C. Hinske1, Eva Schroer1, Nikolaus Kneidinger2, René Schramm3, Gerhard Preisslerr, Roland Tomasi1, Alma Sisic5, Lorenz Frey1, Vera von Dossow1, Patrick Scheiermann1

1) Department of Anesthesiology; 2) Department of Internal Medicine V, Comprehensive Pneumology Center (CPC-M), Member of the German Center for Lung Research (DZL); 3) Department of Cardiac Surgery; 4) Division of Thoracic Surgery; and the 5) Transplantation Center Munich; University Hospital Ludwig-Maximilians-University (LMU) Munich, Marchioninistr. 15, D-81377 Munich, Germany.

BACKGROUND:
During lung transplantation (LuTx), haemodynamic instability or impaired gas exchange may necessitate the use of extracorporeal circulation (ECC). Unplanned ECC occurs in 12% of the cases potentially arising from sudden right-sided heart failure well after clamping of the pulmonary artery or from unexpected impaired gas exchange during single-lung ventilation. The necessity for implementing unplanned extracorporeal circulation (ECC) during LuTx is poorly defined.

METHODS:
We retrospectively investigated a cohort of 170 consecutive patients undergoing single or sequential bilateral LuTx without a priori indication for ECC and evaluated the predictive capability of distinct preoperative and intraoperative variables by using various automated model building techniques at three clinically relevant time points (1. preoperatively, 2. after endotracheal intubation, 3. after establishing single-lung ventilation). In order to evaluate predictive capability, we calculated the area under the Receiver Operating Characteristic curve (ROC AUC).

RESULTS:
None of the single lung transplants required ECC. 64% of 103 sequential bilateral LuTx were performed without any type of ECC device - 36% were performed with ECC. The lung allocation score (LAS) was significantly higher in patients requiring ECC. Preoperative mean pulmonary arterial pressure (mPAP) was the strongest predictor for unplanned ECC, and a 3-point scoring system based on logistic regression model comprising preoperative mPAP (≥35mmHg, 1 point), LAS (≥50, 1 point), and milrinone administration after intubation (if yes, 1 point) achieved an ROC AUC of 0.85.

CONCLUSION:
In conclusion, we show that the necessity for unplanned ECC during LuTx is sufficiently predictable shortly after endotracheal intubation and, hence, propose a novel 3-point scoring system to evaluate ECC necessity prior to LuTx.

Dominik J. Hoechter
Department of Anesthesiology, University of Munich (LMU)
Marchioninistr. 15 – 81377 Munich, GERMANY
dominik.hoechter@med.uni-muenchen.de
+49 (0)1721765357
Characterization of hypertension management strategies in neonates receiving ECMO therapy

Jennifer James, MD, Neonatology, The Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania
James Connelly, RRT, ECMO Center Manager, Neonatology, The Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania
Kevin Dysart, MD, Associate Medical Director, Neonatology, The Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania
Susan B. Williams, RN, ECMO Clinical Specialist, Neonatology, The Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania
Natalie Rintoul, MD, Neonatal ECMO Center Medical Director, Neonatology, The Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania

INTRODUCTION: Recent advances and increased usage of extracorporeal membrane oxygenation (ECMO) in the neonatal population has led to an overall increase in the incidence of hypertension in neonates. Hypertension is generally uncommon in this population, with an estimated incidence of 0.2 percent; however, high-risk neonates (very low birth weight infants, patients with renal failure, and patients requiring ECMO support) admitted to the Neonatal Intensive Care Unit (NICU) have a markedly higher incidence of hypertension, estimated at 0.8-1.7 percent.

Although the awareness of hypertension in the neonatal population has increased, there is limited literature available on the safety, efficacy, and pharmacokinetics of anti-hypertensive agents specifically within this population. Due to the lack of available literature, the selection of anti-hypertensive agents and dosing recommendations for management of hypertension in neonates is based on provider preference. Furthermore, the pharmacokinetics of cardiovascular agents in patients requiring ECMO support is limited.

At The Children’s Hospital of Philadelphia (CHOP), current internal practice is to utilize hydralazine for management of hypertension in neonates requiring ECMO support in the NICU; however, there is no standard dosing regimen or blood pressure goal. The primary objective of this study is to characterize current hypertension management practices in this population.

OBJECTIVES: To characterize existing, institution-specific practices for the management of hypertension, in neonates requiring ECMO support in the NICU. Secondary analyses were designed to identify the time to effect and dose-response of hydralazine, as well as adverse events associated with hydralazine usage. With this information, the multidisciplinary study group plans to develop and implement a standardized protocol for the management of hypertension in neonates requiring anti-hypertensive therapy while on ECMO.

METHODS: A single-center, observational study was conducted at CHOP through a retrospective chart review of all patients admitted to the NICU, who were cannulated on ECMO between January 01, 2013 and December 31, 2015. Eligible patients were further assessed using descriptive and inferential statistics to quantify existing anti-hypertension management practices, as well as assess the safety of current practice.

RESULTS/ CONCLUSIONS: Results and analysis in progress.

Corresponding author:
Marissa L. Hoffman, PharmD
3401 Civic Center Blvd
Philadelphia, PA 19104

(267) 250-8517
hoffmanm2@email.chop.edu
Application of Kaizen to the Initiation of Extracorporeal Membrane Oxygenation: An approach to problem identification and process improvement
Sarah E. Holgren, Jeff Vande Berg, Joseph W. Turek
University of Iowa Hospitals and Clinics

Background: Initiation of ECMO is a crucial event, which is susceptible to complications and is frequently performed under urgent circumstances due to the instability of the presenting illness. In our experience, variable initiation environments promote procedural inconsistencies, leading to error and patient safety concerns. The philosophy of lean management has been widely applied across industry to promote efficiency through identification and reduction of wasteful activities via intensive mapping of the process during kaizen events. At our institution, initiation of ECMO was identified as lengthy, inconsistent and susceptible to many logistic and clinical role errors. Here we describe the utilization of kaizen to facilitate analysis of a single institution’s experience with ECMO initiation, as well as report problematic areas and improvements in our procedure as generated by the kaizen event.

Methods: ECMO initiations were silently observed by a third party in order to objectively identify potential problems. Particular attention was given to the amount of staff and supply resources utilized, procedural steps, and hospital departments required. After this period of observation, a four day kaizen event was subsequently held for staff members who were identified as integral to the ECMO initiation process. The kaizen event consisted of four tasks: extensive mapping of individual roles, identification of problematic areas, generation of solutions, and proposed implementation schedules. A retrospective chart review of 77 patients requiring ECMO support in the three years prior to the kaizen event were analyzed for time required for initiation. The initiation time was calculated from the first mobilization of ECMO resources to when the patient was supported on full flow.

Results: The average initiation time was 143 minutes (SD= 93), with a maximum initiation time of 444 minutes and a minimum initiation time of 18 minutes. The main problem areas identified from the kaizen event included: miscommunication among team members, disorganized transportation of equipment, disjointed preparation for initiation and confusion with role identification.

Discussion: An intricate, high stakes process with a comparatively low incidence, such as ECMO, can be difficult to assess, yet requires high precision and accuracy. These procedures serve to benefit from organized deconstruction and analysis. Current trends in the global discussion of healthcare have advocated for a standardized approach to improvements in patient care, with popular emphasis on the success of checklists for procedural accountability. The philosophy of lean management and kaizen promotes a similar approach to establishing structured methods for process improvement, with the potential to improve complex medical procedures. We are the first to report the application of kaizen principles to ECMO initiation. Overall, the kaizen event was a beneficial tool to promote organized problem itemization with less blame, while also allowing for identification of areas that were not initially recognized as problematic.

References

Contact: Sarah Holgren, 200 Hawkins Drive Iowa City, IA 52242, 319-356-4518, sarah-holgren@uiowa.edu
To Treat, or Not to Treat: Anti-thrombin III levels in Neonatal Respiratory ECMO

Salisbury, C, Davis, JC, Nix, C, Keene, S

Introduction: Heparin dosage rates for neonatal respiratory ECMO patients at our institution have increased by 43% in the past three years without a change in targeted ACTs. Knowing that neonates have lower intrinsic ATIII levels when compared to other populations, we sought to review our ATIII practices. Ideal ATIII levels for neonates on ECMO are unknown.

Methods: Neonatal ECMO patients from 2013-2016 at our institution were reviewed (n=44). These patients were supported by a ¼ inch Sorin S3 rollerhead pump with a better bladder, Maquet Pediatric Quadrox, and Medtronic arterial filter. The following lab values were evaluated: ATIII levels, ATIII dosages, Anti-Xa levels, fibrinogen levels and FFP usage. We also reviewed hematologic complications.

Results: Baseline ATIII levels on ECMO ranged from 21-59%, with an average of 38%. Of the 44 patients, 33 were given ATIII at some point during their ECMO course. Treatment practices were inconsistent. The lowest ATIII level left untreated was 24%, while the highest level treated was 74%. ATIII dosages also varied greatly, ranging from 52 to 579 units per dose. The average ATIII dose was 253. ATIII levels did not consistently affect Heparin drip rates, but did raise Anti Xa levels. Higher ATIII and Anti Xa levels did not significantly correlate with less clotting of the circuit, nor did they result in a significant increase in intracranial hemorrhage.

Discussion: It is unclear whether the routine use of ATIII is warranted in the neonatal ECMO population. The data suggests that increasing ATIII levels may increase AntiXa, but this does not result in consistently lower heparin needs. It is unclear if higher ATIII and Anti Xa levels result in less circuit/component clotting. There are no guidelines for dosage amounts outside of congenital antithrombin deficiency, and the current guidelines for dosing do not account for the ECMO circuit blood volume. In addition, ATIII is extremely costly, especially when compared with heparin. In this population, an average dose of ATIII cost $885.5.

Conclusion: Further study is needed to determine the value of treating ATIII levels in the neonatal ECMO populations. While increasing ATIII did increase Anti Xa levels, this did not correlate with longer circuit life or decreased Heparin dosages.
Safety of Neonatal and Pediatric dialysis during Extra Corporeal Membrane Oxygenation (ECMO) treatment.

Jonas A. Lindholm¹, Johanna Cederbom², Kristina Albo¹, Leif Mitander¹
¹ ECMO center Karolinska University Hospital Stockholm Sweden, ² Paediatric Dep. Linkoping University Hospital Sweden

Background
The Extra Corporeal Membrane Oxygenation (ECMO) intensive care unit at Karolinska University Hospital in Stockholm treats a total of 80 patients per year, Neonates, Pediatrics and Adults. When supporting Neonate patients with ECMO the circulating blood volume is sometimes doubled due to the volume in the ECMO circuit. The ECMO circuit is therefore often primed with blood instead of crystalloids. Connecting a dialysis machine would further dilute the blood and is therefore also often primed with blood in our unit. Heparin is used as anti clotting agent for the ECMO circuit. The dialysis machine is connected into the ECMO circuit leading to excellent access and non existing problems with dialysis catheters allowing dialysis 24 hours per day without interruptions. Still there are risks involved. When using centrifugal pumps pressures in the ECMO circuit are close to zero mmHg and negative pressure can occur with risk of suctioning air into the ECMO circuit. It is therefore important to educate and train the staff in how to handle the connections.

In four years 2010-2011 and 2013-2014 CRRT, Continuous Reno Replacement Therapy, was used in 82 Neonate or Pediatric patients for Acute Kidney Injury (AKI) or fluid balance control. Filters used were Gambro HF20 for patients <12kg, Gambro ST60 >12kg and Gambro ST150 >32kg. Dialysis fluids used were Hemosol® in all 55 Neonate patients and 18 of 27 Pediatric patients. Phoxilium® were used in 9 of 27 Pediatric patients. When transporting a patient to the Operating Room or the Radiology department the dialysis circuit is disconnected from the ECMO circuit and the dialysis is looped running only the blood pump. Filters survival time registered were all due to clotting.

Results
Patients with a registered period of CRRT were identified in the unit’s data base. The patient’s charts were investigated and reasons for start of CRRT were noted. Days of CRRT treatment, filter survival, dialysis settings, weight, weight loss and lab values were transferred to an excel sheet. About 50% of CRRT was started due to AKI and the remaining due to fluid control demands. All filters stopped functioning because of clotting. In some cases CRRT was not restarted. Mortality and survival to discharge from ECMO ICU was also registered. There have been no incidents with suctioning of air into the ECMO circuit or blood loss due to the use of CRRT in our unit.

6 Pediatric patients with weight 57 – 110 kg were considered adult size and were excluded. The mortality in that group excluding ECPR was 0.20. Results of remaining 76 patients in table 1,2,3.

<table>
<thead>
<tr>
<th>n=76</th>
<th>Indication AKI (excl ECPR)</th>
<th>Fluid removal / Fluid control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neo (1.9 – 6.0 kg)</td>
<td>47%</td>
<td>53%</td>
</tr>
<tr>
<td>Ped (6.6 – 32 kg)</td>
<td>43%</td>
<td>57%</td>
</tr>
</tbody>
</table>
Dialysis, CRRT settings, fluid withdrawal, lab values. Mean, min and max values, table 2.

<table>
<thead>
<tr>
<th></th>
<th>CRRT days</th>
<th>Filter time hrs</th>
<th>Dilution post ml/h</th>
<th>Dialysate ml/h</th>
<th>Dose ml/kg/h</th>
<th>Fluid withdrawal ml/h</th>
<th>Weight loss %</th>
<th>Creatinine µmol/L</th>
<th>Urea mmol/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neo</td>
<td>3.92kg (1.9 - 6.0kg)</td>
<td>9 (1-54)</td>
<td>44 (12-120)</td>
<td>81 (20-200)</td>
<td>58 (0-150)</td>
<td>43 (14-115)</td>
<td>26 (5-50)</td>
<td>13 (-79! - 41)</td>
<td>76 (13-189)</td>
</tr>
<tr>
<td>Ped</td>
<td>16.43kg (6.6 - 32kg)</td>
<td>6 (1-27)</td>
<td>47 (16-96)</td>
<td>257 (40-600)</td>
<td>276 (50-750)</td>
<td>37 (8-89)</td>
<td>100 (9-400)</td>
<td>4 (-29! - 17)</td>
<td>51 (17-168)</td>
</tr>
</tbody>
</table>

Mortality during CRRT and ECMO, surviving to discharge from ECMO ICU.
Results inclusive respectively exclusive ECPR patients, table 3.

<table>
<thead>
<tr>
<th></th>
<th>Mortality total</th>
<th>ECPR n</th>
<th>Mortality excl ECPR</th>
<th>Mortality ECPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neo (1.9 – 6.0 kg)</td>
<td>0,16</td>
<td>1</td>
<td>0,17</td>
<td>0</td>
</tr>
<tr>
<td>Ped (6.6 – 32 kg)</td>
<td>0,38</td>
<td>7</td>
<td>0,29</td>
<td>0,57</td>
</tr>
</tbody>
</table>

Discussion
Of the Neonate and Pediatric patients treated in our unit 30% of the patients were scored as AKI (Acute Kidney Injury) using SAPS3 and treated with CRRT, and another 30% of patients are treated with CRRT for fluid control. 11% of the patients got the diagnose AKI in the Epicrisis.
There are no differences in survival between patients treated with CRRT compared to the general survival in our ECMO unit, therefore the mortality seems to decrease for the patients needing CRRT for AKI and not being negatively impaired by the use of CRRT for fluid control in our small number of ECMO patients. A complete follow up 2010 to 2016 is ongoing.

Conclusion
The majority of the ECMO patients in our unit are treated with CRRT connected to the ECMO circuit, either for AKI or fluid control. After years of using the ECMO circuit as access for the CRRT treatment in Neonate patients we conclude it is a safe method and improves outcome for patients with AKI.
Evaluation of the Clear Guide ONE system vs conventional ultrasound-guided vascular cannulation in swine
Vitali Karaliou, MD\textsuperscript{1}, Jim Lantry MD\textsuperscript{2}, Phillip Mason MD\textsuperscript{2},
George Harea\textsuperscript{3}, Brendan Beely RRT\textsuperscript{1,4}, Andriy I. Batchinsky, MD\textsuperscript{1,4,5}
\textsuperscript{1}The Geneva Foundation, Tacoma WA; \textsuperscript{2}San Antonio Military Medical Center, San Antonio TX; \textsuperscript{3}Oak Ridge Institute for Science and Education, Oak Ridge, TN; \textsuperscript{4}United States Army Institute of Surgical Research, San Antonio, TX;
\textsuperscript{5}Department of Translational Medicine, University of the Incarnate Word School of Osteopathic Medicine, San Antonio, Texas.

INTRODUCTION: Use of ultrasound (US) guidance is considered a gold standard when percutaneous vascular access is needed as it allows for optimal visualization and improved accuracy of the procedure. This study explores the potential of a new device, the Clear Guide ONE system (CLEAR GUIDE MEDICAL, Baltimore, MD), for improved percutaneous ultrasound-guided vascular access. The Clear Guide ONE system consists of Clear Guide Core, which is a touchscreen computer connected to a portable ultrasound machine (FUJIFILM SonoSite M-turbo, City and State in the USA), and Clear Guide SuperPROBE, an optical head with stereo cameras mounted onto the ultrasound probe. The system allows performance of stereo imaging with needle detection and real-time needle tracking. It also provides in-situ guidance projection and calculates the alignment deviation in real time while giving visual and audio feedback in the form of beep signals, which helps maintain correct targeting. We hypothesized that use of the ClearGuide system permits faster intravascular access as well as reduced number of attempts needed per successful cannulation.

METHOD AND MATERIALS: This is a preliminary report from an ongoing study. Eight Yorkshire swine were utilized in accordance with an IACUC approved protocol. All animals were anesthetized before, during and after procedures using inhaled Isoflurane at 2-3 Vol/% titrated to effect. Median weight of animals was 36.7 kg. The following vessels were catheterized under ultrasound guidance with and without Clear Guide (CG): right and left external jugular veins (Ø range: 0.29-0.75 mm), right and left femoral veins (Ø range: 0.34-0.59 mm), right and left femoral arteries (Ø range: 0.24-0.49 mm), and right and left carotid arteries (Ø range: 0.29-0.56 mm). Standard vascular access kits with 18G needles were used.

RESULTS: The average number of vascular access attempts per cannulation was 1.2 (SD±0.60) when CG was used and 1.8 (SD ±1.09) with ultrasound only. Median time for vascular access in US+CG group was 60 second (IQR 35-92) and median time in US only group was 82 second (IQR 40-216). This study continues and will include cases of cannulation in non-heart beating conditions.

DISCUSSION: The Clear Guide system is a navigation accessory for ultrasound machines that may potentially decrease complication rates of vascular access. Preliminary results to date show certain favorable outcomes in that Clear Guide reduced the number of attempts and overall time to cannulation and thus may be a useful adjunct during vascular access. The added benefits of Clear Guide might be especially important in complicated cases where additional visualization improvements might be beneficial such as during extracorporeal membrane oxygenation or emergency catheterization of patients in non-heart beating state during ECPR.

Contact person: Vitali Karaliou, MD, phone: 501-766-8424, VitaliKaraliou@gmail.com, VKaraliou@GenevaUSA.org
INSENSIBLE WATER LOSS FROM THE MAQUET QUADROX iD ADULT OXYGENATOR

Kelly, Robert, J; Rimkus, Mark; Ryerson, Lindsay, M; Granoski, Don; Lequier, Laurance
Stollery Children’s Hospital, Edmonton, Alberta, Canada

Introduction: Insensible water loss occurs from many sites during the provision of critical care and extracorporeal life support (ECLS). The objective of this study is to measure water loss from the Quadrox iD adult oxygenator in a blood primed circuit, at flow rates and circuit pressures that approximate the in vivo physiology of a neonate on ECLS. Previous studies focused on oxygenators primed with a clear electrolyte solution, and used sweep gas flow rates much higher than those used in neonatal ECLS.

Methods: Our standard circuit configuration is a Maquet quarter-inch Bioline heparin-coated circuit with a bridge, a Maquet Quadrox iD adult oxygenator, and a Maquet Rotaflow centrifugal pump. Following discontinuation of ECLS, an intact blood filled circuit was recirculated by connecting the arterial and venous lines with a straight connector. RPMs were set at 2000, providing a flow rate of 2.0 ± 0.3 L/min. The circuit was pressurized with a normal saline water column, elevated to keep a pre-oxygenator pressure of >100 mmHg and temperature was maintained at 37ºC. Sweep gas was delivered to the oxygenator with a FiO₂ of 0.50 and flow rates of 0.1, 0.2, and 0.5 L/min. The water column consisted of a 60 ml syringe with the plunger removed, connected to a wide bore extension set, that was connected to the venous side of the circuit at the bridge. Circuits were divided into three groups, one for each sweep gas flow rate, and each group had at least three runs. Each circuit was run for 24 hours, at which time the remaining volume in the syringe was noted, and the water loss was calculated.

Results: A total of 11 circuits were tested. This study found that the relative insensible water loss increased at lower sweep gas flow rates. At sweep gas flow rates of 0.1, 0.2, and 0.5 L/min, the average water loss through the oxygenator was 147, 85, and 76 ml/L of sweep gas/day respectively (P = 0.0012).

Conclusion: This study provides novel data demonstrating increasing net insensible fluid loss from the Maquet Quadrox iD adult oxygenator, at decreasing sweep gas flow rates, using a realistic neonatal experimental ECLS setting. This information may assist the management of fluid and electrolyte balance of critically ill neonatal patients on ECLS.

Robert Kelly RRT
Stollery Children’s Hospital
3A1.34 WMC, 8440 112 Street
Edmonton, Alberta
T6G 2B7
Ph:780.407.8136

Robert.Kelly@albertahealthservices.ca
The Relationship of Patent Ductus Arteriosus Flow Patterns with Clinical Parameters in Children on Venovenous ECMO. A Pilot Study
Adnan Bakar, MD; Denise Hayes, MD; Lindsey McPhillips, MD; Todd Sweberg, MD; Aaron Kessel, MD
Cohen Children’s Hospital of New York, Northwell Health, New Hyde Park, New York

Introduction: Extracorporeal membrane oxygenation (ECMO) is a life-saving modality that has been used for over 50,000 patients by providing support via a modified form of cardiopulmonary bypass. Over 27,000 of these patients are neonates who required ECMO support for respiratory failure associated with respiratory distress syndrome, congenital diaphragmatic hernia (CDH), persistent pulmonary hypertension of the newborn (PPHN), and meconium aspiration syndrome. Of these, approximately 6,700 have been treated with venovenous ECMO (VV ECMO). Recently, a larger proportion of neonates with respiratory failure are being supported with VV ECMO, as ligation of the carotid artery is spared and central nervous system complications are lessened.

The underlying cause of neonatal respiratory failure requiring ECMO is often pulmonary hypertension. The pathophysiology of neonatal pulmonary hypertension includes increases in pulmonary vascular resistance (PVR), leading to extra-pulmonary shunting of blood via right-to-left (R-L) flow through the patent ductus arteriosus (PDA) and patent foramen ovale. The resultant hypoxemia can be refractory to medical therapies such as oxygen, mechanical ventilation and pulmonary vasodilators. The ELSO registry reports the incidence of R-L shunt of 1.8%, and a bidirectional shunt of 1.7% of those supported with ECMO. Previous studies have found that neonates with left-to-right (L-R) flow through the PDA had improved outcomes compared to those with R-L flow, and that the direction of PDA flow could be used as an indicator of appropriate timing for the surgical repair of CDH in neonates not supported with ECMO. No previous studies have used the caliber or direction of PDA flow as a prognostic indicator for improvement or survival in neonates being managed on ECMO. We hypothesize that the direction of flow within, and size of the PDA in children supported with VV ECMO would correlate with the need for conversion to VA ECMO and to survival.

Methods: We performed a retrospective chart review of all patients supported with VV ECMO for neonatal respiratory failure from January 2011 through September 2015. Two pediatric cardiologists independently interpreted echocardiograms during the course of ECMO treatment, looking at PDA size, direction of blood flow, and estimation of PVR. Categorical variables were compared by a Chi-squared or Fisher Exact test where appropriate. We compared variables with survival and need of conversion from VV to VA ECMO for all patients, and separately for patients who were found to have supra-systemic estimations of PVR by echocardiography. All analyses were performed using JMP Pro 12.2 software.

Results: We reviewed the charts of 19 patients who were initially supported on VV ECMO for neonatal respiratory failure. Fifteen patients had echocardiograms while on ECMO and were included in further analyses. Of these 15, seven (46%) were converted to VA ECMO, and twelve (80%) survived. The first echocardiogram performed after 48 hours on ECMO was used for all analyses. The average hour on ECMO for this echocardiogram was 83 hours (range 48-167 hours). When analyzing all patients, although not significant, a small or absent PDA did trend towards increased survival (p=0.08). No other findings looking at PDA size, direction of blood flow in the PDA, or PVR were significantly associated with survival or conversion to VA ECMO. We did not find any significant findings in a subgroup of patients who continued to have supra-systemic estimations of PVR by echocardiography. All analyses were performed using JMP Pro 12.2 software.

Conclusions: Although originally designed as a descriptive pilot study, we found that a smaller caliber PDA may be associated with increased survival when looking at all patients placed on VV ECMO for pulmonary hypertension. Although not significant in our study, a restrictive PDA may be associated with an increased need for conversion from VV to VA ECMO in patients who continue to have supra-systemic PVR after 48 hours on VV ECMO. Additional study is warranted to see if these trends remain with a larger sample of patients.
The use of Pulmonary Vasodilators and ECMO in Children with Persistent Pulmonary Hypertension of the Newborn: An International Survey

Aaron Kessel, MD; Denise A. Hayes, MD; Todd Sweberg, MD
Cohen Children’s Medical Center of New York; Northwell Health; New Hyde Park, New York

Introduction: Persistent pulmonary hypertension of the newborn (PPHN) is a condition with increased pulmonary vascular resistance, decreased perfusion to the lungs, and abnormal shunting of blood in the neonatal circulation. It carries a high morbidity and mortality, and can affect up to 10% of children in the neonatal intensive care unit.

PPHN may be idiopathic, or caused by conditions such as meconium aspiration syndrome, sepsis, respiratory distress syndrome, congenital diaphragmatic hernia, and alveolar capillary dysplasia. Regardless of the cause, the initial treatment of PPHN is similar, and fairly well studied. To date, there is evidence for the successful treatment of PPHN with many agents including inhaled nitric oxide, oral and intravenous sildenafil, milrinone, iv prostanoyl, inhaled prostanoyl, bosefontan, and beraprost. Extracorporeal membrane oxygenation (ECMO), which is a modified form of cardiopulmonary bypass, can be used to provide cardiopulmonary support and has been a mainstay in the treatment of PPHN when conventional medical therapies fail.

There is very limited data describing physician practices and preferences in the usage of pulmonary vasodilators for patients with PPHN. One published study reviews pulmonary vasodilator use in the management of PPHN, however, ECMO support and pulmonary vasodilator support while on ECMO is not reviewed. The goal of this project is to further characterize and describe practices in the initial management of infants with PPHN, and continued management with pulmonary vasodilators for patients already supported on ECMO.

Methods: We performed an internet based survey of all physician program directors and program coordinators listed on the Extracorporeal Life Support Organization (ELSO) website. The survey was approved by the Northwell Health IRB, and was distributed using Research Electronic Data Capture (Redcap) software. All analyses were performed using JMP Pro 12.2 software.

Results: We received 85 responses, with the majority (82%) from North America and Europe. Program sizes were represented equally with responses from small (25%), medium (36%), and large (37%) programs. Of those surveyed, 78% of respondents indicated that their program uses ECMO for PPHN. The diagnosis of PPHN is made by echocardiography (73%), differences in the pre and post-ductal saturation (63%), oxygenation index (45%), and cardiac catheterization (4%). Once the diagnosis is made, the majority of centers (57%) did not have a standardized, written protocol for the treatment of PPHN, which had no correlation with program size (p=0.82). Despite large variability, the general order of pulmonary vasodilator therapies/support was: inhaled nitric oxide, vasopressors, milrinone, ECMO, intravenous sildenafil, oral sildenafil, epoprostenol, treprostinil, and iloprost. Once considered refractory to medical therapy, the top three criteria used to place patients on ECMO included: oxygenation index (OI) > 40 (49%), OI = 25-39 (18%), and PaO2 < 50 mmHg (22%). Only 27% of centers that use both venovenous (VV) and venoarterial (VA) ECMO had strict criteria to decide which modality should be used. Factors used when deciding ECMO modality included hemodynamic instability (38%), vasoactive requirements (27%), left ventricular (LV) dysfunction (25%), right ventricular (RV) dysfunction (23%), and lactate level (11%). Once on ECMO, there was no difference between VA and VV ECMO in the number of centers that continue pulmonary vasodilators (VV:54%, VA:45%, p=0.32), wean vasodilators while on ECMO (VV:53%, VA:52%, p=0.91), or restart vasodilators once weaned (p=0.2) or discontinued (p=0.92), prior to removal from ECMO.

Conclusions: Despite the known efficacy of many therapies for PPHN, there is little agreement in the order in which these therapies should be used, the criteria for ECMO, and the utility of continuing pulmonary vasodilators while on VV and VA ECMO. Further work should be done to investigate the implications of these findings and the benefits of standardizing therapy.

Aaron Kessel, MD
Cohen Children’s Medical Center of NY – 269-01 76th Avenue, New Hyde Park, NY 11040
Tel: (718) 470-3330 Email: akessel@northwell.edu
References:
6. Aaron Kessel, MD
Cohen Children’s Medical Center of NY – 269-01 76th Avenue, New Hyde Park, NY 11040
Tel: (718) 470-3330 Email: akessel@northwell.edu
Risk predictors of nosocomial infection in adult patients with cardiogenic shock undergoing extracorporeal membrane oxygenation

Gwan Sic Kim, Hang Bin Kim, Kwang Ro Joo, Young Chul Jeong, Gwang Il Lee, Chang Ho Kim, Do Wan Kim, Kyo Seon Lee, Yochun Jung, Sang Gi Oh, Byung Hee Ahn, In Seok Jeong

Department of Thoracic and Cardiovascular Surgery, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Republic of Korea

Background: The objective of this study was to analyze the risk factors for nosocomial infections occurring in patients with cardiogenic shock who underwent extracorporeal membrane oxygenation (ECMO) support.

Methods: From January 2011 to December 2015, a total of 259 patients underwent extracorporeal membrane oxygenation. Of these, patients aged 17 years or less and patients undergoing extracorporeal membrane oxygenation for less than 48 hours were excluded. Among them, sixty-one patients diagnosed with cardiogenic shock were evaluated. Mean age was 60.6 ± 14.3 years, 34.4% were female. Preoperative Sequential Organ Failure Assessment (SOFA) score was 8.6 ± 2.2. The mean duration of ECMO support was 6.8 ± 7.4 days. The rate of successful ECMO weaning and survival to discharge was 44.3% and 31.1%, respectively. There were 18 nosocomial infections in 14 (23.0%) patients. These included respiratory tract infection (RTI) in 9 and blood stream infection (BSI) in 9 cases. In multivariate analysis, independent predictors of infection occurring during ECMO were preoperative creatinine (HR: 2.176, 95%CI 1.065-4.447, P=0.033) and duration of ECMO support (HR: 1.400, 95%CI 1.081-1.815, P=0.011).

Conclusions: Preoperative creatinine and duration of ECMO support were risk factors of infection during ECMO. Therefore, to minimize the infection complication, close surveillance might be helpful in the patients with high preoperative creatinine. Also, further efforts might be needed to minimize duration of ECMO support if possible.

Contact person: Gwan Sic Kim, M.D.
Department of Thoracic and Cardiovascular Surgery, Chonnam National University Hospital, Chonnam National University Medical School, 42, Jebong-ro, Dong-gu, Gwangju, 501-757, Republic of Korea
Telephone: 82-62-220-6541, E-mail: lovingmylife@naver.com
Avalon Catheter Related Budd-Chiari Syndrome

Megan Terek, MD; Christopher King, MD; Osman Malik, MD; Jason Vourlekis, MD; Charles Murphy, MD; Liam Ryan, MD; Heidi Dalton, MD

A 49 year-old male collapsed while playing basketball. He received bystander-initiated CPR for 6 minutes with return of spontaneous circulation. He was transported to the emergency room of our hospital where he was found to have an anterior ST-elevation MI. Left-heart catheterization revealed a left main coronary artery lesion which was stented. An intra-aortic balloon pump (IABP) was also placed. The patient received aspirin, ticagrelor, and eptifibatide. The patient developed bloody pulmonary fluid and the eptifibatide and ticagrelor were stopped. He developed hemodynamic instability and worsening hypoxemic respiratory failure. His hemodynamics initially stabilized with inotropes, but given his worsening refractory hypoxemia despite aggressive ventilator support he was placed emergently on VV ECMO with a 19-French right femoral cannula and a 21-French left femoral cannula. On hospital day 2, the patient’s lactate climbed and repeat echocardiography revealed a newly depressed EF of 20%. He was converted to VV A-ECMO. A new right femoral arterial sheath was placed and the previously placed venous cannulas were Y-ed together. Repeat left heart catheterization found a patent left main stent, so his cardiogenic shock was attributed to stress cardiomyopathy. With VVA ECMO support, his acidosis cleared and his hemodynamic status improved although his oxygenation was still poor. His VVA ECMO was converted to VV-ECMO via a 31 mm right internal jugular Avalon catheter on hospital day 7.

On day 2 after conversion to VV ECMO, the bilirubin was noted to be uptrending predominately due to an elevated direct bilirubin. The total bilirubin rapidly increased from 2.5 to 19.4 by the time of decannulation on VV-ECMO day 7. Figure 1 shows the bilirubin trend. Right upper quadrant ultrasonography revealed no gallbladder wall thickening or pericholecystic fluid. Bedside intensivist echocardiography from the subcostal position visualized the Avalon catheter and demonstrated turbulent flow in the hepatic vein. Soon after decannulation, the bilirubin began to fall. Repeat intensivist echocardiography demonstrated a curvilinear thrombus in the intrahepatic inferior vena cava, which was confirmed with a formal radiology study. Interventional radiology placed a temporary suprarenal IVC filter above this thrombus and the patient was continued on anticoagulation. Despite a declining bilirubin, a cholecystostomy tube was placed given fevers and concern for possible acalculous cholecystitis 9 days after decannulation. Cultures of the biliary fluid were negative.

To our knowledge, this is the second reported case of functional Budd-Chiari occurring as a consequence of a bicaval dual lumen ECMO catheter. This should be considered in patients on VV-ECMO support with bicaval cannulas and hyperbilirubinemia. Positioning of the tip of bicaval dual lumen ECMO catheters can be rapidly and easily assessed with bedside intensivist-performed ultrasonography.
ECMO as a bridge to pre-and post-lung transplant support

Christopher King, MD; A Whitney Brown, MD; Oksana Shlobin, MD; Shalika Katugaha, MD; Charles Murphy, MD; Heidi Dalton, MD

A 24-year-old female with cystic fibrosis complicated by severe lung disease with a baseline FEV₁ of 30% predicted was admitted for treatment of an exacerbation. She had persistent airway infection with MRSA and MDR-Pseudomonas aeruginosa. She had an escalating pattern of pulmonary exacerbations and weight loss over the prior 3-6 months, although she remained very functional and continued to work full time. She was admitted to the hospital to start IV antibiotics and for sinus surgery given worsening sinus symptoms that were felt to be contributing to her exacerbation frequency and decline in lung function. Two days after sinus surgery, she developed acute hypoxemic and hypercarbic respiratory failure requiring mechanical ventilation. She became increasingly more difficult to oxygenate and ventilate despite maximal ventilator settings and nitric oxide. On day 4 of mechanical ventilation, a 27-French Avalon catheter was placed in the left internal jugular vein and she was initiated on V-V ECMO. Her ABG on the day of cannulation was 7.15/>110/67 when attempts were made to maintain plateau pressures ≤30 mmHg with lung protective ventilator settings. Her ABG prior to ECMO initiation was 7.33/85/58 on maximal support with unacceptably high plateau pressures in the mid-40’s mmHg.

She was urgently listed for bilateral lung transplant the day after being placed on ECMO and was transplanted 4 days later. Intraoperatively, she required exploratory laparotomy for DIOS given extreme abdominal distension and fear of compartment syndrome. At the conclusion of the transplant surgery, she was decannulated from ECMO as initial oxygenation and lung quality was excellent. However, over the next 12 hours, her oxygenation deteriorated, she developed bilateral diffuse infiltrates, and was placed back on V-V ECMO for severe primary graft dysfunction via a 24-French left common femoral cannula and a 19-French R subclavian venous cannula. The immediate post-operative period was complicated by bleeding requiring massive transfusion, hypotension requiring pressors, acute kidney injury requiring institution of CRRT, and shock liver.

Post-operatively the patient was maintained on broad anti-infectious coverage including piperacillin/tazobactam, ciprofloxacin, micafungin, linezolid, voriconazole and ganciclovir. Despite the broad coverage, she remained in distributive shock requiring vasopressor support. Blood cultures drawn one week after surgery resulted positive for yeast which was initially misidentified as Stephanoascus ciferrii. Liposomal amphotericin was added to Micafungin. Further evaluation of her fungal infection confirmed the actual identity of the organism as Cryptococcus laurentii. Retrospective review of bronchoalveolar fungal cultures prior to transplant identified the same organism, so it appears this unusual fungal infection was responsible for her acute decompensation.

Despite the complex course and numerous complications detailed above, the patient is slowly improving. Extracorporeal support with VV ECMO allowed her to be maintained despite severe hypoxemic respiratory both pre- and post-lung transplant and afforded her care team adequate time to accurately diagnose and appropriately treat the highly unusual fungal infection that led to her decompensation.

Address for correspondence: Christopher.king@inova.org
Background:

There has been an increase in the number of pediatric patients awaiting organ transplantation who require extracorporeal membrane oxygenation (ECMO) and continual renal replacement therapy (CRRT). Because of this, there is a need to standardize this practice. At a large academic medical center’s cardiac surgery intensive care unit (ICU), CRRT is performed using the PRISMAFLEX system. PRISMAFLEX requires banked blood to prime the machine for a pediatric patient. The blood recirculation time for this machine is one hour and the saline recirculation time is two hours. Thus, if a patient is away from the ICU longer than this period of time, the blood will expire and another circuit must be primed. Increased exposure to donor blood can decrease the possibility of a patient receiving an organ transplant due to the higher risk associated with increased antibody levels. Increased donor blood use is associated with increased costs due to the price of donor blood as well as increased risk of blood transfusion reactions. A new procedural guideline was developed and implemented in order to reduce exposure to donor blood for the pre-transplant pediatric patients.

Method:

A guideline has been created to obtain and store the blood from the CRRT machine in case a patient needs to be disconnected from the system for longer than the time approved to recirculate the blood. This guideline was developed referencing American Association of Blood Bank guidelines, consulting hospital transfusion and laboratory personnel to assist with guideline development, and referencing Food and Drug Administration guidelines for appropriate labeling. This guideline was supported by the ECMO Service, perfusion, transfusion medicine, and dialysis service.

Results:

After implementation of the guideline, two pediatric patients were placed on CRRT. The guideline was followed on two occurrences for one patient requiring operating room visits. The second patient was not disconnected from CRRT for longer than two hours throughout the entire ECMO run. Currently, the dialysis service is reviewing this guideline for feasibility of being utilized in the adult ECMO population.

Contact:
Brittany Krom – krom.brittany@mayo.edu  Telephone: 507-259-5984
200 First St. SW Rochester, MN 55905
Use of Extracorporeal Membrane Oxygenation (ECMO) in Critically Ill Obstetric Patients

Kuan-Ying Huang, Yi-Ping Li, Shin-Yu Lin, Yih-Sharng Chen, Chien-Nan Lee

a: Department of Obstetrics and Gynecology, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan
b: Department of Cardiac Surgery, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan

Objective(s): Extracorporeal membrane oxygenation (ECMO) or extracorporeal life support is commonly employed in patients with circulatory arrest or significant cardiac dysfunction and associated with an improvement in clinical outcomes. We described our institutional experience with ECMO usage in critically ill obstetric women in this study.

Methods: We conducted a retrospective observational study on the application of ECMO in critically ill obstetric patients at a single tertiary center, National Taiwan University Hospital in the past five years.

Results: Five critically ill postpartum women were treated with ECMO in 2012-2016. The mean age was 36.8±3.9 year-old and the mean gestational age was 36.8±2.6 weeks. Three patients (60%) were diagnosed with postpartum hemorrhage and one (20%) with suspected amniotic fluid embolism plus postpartum hemorrhage and another (20%) with pulmonary embolism. All patients were treated with veno-arterial (VA) ECMO and the mean ECMO usage duration was 30±19.7 (range: 10-54) hours. Four (80%) patients survived to discharge but one survivor became left hemiplegia; all neonates (100%) survived in 6-month follow-up.

Conclusions: Pre-ECMO hemorrhage may not be contraindications of ECMO application in critically ill obstetric patients. The use of ECMO in this population is associated with high maternal survival rate and good neonatal outcomes.

Name: Kuan-Ying Huang
Address: No. 8, Chung-Shan South Road, Taipei, Taiwan
Telephone: +886972651248  E-mail: conone21@gmail.com
Rejuvenation Of Stored Red Blood Cells Attenuates Hemolysis In A Simple Circuit Design Compared to Only Washed RBCs

Kausch K, Carne J, Gray A, Landrigan M: Zimmer Biomet, Warsaw, IN

**Background:** Red blood cell (RBC) hemolysis and elevated plasma free hemoglobin (PFHb) are observed during extracorporeal circuit membrane oxygenation (ECMO). The objective was to evaluate the durability of washed or rejuvenated RBCs to resist roller-pump induced hemolysis for 19.5 hours on-pump.

**Methods:** Human leukocyte reduced RBC units (n = 10) collected in CPD/AS-1 (stored at 1-6 °C for 35 – 42 days) were subdivided and split equally by weight into aliquots (Control\(_{\text{WASH}}\) and Washed or Control\(_{\text{REJ}}\) and Rejuvenated Groups). Rejuvenated aliquots were processed with 25 mL rejuvesol™ Red Blood Cell Processing Solution and dry air incubated (Sarstedt SAHARA-III) for one hour at 37°C, washed (Haemonetics ACP 215) and re-suspended in saline. Control aliquots were diluted with saline to match the post-wash hematocrit of the paired rejuvenated or washed aliquot. Two identical circuits were set up with a 100 mL reservoir, 1/8 ID IV tubing, and 100 mL/minute roller pump (Watson-Marlow 120U/DV). Paired aliquots were run in parallel for 19.5 hours at 37 °C in a temperature controlled environment. Complete blood counts (CELL-DYN Sapphire), PFHb (HemoCue Plasma/Low Hb), and hemolysis were analyzed.

**Results:** PFHb and hemolysis increased significantly over time for all Groups. PFHb and hemolysis in the Rejuvenated Group were significantly lower than the Control\(_{\text{REJ}}\) group (\(p = 0.02\), Student’s t-test) (Table 1).

**Table 1.** PFHb and % hemolysis for each group at the beginning and end of the circuit run. *denotes significant difference from paired group (\(p < 0.05\)).

<table>
<thead>
<tr>
<th>Group (n = 5)</th>
<th>PFHb (g/dL)</th>
<th>% Hemolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(T = 0 hrs)</td>
<td>(T = 19.5 hrs)</td>
</tr>
<tr>
<td>Control(_{\text{WASH}})</td>
<td>0.17 ± 0.01</td>
<td>8.06 ± 5.22</td>
</tr>
<tr>
<td>Washed</td>
<td>0.09 ± 0.02*</td>
<td>7.08 ± 3.94</td>
</tr>
<tr>
<td></td>
<td>(T = 0 hrs)</td>
<td>(T = 19.5 hrs)</td>
</tr>
<tr>
<td>Control(_{\text{REJ}})</td>
<td>0.20 ± 0.05</td>
<td>7.81 ± 4.24</td>
</tr>
<tr>
<td>Rejuvenated</td>
<td>0.07 ± 0.02*</td>
<td>2.11 ± 0.21*</td>
</tr>
</tbody>
</table>

**Conclusion:** Significantly less roller-pump induced hemolysis and PFHb accumulation were observed with rejuvenated RBCs. RBC washing alone did not significantly improve RBC resistance to hemolysis. Donor to donor variability in RBC resistance to mechanically-induced hemolysis was observed within the Control\(_{\text{WASH}}\), Control\(_{\text{REJ}}\), and Washed Groups. Only RBC rejuvenation prior to circulation attenuated the variability in mechanically-induced hemolysis.

*rejuvesol Solution (50 mL) is FDA approved to be used as an in vitro processing solution for the rejuvenation of a unit of RBC. This protocol is for research only and is not an FDA approved method.*

Matt Landrigan
56 E Bell Dr., Warsaw, IN  46582
574-371-1115
Matt.landrigan@zimmerbiomet.com
Anti-Xa Site Validation

Alecia Solomon MT(ASCP), Gisele Baskin, MScls, MT(ASCP), Debbie Laney MSN*, Jason A. Wicker, M.D., Ph.D., David R. Kelly MD

Children’s of Alabama, Birmingham, Alabama

Background: The plasma anti-Xa assay is a test widely used to monitor patients being treated with low molecular weight heparin (LMWH) or unfractionated heparin (UFH). Our Laboratory Change Control Committee met with the Nephrology Service to consider whether blood samples drawn from a Continuous Renal Replacement Therapy (CRRT) circuit could provide valid anti-Xa results. We determined from the manufacturer of our anti-Xa test kit that the assay was validated only for patient venipuncture and central line draw samples. We contacted other institutions that perform anti-Xa testing and have a dialysis program and an Extracorporeal Life Support (ECLS) program to determine their blood sampling practices during CRRT. Eight of the ten institutional laboratories contacted reported that they obtained blood samples for anti-Xa testing from the patient and not from the Extracorporeal Membrane Oxygenation (ECMO) circuit. The same 10 institutions’ ECMO programs were surveyed to determine what sample site they used for anti-Xa testing. Five institutions reported that they primarily sent samples from patient’s venous/arterial line and used first access on the venous side of circuit if needed. Four centers’ preference was to use the venous (pre-oxygenator) side of the circuit for laboratory test sampling routinely. Only one center reported that, except for blood gases, they never sent laboratory test samples from the ECMO circuit. With this information, we proposed a validation testing plan (approved by the pathologists) for anti-Xa samples obtained from the ECMO circuit for patients undergoing CRRT at our institution.

Method: Paired blood samples from both the patient and the first port of the venous side of the ECMO circuit were sent for anti-Xa and prothrombin (PT) testing from five patients on two separate occasions. Prothrombin time was performed in addition to anti-Xa testing to prove that results obtained from the two methodologies used by the Stago Compact Max® (colorimetric and clot-based) are not affected by specimens collected directly from the ECMO circuit. The ECLS team was blinded to results during the study.

Prothrombin Time Test Principle: The principle of the test consists of the use of calcium thromboplastin to measure the clotting time of the patient’s plasma and to compare it with that of a normal standard. The test measures, as a whole, the activity of coagulation factor II (prothrombin), factor V (proaccelerin), factor VII (proconvertin), factor X (Stuart factor), and factor I (fibrinogen).


Anti-Xa Test Principle: The normal function of a molecule of factor Xa, when present in plasma, is to cleave its natural substrate, prothrombin, to generate thrombin, the enzyme responsible for the formation of the fibrin clot. In the presence of heparin, competition occurs between this mechanism and the inhibitory mechanism exerted by the heparin-antithrombin complex, this inhibition being largely responsible for the anticoagulant action of heparin. The proposed method is a one-step reaction based on a similar principle: as soon as factor Xa is added to the plasma-substrate mixture, two reactions take place simultaneously, namely,

- Hydrolysis of the substrate by factor Xa
- Inhibition of factor Xa by the heparin-antithrombin complex (the heparin-antithrombin complex is made up from the heparin and the antithrombin peculiar to the patient)

After the necessary period of time for the competitive reaction to reach equilibrium, the quantity of paranitroaniline that is released is inversely proportional to the concentration of heparin present in the test medium.


Results:

<table>
<thead>
<tr>
<th>Mean Patient Results</th>
<th>Mean ECMO Pump Results</th>
<th>PT Mean Raw Diff</th>
<th>PT Mean % Diff.</th>
<th>Xa Mean Raw Diff.</th>
<th>Xa Mean % Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT 17.7</td>
<td>Xa 0.37</td>
<td>0.3</td>
<td>1.6%</td>
<td>0.03</td>
<td>8.1%</td>
</tr>
<tr>
<td>PT 17.4</td>
<td>Xa 0.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Difference/Mean Patient Results Acceptable ± 5% for PT and ± 15% for Xa</td>
<td>1.7%</td>
<td>8.4%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions: A comparison of results for anti-Xa and PT testing using blood samples obtained from patient arterial line and from the ECMO circuit revealed no significant differences. Based on this information, we concluded that we could institute a protocol for blood sampling for anti-Xa and PT from patients undergoing CRRT by using samples from the venous side of the circuit without compromising the accuracy of the results. We would also reduce entries and wear and tear on patient lines and provide nontraumatic access for laboratory testing for those patients who do not have other adequate vascular access.

Debbie Laney
1600 7th Ave South, Birmingham, AL 35233
Debbie.laney@childrensal.org 205-638-9962
Veno-arterial Extracorporeal Membrane Oxygenation in Patients with Acute Mitral Regurgitation and Ventricular Septal Rupture after Myocardial Infarction

Leonid Garber, Koji Takeda, Veli Topkara, Hiroo Takayama, Yoshifumi Naka, A. Reshad Garan
Columbia University Medical Center, New York, NY

Introduction: Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) is commonly used for supporting patients with acute refractory cardiogenic shock after myocardial infarction (MI). Although rare, complications of acute mitral regurgitation (AMR) from papillary muscle rupture and ischemic ventricular septal rupture (VSR) carry extremely high mortality. To date, little have been published on VA-ECMO in patients with these complications. Therefore, we sought to investigate clinical outcomes of patients requiring VA-ECMO with ischemic VSR or AMR post-MI.

Methods: We reviewed charts of patients with acute MI supported by VA-ECMO between 3/2012 and 3/2016 and identified those initiated on support prior to definitive repair of AMR or VSR. Data was collected on baseline characteristics, pre- and post-ECMO hemodynamics, clinical outcomes, and adverse events.

Results: Of 84 patients reviewed, we identified 6 cases (7%); 3 patients had AMR due to papillary muscle rupture and 3 patients had ischemic VSR. Four presented initially with ST elevation MI. All patients were supported with either an IABP or a percutaneous left ventricular assist device (pLVAD) prior to initiation of ECMO support (3 IABP, 3 pLVAD). For patients with IABP, 1 was successfully weaned from IABP after ECMO insertion, 1 could not be weaned, and 1 underwent weaning but required immediate transition to central VA-ECMO due to a loss of ventricular ejection. In those with pLVAD at the time of ECMO insertion, the device was removed at ECMO implant in 1 case without need for urgent ventricular decompression prior to surgical MV repair. In the other 2 patients, pLVAD was left in place for ventricular decompression until ECMO removal. Average duration on VA-ECMO for all patients was 9.5 days (1.0 – 20.7). Two patients survived to definitive surgical repair with time on VA-ECMO prior to repair of 6 and 12 days, respectively. Thirty-day survival was 50% (3/6) but only one patient survived to hospital discharge after surgical repair of VSR and simultaneous LVAD insertion. Significant adverse events were present with the following frequencies: 1 serious infection (17%), 4 bleeding/thrombosis (67%), 2 limb ischemia (33%), and 1 stroke (17%). Baseline hemodynamic and outcome data for each patient is detailed in Table 1.

Conclusions: VA-ECMO, while a robust means of supporting circulation, may not be the optimal method of supporting patients with mechanical complications of acute MI. Instead, for appropriate candidates, a strategy for preventing ventricular distention may be preferable.

Table 1 - Baseline hemodynamics and outcomes of AMR and VSD patients on VA-ECMO

<table>
<thead>
<tr>
<th>Pt.</th>
<th>AMR/ VSD</th>
<th>SBP</th>
<th>DBP</th>
<th>SPAP</th>
<th>DPAP</th>
<th>LVEF (%)</th>
<th>Days on VA-ECMO</th>
<th>Additional device w/ VA-ECMO</th>
<th>Survival to repair</th>
<th>30-day survival</th>
<th>Survival to discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AMR</td>
<td>110</td>
<td>67</td>
<td>69</td>
<td>29</td>
<td>20</td>
<td>7.7</td>
<td>Impella</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>AMR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>45</td>
<td>1.0</td>
<td>IABP</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>AMR</td>
<td>97</td>
<td>45</td>
<td>-</td>
<td>-</td>
<td>12.1</td>
<td>3.2</td>
<td>Impella</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>VSD</td>
<td>82</td>
<td>61</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>20.7</td>
<td>Central ECMO</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>VSD</td>
<td>113</td>
<td>42</td>
<td>62</td>
<td>29</td>
<td>35</td>
<td>12.0</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>VSD</td>
<td>90</td>
<td>55</td>
<td>62</td>
<td>29</td>
<td>35</td>
<td>12.0</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*All pressures are reported in mm Hg.

Contact: A. Reshad Garan. 177 Fort Washington Avenue, Suite: MHB5-435. New York, NY 10032. (646)-317-4270. Email: arg2024@columbia.edu
NOTE TO REVIEWERS – WANTS FOR POSTER

Improving Operational Structure to Guide Prospective Case Reviews of Neonatal ECMO patients


Introduction

Adequate management of anticoagulation is key when providing extracorporeal circuit membrane oxygenator (ECMO) support. Controversy exists about the optimal anticoagulation management in neonatal patients, in particular with regard to laboratory studies and heparin dosing. At The Children’s Hospital of Philadelphia (CHOP), Neonatal ECMO Anticoagulation Therapy (ACT) Guidelines were developed in 2012 to reduce practice variation. These guidelines are reviewed and revised periodically to aid in clinical decision making related to optimizing patient safety and circuit integrity. A systems quality framework (SQI) has been operationalized in our Neonatal Intensive Care Unit (NICU) to integrate quality improvement into best practices. Using SQI, the aim of this project was to implement a reliable review process to monitor compliance with ACT guidelines in the NICU and identify reasonable practice variations. The Outcome metric is number of lessons learned or practice changes resulting from Case Reviews. The Process metric is the number of patients reviewed of the total number of neonatal patients on ECMO per month. Balance metric is ACT compliance.

Methods

A multidisciplinary team was formed. Using SQI, we identified the people, process and tools of this system to support three pillars: actionable data management, improved communication, and frontline engagement. To assist with the Case Review process, an Excel spreadsheet tool was created and includes: (1) anticoagulation parameters (PTT, PT, Anti-Xa, ACT, Fibrinogen and Anti-thrombin III); (2) interventions performed (transfusions, heparin infusion dosing, circuit component changes, procedures); (3) clinical status (bleeding, intracranial bleeding); (4) circuit clot status (CHOP ECMO Clot Scale); and (5) ECMO anticoagulation guideline compliance. The spreadsheet is populated with current data from the electronic medical record (EMR). An independent reviewer assesses guideline compliance in three areas: laboratory schedule, heparin infusion and transfusions. Bi-monthly, the Team uses the annotated tool to review each neonatal ECMO patient for: (1) compliance with ACT Guidelines; (2) lessons learned; and (3) reasonable practice variations that could inform guideline revisions.

Results

From January 2016 until March 2016, the team identified the data elements to be used for Case Reviews and then refined the processes for retrieving and organizing the data. From the first Case Review, the Team identified changes that would enhance the case review process. From April to June 2016 the Excel spreadsheet was used to review and discuss 6 neonatal ECMO cases with the multidisciplinary team. As a result of the Case Review process and lessons learned, the Team has identified aspects of the anticoagulation guidelines that need further clarification to improve consistency of management and aid in bedside anticoagulation decision-making.

Conclusions

An improvement effort to provide consistency in structured Case Reviews of these patients has been integral in identifying areas for improving practice and preventing harm. The development of an Excel spreadsheet ‘tool’ enabled a multidisciplinary team to do prospective and comprehensive Case Reviews of the neonatal ECMO patient’s progress and focus discussion on two key areas: (1) anticoagulation guideline clarification and (2) gaps in management and practice changes as relates to continuity of care. The next step to complete this project work will be building an ECMO dashboard that automatically populates from the EMR data.

Additional outcomes from this project work include: (1) a commitment to continue the Case Reviews both prospectively and retrospectively using this structure with additional representation from pharmacy and the clinical laboratory; (2) future related QI projects be defined and implemented; (3) input provided to the CHND 2.0 ECMO module so that data can be collected nationally; and (4) continued efforts to improve patient safety and guide anticoagulation decision-making for neonatal ECMO patients.
A Need for Speed
Extracardiopulmonary Resuscitation (E-CPR) at Birmingham Children’s Hospital
Gareth Lodwick, Margaret Farley, Linda Edwards

Introduction
E-CPR has been recommended in cardiopulmonary resuscitation since 2010 by the American Heart Association (1) and can be employed in all age groups. We have supported patients with E-CPR at Birmingham Children’s Hospital since 2010 and previously reported our programme development and outcomes from 2008 to 2012 (2,3). To ensure on-going programme development and service improvement we have reviewed ECPR cases over the last 4 years. We report our results and problems encountered over this time.

Since starting our ECLS programme in 2008 we have supported 94 patients with 97 ECLS runs with 35% E-CPR cases. We developed and previously reported our “ECPR Activation Pathway” to ensure a streamlined approach to the initiation and management of these patients. This includes an ECPR activation call within 5 minutes of cardiac arrest and the availability at all times of 2 fully clear-primed circuits on PICU which are screened for infection.

Methods
We retrospectively reviewed all ECPR cases including demographic data, duration of CPR and outcome. We reviewed the time of day patients were placed on ECLS as the cannulating surgeon is not on site out of hours. We also reviewed incidents relating to the ready primed circuits to highlight areas for improvement.

Results
We have supported 54 E-CPR cases accounting for 35% of our total ECLS runs. 62% wean successfully off ECLS with 53% survival to PICU discharge. The time to initiate ECLS (cardiac massage time) has fallen from mean 160 minutes in 2011 to 48 minutes in 2016 (range 12 – 195 minutes). Patients who survived to PICU discharge had a mean CPR time of 41 minutes compared to 57 minutes in non-survivors. 59% of our patients were put on ECLS during the daytime with a mean CPR time of 34 minutes and 55% survival to PICU discharge. Although mean CPR time for patients placed on ECLS at night was considerably longer at 86 minutes, this did not affect survival to PICU discharge being 57% in this group. However if non-cardiac patients are excluded daytime survival is 61% compared to 54% at night. Overall survival in all cardiac patients was 55% compared with 33% in non-cardiac diagnosis although only 3 non-cardiac patients were supported. The mean weight of patients supported 9.5kg (range 3-30kg) with 44% less than or equal to 4.5kg, weight did not affect survival with mean weight of survivors 9.3kg compared to 9.6kg in non survivors. There were 2 cases of organisms isolated from the emergency wet-primed circuits taken at the time of initiating ECPR (Pseudomonas Cepatia and Orzyzihabitans); neither case resulted in positive cultures in the patient.

Discussion
Ongoing service review is paramount with any ECLS programme. With increasing E-CPR experience at Birmingham Children’s Hospital we have seen a significant reduction in our cardiac massage time to establishing ECLS. The mean time to establish support at night is much greater (86m) when compared to the daytime (34m) but there was no difference in survival (57% vs. 55%). With non-cardiac patients excluded ECPR survival to discharge is 61% (day) vs 54% (night), demonstrating an improved survival when initiating ECPR in the day. There will always be risk of infection with readily available wet primed ECPR circuits. The two cases of pseudomonas growth in our ECPR circuits was fully investigated allowing changes to priming and storage of the circuits. The considerable time difference in CPR during daytime compared to night time is something we will strive to improve upon through further audit as robust clinical governance remains paramount in any safe service.


Gareth Lodwick, gareth.lodwick@nhs.net, Birmingham Children’s Hospital, Steelhouse Lane, Birmingham, UK. 07725850005
Reducing Hospital-Acquired Pressure Injuries in Adult ECMO Patients

Authors: Erin A Lomas, BSN RN CCRN-CSC; Jason Felt, BSN RN CCRN; Matthew Hammond, RN CCRN; Christine Meyers, MSN RN; John Mignone, MD PhD; David Horne, BSN RN; Amanda Browne, ARNP

Institution: Swedish Medical Center, Seattle, WA

Background: Over the last year, our ECMO program has experienced a large number of Hospital-Acquired Pressure Injuries (HAPI). This is likely due to the inability to effectively reposition due to open chest central cannulation or unstable sternums. As a result, our hospital lost a significant amount of money to HAPI in 2015.

Objectives: To assess if a Turn and Reposition System (TAPS) would allow us to safe and effective repositioning of ECMO patients and reduce the incidence of HAPI, thereby reducing the cost of HAPI to our institution.

Methods: In February 2016, we implemented a successful trial of a TAPS program and now utilize the system with each of our ECMO patients. A TAPS system is placed on the bed while the patient is cannulated in the operating room. Patients are subsequently repositioned a minimum of every two hours. An electronic medical record review of 18 mixed VA and VV ECMO patients (10 patients pre-TAPS initiation and 8 patients post-TAPS initiation) was performed to analyzed the incidence of HAPI and calculate the total cost of HAPI in this patient population (based on HAPI stage and Centers for Disease Control HAPI cost averages).

Results: The sample size includes 4 VV patients, 11 centrally cannulated (open chest) VA patients, and 3 peripherally cannulated VA patients. The average length of ECMO run was 10.8 days (longest run was 27 days and shortest run was less than 1 day); the average total length of stay was 35.4 days (longest as 161 days and shortest was less than 1 day). There were a total of 11 HAPI among 4 patients in the pre-TAPS ECMO group with 6 HAPI occurring in two centrally cannulated VA patients and 5 occurring in two VV patients. Using the TAPS system and reducing the incidence of HAPI to zero has shown a cost saving of up to $173,870.

Conclusion: Having products and resources available to effectively and safety reposition ECMO patients, no matter their cannulation strategy, has not only greatly reduced our incidence of HAPI in our ECMO patient population, but has also resulted in cost savings. The average cannulation time did not affect the incidence of HAPI, but the patients with HAPIs experienced the longest average lengths of stay.

Contact:

Erin A Lomas, BSN RN CCRN-CSC
2312 202nd St SW
Lynnwood, WA 98036
360.265.2684
erin.lomas@swedish.org
Use of v-v ECMO to support perioperative management of iatrogenic tracheal injury.

L. Cremascoli, M. Maurelli, A. Aliberti, A. Amatu, A. Bottazzi, C. Pellegrini, M. Belliato, GA. Iotti.

* Scuola di Specializzazione in Anestesia e Rianimazione Università degli Studi di Pavia, Fondazione IRCCS Policlinico S. Matteo
** S.C. Anestesia e Rianimazione 3, Fondazione IRCCS Policlinico S. Matteo
*** S.C. Anestesia e Rianimazione 2, Fondazione IRCCS Policlinico S. Matteo
**** S.C. Cardiochirurgia, Fondazione IRCCS Policlinico S. Matteo

INTRODUCTION: Airway injuries are life-threatening conditions. The goal of conservative management of major airways injuries is preserving spontaneous breathing, until safe airway and ventilation has been achieved, to avoid positive pressure ventilation that may encourage passage of air and secretion through the tear into the mediastinum. Surgical treatment is indicated when air leak persist despite conservative approach.

CLINICAL CASE: The patient is a 39 years-old woman who developed left pneumothorax (PNX), pneumomediastinum and large subcutaneous emphysema at the end of laparoscopic surgical treatment of adhesions after gynecologic surgery. She was transferred to our Intensive Care Unit for specialized treatment. We inserted a chest tube to remove PNX and we done a CT scan and a fibrobronchoscopy to make diagnosis of tracheal injury of 2 cm with complete interruption of membranous portion. In this case it has been necessary to perform surgical repair for persistent of air leak.

We peripherally placed veno-venous extracorporeal membrane oxygenation (v-v ECMO) with local anaesthesia before intubation to guarantee gas exchange during surgical intervention.

ECMO configuration was femur-jugular with blood flow 4.0 L/min and FiO2 70% without anticoagulation. Once we assured adequate oxygenation with v-v ECMO the patient was successfully sedated for selective left bronchial intubation. Ventilator settings during surgery were low respiratory frequency, very low positive inspiration pressure with low PEEP. Right thoracotomy was performed to identify longitudinal laceration of membranous portion with wide air leak. ECMO support was useful after extubation to safety check the endurance of tracheal suture during spontaneous breathing. ECMO was successfully removed one our later and the patient was discharged after 2 days to non-intensive ward without complications.

CONCLUSIONS: ECMO has been demonstrated to be beneficial for the life support of selected traumatic tracheobronchial injury as a bridge to surgery. In our case we used ECMO to support anaesthesiology management of elective surgical repair of tracheal injury and to allow a better and safer surgical repair of airways injury. The present technological advancements, making ECMO easier to manage and safer, allow to consider extracorporeal support as a reasonable alternative to mechanical ventilation in selected groups of patients.

References:


Dr. Luca Cremascoli
Resident Physician
Scuola di Specializzazione in Anestesia e Rianimazione Università degli Studi di Pavia, Fondazione IRCCS Policlinico S. Matteo
S.C. Anestesia e Rianimazione 2, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy
E-mail: doc.cremascoli@gmail.com
Extracorporeal membrane oxygenation (ECMO) has potential complications including hemorrhage that may be exacerbated by anticoagulation, platelet dysfunction, and hemodilutional or consumptive coagulopathy. While anticoagulated ECMO patients are monitored by activated partial thromboplastin time (aPTT) and prothrombin time (PT), these values may not accurately represent the actual coagulation status of the patient. TEG provides a more complete analysis of coagulation status through the use of whole blood rather than plasma fractions.

Case: a 49-year-old male with severe pneumoconiosis underwent bilateral lung transplant with venovenous ECMO support. On post-operative day (POD) 6, ECMO was discontinued. The patient was placed back on ECMO on POD 8 due to aspiration pneumonia and non-HLA antibody mediated rejection requiring plasma exchange. Three weeks post-transplant, coagulopathy was identified after due to continuous bleeding from the percutaneous tracheostomy site. After multiple transfusions and attempts to cauterize the site, serial TEG analyses (Table 1) was performed.

TEG 1, drawn prior to decannulation on POD 22, demonstrated an elevated LY30 (fibrinolysis) and low MA (platelet function). Although the LY30 improved after decannulation, it did not normalize. Subsequent TEG analyses guided directed transfusion therapy of his coagulopathy: platelets for a low MA and cryoprecipitate for low fibrinogen. Analysis 4 was particularly striking with evidence of early disseminated intravascular coagulation (DIC) and secondary fibrinolysis demonstrated by the shortened R time, elevated LY30, and angle. Based on this TEG, 500 units of intravenous heparin were administered. Repeat TEGs performed (with heparinase) showed rapid correction of the coagulopathy and fibrinolysis with cessation of tracheostomy bleeding. Further transfusions were not required due to the corrected MA.

TEG is not yet the standard practice for monitoring patients’ coagulation state. It may serve as a diagnostic tool that enables tailored treatment of coagulopathies. In this case, TEG assisted in the diagnosis of a difficult to detect disease state, low grade DIC on ECMO, thus enabling a rapid therapeutic intervention that otherwise would not have been made.

Table 1: Timeline of TEG analysis and interventions taken

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<th>K-value (min)</th>
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POD 24 - 03:51

Table 1: Timeline of TEG analysis and interventions taken

Figure 1: TEG 4 Analysis

Figure 2: TEG 5 Analysis
Outcomes of Extra-Corporeal Membrane Oxygenation (ECMO) by Etiology: A Single Center Experience
Ben Magod¹, Kelly Wilson¹, Ross Garberich¹, and Katarzyna Hryniewicz², M.D.

¹. Minneapolis Heart Institute Foundation, Abbott Northwestern Hospital, Minneapolis MN
². Minneapolis Heart Institute, Abbott Northwestern Hospital, Minneapolis, MN

Background: Extra-corporeal membrane oxygenation (ECMO) is becoming the standard of care for refractory cardiogenic shock and severe ARDS. Overall, the Extracorporeal Life Support Organization (ELSO) Registry reports a survival to discharge in adults of 58% for pulmonary patients and 41% for cardiac patients. However, the specific etiologies and etiology-dependent outcomes of these populations have not been well defined. We report our outcomes of patients supported by ECMO based on the etiology of shock.

Methods: Between January, 2012 and May, 2016, we reviewed electronic medical records of patients supported with ECMO at our institution as part of our center’s quality improvement initiative. We analyzed demographics, survival to discharge and etiology of shock. Patients supported by VA ECMO were categorized by etiology of cardiogenic shock that included post-cardiotomy, acute myocardial infarction (AMI), preexisting cardiomyopathies, pulmonary embolism; also septic shock and supported by VV ECMO for severe ARDS. We excluded patients who were on ECMO less than six hours. Six patients were converted from veno-arterial (VA) to VV ECMO; these patients were therefore counted as separate incidences.

Results: A total of 129 patients were analyzed, 81 (63%) male, average age of 55.8±13.9 years. Thirty two patients presented with acute myocardial infarctions, 23 post-cardiotomy with peripheral cannulation, 7 post-cardiotomy with central cannulation, 19 septic shock, 19 VV ECMO, 5 new diagnosis of non-ischemic cardiomyopathy, 6 end-stage cardiomyopathy, 3 pulmonary embolisms and 15 other etiologies. Fifteen (11.6%) patients were bridged to LVAD support. Overall survival to discharge was 63% for VA ECMO patients and 55.6% for VV ECMO patients. AMI patients had the highest survival to discharge of 75%, and the lowest median time on ECMO support of 5 days. There was no difference in survival of post-cardiotomy patients cannulated peripherally vs centrally (56.5% and 57.1% respectively). Survival to discharge of patients with septic shock was 68.4%. One (33.33%) of the pulmonary embolism patients expired. Patients with pre-existing end-stage ischemic cardiomyopathy had the lowest rate of survival to discharge at 33.3%. VV ECMO patients had the longest median time on ECMO of 10 days, while acute myocardial infarction, septic shock, and pulmonary embolism patients all had similar median times on ECMO support of 5 days.

Conclusion: Despite overall dismal prognosis in profound shock regardless of etiology, in our study ECMO support provided a reasonable survival rate in the sickest population of patients. Myocardial infarction as etiology of refractory shock appears to have best survival. More randomized, controlled trials are needed to evaluate more routine use of ECMO in this patient population.

Contact: Kasia Hryniewicz, M.D.
Minneapolis Heart Institute, Section of Heart Failure/Transplant/MCS, Abbott Northwestern Hospital
920 E 28th street, suite 300. Minneapolis MN 55407
katarzyna.hryniewicz@allina.com
Retrospective Outcomes Review of 158 ECMO Patients Anticoagulated with Bivalirudin

McCaela Moes,1 Eve Anderson, Daniel Gutteridge, Chadi Hage, Courtney Khouli, and I-wen Wang
1Department of Biomedical Engineering, Purdue University, West Lafayette, IN
Indiana University School of Medicine and Indiana University Health Methodist Hospital, Indianapolis, IN

Background: The optimal systemic anticoagulant to use in patients receiving extracorporeal membrane oxygenation (ECMO) therapy has yet to be determined. Heparin has been the standard agent of choice due to familiarity, ease of reversal, and low drug cost. There has been increasing awareness of the clinical constraints of heparin, such as development of thrombocytopenia (heparin-induced vs. mechanical consumption vs. inherent illness), heparin resistance, and blood product transfusion. Bivalirudin, a direct thrombin inhibitor, is an alternative anticoagulant used in ECMO patients with increasing frequency. While preliminary results are positive, studies are limited to case reports and small population studies. Bivalirudin replaced heparin as the anticoagulant of choice for ECMO patients at IUH Methodist hospital in 2013. We sought to examine efficacy and safety of bivalirudin in a large, single institution review of patients receiving ECMO treatment.

Methods: A retrospective review of patients treated with ECMO between January 2010 and May 2016 was performed. Patients were included if they were on ECMO for at least 24 hours and were anticoagulated with bivalirudin during ECMO therapy. Patients were excluded if they were younger than 18 years, pregnant, or prisoners. Demographics including age, gender, type of ECMO circuit, time on ECMO, and indication for ECMO were collected. The incidence of symptomatic thrombosis was used to measure the anticoagulant efficacy of bivalirudin. The number of specific blood products transfused after bivalirudin was initiated and while patients were on ECMO was also quantified.

Results: 158 patients met the inclusion criteria, of which 65 (40%) were females. The median patient age was 53 years (range: 18-77). The most common indication for ECMO was ARDS (n=46, 30%). Eighty-five patients (54%) required V-V ECMO, 66 (42%) required V-A ECMO, and 7 (4%) required the combination (VA-V). The mean number of blood products transfused per patient was 11 units (range: 0-112, SD + 16) after starting anticoagulation with bivalirudin. Symptomatic venous thromboembolism occurred in 39 (25%) patients. There were 120 (76%) patients who survived to decannulation from ECMO support. Of those who survived through decannulation, 89 (74%) survived to discharge; this corresponds to an overall survival rate of 56% for all modes of ECMO. For patients treated with V-V ECMO, 72 patients survived to decannulation (85%) and 55 (65%) survived to discharge. Of the 66 patients treated with V-A ECMO, 41 (62%) survived to decannulation and 39 (59%) survived to discharge. The 7 combination patients on VA-V ECMO saw a survival rate to decannulation of 100% with 5 (71%) surviving to discharge.

Conclusion: ECMO patients anticoagulated with bivalirudin have survival outcomes varying with the mode of ECMO support. The survival for each mode is comparable to ELSO Registry results. Transfusion requirements and thrombotic complications are related to the underlying indications for support. Bivalirudin appears to be a safe and effective systemic anticoagulant for patients on ECMO.

Contact: I-wen Wang, MD, PhD., IU Health Methodist Hospital
1801 N. Senate Blvd., MPC-2, Suite 2000, Indianapolis, IN 46202, iwang@iuhealth.org, 317.923.1787
INTRODUCTION

St Vincent’s Hospital (SVH) and Royal Prince Alfred (RPA) Hospital serve as the two ECMO referral centres for New South Wales (population of approximately 7.5 million). Resuscitative extracorporeal membrane oxygenation (ECMO) has been used in our institutions for several years now, with selected cases of refractory cardiac arrest supported by deploying ECMO during cardiopulmonary resuscitation (ECPR). We describe our experience with ECPR, with particular focus on survival and functional outcomes.

METHODS

Adult patients undergoing ECPR from 2009-2015 were identified from our respective ECMO databases. Cases of ECPR for both in-hospital cardiac arrest out-of hospital were included. Data gathered included demographics, cardiac arrest details, ECMO data, and survival and morbidity outcomes.

RESULTS

Thirty-seven patients underwent ECPR, the majority being for in-hospital cardiac arrest (n=25, 68%). Mean age was 53 years (+/-15), and 27 (73%) were male. Initial rhythm was VF or VT in 19 patients (51%), with the remainder comprising PEA (n=14, 38%), and asystole (n=3, 8%). Mean time from arrest to initiation of ECMO flow was 53 minutes (+/-28), and mean ECMO run was 4 days (+/-3). Angiography was performed in 53% of patients, with 27% requiring subsequent coronary intervention (stenting=24%, surgical grafting=3%). A total of 13 patients (35%) survived to hospital discharge (IHCA=33% vs OOHCA 37%). All survivors were discharged with favourable neurological outcome (Cerebral Performance Category 1 or 2).

CONCLUSIONS

In selected patients with refractory cardiac arrest, ECPR may allow temporary support as a bridge to intervention or recovery. We report favourable survival and neurological outcomes in over one third of patients. Further studies are required to determine optimum selection criteria for ECMO support in this select patient group.

CONTACT: Dr Peter McCanny, email: petemccanny@hotmail.com, Tel: +61 404624694
**Centrifugal vs. Roller Head Pumps in Cardiac ECMO: A Comparison of Hemolysis and Component Failure**

Heard ML, Wagoner SF, Nix, CW; Davis JD, Salisbury CM and Deshpande S
Children’s Healthcare of Atlanta at Egleston, Atlanta, Georgia

**Introduction:** In November 2013, we began using the centrifugal pump for all patients in the cardiac and pediatric intensive care units, without regard to size or diagnosis. We immediately noted that we had an increased occurrence of hemolysis as measured by plasma free hemoglobin levels, as high as 500 mg/dL. Additionally, we noted that the incidence of removing the arterial filter had increased. For the next 18 months we hypothesized this may be attributed this to the use of the centrifugal pump. Recently, another Children’s Hospital presented an abstract that noted an increase in complication rates for neonates who were placed on the centrifugal pump as compared to those who were on the roller head pump. This prompted our program to review the same groups of patients.

**Methods:** All cardiac and ECPR patients who were placed on the roller head pump between January 2011 to December 2013 and those placed on the centrifugal pump between November 2013 to January 2016 were reviewed. These patients were divided into four groups: roller head (RH) patients less than 5 kilograms (n=27); centrifugal (C) patients less than 5 kilograms (n=50); RH patients greater than 5 kilos (n=18) and C patients greater than 5 kilos (n=18). All demographic, diagnoses and ECMO run specific information was collected. Additionally, daily creatinine, total bilirubin, lactic acid and plasma free hemoglobin levels were obtained immediately pre and daily throughout the ECMO run.

**Results:** The review first demonstrated a significant increase in total patient numbers during the centrifugal pump period. (45 to 78). Additionally, the survival rates decreased from 48.1% (RH) to 30.0% (C) between the two groups. The review of complications noted a significant increase in hemolysis as noted by a plasma free hemoglobin level greater than 50 in the smaller C group compared to the RH group (29.6% to 76%, p = 0.00002). These differences were also noted in the larger patients, but not significantly. Hemolysis was noted at 36.8% in the RH >5 kg vs. 55.6% in the C >5 kg. The incidence of removal of the arterial filter also increased in both of the centrifugal groups compared to the roller head groups: C <5 from 3.7% to 26% and C >5 from 10.5% to 44.4%.

**Discussion:** The significant difference in complication rates for hemolysis and component failure was noted especially in the < 5 kg cardiac patients supported with centrifugal pump compared to roller head pump. This information was presented and discussed at the ECMO Leadership meeting in January 2016 with all ECMO Medical Directors. They unanimously agreed that this represented an unacceptable increase in complication rate and we would discontinue use of the centrifugal pump in the neonatal, less than 5-kilogram population.

**Conclusion:** The occurrence of hemolysis is concerning in the smaller cardiac population. Use of currently available centrifugal pumps in the neonates and infants warrants continued evaluation and study.

Micheal Heard, RN ECMO & Advanced Technologies, Children’s Healthcare of Atlanta, 1405 Clifton Road, NE, Atlanta, Georgia 30322  micheal.heard@choa.org
Transforming an ECMO Practice

Brandy Morris, RN, Adult ECMO Coordinator
Jessie Critser, BSN, RN, CCRN, Adult ECMO Coordinator

Chart audits in July 2014, revealed that 15% of patients placed on ECMO could have been placed on ECMO sooner, while 25% could have been discontinued earlier. In fiscal year 2014, our ECMO mortality rate was 84%. This low point is what began the transformation to our current practice. At the time we were using the perfusion department to care for and manage the pump 24 hours per day. To have the perfusionist group continue to manage the pump was not a sustainable solution due to their high demand in the operating room and pediatric ECMO commitments. It was also very costly to use perfusion for pump coverage. We added a team of nurses that became ECMO Specialists. These nurses were required to attend an ELSO training course. The group of nurses were instructed on indications/contraindications for ECMO, management of both the patient and ECMO circuitry, as well as device trouble shooting. The ECMO specialist later replaced the perfusionist at the bedside. This was the beginning of the program's transformation. Two of the ECMO specialists began to take ownership of the team and became the ECMO Coordinators. The ECMO Coordinators began writing guidelines using both ELSO recommendations and research articles as references. Two physicians were also added as ECMO Directors. The directors implemented patient selection criteria. To further improve the program, the team agreed that all involved in the care of the ECMO patients would be required to attend an ELSO (Extracorporeal Life Support Organization) training course. This included physicians, PA's, APN's, perfusionist and nursing staff. The team began to take a more proactive approach by reviewing patients prior to cannulation. A Triad was developed which includes the Directors and at least 1 of the Coordinators. The patient being considered for ECLS is evaluated by each member of the Triad. The three discuss the patient’s condition and whether or not it is reversible. The triad also reviews if the patient meets the criteria for cannulation. From there, 2 out of the 3 members must agree in order to initiate cannulation for ECMO. The implementation of the Triad improved the outcomes in 2 ways; first by initiating ECMO earlier and second by appropriate selection of candidates. The team initiated mandatory consultations for Critical Care Services, Hematology and Palliative Care. The ECMO team implemented mandatory interdisciplinary rounding and initiated use of a rounding checklist. The interdisciplinary team meets every morning at 8 to round on the patient receiving ECLS. The interdisciplinary team consists of the cardiovascular surgeon, the on-service intensivist, cardiologist, bedside RN, ECMO RN, charge nurse, APN, PA, perfusionist, pharmacist, hematologist, and palliative care. The ECMO specialist and bedside nurse are both responsible for completing the rounding log. The rounding log contains a review of the patient by systems. During rounds the interdisciplinary team determines and evaluates the plan of care. Each day the efficacy of the treatment is questioned. This process has led to weaning patients off of ECMO in a more timely fashion. Patient’s families have been well informed since involving Palliative Care. Finally, an escalation policy was generated to allow issues or concerns during the care of an ECMO patient to be taken to ECMO leadership. The transformation of our practice had a significant impact for fiscal year 2015. FY15 survival rate increased to 71% from 16% the previous year. The number of patients supported by ECMO has increased dramatically, while length of stay and cost per case have markedly decreased. The team has continued to embrace their new practice while continuing to examine opportunities to improve quality of care.

Brandy Morris RN, ECMO Coordinator
OSF Saint Francis Medical Center
530 NE Glen Oak Ave, Peoria IL 61637
309-368-4531
Description of the ELSO Excellence in Life Support Award Scoring Rubric

T Morrison MSQA RN, WC Ellis CCP, Barb Haney, RNC-NIC, MSN, CPNP-AC, M.L.Heard, RN, J Connelly RRT-NPS,
ELSO Excellence in Life Support Award Committee

Introduction

Current trends in healthcare demand thoughtful development of programs with an emphasis on quality. Development of quality driven programs is especially important in high risk, low volume techniques like extracorporeal membrane oxygenation (ECMO). The Extracorporeal Life Support Organization (ELSO) has a mission to provide support to institutions delivering extracorporeal life support through continuing education, guidelines development, original research, publications and maintenance of a comprehensive registry of patient data. The ELSO Excellence in Life Support award is an extension of that mission by recognizing ECLS programs worldwide that distinguish themselves by having processes, procedures and systems in place that promote excellence and exceptional care in extracorporeal membrane oxygenation. ELSO centers may apply to be considered for designation as an ELSO Center of Excellence. Applications are reviewed by the Center of Excellence Award committee. A scoring rubric was developed to standardize the scoring process for award applicants between committee members. This project aims to describe the development of the scoring rubric and demonstrate validity and reliability in scoring applications.

Methods

The Excellence in Life Support Award was instituted in 2006 and both the application and the scoring rubric are reviewed annually. Scores for individual questions are reviewed annually to ensure clarity of application questions and consistency in application responses. A process was created to review and compare scores by committee members for reliability testing. This interrater reliability data is collected and reviewed annually, with changes made to the scoring tool as needed to improve validity. The application and scoring rubric have undergone only minor revisions since 2013. Each question is scored based on a 5 point scale (does not meet, somewhat meets, meets, somewhat exceeds, exceeds) based on specific defined criteria for each question. Rubric scoring criteria for each question are based on ELSO guidelines. The scoring rubric for question 4.1, related to initial physician education according to the ELSO guidelines, demonstrates how each question is scored (Table 1). Specific requirements have been developed for each question and sub-question of the application.

Conclusion

A defined rubric for scoring ELSO Award for Excellence applications has made scoring between committee members consistent. The use of a robust scoring rubric is necessary to ensure standardization in the review process. The annual review process allows for development and clarification of application questions and scoring criteria.

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Cory Ellis - 13123 E 16th Avenue, Aurora, CO 80045 – 720-935-8024 – William.ellis@childrenscolorado.org
A new approach for connecting Prismaflex to CardioHelp under positive pressure conditions

Willieford Moses, Shelley Diane, Clinton Jones, Patricia Dillon, Rudolph Pacol, Paul Brakeman, Peter Oishi, Benjamin Padilla
University of California, San Francisco

Introduction
Many neonatal and pediatric patients requiring extracorporeal membrane oxygenation (ECMO) develop volume overload and/or renal failure and thus also require concurrent renal replacement therapy (CRRT). Traditionally this has necessitated either separate vascular access points with the two circuits (ECMO and CRRT) running in parallel or the ECMO circuit must be disrupted pre-pump and bridged to the CRRT circuit. We tested and implemented a process of adding and removing the Prismaflex CRRT circuit to the Maquet CardioHelp circuit without altering flow dynamics or disrupting the ECMO circuit.

Methods
An interdisciplinary team of physicians, nurses, and perfusionists collaborated to develop an alternative configuration for combining the systems, incorporating the Prismaflex into the post-pump portion of the CardioHelp oxygenator without having to disrupt the flow through the circuit. Specifically, the inflow to the Prismaflex circuit was drawn off the post-oxygenator bubble port of the CardioHelp with the outflow returned to the pre-oxygenator bubble port. Therefore the hemofilter membrane was exposed to positive pressure conditions, which represented a divergence from standard clinical practice. As such, this represented an off-label use of the Prismaflex system. We present a small retrospective case series of our initial experience with this new arrangement. The Committee on Human Research at the University of California, San Francisco, approved this retrospective review.

Results
To confirm the feasibility of this arrangement, ex-vivo bench-top tests were performed. Both systems were primed with heparinized blood and the Prismaflex via CVVHDF mode was set to POSITIVE monitoring pressure. Three different settings were used to simulate the potential flow and clearance needs of a neonate, a school-aged child and a large adult to ensure the Prismaflex system would allow for the required low and high positive pressures without activating end therapy alarms. The access pressures ranged from positive 137 to 220mmHg, filter pressure ranged from 370 to 385mmHg and effluent pressures from 285 to 311mmHg. During the testing, the filter remained intact without leak and no alarms occurred.

Between March 2015 and July 2015, four neonatal and pediatric patients, who were treated with ECMO, required CRRT for volume overload and were thus candidates for this configuration. They were systemically heparinized for the ECMO circuit, thus no additional anticoagulation was required for the CRRT circuit. The average number of days on the combined ECMO and CRRT circuits was 9 (STD 5.52). The average initial blood flow rate was 68ml/minute (STD 34.21) with an average access pressure of 52.2mmHg (STD 140.04) and average filter pressure of 195.6mmHg (STD 38.46). The effluent and return pressures were 145.2mmHg (STD 29.38) and 174.6mmHg (STD 31.08), respectively, with an average transmembrane pressure of 23.4mmHg (STD 12.99). Average initial fluid removal was 63.8ml/hr (STD 66.0). The hemofilter membranes remained intact without any leaks, cracks or complications.

Conclusion
Continuous renal replacement therapy with the Prismaflex system can be performed safely under positive pressure conditions via post-pump connection to the CardioHelp extracorporeal membrane oxygenator. Specific to our experience, the Prismaflex inflow can be drawn from the post-oxygenator bubble port of the CardioHelp to allow for positive monitoring pressure range renal replacement therapy. This arrangement obviates the need for either a separate vascular connection (e.g., hemodialysis catheter) or the need to open the ECMO circuit and form a new bridge to the hemofilter.
Veno-venous Extracorporeal Membrane Oxygenation Can Be Managed with Lower Activated Clotting Times

Farzad Najam, MD, FACS, Bruno Sambuco, CCP, Melody Ricks, RN, Elizabeth Pocock, MD

The Division of Cardiac Surgery, The George Washington University Hospital, Washington, DC

Introduction:

Veno-venous Extracorporeal Membrane Oxygenation (V-V ECMO) is utilized for the management of patients in respiratory failure. The use of anticoagulation is necessary for the management of the V-V ECMO circuit but can be associated with hemorrhagic complications. We propose that patients on V-V ECMO can be managed with lower activated clotting times (ACT).

Methods:

At our institution, we managed seven patients who required utilization of V-V ECMO with heparinization and lower ACT goals of 160-180 seconds. Tubes containing celite were used to measure the ACTs. There were four female and three male patients in the group. All patients were placed on V-V ECMO using a bicaval, dual lumen, single site cannula inserted via the right internal jugular vein. Patients’ age ranged from thirty years to seventy years. The total number of days on V-V ECMO for all patients was one hundred and eighty.

Results:

Five patients were successfully weaned off of ECMO. Five patients were successfully discharged from the Intensive care unit and the hospital. Four patients required their oxygenator to be replaced. One patient needed the circuit to be replaced. The total number of units of packed red blood cells used for our patients was one hundred and forty three.

Conclusion:

Patients who require V-V ECMO for respiratory failure can be safely managed with lower ACT goals that can reduce the incidence of hemorrhagic complications without compromising the safety of V-V ECMO.

Address correspondence to:

Farzad Najam, MD
2131 K Street, NW, #700
Washington, DC 20037
Tel: 202-715-5700
Email: farzad.najam@gwu-hospital.com
Sedative And Analgesic Drug Sequestration In Modern Extracorporeal Membrane Oxygenation Circuits-Pilot data

Nasr VG, Meserve J, Faraoni D, Pereira L, Brediger S, Goobie S, DiNardo J, Thiagarajan R.
Boston Children’s Hospital, Harvard Medical School, Boston, MA

Introduction: Extracorporeal membrane oxygenation (ECMO) is a temporary treatment for cardiac and/or respiratory failure not responsive to conventional therapies. Since its inception in the 1970’s, it is increasingly being used in pediatric patients as a bridge to recovery, placement of a cardiac assist devices, or heart/lung transplantation. Sedation and analgesia while on ECMO is vital for patient safety and comfort, yet drug pharmacokinetics change markedly with initiation of ECMO therapy. (1) ECMO circuits have been shown to alter patients’ pharmacokinetics with an increased volume of distribution, decreased clearance and increased drug adsorption onto the ECMO circuit itself. (2) Previous studies have shown that lipophilic drugs such as fentanyl are rapidly and thoroughly adsorbed by ECMO circuits, sequestering as much as 100% of fentanyl at 24 hours after single bolus injection. (2) These studies were performed using older ECMO circuits that included traditional silicone membrane oxygenators (MO), and non-coated polyvinylchloride (PVC) tubing. In clinical practice today, PVC tubing is coated with agents such as heparin or other proteins, and silicone is replaced with polymethylpentane (PMP) in the MO to decrease size and increase efficiency.

As such, previous studies characterizing the pharmacokinetic changes in ex-vivo ECMO circuits have become less applicable to current clinical practice. This study seeks to better characterize drug adsorption of Fentanyl and Morphine in modern neonatal ECMO circuits utilizing a polymethylpentane (PMP) membrane oxygenator (MO) with protein bounded polyvinylchloride (PVC) tubing.

Methods: Closed-loop ex-vivo ECMO circuits are prepared using P.h.i.s.i.o coated PVC neonatal tubing (Sorin Group USA, Inc.) and a Quadrox-iD Pediatric polymethylpentane MO (Maquet Cardiopulmonary AG). A closed-loop system is created by connecting the ends of the arterial and venous cannulae to a reservoir bag, allowing continuous flow of the priming fluid around the circuit with Revolution Centrifugal Pump (Sorin Group USA, Inc.). The priming solution contain blood products, heparin, albumin, sodium bicarbonate and calcium gluconate per standard routine practice. One drug is injected per circuit time to avoid binding competition between drugs for a patient weight of 5 kg. Drug samples will be drawn at baseline (P0) followed by 2, 5, 15, 30, 60, and 120 minutes and then at 4, 12, 24, 36 and 48 hours and analyzed in duplicate using liquid chromatography with mass spectrometry (LC/MS).

Results: As pilot data, two ECMO circuits per drug have been used to characterize the fentanyl and morphine pharmacokinetics. Fentanyl 10mcg (2ug/kg) was injected into the circuit and morphine 0.5mg (0.1mg/kg) was injected in a separate circuit. The preliminary data for these two circuits have shown that only 56% of fentanyl remains in the ECMO circuit while there was no change in morphine concentration after 48 hours. (Table) This shows a possible sequestration of fentanyl into the circuit tubing or the membranes that may limit the amount of drug delivered to the patients. The figure below is a representation of the concentrations’ profile of fentanyl and morphine following injection. Additional ECMO circuits are needed to validate these data and understand the mechanism described above.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Total volume (ml)</th>
<th>Dose (ug)</th>
<th>Theoretical conc.</th>
<th>Actual conc.</th>
<th>Remaining drug % in the circuit (mean±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fentanyl</td>
<td>600</td>
<td>10</td>
<td>16.67 ng/mL</td>
<td>9.46 ng/mL</td>
<td>56±11%</td>
</tr>
<tr>
<td>Morphine</td>
<td>600</td>
<td>500</td>
<td>0.833 ug/mL</td>
<td>0.856 ug/mL</td>
<td>103±3%</td>
</tr>
</tbody>
</table>

The figure above is a representation of the concentrations’ profile of fentanyl and morphine following injection. Additional ECMO circuits are needed to validate these data and understand the mechanism described above.

Conclusion: The understanding of the pharmacokinetics of these drugs in ex-vivo may help pediatric anesthesiologists and intensivists provide a better sedative and analgesic strategy for patients on ECMO to be followed by in-vivo application.

Contact person: Viviane G. Nasr, MD.300 Longwood Ave, Bader 3, Department of Anesthesiology, Perioperative and Pain Medicine. Phone 617-933-6225. Email: viviane.nasr@childrens.harvard.edu.

References:
**Redo-Bilateral Lung Transplant of Veno-venous ECMO Patient**

David Fary, CCP; Marissa Nides, RRT; Deborah White, CCP; Jamie O'Flynn, CCP; Michael J. Bates, MD; Patrick E. Parrino, MD

Ochsner Medical Center

**Abstract**

Cystic fibrosis is an autosomal recessive genetic disorder in which the defective gene produces a mutant protein that can attack the respiratory, digestive, and endocrine systems. This protein interferes with the body’s ability to manage and produce chloride, leading to a chloride deficit which thickens secretions throughout the body. In the lungs, this viscous buildup of mucus creates a risk of mucus plugs and leads to severely decreased lung functions and to life-threatening respiratory infections. In the digestive and endocrine systems, ducts become blocked stopping the flow of digestive enzymes which affects the body’s ability to break down the food it consumes and the pancreas does not function properly, inducing diabetes. Currently, there is no cure for cystic fibrosis, only symptom management. As this disease progresses and pulmonary function continues to decline, the best option for many cystic fibrosis patients is lung transplantation. Here, we present a 24-year-old female who received a double lung transplant in 2013 due to complications from cystic fibrosis. The patient did well post-transplant until 2015 when she presented with a respiratory infection that led to rapid, progressive decline in lung function and chronic rejection.

In October 2013, a 22-year-old underwent a bilateral lung transplant as a result of complications from cystic fibrosis. The patient tolerated the procedure on cardiopulmonary bypass and was transported to the intensive care unit in stable, yet guarded condition. Her recovery went well, and the patient was discharged home. She continued to progress until November 2015 when she developed an upper respiratory infection which resulted in a rapid decline in her lung function, as shown on her pulmonary function tests, and brought her into chronic rejection. She presented to the emergency room in April 2016 with hypercapnic respiratory failure. She was relisted for lung transplantation and with the help of a team of doctors, it was decided that extracorporeal membrane oxygenation was her best option as a bridge to transplant. She was brought to Cath Lab, placed under local anesthesia, and was cannulated in the right internal jugular vein with a 29 French ProteckDuo Dual-Lumen Cannula with the distal port in the main pulmonary artery and the proximal port in the right atrium. Veno-venous ECMO was then initiated with a Thoratec Centrimag centrifugal pump and a Maquet Quadrox-I adult oxygenator.

The patient remained on VV ECMO for 11 days; during which time, she was able to ambulate each day with the assistance of a team of specialist consisting of perfusionists, nurses, and ECMO specialists. The patient was able to walk out of her room and down the hall of the ICU, as well as move from her bed to an upright chair for a couple of hours each day. To do this the cannula and lines were secured with a bandage around the cannula and patient’s head and a helmet that a team of perfusionists created. On the eleventh day of ECMO, she was matched with a pair of lungs and was brought to the operating room to undergo a redo bilateral lung transplant.

Surgery was well tolerated; she remained in the hospital for another 20 days until discharged home where she continues to recover from her second bilateral lung transplant status post VV ECMO.
Utilizing Veno-Venous Extracorporeal Membrane Oxygenation in Cases of Respiratory Failure due to Severe Mucous Plugging

Steven Nye, MD¹, Ashley Brown, MD¹, Debbie Laney, MSN², Margaret Winkler, MD¹, Chrystal Rutledge, MD¹

¹University of Alabama at Birmingham School of Medicine, Department of Pediatrics, Division of Pediatric Critical Care, Birmingham, Alabama
²Children’s of Alabama, ECMO Services, Birmingham, Alabama

Veno-Venous Extracorporeal Membrane Oxygenation (VV ECMO) is becoming more commonly used in the treatment of refractory status asthmaticus in pediatric patients. However, not everything that wheezes turns out to be asthma. We present the cases of two pediatric patients who presented to our institution within one month of each other with presumed refractory status asthmaticus. Both patients failed medical management, including continuous albuterol, intravenous steroids, intravenous magnesium, and continuous terbutaline. Additionally, both patients required intubation and failed to improve with sedation using Ketamine, paralysis, and inhaled anesthesia with isoflurane, ultimately requiring VV ECMO until recovery of lung function. Both patients were maintained on circuit utilizing an EOS membrane oxygenator, a Sorin Revolution centrifugal pump, and a Minntech 400 hemofilter.

The first patient, a 12 year-old African-American (AA) female with a history of severe, poorly-controlled asthma and multiple PICU admissions, presented with a one-day history of cough, chest tightness and wheezing. She progressively worsened despite the medical management outlined above (except continuous terbutaline), necessitating intubation and inhaled isoflurane. After intubation she developed bilateral pneumothoraces requiring chest tube placement. Due to worsening hypercarbia, she was cannulated for VV ECMO with a Biomedicus 21 French (Fr) cannula in the right internal jugular vein and a 19 Fr cannula in the right femoral vein. Bronchoscopy while on ECMO revealed significant secretions and mucous plugging, which were successfully removed, improving lung compliance. She required 163 hours of ECMO until recovery.

The second patient, an 8 year-old AA male, had a remote history of asthma without regular symptoms or the routine use of beta agonists. He presented with a two-day history of fever, cough, congestion and wheezing and was presumptively diagnosed with status asthmaticus. Even with maximal therapy as detailed above, he worsened and required intubation and trial of isoflurane. He had significantly elevated peak inspiratory pressures, resulting in a left-sided pneumothorax requiring chest tube placement. He was placed on ECMO for refractory status asthmaticus. In preparation for ECMO, he was cannulated with a Biomedicus19 Fr cannula in the right internal jugular vein and a 17 Fr cannula in the right femoral vein. Bronchoscopy while on ECMO revealed significant secretions and mucous plugging, which were successfully removed, improving lung compliance. She required 163 hours of ECMO until recovery.

These cases serve to illustrate the utilization of ECMO in cases of respiratory failure refractory to traditional therapies when diffuse bronchial plugging is presumed. In addition, these cases identify the safety and utility of therapeutic bronchoscopies in patients requiring VV ECMO for respiratory failure.

Steven Nye, MD
Children's of Alabama, 1600 7th Ave South, CPPI Suite 102, Birmingham, AL 35233
Phone: 205-638-3342, Email: stevennye@uabmc.edu
Title: Catecholamine Induced Ventricular Fibrillation and Extracorporeal Membrane Oxygenation in a Pediatric Patient: A Unique Case Report

Authors: Dan Patrick BSN, RN; Betsy Moore MSN, RN; Samantha Ransone BSN, RN

Institution: Le Bonheur Children’s Hospital, Memphis, Tennessee

Background: In January of 2015, a four year old female was brought into an outlying emergency department following a witnessed pulmonary arrest. En route to the emergency department she began having seizure like activity and upon arrival was pulseless and cyanotic. Cardiopulmonary resuscitation (CPR) was initiated and the patient was intubated. Following a brief return to normal sinus rhythm, the patient went into ventricular fibrillation requiring defibrillation. After defibrillation, the patient was asystolic and chest compressions were given along with two doses of epinephrine which elicited a sinus tachycardic rhythm with adequate circulation and pulses. The patient was immediately transported to the regional pediatric ECMO center and admitted to the Pediatric Intensive Care Unit (PICU). Initial vital signs on admission to PICU were a heart rate of 163, blood pressure of 121/78, temperature of 35°C, and oxygen saturation of 99%. The next morning, the patient again went into ventricular fibrillation which led to 87 minutes of on-again, off-again CPR that required nine doses of epinephrine, one defibrillation attempt, two doses of amiodarone, two doses of sodium bicarb, one dose of calcium chloride, one dose of magnesium, a normal saline bolus, an amiodarone drip, and an epinephrine drip. Despite medical interventions, the patient persisted in ventricular fibrillation and was placed on ECMO.

ECMO Course: The patient was cannulated and placed on Veno-Arterial ECMO with 15 French arterial and 17 French venous cannulae. The initial ECMO flow rate was approximately 1.3 liters per minute (LPM) with an initial sweep gas setting of 0.5 LPM and the patient was placed on resting ventilator settings with a respiratory rate of 20 and a peak end expiratory pressure of 10. Twenty-four hours post-ECMO initiation, the blood gas displayed a pH of 7.37, PaCO2 of 41, PaO2 of 225, and HCO3 of 25 with an ECMO flow of 1.638 LPM. During the ECMO run the patient was maintained on minimal sedation and responded easily to yes/no questions. Flow rates during the ECMO run ranged between 1.3 -1.7 LPM along with a sweep gas rate between 0.5-1.1 LPM. The ECMO course was relatively uneventful and consisted of one venous air emergency where flow was immediately restored and the patient did not decompensate.

Conclusions/Implications: While on ECMO the patient was diagnosed with catecholamine induced ventricular fibrillation and was started on beta blocker medication. After four days on ECMO, the patient was successfully weaned and decannulated and transferred to the Cardiovascular Intensive Care Unit for follow-up cardiac care where she was extubated the next day. Following extubation, the patient remained on a beta blocker and showed no further signs of ventricular fibrillation. A permanent cardiac pacemaker was eventually placed along with a single chamber implantable cardioverter/defibrillator. The patient tolerated all post-ECMO procedures exceptionally well and was discharged home eight days after coming off ECMO support.

This case highlights a unique condition not often seen or diagnosed in pediatric patients. The use of VA ECMO to maintain the patient’s condition while working toward a diagnosis and plan of care is an example of ECMO as a bridge, even when the team is not sure where that bridge will end. In this situation, quick decision-making and excellent care led to a child with a rare condition recovering and going home to her family.

Contact Information: Dan Patrick
848 Adams Avenue, 5th floor PICU, Memphis, TN 38103
901-287-8500
Daniel.patrick@lebonheur.org
Impact of hemodialysis on mortality rate in children with extracorporeal membrane oxygenation: an analysis of KID database

Himani Pulivarthi, MD¹; Fernando Beltramo, MD²; Balagangadhar R. Totapally, MD²,³

¹Medical Graduate, Mamata Medical College, India.
²Division of Critical Care Medicine and Nicklaus Children’s Hospital, Miami, FL 33155,
³Herbert Wertheim College of Medicine, Florida International University, Miami, FL 33199

BACKGROUND: Acute kidney injury (AKI) and fluid overload is common among children on Extra Corporeal Membrane Oxygenation (ECMO) support. Ongoing systemic inflammation, hypercoagulable state and hemoglobinuria results in AKI. High volume of distribution and need for frequent blood product transfusion during ECMO therapy causes significant fluid overload.

OBJECTIVE: The objective of this study was to evaluate the effect of the use of dialysis on mortality rate in children receiving ECMO therapy.

DESIGN/METHODS: A retrospective analysis of the Healthcare Cost and Utilization Project 2012 Kids’ Inpatient Database was performed. The database was filtered using ICD-9 procedure code for extracorporeal membrane oxygenation (39.65 and 39.66), hemodialysis (39.95). Sample weighting was employed to produce national estimates. Chi-square test, student t-test and binary regression analyses were performed using SPSS to analyze the data.

RESULTS: A total of 2111 children, including neonates who received ECMO therapy during 2012 with an overall mortality rate of 40.5%. Hemodialysis was done in 161 (7.6%). The mortality was significantly higher in children receiving hemodialysis (56.5% vs 39.2%) and cardiac surgery (46.2% vs 38.2%). Hemodialysis is associated with increased mortality in neonates (51.6% vs. 38.7%; p<0.05) and children (59% vs. 39.7%; p<0.05) but not in infants (60.8% vs. 40% p>0.05) or in cardiac surgical patients (54.8% vs 45.7%; OR 1.4, CI: 0.7-3.0).

CONCLUSIONS: This study provides an estimate of overall mortality rate in pediatric patients on ECMO and those who required renal support. The mortality rate was higher in patients with concurrent ECMO and hemodialysis compared to ECMO alone, especially in the neonatal age group and children.

Contact Author:
Balagangadhar R. Totapally MD, DCH, MRCP, FAAP, FCCP, FCCM.
Division of Critical Care Medicine and Nicklaus Children’s Hospital, Miami, FL 33155.
Herbert Wertheim College of Medicine, Florida International University, Miami, FL 33199.
Email Id: Balagangadhar.Totapally@mch.com
Tel: 305 662 2639 / Fax: 305 663 0530
Fluid Administration and Survival in Patients Receiving Veno-venous ECMO for ARDS

Britton A Blough, MD, Desiree Bonadonna, BSE, CCP, LP, Mani A Daneshmand, MD, Craig R Rackley, MD
Duke University Medical Center
Durham, North Carolina

Objective: To determine if larger volume of fluid resuscitation correlates with worsened survival in patients receiving veno-venous ECMO support for acute respiratory distress syndrome (ARDS).

Methods: Adult patients with severe ARDS at a single institution supported with veno-venous ECMO from January 2014 through May 2016 were evaluated to determine the relationship between overall survival and the average fluid balance over the first 5 days of ECMO support. Using the Respiratory ECMO Survival Prediction (RESP) score, we compared the predicted and actual mortalities for those patients with <1.5 L/day positive fluid balance versus those patients with >1.5 L/day positive fluid balance.

Main Results: Of the 53 patients evaluated, the predicted versus actual survival was 67% and 57%, respectively. There were a total of 29 patients who had an average of <1.5 L/day positive fluid balance and 24 patients with an average of >1.5 L/day positive fluid balance. In the group positive <1.5 L/day, the predicted survival was 70% and the actual survival was 79% (p=.37). Conversely, in the group positive > 1.5 L/day the predicted survival was 64% and the actual survival was 29% (p = .02). The average daily fluid balance of patients who survived was 1.1 L (standard deviation 2.1 L) compared to 2.9 L (standard deviation 1.0 L) in the patients who expired (p = 0.001). There was no difference in vasopressor requirements, need for hemodialysis, or total duration of ECMO support between groups.

Conclusions: In patients receiving veno-venous ECMO support for severe acute respiratory failure, larger volume of fluid resuscitation is associated with worsened survival.
Prevalence and pattern of thrombelastography-based hyperfibrinolysis in children during ECMO

Shashi Raj MD1, M Bridget Zimmerman PhD2, Vasundhara P Kailasnath MD1, W Joseph Turek MD, PhD1

1Stead Family Department of Pediatrics, University of Iowa Children's Hospital, 2University of Iowa, Iowa City, IA.

Background: Coagulopathy due to hyperfibrinolysis (HF) is not well described in patients supported on extra corporeal membrane oxygenation (ECMO) despite the known challenges of hemostasis in such patients. This is partly related to the inability of conventional laboratory tests like platelet count, fibrinogen level and fibrin degradation products including D-Dimer to quantify fibrinolysis. We hypothesized that whole blood viscoelastic coagulation testing using thrombelastography (TEG®) will identify the prevalence and pattern of hyperfibrinolysis in children supported on ECMO.

Methods: This retrospective chart review of prospectively collected data was approved by the institutional review board and included all children admitted to the pediatric critical care unit who required ECMO support since January 1, 2012 when the TEG® testing was introduced as part of hemostasis management in our institution. We collected demographic data, pediatric logistic organ dysfunction score (PELOD-2), use of blood products and antifibrinolytic agents (aminocaproic acid or tranexamic acid), mode and duration of ECMO, conventional coagulation assays, TEG® parameters (citrated kaolin with and without heparinase) and clinical outcome data. LY3-30 is a measure of fibrinolysis determined by TEG® that reflects the reduction in the tracing area 30 minutes after maximum amplitude. HF was defined as LY-30 ≥ 7.5%.

Results: There were 4168 total admissions to the pediatric critical care unit during the study period out of which 44 children (age range 1day – 18 years; 19 male: 25 female) required ECMO support with a total of 47 ECMO runs. ECMO survival was 61.7% (29/47 ECMO runs) and hospital survival was 38.6% (17/44 patients). There were 228 TEG® results available in 33 ECMO patients. LY-30 range was 0-21.9 % (median LY-30 = 0; interquartile range = 0-0.3). HF was observed in 9 out of 228 TEG® results (3.9%) and the overall prevalence of HF was 18% (6/33 patients). All patients with HF had coagulation index ≤ 1 possibly suggesting primary HF although data on D-Dimer in those patients were incomplete. We found no patient with HF and coagulation index ≥ 3 (secondary HF). On bivariate association using Fisher exact test, there was no significant difference in HF between the groups (with and without ECMO survival p = 1 and with and without hospital survival p= 0.375). By multivariate analysis of variance using Wilcoxon Rank sum test, HF was significantly associated with older age (p = 0.02), peak lactate prior to ECMO (p = 0.03) and antithrombin III administration (p = 0.005) but not with use of antifibrinolytic agents, or other blood product administration.

Conclusions: In our single center cohort of children supported on ECMO, the prevalence of hyperfibrinolysis based on TEG® testing was 18%. HF in children on ECMO was not associated with use of antifibrinolytic agents or blood product utilization except administration of anti-thrombin III concentrate. HF was not significantly different from those who survived ECMO and those that had successful hospital discharge.

Figure1: Thromboelastography tracings of ECMO patients with and without hyperfibrinolysis [Panel 1 (HF with normal maximum amplitude); Panel 2 (HF with abnormal maximum amplitude); Panel 3 (normal tracing without HF)].
Open Femoral Cannulation in Extracorporeal CPR: A Faster and Safer Method than Percutaneous Cannulation

David N Ranney MD, Babatunde Yerokun MD, Desiree Bonadonna, John C Haney MD, Jacob N Schroder MD, Carmelo A Milano MD, Mani A Daneshmand MD
Duke University Medical Center

PURPOSE – Percutaneous femoral cannulation for extracorporeal CPR (ECPR) is prone to vascular complications and delays in cannulation. Cannulation technique in ECPR has not been previously or adequately evaluated. The purpose of this study was to compare the incidence of complications and cannulation times for open versus percutaneous femoral cannulation in ECPR.

METHODS – We retrospectively reviewed 19 adults undergoing emergent femoral arterial and venous cannulation for veno-arterial (VA) ECMO at our institution from January 1, 2014 to April 1, 2016. Patients were divided into two cohorts, those undergoing open cannulation and those undergoing percutaneous cannulation. Patient characteristics, cannulation technique, use of a distal perfusion cannula, incidence of vascular complications, and cannulation and deployment times were extracted from the medical record. Patients with prior femoral vascular access were excluded from the study. Standard descriptive statistics were used to represent our findings.

RESULTS – Of 19 adults, 5 underwent open cannulation and 14 underwent percutaneous cannulation. Patient characteristics and arterial cannula size were similar between groups. Distal perfusion cannulae were placed in all 5 (100%) open cannulations compared to 4 of 14 (28.6%) percutaneous cannulations. Overall vascular complications occurred in 2 of 5 (40%) open cannulations compared to 11 of 14 (78.6%) percutaneous cannulations. Both open complications were limb ischemia requiring one amputation and one conversion to central cannulation. Percutaneous complications included 3 placements in the incorrect lumen, 4 mechanical vessel injuries requiring repair, 2 major cannula site bleeds, 3 unsuccessful attempts requiring crossover to open cannulation, and 8 episodes of limb ischemia, 3 of which required fasciotomy and/or amputation. Median time from deployment to cannulation was 15 minutes (range 9-23) in the open group compared to 21 minutes (range 17-73) in the percutaneous group.

CONCLUSIONS – Open femoral cannulation in ECPR can be performed in less time and with less vascular complications compared to percutaneous cannulation. Early antegrade limb perfusion can be successfully achieved more frequently with open cannulation. Open cannulation speed will improve with surgeon experience and may eventually improve ECPR survival.

<table>
<thead>
<tr>
<th></th>
<th>Total (N=19)</th>
<th>Open (N=5)</th>
<th>Percutaneous (N=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with any vascular complication</td>
<td>13 (68.4)</td>
<td>2 (40)</td>
<td>11 (78.6)</td>
</tr>
<tr>
<td>Failed attempts requiring crossover</td>
<td>3</td>
<td>0 (0)</td>
<td>3 (21.4)</td>
</tr>
<tr>
<td>Extraluminal/wrong lumen</td>
<td>2 (10.5)</td>
<td>0 (0)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Mechanical vessel injury requiring repair</td>
<td>4 (21.1)</td>
<td>0 (0)</td>
<td>4 (28.6)</td>
</tr>
<tr>
<td>Major cannula site bleeding</td>
<td>2 (10.5)</td>
<td>0 (0)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Relocation of cannula, non-ischemic</td>
<td>2</td>
<td>0 (0)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Limb ischemia requiring:</td>
<td></td>
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<tr>
<td>Relocation of cannula</td>
<td>4</td>
<td>1 (20)</td>
<td>3 (21.4)</td>
</tr>
<tr>
<td>DPC placement</td>
<td>2 (10.5)</td>
<td>0 (0)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Fasciotomy/Amputation</td>
<td>4 (21.1)</td>
<td>1 (20)</td>
<td>3 (21.4)</td>
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<td>Survival to decannulation</td>
<td>7 (36.8)</td>
<td>2 (40)</td>
<td>5 (35.7)</td>
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<td>Survival to hospital discharge</td>
<td>3 (15.8)</td>
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<td>3 (21.4)</td>
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<td>Ambulatory survivors at discharge</td>
<td>2 (66.7)</td>
<td>0 (0)</td>
<td>2 (14.3)</td>
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</table>
Veno-Arterial ECMO Improves Renal Function in Cardiogenic Shock

David N Ranney MD, Babatunde Yerokun MD, Kevin Anderson, Carol Traynor MD, Desiree Bonadonna, John C Haney MD, Jacob N Schroder MD, Carmelo A Milano MD, Raquel Bartz MD, Ruediger Lehrich MD, Mani A Daneshmand MD

Duke University Medical Center

INTRODUCTION – Acute renal failure is a predictor of mortality in cardiogenic shock. The association between acute renal recovery and use of veno-arterial (VA) ECMO has not been previously described. The purpose of this study was to describe the incidence and predictors of renal recovery in adults on VA ECMO.

METHODS – We reviewed 54 adults undergoing VA ECMO at our institution between 8/2013 and 12/2015. Creatinine (Cr) and urine output within 48 hours of cannulation were collected. Renal recovery (RR) was defined as a decrease in Cr following cannulation without the use of renal replacement therapy (RRT). Patients on chronic dialysis were excluded. RR and non-RR patients were compared using univariate analysis. Predictors of renal recovery were assessed using multivariable logistic regression.

RESULTS – Of 54 patients, RR occurred in 24 following cannulation (44.4%). Demographics were similar between cohorts, although BMI was greater in RR vs non-RR patients (26.7 vs 32.6, p=0.025). The prevalence of diabetes, hypertension, and pre-ECMO balloon pump were not statistically different. Pre-ECMO CKD was present in 4.2% of RR versus 17.2% of non-RR patients (p=0.289). Mean Cr at time of cannulation was 1.6 (IQR 1.3-2.1) for RR patients and 2.1 (IQR 1.7-2.8) for non-RR patients (p=0.029). Among 30 non-RR patients, RRT was required in 3 (10%) and 15 (50%) patients before and after cannulation, respectively. No hospital survivors required dialysis at discharge. Overall survival at a mean follow up of 7 months was 45.8% in RR patients and 31.0% in non-RR patients (p=0.411). Cr at time of cannulation (OR 0.38, CI 0.14-0.94, p=0.05) and history of cardiac surgery (OR 6.10, CI 1.56-30.29, p=0.02) were predictors of RR. BMI as a negative predictor of RR trended towards significance (OR 0.89, CI 0.77-1.00, p=0.06).

CONCLUSIONS – VA ECMO improves renal function in cardiogenic shock. Lower pre-ECMO Cr, lower BMI, and history of prior cardiac surgery were associated with renal recovery.
Title: Extracorporeal Membrane Oxygenation in a Pediatric Allogeneic Hematopoietic Stem Cell Transplant Recipient: A Case Report of an Evolving Practice

Authors:
Samantha Ransone, BSN, RN; Caitlin Hurley, MD; Hitesh Sandhu, MD; Saad Ghafoor, MD; R. Ray Morrison, MD; Samir Shah MD, MBA, FRCPC

Institutions: Le Bonheur Children’s Hospital; Department of Oncology, St. Jude Children’s Research Hospital; Department of Pediatrics, University of Tennessee Health Science Center; Department of Pediatric Medicine, St. Jude Children’s Research Hospital; Memphis, Tennessee

Background: A severely immunocompromised, 18 year-old female was placed on extracorporeal membrane oxygenation (ECMO) for acute respiratory failure and sepsis post hematopoietic stem cell transplant (HSCT) from a matched unrelated donor as curative therapy for Diamond Blackfan Anemia. She was conditioned with chemotherapy, and the post HSCT course included respiratory, cardiac, and infectious complications requiring intensive care and mechanical ventilation on day 69 post HSCT. Her pulmonary status deteriorated further on day +72 with bilateral pulmonary infiltrates and hypoxia requiring high frequency oscillatory ventilation. On day +76 with OIs of 39-41 and ventilatory failure, she was transferred to the regional pediatric ECMO center.

ECMO Course: Percutaneous veno-venous cannulation was performed with two 21-french Biomedicus (Medtronic, Minneapolis, MN, USA) cannulas placed in the right femoral and right internal jugular veins. The patient was supported with initial blood flows of 2.16 liters per minute (LPM) and a sweep gas flow of 3 LPMs using the Maquet Rotaflow centrifugal pump and Quadrox-iD adult oxygenator (Maquet, Harlingen, Germany). Over the 7 day ECMO course, pump blood flows ranged from 2.16 LPM to 3 LPM and sweep gas flow from 1 LPM to 6 LPMs. While on ECMO, the patient was minimally sedated, frequently repositioned and received aggressive pulmonary clearance. On ECMO day 5, the chest x-ray and arterial blood gases were markedly improved. The sweep was weaned and the patient was successfully trialed off ECMO and decannulated. She returned to the referring institution 3 days later.

Conclusions/Implications: While provision of ECMO as a supportive therapy for patients post HSCT remains controversial, this case illustrates the potential for therapeutic benefit in this population. The patient was transplanted for a non-malignant disease, she had few comorbidities, and HSCT conditioning was the only chemotherapy exposure, all factors that favored recovery with ECMO support. Therefore, use of ECMO in immunocompromised patients should be evaluated on an individual basis, particularly in the HSCT population. In addition, early recognition of need for ECMO, timely inter-institutional transfer, modification of institutional ECMO exclusion criteria and the success of minimal sedation are highlighted by this case. Both the accepting and referring institutions continue to develop a standard pathway for early recognition and transfer of patients who may require ECMO. Second, the sedation practices of the ECMO institution were challenged and early mobilization techniques utilized were effective. Institutions caring for patients on ECMO should continuously evaluate sedation practices to promote early patient mobilization.

Contact Information: Samantha Ransone
848 Adams Avenue, 5th floor PICU, Memphis, TN 38103
901-508-1672
samantha.ransone@lebonheur.org
**Plasma F₂-Isoprostanate Levels In Neonatal Extra Corporeal Membrane Oxygenation**

Reitman AJ¹,², Chapman R¹, Bliss D³, Wisnowski JL¹, Coates TD⁴, Friedlich PS¹, Milne GL⁵, Wood JC⁶

¹USC Division of Neonatal Medicine LAC+USC Medical Center; ²Center for Fetal and Neonatal Medicine, USC Division of Neonatal Medicine, Children's Hospital Los Angeles, Keck School of Medicine of USC, Los Angeles, CA, United States; ³Division of Pediatric Surgery, Children's Hospital Los Angeles, Keck School of Medicine, USC, Los Angeles, CA ⁴Children’s Center for Cancer and Blood Diseases, Children's Hospital Los Angeles, Los Angeles, CA; ⁵Eicosanoid Core Laboratory, Vanderbilt University School of Medicine, Nashville, TN; ⁶Division of Cardiology Children's Hospital Los Angeles, Keck School of Medicine, USC, Los Angeles, CA.

**Background:** Neonates are managed with extracorporeal membrane oxygenation (ECMO) for refractory hypoxemic respiratory failure. While on ECMO, the blended oxygen exposes the neonate to high oxygen concentrations. It is believed that neonates treated with ECMO are exposed to reactive oxygen species, typically free radicals that can induce oxidative injury. F₂-isoprostanate (F₂-Isop) is a prostaglandin-like molecule formed in vivo by free radical mediated oxidation of arachidonic acid. F₂-Isop is an ideal biomarker to assess in vivo oxidant stress.

**Purpose:** The purpose of this study is to evaluate oxidative stress by measuring plasma F₂-Isop levels during ECMO treatment in neonates.

**Methods:** In this prospective study, plasma F₂-Isop levels were measured in term neonates at three different time points: immediately before ECMO support, 24 hours into ECMO, and 24 hours post ECMO. Plasma F₂-Isop levels were analyzed by using gas chromatography and mass spectrometry and compared across time points using paired-t-tests.

**Results:** To date, we have enrolled 21 patients and here we present the preliminary data from the eleven patients (mean gestational age 40.1 ± 1.9 weeks; birth weight of 3.66 ± 0.4 kg). The average duration of ECMO support was 189 ± 130 hours [64-555 hours]. We observed higher F₂-Isop levels before ECMO (0.10±0.05 ng/ml) and during ECMO (0.11±0.05) as compared to after ECMO (0.05 ± 0.01 ng/ml). Paired t-tests: \( p_{(pre-post)} = 0.09; p_{(during-post)} < 0.01 \). Interestingly, we observed individual variability in F2-Isop levels pre-ECMO and during ECMO, with the highest values observed among neonates with sepsis.

**Conclusion:** This is the first study to use F₂-IsopS to evaluate oxidative stress in neonates being treated with ECMO. These preliminary data suggest that the oxygen-enriched environment during ECMO may contribute to oxidative stress in neonates as quantified by a significant decrease in F₂-IsopS following ECMO. Additionally, it appears that the underlying disease may contribute to an independent rise in F₂-IsopS. Further studies are warranted to delineate the oxidative stress responses related to ECMO therapy.

Funding provided by The Gerber Foundation.

Contact: Aaron J. Reitman
144 N. Carson Rd
Beverly Hills, CA 90211
Cell: 847-530-1019
areitman@chla.usc.edu
Extracorporeal Membrane Oxygenation (ECMO) Single Caregiver Model: A Simplified Approach to a Complex Treatment Modality

Melody Ricks, RN, Bruno Sambuco, CCP, Farzad Najam, MD, Elizabeth Pocock, MD

The George Washington University Hospital

Introduction: Use of extracorporeal membrane oxygenation (ECMO) in the adult population has seen an exponential increase over the past decade. One of the main limitations to its widespread application is the complexity of the device, and the need for care to be provided by multiple caregivers. Our institution has adopted a simplified circuit that has enabled us to provide care by a single bedside nurse.

Methods: At The George Washington University Hospital (GWUH), a cardiac-trained nurse undergoes ECMO training and certification consisting of an eight hour didactic course, and one simulation course per year. Annually, a written exam and simulation demonstration is required.

One integral component is a simple and modified circuit with the Tandem Heart ™ (Cardiac Assist, Pittsburgh PA) pump and controller, with user friendly display and controls. This enables the bedside nurse to perform all required critical care for the patient, as well as ECMO management.

Results: In 2008 the ECMO program at GWUH was established, and the single caregiver model adopted. The role of the single ECMO nurse has proven to simplify care delivery to these complex patients, increase job satisfaction and retain experienced nurses. This has resulted in a significant cost-saving measure as a separate perfusionist is no longer required.

Conclusions: This emphasis on optimal resource utilization with a simplified method of care delivery and equipment has enabled the success and growth of our ECMO program. These changes have transitioned a cost-prohibitive treatment into a feasible modality.

Melody Ricks, RN

2131K St, NW, Suite 700, Washington, DC 20037

202-715-5700

melody.ricks@gwu-hospital.com

This abstract was previously entered at EuroELSO. Mr. Rycus is aware.
Veno-venous Extracorporeal Membrane Oxygenation Can Be Managed with Lower Activated Clotting Times

Farzad Najam, MD, FACS, Bruno Sambuco, CCP, Melody Ricks, RN, Elizabeth Pocock, MD

The Division of Cardiac Surgery, The George Washington University Hospital, Washington, DC

Introduction:

Veno-venous Extracorporeal Membrane Oxygenation (V-V ECMO) is utilized for the management of patients in respiratory failure. The use of anticoagulation is necessary for the management of the V-V ECMO circuit but can be associated with hemorrhagic complications. We propose that patients on V-V ECMO can be managed with lower activated clotting times (ACT).

Methods:

At our institution, we managed seven patients who required utilization of V-V ECMO with heparinization and lower ACT goals of 160-180 seconds. Tubes containing celite were used to measure the ACTs. There were four female and three male patients in the group. All patients were placed on V-V ECMO using a bicaval, dual lumen, single site cannula inserted via the right internal jugular vein. Patients’ age ranged from thirty years to seventy years. The total number of days on V-V ECMO for all patients was one hundred and eighty.

Results:

Five patients were successfully weaned off of ECMO. Five patients were successfully discharged from the Intensive care unit and the hospital. Four patients required their oxygenator to be replaced. One patient needed the circuit to be replaced. The total number of units of packed red blood cells used for our patients was one hundred and forty three.

Conclusion:

Patients who require V-V ECMO for respiratory failure can be safely managed with lower ACT goals that can reduce the incidence of hemorrhagic complications without compromising the safety of V-V ECMO.

Address correspondence to:

Farzad Najam, MD

2131 K Street, NW, #700

Washington, DC 20037

Tel: 202-715-5700

Email: farzad.najam@gwu-hospital.com
ECMO Transport: The Mobile Cannulation Experience

Melody Ricks, RN, Bruno Sambuco, CCP, Farzad Najam, MD, Elizabeth Pocock, MD

The George Washington University Hospital

Introduction: Critically ill patients frequently require transfer to a facility with higher level of care capabilities. In order to safely transport this patient population, The George Washington University Hospital (GWUH) has implemented a mobile ECMO cannulation and transport team. The team and equipment were carefully selected to accommodate space limitations. Training and activation protocols were established. The transportation vehicle was designed to accommodate our unique population.

Methods: A large ambulance was selected to accommodate five providers and an adult patient. The team included a cardiac surgeon, perfusionist, cardiac operating room scrub nurse, ECMO nurse and paramedic. The Tandem Heart ™ (Cardiac Assist, Pittsburgh PA) pump was chosen for the ECMO circuit secondary to its compact size and user-friendly controller. A stretcher was reconfigured to securely support an ECMO console, monitor and IV infusion pumps. The patient placement within the ambulance was modified in order to increase work space. Supplementary equipment including a power inverter, medical air and additional oxygen were installed.

Results: The ECMO transport team has become proficient moving critically ill patients safely within the region. At The GWUH, this approach has enabled safe transport of all patients to date.

Conclusions: Safe, mobile ECMO cannulation and transfer has been made possible by careful planning, training, vehicle modification, user friendly equipment and safety considerations. We have determined for our team a radius of 100 miles, or 2 hours of travel time as our limit. The limiting factors are based on oxygen, medical air consumption, amount of drugs, and blood products available.

The challenges identified at this time include; community hospital physician education, developing a plan for activation from neighboring hospitals, and air transport.

Melody Ricks, RN

2131K St, NW, Suite 700, Washington, DC 20037

202-715-5700

melody.ricks@gwu-hospital.com

This abstract was previously submitted to EuroELSO. Mr. Rycus is aware.
Extracorporeal membrane oxygenation (ECMO) has potential complications including hemorrhage that may be exacerbated by anticoagulation, platelet dysfunction, and hemodilutional or consumptive coagulopathy. While anticoagulated ECMO patients are monitored by activated partial thromboplastin time (aPTT) and prothrombin time (PT), these values may not accurately represent the actual coagulation status of the patient. TEG provides a more complete analysis of coagulation status through the use of whole blood rather than plasma fractions.

Case: a 49-year-old male with severe pneumoconiosis underwent bilateral lung transplant with venovenous ECMO support. On post-operative day (POD) 6, ECMO was discontinued. The patient was placed back on ECMO on POD 8 due to aspiration pneumonia and non-HLA antibody mediated rejection requiring plasma exchange. Three weeks post-transplant, coagulopathy was identified after due to continuous bleeding from the percutaneous tracheostomy site. After multiple transfusions and attempts to cauterize the site, serial TEG analyses (Table 1) was performed.

TEG 1, drawn prior to decannulation on POD 22, demonstrated an elevated LY30 (fibrinolysis) and low MA (platelet function). Although the LY30 improved after decannulation, it did not normalize. Subsequent TEG analyses guided directed transfusion therapy of his coagulopathy: platelets for a low MA and cryoprecipitate for low fibrinogen. Analysis 4 was particularly striking with evidence of early disseminated intravascular coagulation (DIC) and secondary fibrinolysis demonstrated by the shortened R time, elevated LY30, and angle. Based on this TEG, 500 units of intravenous heparin were administered. Repeat TEGs performed (with heparinase) showed rapid correction of the coagulopathy and fibrinolysis with cessation of tracheostomy bleeding. Further transfusions were not required due to the corrected MA.

TEG is not yet the standard practice for monitoring patients’ coagulation state. It may serve as a diagnostic tool that enables tailored treatment of coagulopathies. In this case, TEG assisted in the diagnosis of a difficult to detect disease state, low grade DIC on ECMO, thus enabling a rapid therapeutic intervention that otherwise would not have been made.

Table 1: Timeline of TEG analysis and interventions taken

<table>
<thead>
<tr>
<th>Day - Time</th>
<th>TEG</th>
<th>R-value (min)</th>
<th>K-value (min)</th>
<th>Angle (degrees)</th>
<th>MA (mm)</th>
<th>LY30 (%)</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>POD 22 - 05:49</td>
<td>1</td>
<td>4.8 (L)</td>
<td>1.7</td>
<td>66.1</td>
<td>37.2 (L)</td>
<td>30.2 (H)</td>
<td>-1.9</td>
</tr>
<tr>
<td>POD 22 - 09:29</td>
<td></td>
<td></td>
<td></td>
<td>Decannulated from ECMO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POD 22 - 09:37</td>
<td>2</td>
<td>4.7 (L)</td>
<td>1.9</td>
<td>64.5</td>
<td>37.6 (L)</td>
<td>11.0 (H)</td>
<td>-2.1</td>
</tr>
<tr>
<td>POD 22 - 12:49</td>
<td></td>
<td></td>
<td></td>
<td>Received cryoprecipitate &amp; Plts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POD 22 - 12:24</td>
<td>3</td>
<td>4.6 (L)</td>
<td>1.2</td>
<td>72.0</td>
<td>47.4 (L)</td>
<td>12.2 (H)</td>
<td>0.0</td>
</tr>
<tr>
<td>POD 23 - 03:54</td>
<td>4</td>
<td>2.8 (L)</td>
<td>1.0</td>
<td>76.4 (H)</td>
<td>64.1</td>
<td>14.7 (H)</td>
<td>3.6</td>
</tr>
<tr>
<td>POD 23 - 10:16</td>
<td></td>
<td></td>
<td></td>
<td>Received platelets &amp; IV Heparin Administered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POD 23 - 12:25</td>
<td>5</td>
<td>5.9</td>
<td>1.2</td>
<td>72.0</td>
<td>64.1</td>
<td>0.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>POD 24 - 03:51</td>
<td>6</td>
<td>5.7</td>
<td>1.1</td>
<td>73.2 (H)</td>
<td>64.6</td>
<td>0.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Figure 1: TEG 4 Analysis

Figure 2: TEG 5 Analysis
**Prospective side by side comparison of outcomes and complications with a minimalist versus intensive anticoagulation monitoring strategy in pediatric ECLS patients**

J Yu¹, R Barbaro², D Granoski³, M Bauman³, MP Massicotte³, L Lequier³, G Annich⁴, **L Ryerson³**

¹University of California San Francisco, San Francisco, USA
²University of Michigan. Ann Arbor, Michigan, USA
³Stollery Children’s Hospital, Edmonton, Alberta, Canada
⁴Hospital for Sick Children. Toronto, Ontario, Canada

**Objective:** A continuous infusion of unfractionated heparin (UFH) is the most common anticoagulant used for pediatric patients on extracorporeal life support (ECLS). The optimal laboratory method to measure heparin efficacy on ECLS is unknown. The goal of this study was to compare ECLS complications and outcomes between two large volume pediatric ECLS centers who manage anticoagulation differently. The University of Michigan (UM) uses a minimalist anticoagulation monitoring strategy based exclusively on ACT while the University of Alberta (UA) employs an intensive anticoagulation monitoring strategy using anti-Xa, ACT as well as routine antithrombin monitoring and replacement.

**Methods:** Prospective, observational cohort study comparing minimalist anticoagulation monitoring center (UM) and intensive monitoring center (UA). The primary outcome measure was major bleeding per run defined as bleeding that was retroperitoneal, pulmonary or involved the central nervous system; bleeding > 20ml/kg over 24 hours or bleeding that required surgical intervention. Secondary outcomes included patient thrombosis per run, defined as central nervous system or solid organ infarct diagnosed by imaging; circuit thrombosis per run requiring complete circuit or component change; and survival to hospital discharge per patient.

**Results:** 88 patients (95 runs) less than 18 years of age were enrolled at the two centers over two years. 32 patients from UM had 33 runs and 56 patients at UA had 62 runs. The two centers enrolled different ECLS populations; UA enrolled more patients post cardiac surgery (74% vs. 47%; p=0.005). Expectedly, the indication for ECLS support also varied by center (p=0.04); UM cared for a greater proportion of respiratory support and UA cared for more ECPR. Nonetheless, two centers used similar proportions of VA ECLS (85% UM vs. 92% UA; p=0.3). Median (IQR) packed red blood cell transfusion requirements were lower at UM compared to UA (17 (11-27) ml/kg/day vs. 34 (19-49) ml/kg/day; p<0.001). Median (IQR) UFH doses were similar between UM and UA; 30 (21-34) U/kg/hr and 26 (22-31) U/kg/hr; p=0.2, respectively. ACTs were not comparable as different monitoring analyzers were used. Median (IQR) anti-Xa was lower in UM cohort (0.23 (0.19-0.28) U/ml vs. 0.41 (0.36-0.46) U/ml; p=0.001). Despite differences in patient cohort, blood product transfusion, monitoring intensity, and laboratory measurements, there were no differences in major clinical outcomes. There was no significant difference in major bleeding (27% UM vs. 21% UA; p=0.6) nor in patient thromboses (19% UM vs. 13% UA; p=0.5). There was no significant difference in survival to hospital discharge 63% vs. 75% for UM and UA, respectively. There were some differences, UM changed more oxygenators (16% vs. 3%; p=0.04) while UA performed more circuit changes (31% vs. 9%; p=0.02).

**Conclusion:** While this prospective cohort study compared different pediatric ECLS populations, the results did not identify a difference in outcomes between simple and intensive anticoagulation monitoring methods.

Lindsay Ryerson
Stollery Children’s Hospital, 8440-112 Street, WMC 3A3.19, Edmonton, AB T6G 2B7
ryerson@ualberta.ca
**Salisbury, C.** Davis, JC, Nix, C, Keene, S, Children’s Healthcare of Atlanta at Egleston

**Introduction:** Heparin dosage rates for neonatal respiratory ECMO patients at our institution have increased by 43% in the past three years without a change in targeted ACTs. Knowing that neonates have lower intrinsic ATIII levels when compared to other populations, we sought to review our ATIII practices. Ideal ATIII levels for neonates on ECMO are unknown.

**Methods:** Neonatal ECMO patients from 2013-2016 at our institution were reviewed (n=44). These patients were supported by a ¼ inch Sorin S3 rollerhead pump with a better bladder, Maquet Pediatric Quadrox, and Medtronic arterial filter. The following lab values were evaluated: ATIII levels, ATIII dosages, Anti-Xa levels, fibrinogen levels and FFP usage. We also reviewed hematologic complications.

**Results:** Baseline ATIII levels on ECMO ranged from 21-59%, with an average of 38%. Of the 44 patients, 33 were given ATIII at some point during their ECMO course. Treatment practices were inconsistent. The lowest ATIII level left untreated was 24%, while the highest level treated was 74%. ATIII dosages also varied greatly, ranging from 52 to 579 units per dose. The average ATIII dose was 253. ATIII levels did not consistently affect Heparin drip rates, but did raise Anti Xa levels. Higher ATIII and Anti Xa levels did not significantly correlate with less clotting of the circuit, nor did they result in a significant increase in intracranial hemorrhage.

**Discussion:** It is unclear whether the routine use of ATIII is warranted in the neonatal ECMO population. The data suggests that increasing ATIII levels may increase AntiXa, but this does not result in consistently lower heparin needs. It is unclear if higher ATIII and Anti Xa levels result in less circuit/component clotting. There are no guidelines for dosage amounts outside of congenital antithrombin deficiency, and the current guidelines for dosing do not account for the ECMO circuit blood volume. In addition, ATIII is extremely costly, especially when compared with heparin. In this population, an average dose of ATIII cost $885.5.

**Conclusion:** Further study is needed to determine the value of treating ATIII levels in the neonatal ECMO populations. While increasing ATIII did increase Anti Xa levels, this did not correlate with longer circuit life or Heparin dosages.

Christina Salisbury
1405 Clifton Road NE
Atlanta, GA 30322
(404) 785-1799
Christina.salisbury@choa.org
From the OR to the Bedside: Hemoconcentration in the ECMO Population

Authors: Bruno Sambuco, CCP; Melody Ricks, RN; Elizabeth Pocock, MD; Farzad Najam, MD

Institution: The George Washington University Hospital

Introduction

Hemoconcentrators are routinely utilized in open heart surgery in conjunction with a heart-lung machine for volume removal. This technology can also be used in the critical care setting.

At The George Washington University Hospital, we have used hemoconcentration for patients requiring extracorporeal membrane oxygenation (ECMO) support. One of the common findings in this critically-ill population is volume overload. Unlike continuous veno-venous hemodialysis (CVVHD), hemoconcentration enables rapid removal of plasma free water. This technology causes less electrolyte disturbances than CVVHD or intravenous diuretics. It can be incorporated into the ECMO circuit, thereby eliminating need for additional venous access. In addition, this has proven to be a cost-effective technology.

Methods

The hemoconcentrator membrane is primed and connected to the ECMO circuit. The perfusionist titrates the rate of volume removal, ranging from 10 minutes to several hours, as hemodynamically tolerated. During this time, several liters of fluid can be removed. The perfusionist manages the hemoconcentrator, eliminating the need for additional team involvement.

Results

Use of hemoconcentration has resulted in a significant cost-savings compared to CVVHD. In addition, it can be performed in a far shorter period of time, with less electrolyte disturbances, compared to CVVHD or IV diuretics. Hemoconcentration has helped us achieve earlier euvolemic status.

Conclusion

Hemoconcentration is a safe and effective way to remove volume. Plasma water can be removed without creating significant electrolyte imbalance. There is no requirement for additional vascular access. Compared to CVVHD, hemoconcentration is more cost-effective and a greatly simplified circuit.

Bruno Sambuco, CCP
4131 K Street NW, Suite 700, Washington, DC 20037
724-516-6833, Bruno.sambuco@gmail.com
*Presented at EuroELSO 2016 Conference and approved for submission by Peter Rycus
**Survey of ECMO Practices for Infants with Hypoxic Ischemic Encephalopathy**

Hitesh S. Sandhu, Kirtikumar Upadhyay, Mark F. Weems
Le Bonheur Children’s Hospital, University of Tennessee Health Science Center, Memphis, TN

**Purpose:** Therapeutic hypothermia is the standard of care for treating term neonates born with hypoxic ischemic encephalopathy (HIE). Up to 25% of these infants also suffer from pulmonary hypertension. Extracorporeal membrane oxygenation (ECMO) improves survival in neonates with pulmonary hypertension but is controversial in HIE patients because irreversible brain injury is a contraindication for ECMO. There is a concern that these patients may have increased risk of intracranial bleeding, ischemia, or stroke. The aim of this study is to identify ECMO practice preferences among centers and practitioners caring for infants with HIE.

**Methods:** A 22 question electronic survey was sent to neonatal medical directors and ECMO directors at 149 hospitals in the USA and Canada. Participants were asked if they would offer ECMO on a scale of 1 (Never) to 5 (Always) the responses were compared to Chapman et al, *J Perinatology*, 2008.

**Results:** We collected 89 responses representing 68 of 149 invited institutions (46%). Participants were 53% ECMO director, 57% NICU director, and 15% both. 72% of respondents had initiated or referred for ECMO during cooling therapy. Only 24% of institutions had a written ECMO criteria for HIE patients. During ECMO, 30% of institutions used the circuit only for therapeutic hypothermia while 28% used the circuit with body or head cooling; 15% discontinued cooling. Compared to 2008 survey, participants were more likely to offer ECMO for moderate and severe HIE (Figure). Neonatologists were more likely than non-neonatologists to offer ECMO for all severities of HIE. Most providers stated that they would be less likely to offer ECMO for clinical variables listed in the table or if they could accurately predict severe or profound neurodevelopmental delay.

**Conclusion:** There is wide variability among institutional ECMO practices for patients with HIE, and few institutions have written criteria to address this issue. There has been a shift towards offering ECMO for all neonates with HIE since 2008. Additional research is needed to determine if ECMO improves outcomes for patients with severe HIE.

**Table.** Clinical variables making providers less likely to offer EMCO.

<table>
<thead>
<tr>
<th>Clinical variable</th>
<th>Less likely to offer EMCO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aEEG/EEG</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Moderately abnormal</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Severely abnormal</td>
<td>51 (78%)</td>
</tr>
<tr>
<td>No effect</td>
<td>7 (10%)</td>
</tr>
<tr>
<td>Posture</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Flexion</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Decerebrate</td>
<td>49 (71%)</td>
</tr>
<tr>
<td>No effect</td>
<td>15 (22%)</td>
</tr>
<tr>
<td>Activity</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Decreased</td>
<td>5 (7%)</td>
</tr>
<tr>
<td>No activity</td>
<td>47 (68%)</td>
</tr>
<tr>
<td>No effect</td>
<td>12 (17%)</td>
</tr>
<tr>
<td>Cord pH</td>
<td></td>
</tr>
<tr>
<td>&gt;7.00</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>6.70-7.00</td>
<td>10 (15%)</td>
</tr>
<tr>
<td>≤6.70</td>
<td>29 (43%)</td>
</tr>
<tr>
<td>No effect</td>
<td>6 (9%)</td>
</tr>
</tbody>
</table>

**Figure.** How often would you offer ECMO if the following conditions were present? Compared to Chapman et al, *J Perinatology*, 2008.
Use of a BiVAD and Oxygenator for Cardiopulmonary Support: Case Report

Derrick Scott, BS, CCP
Arkansas Children’s Hospital

A 20 month-old female was transferred to ACH from an outside hospital for dehydration and possible pneumonia or edema. According to the mother, the child began having a cough, difficulty breathing and a fever 6 days prior to the visit. After arriving at ACH, a chest x-ray was obtained which showed cardiomegaly, prompting an EKG and Echocardiogram. The EKG and Echocardiogram revealed a wide complex tachycardia consistent with Wolff-Parkinson-White syndrome, a severely dilated LV and reduced LV systolic function. The decision was made to attempt an ablation in the cath lab and was unsuccessful. The patient was sent to the CVICU, sedated and placed on inotropic support. A serology exam showed her to be positive for Human Metapneumovirus, which has been shown to cause ARDS in the pediatric patient.

Due to her severe hemodynamic instability, the decision was made to implant an LVAD. After successful implantation of a Berlin EXCOR LVAD, the patient was unable to be weaned from bypass due to severe oxygen desaturation. TEE showed moderately reduced RV function, no LV apical cannula inflow obstruction and severe tricuspid regurgitation; subsequently an RVAD was implanted. Again, with biventricular support, the patient was unable to be weaned from bypass. Pulmonary suctioning was performed and a chest x-ray was ordered, which showed good endotracheal tube position and very hazy bilateral lung fields. The decision was then made to place a Maquet QUADROX-D oxygenator in the BiVAD circuit.

The oxygenator was primed in the sterile field and spliced between the RVAD EXCOR pump and the pulmonary artery. Adequate oxygenation was obtained and the patient was successfully weaned from CPB and ventilated with ARDS rest-settings. Following the BiVAD implantation, a successful ablation was performed in the cath lab and, on post-op day 3, the oxygenator was weaned from the circuit. After 48 days, the patient was successfully weaned from bi-ventricular support and is currently healthy and asymptomatic. We conclude that the patient was in end-stage heart failure due to Wolff-Parkinson-White syndrome which was complicated by an infection of Human Metapneumovirus, and the addition of a membrane oxygenator is an acceptable adjunct to a BiVAD circuit.

Derrick Scott
3050 Shady Side Dr.,
Sherwood, AR 72120
Cell: 731-571-9446
Email: josdscott@gmail.com
Clinical changes in practice for refractory cardiac failure patients supported with VA ECMO
Merna Cucanic, Jayne Sheldrake and Dr Vincent Pellegrino
The Alfred Hospital, Melbourne, Australia

Introduction: VA ECMO therapy for refractory cardiac failure has traditionally been utilized as a short term support. This therapy aims to successfully wean patients from extra corporeal life support (ECLS) over a period of days. Patients were commonly sedated and intubated for safety. VA ECMO is now being used to support increasingly complex cardiac failure patients, including as a bridge to longer-term support using a VAD. The technical and clinical care of these patients has needed to evolve whilst decisions of long term management are sought. This patient group often requires a longer ECMO run.

A relatively challenging and promising strategy is to initiate and provide ECMO support whilst patients remain awake. Benefits of awake ECMO have been described in recent literature and suggest ECMO therapy facilitates physical therapy, prevents deconditioning, and optimizes patient outcomes. Sonett & Bacchatta (2012). Awake ECMO therapy requires less sedation and carries less sedation related complications. Brodie (2014)

This new approach resulted in an increased challenge for the bedside nurse caring for the patient. The nurse is the primary care service provider for the awake patient by the bedside, as the unit manages the ECMO service using the single caregiver model.

We examined all patients initiated on VA ECMO with refractory cardiac failure admitted to The Alfred Hospital in the period of 2012-2016 in order to describe the changes in clinical practice that have occurred. We excluded cases of VA ECMO commenced for refractory cardiac arrest (ECMO-CPR) as very few of these patients ever meet the requirement for awake ECMO.

Results: Since 2012 one third of our patients have benefited from this change in practice. In 2012 there were 37 (49%) of our total VA ECMO patients managed awake and extubated. 49(33%) in 2013 were awake and extubated, 35 (49%) in 2014, 49 (27%) in 2015 and to date in 2016 there are 18(56%). The majority of these patients had an initial percutaneous femoral-femoral configuration with a distal perfusion cannula. Awake patients receiving prolonged support have recently been reconfigured during their ECMO run to subclavian artery return to facilitate long-term care.

Conclusion: Benefits from patient involvement during awake ECMO support for patients with refractory cardiac failure are clear compared to being sedated and intubated. Empowering patients to be actively involved in decision-making, their long term goals and end of life care is extremely important. Active physiotherapy such as the use of the recumbent bike, tilt table and early ambulation also provides daily patient goals and an opportunity to directly participate in care, improve tolerance of position restrictions and may optimise the muscle mass and maintain patient physical condition. Hodgson 2012 however challenges to meeting the needs of patients with refractory cardiac failure include loss of respiratory support from IPPV, ICU delirium, managing extended position restrictions and cannula site bleeding secondary to movement. A change in configuration from our unit’s current femoral-femoral approach for some patients whilst minimising these complications may also aid longer-term support. Assessment and decision-making for long term feasible outcomes can be then completed in a more considered timeframe.

The additional patient care needs as a result of this change in practice has fallen to the bedside nurse. This change in practice required a huge cultural shift in both bedside management for the nurse’s holistic approach to ECMO safety, whilst enabling patient empowerment, involvement and ensuring the patient are instrumental their treatment goals.

Merna Cucanic, m.cucanic@alfred.org.au, The Alfred Hospital, Melbourne, Australia
Survival after extracorporeal cardiopulmonary resuscitation in children

Shunpei Okochi, MD1, Svetlana Streltsova, RN, MSN, CCRN1, Eva W. Cheung, MD2, Aqsa Shakoor, MD1, Onur Baser, PhD, MS, MA1, Gudrun Aspelund, MD1, Ganga Krishnamurthy, MD2, Michael P. Brewer, MS CCP3, Emile Bacha, MD1, William Middlesworth, MD1

1Department of Surgery, 2Department of Pediatrics, 3Cardiovascular Perfusion, New York - Presbyterian, Columbia University Medical Center, New York, NY, USA

Objective: Extracorporeal cardiopulmonary resuscitation (ECPR) has been employed with increasing frequency in many centers. We reviewed outcomes of children cannulated by ECPR at our institution since introduction of an ECPR program. Our objective was to identify possible pre-cannulation and post-cannulation prognostic markers of survival to hospital discharge and favorable neurologic outcome.

Methods: We performed a single-center, retrospective review of all patients cannulated for ECPR between January 2010 and November 2015. Categorical variables were analyzed with chi-square or Fisher’s exact test and continuous variables with a two-tailed heteroscedastic t-test. All statistical analysis was performed with SPSS.

Results: Forty-six neonatal and pediatric patients with failure to respond to cardiopulmonary resuscitation (CPR) were cannulated for venoarterial extracorporeal membrane oxygenation (ECMO) during the study period. ECPR represented an increasing proportion of ECMO cannulations, from 4% in 2010 to 35% in 2015. Diagnoses included: biventricular congenital cardiac disease (41%), single ventricle heart disease (30%), cardiomyopathy/myocarditis (20%), respiratory failure (4%) and sepsis (4%). Cannulation sites were: chest (n=22), neck (n=17) and femoral (n=7). Thirty (65%) patients were successfully decannulated and twenty-five (54%) patients survived to hospital discharge. Median serum pH during CPR was higher among ECPR survivors compared to non-survivors (7.14 vs. 6.90, p<0.01). Pre-cannulation parameters that did not show statistical significance included serum bicarbonate (17.5 vs. 13.6mmol/L, p=0.32), lactate (10.3 vs. 12mEq/L, p=0.17) and time to cannulation (56 vs. 66 minutes, p=0.20). One hour after cannulation, ECPR survivors had a higher median serum pH (7.36 vs. 7.12, p<0.001), bicarbonate (19.5 vs. 10.3mmol/L, p<0.001) and lower lactate (10.1 vs. 18mEq/L, p<0.01) compared to non-survivors. There was no difference in duration of ECMO support (121 vs. 160 hours, p=0.43). Sixteen of the twenty-five ECPR survivors (64%) had radiographic and/or clinical findings concerning for neurologic injury. Survivors without neurologic injury had lower AST (38 vs. 47, p<0.05) and ALT (116 vs. 212, p<0.05) values 24 hours after cannulation compared to those with neurologic injury. No patients with a pH<6.9 during CPR survived to discharge neurologically intact.

Conclusions: Pediatric ECPR is a resource intensive initiative; therefore careful patient selection is crucial for efficient use of limited resources. Our pre-cannulation data showed that the magnitude of acidosis during CPR correlated with clinical outcome. Persistence of lactic acidosis post-cannulation was also a strong indicator of poor survival. Further studies are necessary to identify possible prognostic factors or potential interventions during ECPR with respect to neurologic outcomes.

Contact: Shunpei Okochi, MD. Address: 3959 Broadway, 2-Central, Division of Pediatric Surgery, New York, NY 10032. Phone: (917)2090589. Email: sho9028@nyp.org
The introduction of new technology into a complex clinical environment such as the Pediatric Intensive Care Unit (PICU) is a challenging process. When the technology provides life-saving care used only in high-intensity and high-risk situations the risks are magnified. Pediatric Extracorporeal life support (ECLS) is a low volume high-risk procedure that involves extensive multidisciplinary coordination to initiate rapidly and effectively. The aim of this study was to review the early experience in a non-cardiac centre performing rescue ECLS with delayed transport to a regional cardiac surgery program for definitive care.

The Alberta Children’s Hospital is a large freestanding tertiary care center in Calgary, AB servicing a population of approximately three million. The Pediatric Intensive Care Unit (PICU) is a 16 bed unit that sees over 1000 admissions annually. All patients requiring cardiac surgery resources, including those for an ECLS run, are transported a regional centre (Stollery Children’s Hospital, Edmonton, AB). Prior to October 2011 any patient requiring ECLS therapy required pre-emptive transport or having a team fly to Calgary to perform the operative procedure, then transport the patient back to Edmonton for ongoing management. This posed many organizational challenges resulting in critical patients dying prior to ECLS initiation.

In October 2011 our institution launched an in-house rescue cannulation program where patients are cannulated, stabilized and medically managed for the first 12-24 hours, and then air transported to the regional center for the remainder of an ECLS run. The program is inclusive of ECLS and ECPR in the PICU, ED and OR setting. This is a unique structure with unique partnerships. There was a universal deficiency of skills across medical specialities and health professions given the absence of a cardiac surgery program. To become clinically proficient extensive training was undertaken including advanced education for all medical personnel involved.

Between October 2011 and May 2016, the ECLS team was activated 76 times, resulting in 36 cannulations with 27 of those children surviving to hospital discharge. All patients were successfully cannulated including 11 cases of ECPR; 5 VV cannulations and 31 VA cannulations. The most common diagnoses for cannulation were sepsis (n=14), respiratory failure (n=13) and primary cardiac failure (n=8). Complication rates are in keeping with the literature and ELSO database. 32 patients survived to transport, 75% survived to discharge home. During transport one patient had to be temporarily taken off support for a large amount of air in the circuit (venous) but no significant morbidity resulted.

A rescue ECLS program run in a non-cardiac centre with delayed patient transfer can achieve excellent results with a multi-disciplinary approach and intensive educational curriculum.
Comparison of In-Line versus Conventional Independent Continuous Renal Replacement Therapy in Extracorporeal Membrane Oxygenation Patients

Nicole Stansbury¹, Taryn Samet¹, Rita Pechulis, MD², James Burke, MD¹, Timothy Misselbeck, MD¹, James Wu, MD¹.
Division of Cardiothoracic Surgery¹, Division of Pulmonary and Critical Care Medicine², Division of Cardiology³, Lehigh Valley Health Network, Allentown, PA, United States.

Abstract:

Objectives:

Extracorporeal Membrane Oxygenation (ECMO) patients are often at high risk of developing acute kidney injury or renal failure. Continuous renal replacement therapy (CRRT) has proven to be an effective technique in providing constant management of renal functions and can be administered either independently or in-line with ECMO. This study seeks to determine if using the in-line technique provides comparable results to those using the conventional independent access.

Method:

ECMO patients were evaluated from the in-house database for the years 2015 and 2016 at the Lehigh Valley Health Network who developed renal failure and required CRRT. The in-line technique results were compared to the conventional independent access (IC) results.

Results:

Out of a total 91 patients, there were 57 patients with renal complications, and 21 patients required CRRT. CRRT was deployed with IC in 11 cases, with a discharge rate of 45.5%, and in-line with the ECMO circuit in 10 cases, with a discharge rate of 30%. Of the patients that were discharged, 2 out of 3 patients that underwent CRRT in-line with ECMO regained renal function and 4 out of 5 of the IC patients regained function. Patients that experienced renal complications spent an average of 6.38 days on ECMO, patients that underwent CRRT independently spent an average of 7.45 days on ECMO, and patients that underwent CRRT in line with ECMO spent an average of 11.5 days on it.

Conclusions:

Patients who required CRRT with in-line technique often were sicker and had more central access issues. This was reflected in the lower discharge rate and increased time on ECMO. However, there were no additional complications from in-line technique, and renal recovery was comparable.

Contact Information:
Nicole Stansbury
2867 Apple Valley Estates Drive, Orefield, PA 18069
(610) 462-8000
Nstansbury96@gmail.com
IMPACT OF AGE OF PACKED RED BLOOD CELL TRANSFUSION ON OXYGENATION IN PATIENTS RECEIVING EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO) SUPPORT

Sumit Datta MD1, Shelley Chang MD2, PHD, Nick Jackson3, Alyssa Ziman MD2, Myke Federman MD4
Ochsner Hospital for Children, Department of Pediatric Critical Care1
UCLA Department of Pathology and Laboratory Medicine-Transfusion Medicine2
UCLA Biostatistics Department3
UCLA Department of Pediatric Critical Care3
David Geffen School of Medicine at UCLA

Background

The length of red blood cell storage prior to transfusion affects the integrity and function of red blood cells. Recently, studies have demonstrated that red blood cells with shorter storage times have a greater ability to improve tissue oxygenation than red blood cells with longer storage times. Children supported with extracorporeal membrane oxygenation often have issues with tissue oxygenation given their underlying cardiac and pulmonary condition. However, the relationship between the age of packed red blood cells and tissue oxygenation, specifically within the pediatric ECMO population, has not been well delineated.

Objectives

To determine the effect of age of packed red blood cells on tissue oxygenation in children receiving ECMO support.

Methods

A retrospective study of all children, ages 0 to 18 years, who required ECMO support at Mattel Children’s Hospital between March 2013 and August 2015 was conducted. With regards to each transfusion, we collected the following biomarkers six hours prior to and six hours after the conclusion of a transfusion: serum and circuit hematocrits (HCT- lab and HCT- circ, respectively), serum and circuit venous saturations (SVO2-lab and SVO2- circ, respectively), PaO2 (mmHg), serum lactate levels (mg/dL) and cerebral saturation via near infrared spectroscopy (NIRS).

Biomarkers were examined with respect to time relative to transfusion in the following three ways: using time relative to a transfusion as a continuous variable, using 4 discrete categories (<3 hours, -3 to 0 hours, 0 to +3 hours, >3 hours) and as 2 discrete categories (<0 hours, >0 hours).

The association between age of blood transfusion and change in biomarkers was then accessed analyzing time relative to transfusion in the 3 ways described above. In addition, the age of blood transfusion was analyzed in three ways: using age of individual blood transfusion linearly in five day increments), as four discrete categories (0-7 days, 7-14 days, 14 -21 days and >21 days) and dichotomously (>14 days, < 14 days).

Results

20 patients and 119 individual transfusions were included in the analysis. The average age of patients was 63.8 months. Average age of transfusion was 16.4 days.

SVO2 (circ) demonstrated a 0.538%/hr (p=0.000) increase in the first 3 hours post transfusion when time treated linearly. There was an increase of 2.62% (p <0.001) when time was modeled in 4 categories. The change was not statistically significant when time was treated dichotomously. In addition, when SVO2 (lab) were analyzed there was no statistically significant change with relation to transfusions. Lactate level decreased by 0.513 mg/dL per hour (p= 0.0105) in the first 5 hours post transfusion when time was viewed continuously. However, there was no observed statistical change observed when time was modeled in 4 categories and dichotomously (>14 days, < 14 days).

With regards to the relationship between the age of red blood cell transfusion and tissue oxygenation biomarkers, none of the biomarkers exhibited a consistent interaction.

Conclusions

Our study demonstrates that the age of packed red blood cell transfusion does not affect the degree tissue oxygenation in children receiving ECMO support, as measured by SVO2, lactate and NIRS. In addition, packed red blood cell transfusion, in general, did not produce any meaningful change in these markers of tissue oxygenation.

Based upon the findings over our study, we caution against the use of frequent transfusions to improve tissue oxygenation. Furthermore, we find no evidence to support the use of younger red blood cell transfusions in this patient population.

Contact: Sumit Datta
Address: 5037 Purdue Dr, Metairie, LA 7003
Phone: 714 423 2446
Email: sdaatta.ucla@gmail.com
Incidence of Deep Vein Thrombosis in patients undergoing Right Internal Jugular Vein cannulation for Veno-Venous Extracorporeal Membrane Oxygenation

Taryn Samet¹, Nicole Stansbury¹, Rita Pechulis, MD², James Burke, MD³, Timothy Misselbeck, MD¹, James Wu, MD.¹

Division of Cardiothoracic Surgery¹, Division of Pulmonary and Critical Care Medicine², Division of Cardiology³, Lehigh Valley Health Network, Allentown, PA, Unites States.

Abstract:

Background:

Veno-Venous Extracorporeal Membrane Oxygenation (VV-ECMO) has been used more frequently for adult patients over the past six to eight years. However, because of large bore right internal jugular (RIJ) cannulation, there may be an increased incidence of RIJ deep vein thrombosis (DVT) which may result negatively for central access and thromboembolism. The following study seeks to find the incidence of RIJ DVT in patients who were weaned off VV-ECMO.

Methods:

A retrospective review of all VV-ECMO patient records from 2013-2016 at the Lehigh Valley Health Network through the in-house database and EHR was conducted. Upper Extremity venous duplex studies were used to evaluate the presence of DVT.

Results:

Of 88 patients who underwent RIJ cannulation, 62 were weaned off, of whom, 55 were discharged. 41 that were eventually weaned had Upper Extremity venous duplex studies done. Of those 41 patients, 43.9% developed a DVT—55.5% were occlusive while 44.4 % were non-occlusive. Of patients whom were at least fifty-years-old (n=19), 57.9% developed DVT (p=0.0442). In males over fifty years of age (n=8), there was a 75% chance of developing a DVT. They were over 1.5 times more likely to develop RIJ DVT than age-matched females. DVT’s developed in 51.6% of patients if treated for at least seven days (n=31) (p=0.0443). All men who were at least fifty-years-old and were also on ECMO for at least seven days developed a DVT; however, only half of women under those same conditions developed DVT.

Conclusion:

Large bore cannulation to the RIJ resulting in DVT is observed in less than half of patients. Of those observed, the majority were occlusive. For males whom are at least fifty-years-old, and an increased duration on ECMO increases the incidence.

Name: Taryn Samet

Address:

1605 Middle Gulf Drive, Apt 128
Sanibel, FL 33957

Telephone: 914-708-9916

Email: tarynsamet@gmail.com
Incidences and origin of infection of paediatric ECLS in a Tertiary Care Centre, Paediatric Cardiac Intensive Care Unit
Till N Judit, Mendonca H Malaika, Kiraly Laszlo
Sheikh Kalifa Medical City, Critical Care Department, Pediatric Cardiac ICU
Abu Dhabi, United Arab Emirates

Introduction: Mortality of patients on extracorporeal membrane oxygenation (ECMO) remains high. Diagnosis of infection during ECLS is still challenging and prevention strategies vary widely from center to center. These important facts led us to analyse the occurrence rate, site and organism in our ECLS patients in order to implement infection control measures to reduce the incidence of infections during ECLS.

Objectives: To analyse our ELSO centre data specifically focused on incidence of infection, typical microorganisms, time of manifestation, site of cultures in the settings of tertiary paediatric cardiac intensive care unit mainly utilising transthoracic cannulation and VA-ECMO and compare to ELSO database.

Methods: Retrospective study analysing 25 neonatal and paediatric ECMO cases in relation to infection from January 2014- December 2015, in comparison of the ELSO database age and modality specific data. We examined the prevalence of infection; the time of the first positive cultures; the site of the positive cultures and the underlying microorganisms and compared with ELSO data whenever was feasible.

Results: No specific data on incidence of infection in ELSO database with open chest/transthoracic cannulation; our incidence was 0.44. The Candida species was the highest offending organism (24% v ELSO 12%), followed by Klebsiella 20%, E. coli 16% and Pseudomonas 12%. The first positive culture was taken on the 8th day of ECMO (median). By site the highest prevalence: VAP 41% followed by BSI 22% and CAUTI 12%.

Conclusions: The highest prevalence of Candida infections are most probably due to the combined antibiotic and steroid therapy for patients with Capillary Leak Syndrome. This may prompt that routine antifungal prophylaxis can be added after 1 week of ECMO for this patient group. Alternatively the early detection with fungal PCR assay should be evaluated. The high occurrence of VAP may indicate the need of reinforcing enteral feeding, oral decontamination protocol along with VAP bundle and investigation of alternative source of contamination. As Gram negative Enterobactericeae and Pseudomonas were in second line as typical MDR organisms, those should be covered whenever need of empiric antibiotic therapy arises.

Contact:
Judit Noemi Till, MD
Pediatric Cardiac ICU, Sheikh Kalifa Medical City,
Karama Street, P.O.Box.: 51900, Abu Dhabi, United Arab Emirates
Mobile: +971504452409, Tel:+97128193170, Email: jtill@skmc.ae
Evaluation of the EOS PMP Oxygenator as a Viable alternative for Extracorporeal Membrane Oxygenator


Until recently, ECMO centers in the United States had only one option for PMP oxygenators that were FDA approved for use. At Children’s of Alabama, we had an opportunity to be the first center in the United States to evaluate the EOS (PMP) oxygenator from Sorin/LivaNova. In the early stages of our trial, Maquet was going through distribution challenges and so it was an important time to have access to another viable option.

We have historically used the Maquet Quadrox iD PMP at Children’s of Alabama, but recent supply issues prompted us to pursue an alternative supplier for an ECMO PMP oxygenator and disposables. The Sorin/LivaNova PMP, (EOS) oxygenator was recently approved by the FDA for procedures lasting up to 6 hours and we decided to see if it was a viable alternative for our ECMO program. Compared to the Quadrox iD, the EOS has a 30% lower priming volume of 150 mL, a lower max flow rate of 5 L/min, a smaller membrane surface area of 1.2 m², and a smaller heat exchanger area of 0.14 m². Our clinical trial consisted of 15 Sorin EOS PMP oxygenators and 6 Sorin ¼” tubing packs. We collected daily data for the average pressure drop (ΔP) across the oxygenator, the plasma free hemoglobin (pfHb), the change from baseline of the pfHb (%pfHB), blood product administration, and heparin dosing level. It was determined that there was no significant difference in any of the parameters collected. The flow path through the oxygenator is quite different than the Quadrox iD, and we noticed a larger pressure drop once the flow exceeded 1 L/min. Despite the larger pressure drop, this did not translate to more hemolysis clinically. We have noticed that small amount of fibrin that was deposited on the EOS seemed to affect the efficacy of oxygenation but not ventilation of the oxygenator. This may not be as noticeable on the Quadrox iD, due to the larger membrane surface area and the flow path through the oxygenator. There was no difference seen in the heating and cooling ability of the EOS.

Although we will continue to use the Quadrox iD for our ECMO program, we feel that the EOS is a viable alternative for ECMO.
Impact of hemodialysis on mortality rate in children with extracorporeal membrane oxygenation: an analysis of KID database

Himani Pulivarthi, MD1; Fernando Beltramo, MD2; Balagangadhar R. Totapally, MD2,3

1 Medical Graduate, Mamata Medical College, India.
2 Division of Critical Care Medicine and Nicklaus Children’s Hospital, Miami, FL 33155,
3 Herbert Wertheim College of Medicine, Florida International University, Miami, FL 33199

BACKGROUND: Acute kidney injury (AKI) and fluid overload is common among children on Extra Corporeal Membrane Oxygenation (ECMO) support. Ongoing systemic inflammation, hypercoagulable state and hemoglobinuria results in AKI. High volume of distribution and need for frequent blood product transfusion during ECMO therapy causes significant fluid overload.

OBJECTIVE: The objective of this study was to evaluate the effect of the use of dialysis on mortality rate in children receiving ECMO therapy.

DESIGN/METHODS: A retrospective analysis of the Healthcare Cost and Utilization Project 2012 Kids’ Inpatient Database was performed. The database was filtered using ICD-9 procedure code for extracorporeal membrane oxygenation (39.65 and 39.66), hemodialysis (39.95). Sample weighting was employed to produce national estimates. Chi-square test, student t-test and binary regression analyses were performed using SPSS to analyze the data.

RESULTS: A total of 2111 children, including neonates who received ECMO therapy during 2012 with an overall mortality rate of 40.5%. Hemodialysis was done in 161 (7.6%). The mortality was significantly higher in children receiving hemodialysis (56.5% vs 39.2%) and cardiac surgery (46.2% vs 38.2%). Hemodialysis is associated with increased mortality in neonates (51.6% vs. 38.7%; p<0.05) and children (59% vs. 39.7%; p<0.05) but not in infants (60.8% vs. 40% p>0.05) or in cardiac surgical patients (54.8% vs 45.7%; OR 1.4, CI: 0.7-3.0).

CONCLUSIONS: This study provides an estimate of overall mortality rate in pediatric patients on ECMO and those who required renal support. The mortality rate was higher in patients with concurrent ECMO and hemodialysis compared to ECMO alone, especially in the neonatal age group and children.

Contact Author:
Balagangadhar R. Totapally MD, DCH, MRCP, FAAP, FCCP, FCCM.
Division of Critical Care Medicine and Nicklaus Children’s Hospital, Miami, FL 33155.
Herbert Wertheim College of Medicine, Florida International University, Miami, FL 33199.
Email Id: Balagangadhar.Totapally@mch.com
Tel: 305 662 2639 / Fax: 305 663 0530
In-Vitro Comparison of Hemodynamic Performance and Gaseous Microemboli Handling By Two Different Pumps and Oxygenators in a Neonatal ECLS Circuit

Payal Trivedi, DO1,2, Shigang Wang, MD1, Kristen Glass, MD2, Karl Woitas CCP1, Allen R. Kunselman, MA1, and Akif Ündar, PhD1, 4

Penn State Hershey Pediatric Cardiovascular Research Center, Department of Pediatrics1, Neonatal Intensive Care Unit2, Public Health and Sciences3, Surgery and Bioengineering4, Penn State Milton S. Hershey Medical Center, Penn State Hershey College of Medicine, Penn State Hershey Children’s Hospital, Hershey, PA, USA

Background: Neurologic complications secondary to neonatal ECLS are associated with significant morbidity and mortality. While these complications are likely multifactorial, gaseous microemboli (GME) in the ECLS circuit may be a possible cause. Advances in neonatal circuitry may improve hemodynamic performance and GME handling leading to reduction in patient complications.

Objective: In this study we compared two different centrifugal pumps (Maquet RotaFlow and Medos Deltastream DP3) and oxygenators (Maquet Quadrox-iD and Medos Hilite LT) on hemodynamic performance, specifically pressure drops and total hemodynamic energy (THE) levels and GME handling in a neonatal ECLS circuit model.

Methods: The experimental circuit consisted of Maquet RotaFlow pump, Quadrox-iD Pediatric oxygenator, Medos Deltastream DP3 pump, and Hilite 800 LT oxygenator, and the Better-Bladder arranged in parallel using a “Y” connector. The circuit was primed with lactated Ringer’s solution and packed human red blood cells with hematocrit 40%. Hemodynamic trials collecting real-time pressure and flow data were conducted at flow rates of 300 and 500 ml/min at 36°C. To evaluate GME handling, 0.5 cc of air was injected into the venous line testing 8 unique combinations of pump and oxygenator with or without the Better Bladder at both flow rates. The Emboli Detection and Classification Quantifier (EDAC) System was used for GME detection and size characterization.

Results: THE levels at pre-oxygenator and post-arterial cannula sites and GME handling results are displayed below in Figure 1 and Table 1 respectively.

Conclusions: All oxygenator and pump arrangements had similar hemodynamic energy performance with a significant percentage of THE lost primarily in the arterial cannula. All oxygenator and pump combinations had similar GME handling performance. The Better-Bladder significantly decreased GME at all stages of the experiment. Further in vivo studies are necessary to validate these findings.
Code ECMO: Development and Successful Implementation of ECPR in a Community Hospital
Travis VanDinh RN, Michael Gaber RN, & Jordan S. Weingarten MD
Seton Medical Center Austin

Abstract

Background: Interest in ECPR has been rapidly growing, fueled in part by the updated American Heart Association’s 2015 guidelines that include ECPR as a modality to be considered for patients who have not responded to initial conventional CPR. However, ECPR is a complex and highly time-sensitive process. Even though we do not have continuously available in-house cannulating physicians and perfusionists at our 474-bed community hospital, we have nonetheless performed ECPR 13 times since 2011. However, this was an informal process with resulting variability in timing, personnel, and equipment. We therefore developed a streamlined process that allows a more rapid and orderly initiation of VA-ECMO.

Process: We utilized a rapid cycle model of process improvement after first obtaining administrative, legal and financial approval. A committee with broad representation of the specialties involved met to analyze in detail all of the procedures, people, equipment, and education necessary to initiate ECPR. A top priority was minimizing the number of discrete phone calls necessary; ultimately a single call to the hospital operator now simultaneously pages the ICU nurse supervisor, facility head supervising nurse, OR tech, ICU pharmacist, and Chaplain services. Using a cascading system of assigning duties, the ICU nurse supervisor then personally makes, as well as assigns, additional calls to a cannulating surgeon, anesthesia, and a pulmonary intensivist. Cannulating supplies have been pre-packaged in sealed bags and boxes, grouped by need (e.g., supplies for cleansing and draping are separate from those for dressing and securing cannulas). Medications are stored in a dedicated transport box. To minimize cost and duplication of equipment, some supplies we use for off-site transport and cannulation serve a dual purpose, supporting on-site ECPR. A primed circuit is readily accessible and delivered to the ECPR location. We identified the need to have blood immediately available, and developed a process for the immediate release of 4 units of O-negative blood, to be placed in a cooler and delivered where needed. We named our process “Code ECMO”, and ran a number of “mock codes”, analyzing each code in terms of timing of arrival of individuals and supplies, with a formal debrief afterwards and adjustment of processes as needed. We allowed the process to go-live before all details were fully resolved, deciding that some improvement over existing processes was better than no improvement, with additional debriefs and refinement after each real ECPR.

Results: Prior to developing our Code ECMO process, it could take up to 45 minutes to get all of the equipment and personnel needed to the bedside, with one physician making a minimum of 6 separate phone calls to initiate. With our new process, a Code ECMO can be initiated with a single phone call. Response time to get all equipment and personnel to the bedside has been reduced to as little as 10 minutes. Since going live we have had 2 ECPRs, both successfully cannulated, with one patient surviving neurologically intact to hospital discharge. We believe that this model can be generalized with local modifications to allow broader utilization of ECPR within the ECLS community.

Travis VanDinh BSN, RN, CCRN
Critical Care Transport Coordinator
Seton Medical Center Austin ICU
tbvandinh@seton.org (512)-466-4604

Seton Medical Center Austin ICU
C/O: Heather De La Paz Barroso
Senior Department Assistant
1201 W. 38th St Austin TX 78705
Multidisciplinary ECMO Simulation using High Fidelity Cannulation Mannequin
Richard Berens MD, Heidi Wellner RN, Caleb Varner CCP LP- Children’s Hospital of Wisconsin

Introduction:
Cannulation for emergent ECMO procedures requires succinct decision making and multidisciplinary teamwork. Children’s Hospital of Wisconsin ECMO initiative has developed a series of ECMO cannulation simulations across a broad spectrum of patient scenarios and locations allowing team members to practice in a realistic environment. These simulations take place with high fidelity, hemodynamically responsive, pulsatile cannulation mannequins in ICU rooms with a full surgical team. We present our simulation process, describe the attributes of the mannequin, and the modifications to the circuit allowing changes circuit pressures to simulate common issues identified during an ECMO run.

Methods:
The mannequin is a modified, commercially available, pediatric vascular mannequin (Vascular Access Child™ Simulab Corporation, Seattle Wa). The mannequin was modified to allow cannulation via the neck or groin. A hidden venous reservoir within the mannequin, along with a suspended IV bag, act as a variable compliance chamber for the venous system. The pulsatile arterial system is generated by a roller pump, which gives the vessel’s their pulse; allowing the surgeon the ability to palpate and doppler the vessels prior to cannulation.

ECMO simulations are executed in realistic settings, such as the ICU or cath lab, with team members from perfusion, surgery, anesthesia, critical care, nursing, surgical technician and pharmacy present and participating. For AV cannulation, chest compressions are performed until cannulation is achieved, with rotating compressors and a quality observer providing point of care feedback. VV ECMO is performed with pulsatility provided through the roller pump to give the surgeons a realistic vascular experience during the cannulation. Simulations are structured to follow two pathways; one in which reactions and decisions of the team are carried out in finality, and the other, where undesired actions are noted and discussed in the moment while steering the team back as if the desired action had been taken. Lastly, once an end point has been reached, simulation is halted and a discussion involving all specialties takes place over the events of the case and how they affected the patient and subsequent teams.

Once cannulated, the simulation manager creates changes in the circuit pressures that change flow characteristics similarly to those events seen in patient care scenarios. Using a Bluetooth enabled syringe pumps, air can be discretely entrained into the mannequin reservoir and ECMO circuit during cannulation, as well as causing large pressure swings inside the ECMO circuit simulating clot and obstruction. SimBaby software may be used during the simulation to project the patient’s vitals for all participants to see. Being sensitive to the team member’s time and other tasks, the simulation takes about 30 – 45 minutes followed by whole team discussion with breakout amongst individual specialties thereafter. We perform 6 – 10 whole team simulations a year, with partial simulations occurring roughly 12 times a year for section specific training. The simulation mannequins (3 total) are used to provide the biannual wet lab teachings for all ECMO technicians.

Conclusions:
The use of a high fidelity ECMO simulator for full and partial team simulations is critical to maintain team function and confidence during periods of low ECMO use. The mannequins add a component of reality that water labs, using reservoir bags, fail to capture. Simulations have been well received by all who participated and groups have requested more simulation experience. This has improved staff satisfaction overall in regards to preparing disciplines for ECMO cannulation. Providing quantifiable baseline training and high fidelity ECMO simulation for multidisciplinary teams has allowed for greater comfort and decision making for teams as they come together to cannulate patients in real-life scenarios.

Heidi Wellner - 9000 W. Wisconsin Ave. Milwaukee, WI 53201 - 414-266-4198 hwellner@chw.org
“The Ethical Dilemmas Behind Acute Mechanical Circulatory Support”

Viktoriya Kagan, Rebecca Rose, Colleen Juricek, Thomas Lammy, Sirtaz Adatya, Valluvan Jeevanandam, Nir Uriel, Peter Angelos, Tae Song.
The University of Chicago Medical Center, Chicago IL.

**Background:** Acute mechanical circulatory support (MCS) is frequently utilized in the stabilization of critically ill patients and can be used as a bridge to transplantation, durable MCS or recovery. Ethical dilemmas can arise when patients stabilized on acute support are no longer candidates for transplant or long-term MCS due to changes in clinical status. This becomes more complex when patients have an intact mental status and express their desire to continue MCS. Very little literature is available on the ethical challenges of decision making in these complex situations.

**Method:** A retrospective chart review was performed on patients who were stabilized on acute MCS including Extracorporeal Membrane Oxygenation (ECMO) and temporary Ventricular Assist Devices (VADs) between January 2016 and June 2016 at a large academic hospital. Patients who received acute MCS for stabilization who later were deemed ineligible for transplantation or durable MCS were included in the study.

**Results:** During the study period, three patients were placed on acute MCS as a bridge to recovery, durable MCS, or transplant; and due to their clinical course, they were determined to no longer qualify for other options. All three patients expressed their clear wishes to continue with full temporary MCS. Patient 1 received biventricular support for 144 days and after recovery of kidney function, ultimately received implantation of a Total Artificial Heart. Patient 2 received biventricular support for 56 days and patient 3 was supported on ECMO for 114 days until both ultimately requested termination of support and expired after decannulation.Extensive multidisciplinary discussions were held with the patients, including the Ethics Consultation Service, the Palliative Care Service, Psychiatry, Cardiology, Cardiac Surgery, Social Services, and Case Management, regarding continuation of treatment and ultimately withdrawal of support.

**Discussion:** Advancement in medical technology allows for acute stabilization of patients, however, ethical dilemmas arise when support cannot be weaned off and further advanced options are unavailable. With increasing use of MCS, such obstacles will become more prevalent and health care providers and patients will face increasingly complex end-of-life scenarios. Among the questions that will need to be addressed: Is it ethical to withdraw support from a patient in a medically futile situation when the patient desires to remain on support? Is it ethical to continue support with intense resource utilization in apparently futile situations when these resources could be used for other patients? Establishing a multidisciplinary team including Palliative care and Ethics may help navigate these challenging decisions.

Contact Person: Viktoriya Kagan 5841 S Maryland Ave, Chicago IL 60637 Email: vkagan@surgery.bsd.uchicago.edu Phone: 248.469.3811
Influenza Vaccination on the Survival of H1N1 Influenza-related Acute Respiratory Distress Syndrome Supported by Extracorporeal Membrane Oxygenation

X Ding MD, D Roe MD, C Hage MD, M Duncan MD, Z Hashmi MD, T Wozniak MD, and I Wang MD PhD
Indiana U School of Medicine - Indiana U Health Methodist Hospital, Indianapolis, IN 46202

Introduction: A potentially fatal complication of H1N1 influenza is fulminant acute lung injury and acute respiratory distress syndrome (ARDS). Extracorporeal membrane oxygenation (ECMO) has been advocated for and applied in such severe complicated H1N1 infections. Relatively young ages, minimal or less severe comorbidities, and prolonged support (more than one week) all could contribute to the effectiveness of this approach and reduced risk of in-hospital death. The annual influenza vaccination has been recommended as an effective and economical means to prevent the infection and reduce its severity if infected. The aim of this retrospective study is to evaluate the effect of vaccination on the outcome of ECMO-supported ARDS induced by H1N1 influenza.

Methods: Thirteen patients, seven males and six females in the age of 20-67 years old, were diagnosed with deteriorating H1N1 influenza infection and admitted to the hospital from late February to early April of 2016. They eventually developed ARDS and were placed on venous-venous ECMO. The duration of ECMO support ranged from 1 to 33 days, with 12 patients on ECMO for 5 days or more. Their influenza vaccination status were established based on the case histories upon admission or archived medical records. The survival rates were calculated and compared between the groups with or without the seasonal vaccination. The distributions of survivors divided by their ages or durations of ECMO support were analyzed.

Results: Eight patients survived to be discharged. Three of these survivors were vaccinated, four were not, and one failed to provide definitive vaccination information. None of the five deceased patients were vaccinated for the season. Therefore, the survival rate among vaccinated patients was 100%; while the rate among un-vaccinated was 44.4%. A majority of patients (i.e. 9 out of 13) fall in the age group of 40-60 years, and all the mortalities occurred to this group. The remaining 4 patients, either relatively young or old, survived. The deceased patients received ECMO support for the duration of 1-20 days; hence no obvious trend was identified between the survivals and duration of support.

Conclusions: This represents a small case series in our institution. Nevertheless, unvaccinated patients who developed ARDS following H1N1 infection have clinically worse outcomes despite support with ECMO. Weighing the cost of ECMO therapy versus vaccination, the epidemiologic consequences are readily evident.
Poster Title: **Taking ECMO on the Road and Beyond: Inter-hospital ECMO Transport**

**Authors:** Susan B. Williams BSN, RNC, Michael Regan RN, Lou Bellace BSN, MS, Jim Connelly BS, RRT-NPS

**Institution:** The Children’s Hospital of Philadelphia, Philadelphia PA 19104 ECMO Center

**Objectives:**

- Policies, procedures and job aids will be created to reflect best practices and safe quality care regarding a new CardioHelp HLS ECMO system.
- Policies, procedures and job aids will be created to reflect best practices and safe quality care regarding a safe circuit change from the outside hospital ECMO system onto the CardioHelp HLS ECMO system prior to inter-hospital pediatric ECMO transports (fixed wing, rotary and ground).
- All personnel involved with the inter-hospital transport on ECMO support will be educated and proficient in basic and emergency procedures in order to support the ECMO staff as required to provide safe, efficient care.

**Abstract:**

**Introduction:** The need for inter-hospital transport of pediatric ECMO patients from regional hospitals to CHOP required the development of educational lectures and simulations for multiple disciplines including ECMO trained Specialists/Primers, transport team RN’s, RRT’s and Paramedics. Innovative transport system process development with multidisciplinary collaboration and continuing education includes the development of safety checklists to prevent variability and potential ECMO complications. Utilizing the compact CardioHelp HLS ECMO system for safe fixed wing, rotary and ground pediatric transports requires accessibility of this device and the creation of policies, procedures and job aids to clarify roles and responsibilities before, during and after transport of the pediatric ECMO patient.

**Methods:**

Combination of didactic and hands-on demonstrations, followed by simulations including basic and emergency procedures related to ECMO.

Simulation/practice of ECMO runs will be conducted to enhance proficiency in a potentially harsh environment.

Competency assessments will be conducted with ECMO and Transport staff, simulating ECMO procedures until proficient and approved by a qualified observer.

**Conclusion:** Inter-hospital pediatric ECMO transports are not common. Learning and retaining technical, behavioral and critical thinking skills to troubleshoot potential ECMO emergencies requires advanced adult education specific to ECMO transport. Transparent communication and collaboration will improve ECMO patient safety and build higher standards of care. Due to the innovation of transport ECMO, an alternative, safe procedure for in-house ECMO circuit changes was created and taught to general surgeons involved with neonatal, cardiac and pediatric ECMO at CHOP.

**Contact:** Susan B. Williams williamssu@email.chop.edu 609 560-7665 CHOP ECMO Center
Successful Use of Extracorporeal Life Support in a Hematopoietic Stem Cell Transplant Patient with Neuroblastoma

Feifei Z. Williams1, MD; Atul Vats1,3, MD, FCCM; Thomas Cash2,4, MD; James Fortenberry1,3, MD, MCCM

1Division of Pediatric Critical Care Medicine, Emory University School of Medicine, Atlanta, GA
2Division of Pediatric Hematology Oncology, Emory University School of Medicine, Atlanta, GA
3Children’s Healthcare of Atlanta at Egleston, Atlanta, GA
4Aflac Cancer and Blood Disorders Center, Atlanta, GA

The benefit of extracorporeal support for patients following hematopoietic stem cell transplantation (HSCT) who develop subsequent respiratory failure remains controversial, and has often been considered a relative contraindication for use of extracorporeal membrane oxygenation (ECMO) at many centers. We describe a child with neuroblastoma and severe hypoxic respiratory failure, successfully managed with veno-venous (VV) ECMO. The patient is an 18-month-old female with high-risk neuroblastoma status post tumor resection, chemotherapy, single autologous HSCT, and primary site radiation to her left adrenal gland. On day +113 post-transplant while receiving her second cycle of maintenance immunotherapy with dinutuximab and interleukin-2, she was transferred to the pediatric intensive care unit (PICU) after an acute respiratory decompensation due to rhinovirus, aspiration pneumonia, and capillary leak syndrome. She was intubated on arrival to PICU and quickly transitioned to an oscillator with inhaled nitric oxide. Due to persistently high oxygenation index (up to 62), she was cannulated for VV ECMO with a 19 French bicaval dual lumen cannula. During her ECMO run, therapeutic bronchoscopy (on days 5 and 6) was used for lung recruitment and removal of secretions, biventricular mildly depressed cardiac function was managed with a milrinone infusion, and continuous veno-venous hemofiltration was used for fluid management (patient maintained good urine output). She was empirically treated with broad spectrum antibiotics (vancomycin and piperacillin/tazobactam) as well as fluconazole when the respiratory culture grew Candida albicans. There were no significant bleeding episodes. She was weaned and decannulated after 7.5 days on ECMO, then subsequently transferred for inpatient rehabilitation on hospital day 23. Patient has since completed all therapy for neuroblastoma and remains in clinical remission. Previous analysis of the Extracorporeal Life Support Organization registry showed that 29 pediatric patients received ECMO support after HSCT. Out of the 3 patients who survived to discharge, 1 patient had an oncologic diagnosis with respiratory failure due to respiratory syncytial virus. Although the reported survival remains low, each patient should be thoughtfully evaluated for ECMO candidacy and HSCT status should not be an automatic exclusion. We believe that our patient was a good candidate for the following reasons: reversible single organ failure, neurologically-intact baseline, non-neutropenic, and no significant risk of bleeding. Our case supports that careful patient selection can lead to a successful outcome.

Contact:
Feifei Williams, MD
Division of Critical Care Medicine
Children’s Healthcare of Atlanta at Egleston
1405 Clifton Rd NE
Atlanta, GA 30322
feifei.williams@choa.org
Assessing effects of a lower hematocrit transfusion threshold on neonatal ECMO outcomes
Sawyer, A., Stansfield, B., Wise, L., Bhatia, J. Children’s Hospital of Georgia, Augusta University, Augusta, Georgia

Objective: Infants receiving support from extracorporeal membrane oxygenation (ECMO) require replacement of blood products due to the relative coagulopathy maintained in the ECMO circuits and high risk of bleeding complications, but the optimum threshold hematocrit level to trigger transfusions has not been established. The objective of this study was to examine the effect of lowering the hematocrit threshold for transfusion on blood product utilization and patient outcomes.

Design: Retrospective cohort study

Setting: Neonatal ICU at a single tertiary care center

Patients: Infants requiring ECMO for respiratory support from December 2009 to November 2014

Interventions: None

Measurements: Demographic data, blood product usage, coagulation profile, complications as reported to ELSO; to include clots, hemorrhage, tamponade and component failure; and mortality were compared between a group of infants with a transfusion threshold hematocrit of 40% (n=37) and those with a transfusion threshold of hematocrit 35% (n=35). SAS 9.4 was used for all statistical analyses. An alpha level of 0.05 was used to assess statistical significance.

Main Results: Infants with the transfusion threshold hematocrit of 35% had a lower average hematocrit (38.34% vs. 41.38%, p < 0.0001) and received less packed red blood cells compared to the threshold hematocrit of 40% group (10.39 mL/kg/d vs. 13.31 mL/kg/d, p = 0.002). There was no significant difference in reportable complications during ECMO, survival off ECMO, or survival to discharge between groups.

Conclusions: Lowering the threshold for administering a transfusion to a neonate on ECMO from a hematocrit of 40% to 35% resulted in a decreased exposure to red blood cells with no increase in adverse effects or mortality.
Changes in VCAM-1 and ICAM-1 during ECMO support in Infants are different than adults

Yates, Andrew R.; Chicoine, Louis G.; Cismowski, Mary; Robinson, Melissa; Duffy, Victoria; Frazier, W. Joshua; Nationwide Children's Hospital, U.S.A.

Background: ICAM-1 and VCAM-1 are endothelial adhesion proteins involved in leukocyte translocation and vascular inflammation. Non-ECMO congenital diaphragmatic hernia (CDH) patients have demonstrated elevated ICAM and VCAM in patients with pulmonary hypertension. Additionally, ICAM-1 is not altered by cardiopulmonary bypass in children undergoing cardiac surgery while VCAM-1 drops in all patients other than those that developed low cardiac output syndrome. The impact of ECMO support on soluble ICAM-1 and VCAM-1 has not been evaluated.

Methods: Serial blood sampling of infants and adults undergoing ECMO support were obtained. Enrolled subjects underwent whole blood collection at time points: pre-ECMO, 4 h post-cannulation, ECMO days 1, 3, 5, 7, pre-decannulation, and post-decannulation. Samples were immediately processed into platelet poor plasma and frozen at -80°C. ICAM-1 and VCAM-1 were analyzed using ELISAs. Basic demographic and clinical data were obtained on all patients.

Results: 7 infants requiring ECMO support for CDH and 3 adults requiring ECMO support for lung graft failure (LGF) after transplantation have been enrolled to date. There was no difference in soluble VCAM-1 between CDH and LGF pre-ECMO, 4 hrs. on ECMO, day 1, 3, 5, and 7 of ECMO support, prior to decannulation or after decannulation. VCAM-1 levels did not change over time in the LGF patients (p=0.7), but change over time in the CDH patient population (p=0.02). ICAM-1 was higher in LGF prior to ECMO (median 1392 ng/ml (range 906.4-1506 ng/ml)) vs. 178.8 ng/ml (151.6-514.5), p=0.02, 4 hours on ECMO (1361 ng/ml (643.3-1399) vs. 192.9 ng/ml (143.8-418.4), p=0.02), and remained higher on day 1 of ECMO support (1337 ng/ml (631.2-1721) vs. 211.7 ng/ml (136.3-389.9), p=0.02). There was no difference between ICAM-1 levels on day 3 or 5 of ECMO (p>0.05) in LGF patients. Additionally, there was no difference in pre-decannulation and post-decannulation ICAM-1 levels in CDH compared to LGF. ICAM-1 levels in CDH increased over time (p=0.03) unlike LGF patients where ICAM-1 levels did not change with time (p=0.86).

Conclusions: VCAM-1 and ICAM-1 patterns on ECMO are different than CPB or non-ECMO CDH patients. Further investigation is warranted into endothelial function for patients supported by ECMO.

Andrew R. Yates
The Heart Center
Nationwide Children's Hospital
700 Children's Drive
Columbus, OH 43212
614-722-3135
Transfusion related Changes in Blood Virome during ECMO

Yates, Andrew R; Chicoine, Louis G; Frazier, W. Joshua; Kapoor, Amit
Nationwide Children’s Hospital, U.S.A.

Background: Blood borne viruses (BBV) can be either endemic viruses, that are constantly present in defined communities (different herpes viruses, HIV, HCV, HBV etc.) or epidemic viruses that are introduced due to recent introduction in a community (West Nile, Dengue virus, Zika etc.). Identification and characterization of BBVs is the most important and necessary step for formulating strategies to prevent virus transmission and diseases in transfusion recipients. Torque teno viruses (TTVs), one of the most common constituents of human blood virome can transmit through blood transfusions. Although, largely disregarded as a non-pathogenic DNA virus, a few studies found association between high-titer TTV viremia and immunosuppression. Interestingly, newer compelling data indicate TTV-encoded microRNA can interfere with human interferon signaling.

Methods: With IRB approval, paired blood samples prior to and after ECMO support were obtained. We examined samples for TTV virus DNA using generic PCR assays. Basic demographic information was obtained including exposure to blood products and details related to outcomes were tracked. Non-parametric statistics were utilized for comparisons with p<0.05 as significant.

Results: 8 infants were included in the study with a median age of 1 day (range 0-18), and weight of 3.6 Kg (range 2.7 – 4.6 Kg) supported for a median time of 6 days (range 1 – 15) of ECMO support. 3 of 8 (37.5%) neonates were found positive for TTV. In these three neonates, only the post transfusion sample showed presence of TTVs indicating their recent infection. Infants who developed new infection with TTV had more exposure to packed red blood cells (PRBC) [median 16 units (range 5-16) vs. 4 units (range 4-9), p=0.04]. There was no difference in unit exposures for Plasma (FFP; p=0.4), platelets (p=0.18), or cryoprecipitate (p=0.46).

Conclusions: Newly detected Torque Teno Virus may be associated with transfusion of blood products in neonates. Further investigation into clinical significance and persistence is warranted.

Andrew R. Yates
The Heart Center
Nationwide Children’s Hospital
700 Children’s Drive
Columbus, OH 43212
614-722-3135
Andrew.yates@nationwidechildrens.org
When to say yes, pushing the boundaries for inclusion criteria

Presented by:
Katrina Younger, RRT
Craig Beckman, RN
Annie Anderson, RN
Dr. Anthony Charles, MD, MPH, FACS

University of North Carolina Health Care
Chapel Hill, North Carolina

A 23 year old male patient with a complex medical history including widely metastatic testicular cancer with suspected intra-alveolar hemorrhage due to tissue necrosis and known polysubstance abuse, presented with acute respiratory distress syndrome post chemotherapy treatment. Despite multiple attempts to ventilate and oxygenate the patient was cannulated for veno-venous ECMO for six days. The patient was then successfully decanulated, and was able to be weaned off of all ventilatory support.

Contact: Katrina Younger, B.S., RRT-ECMO Specialist
UNC Children’s Hospital
101 Manning Drive, Chapel Hill, NC 27514
984-974-1336
kyounger@unch.unc.edu
A two year old female with a known atrial septal defect (ASD) from birth presented for transthoracic echocardiogram, and was found to have moderate right atrium/right ventricle dilation for which surgical repair was recommended. The patient was admitted to the pediatric intensive care unit (PICU) following ASD repair. Subsequently the patient’s post operative course was complicated by the development of a junctional ectopic tachycardia, leading to low cardiac output syndrome and cardiac arrest. As a result the patient was emergently placed on veno-arterial (VA) extracorporeal life support (ECLS) via central cannulation. After a six day initial VA ECLS run the patient was weaned from ventilator support, extubated and prepared for transfer to the pediatric floors. During this post-ECLS period she suffered from an aspiration pneumonia event, which led to re-intubation and escalation to high frequency oscillation ventilation (HFOV). She nearly required ECLS for this event but recovered and was able to be extubated again. Her vocal cords were evaluated and she was found to have a paralyzed right vocal cord, but good glottis closure. She subsequently had yet another aspiration event leading to another re-intubation. This time she failed rescue with HFOV and ultimately required veno-venous ECLS cannulation via percutaneous neck cannulation with a double lumen cannula. Following an eight day course, the patient was successfully weaned from VV ECLS support.

This case presents successful ECLS course for both VA cardiac ECLS run post cardiac arrest and a VV respiratory ECLS run for acute respiratory distress syndrome with in the same patient during the same admission.

Contact: Katrina Younger, B.S., RRT-ECMO Specialist
UNC Children’s Hospital
101 Manning Drive, Chapel Hill, NC 27514
984-974-1336
kyounger@unch.unc.edu
Extracorporeal Life Support As Rescue Therapy For Pediatric Out-of-Hospital and Emergency Department Cardiac arrest: A 20 year Single Center Experience

Priscilla Yu, Aditya Badheka, Joseph W. Rossano, J. William Gaynor, Chitra Ravishankar, James T. Connelly, Mahsun Yuerek, Maryam Y. Naim

The Children’s Hospital of Philadelphia

Introduction:
The role of extracorporeal life support (ECLS) is well established for refractory pediatric in-hospital cardiac arrest however, there are few data on the use of extracorporeal cardiopulmonary resuscitation (ECPR) for pediatric out-of-hospital cardiac arrest (OHCA). We aimed to describe our institution’s experience with ECPR as a rescue strategy for pediatric OHCA and emergency department (ED) cardiac arrests.

Methods:
A retrospective study was conducted of children admitted to a single institution treated with ECPR for OHCA and ED cardiac arrest from January 1995 to December 2015. The primary outcome was survival to hospital discharge. Neurological status at discharge was assessed using pediatric cerebral performance category (CPC) scoring. Good neurological outcome was defined as CPC score of 1 or 2 at the time of discharge.

Results:
A total of 14 patients received ECPR for OHCA (n=10) and ED (n=4) cardiac arrest. Mean age was 5.7 ± 5.9 years, 60% were male, and 50% were white. Initial cardiac rhythms were ventricular fibrillation or pulseless ventricular tachycardia in 36%, and asystole, bradycardia and pulseless electrical activity in 64%. The most common etiology of arrest was presumed cardiac in 11/14 (79%). Five children (35.7%) were successfully weaned off the ECLS, including 100% of ED cardiac arrests. There was one patient who was successfully weaned off ECLS who did not survive to hospital discharge. All four survivors (28%) had cardiac arrests due to presumed cardiac etiology with good neurologic outcome. Mean time from onset of cardiac arrest to initiation of ECLS was 97 ± 67 min (range 45-270 minutes); lower in survivors 61 ± 17 minutes (range 44-270 minutes) compared to non-survivors 112 ± 78 minutes (range 45-85 minutes), p=0.04. Mean peak lactate was lower in survivors 6.1 ± 1.9 mmol/L (range 4.2-7.8 mmol/L) compared to non-survivors 13.8 ± 5.3 mmol/L (range 8.9-24.8 mmol/L), p<0.01. Mean duration of ECLS was 3 ± 2.8 days; lower in the non-survivor group 1.7 ± 1.6 days compared to the survivor group 6.1 ± 3 days, p=0.03. The lower duration of ECLS in the non-survivor group was due to withdrawal of support secondary to poor neurologic prognosis.

Conclusion:
In this single center report, ECPR was used infrequently over two decades in refractory OHCA and ED cardiac arrests with an overall survival of 28% with neurologically favorable outcome in all survivors. This study suggests that rescue ECPR in children may be effective when used for refractory ED cardiac arrests of presumed cardiac etiology but not for prolonged OHCA. Further investigation is needed to define cost-effectiveness of this resource intense therapy with an emphasis on patient selection to improve outcomes.

Contact: Priscilla Yu, MD, 4612 Meadow Ridge Dr, Plano, TX 75093, (310) 433 8607, dr.priscilla@yahoo.com
Effect of hemofiltration on heparin dose in pediatric extracorporeal membrane oxygenation (ECMO)

Keegan Ziemba, MD, MPH; W. Joshua Frazier, MD; Melissa Clingenpeel-Moore, MAAS
Nationwide Children’s Hospital, Columbus, OH

Patients requiring ECMO are often fluid overloaded as a result of pre-ECMO fluid resuscitation or ongoing inflammation. Continuous hemofiltration (HF) allows for net fluid removal but the effects of HF on drug clearance are largely unknown. Since unfractionated heparin is the anticoagulant used to maintain ECMO circuit function in our hospital, we conducted this retrospective review of consecutive ECMO patients undergoing HF to test the hypothesis that initiation of HF would affect heparin dosing requirements.

Data were reviewed for all ECMO patients in the pediatric and cardiac ICUs at Nationwide Children’s Hospital who received HF for fluid removal from 01/2010 – 06/2015. HF was accomplished with Terumo components. We examined activated clotting time (ACT), antifactor-Xa (anti-Xa), activated partial thromboplastin time (aPTT) and heparin dose (U/kg) in the 6 h pre- and 6 h post-HF initiation. Transmembrane oxygenator gradient pressure, as a surrogate of circuit clotting, was also measured pre-and post-HF. All data were analyzed by Wilcoxon matched-pairs signed rank test.

63 patients were analyzed. Heparin dose to maintain goal anticoagulation (ACT 180-220, anti-Xa 0.3-0.6, aPTT 60-80) was higher after HF (p = 0.0001). A decrease in ACT by 10% was associated with increased heparin doses (p < 0.05). No differences were noted between pre- and post-HF anti-Xa, aPTT, or transmembrane oxygen gradient.

HF increased heparin dose in ECMO patients at our center which was likely prompted by lowered ACT. The lack of change in anti-Xa and aPTT post-HF is perhaps due to the infrequency of measurement relative to ACT at our hospital, meaning adjustment of heparin based on ACT prevented changes in other measures. Our data support the conclusion that HF increases heparin requirement, likely thru increased clearance. Our data also suggest ACT trend continues to have a role in management of ECMO patients undergoing HF or other interventions which can rapidly alter heparin dynamics.

Keegan Ziemba, MD
Pediatric Critical Care- FB, Suite 2B.1
Nationwide Children’s Hospital
700 Children’s Drive
Columbus, OH 43205
614-722-3613
keegan.ziemba@nationwidechildrens.org
Survey of ECMO Practices for Infants with Hypoxic Ischemic Encephalopathy

Hitesh S. Sandhu, Kirtikumar Upadhyay, Mark F. Weems
Le Bonheur Children’s Hospital, University of Tennessee Health Science Center, Memphis, TN

Purpose: Therapeutic hypothermia is the standard of care for treating term neonates born with hypoxic ischemic encephalopathy (HIE). Up to 25% of these infants also suffer from pulmonary hypertension. Extracorporeal membrane oxygenation (ECMO) improves survival in neonates with pulmonary hypertension but is controversial in HIE patients because irreversible brain injury is a contraindication for ECMO. There is a concern that these patients may have increased risk of intracranial bleeding, ischemia, or stroke. The aim of this study is to identify ECMO practice preferences among centers and practitioners caring for infants with HIE.

Methods: A 22 question electronic survey was sent to neonatal medical directors and ECMO directors at 149 hospitals in the USA and Canada. Participants were asked if they would offer ECMO on a scale of 1 (Never) to 5 (Always) the responses were compared to Chapman et al, *J Perinatology*, 2008.

Results: We collected 89 responses representing 68 of 149 invited institutions (46%). Participants were 53% ECMO director, 57% NICU director, and 15% both. 72% of respondents had initiated or referred for ECMO during cooling therapy. Only 24% of institutions had a written ECMO criteria for HIE patients. During ECMO, 30% of institutions used the circuit only for therapeutic hypothermia while 28% used the circuit with body or head cooling; 15% discontinued cooling. Compared to 2008 survey, participants were more likely to offer ECMO for moderate and severe HIE (Figure). Neonatologists were more likely than non-neonatologists to offer ECMO for all severities of HIE. Most providers stated that they would be less likely to offer ECMO for clinical variables listed in the table or if they could accurately predict severe or profound neurodevelopmental delay.

Conclusion: There is wide variability among institutional ECMO practices for patients with HIE, and few institutions have written criteria to address this issue. There has been a shift towards offering ECMO for all neonates with HIE since 2008. Additional research is needed to determine if ECMO improves outcomes for patients with severe HIE.

Table. Clinical variables making providers less likely to offer EMCO.

<table>
<thead>
<tr>
<th>Clinical variable</th>
<th>Less likely to offer EMCO (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aEEG/EEG</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Moderately abnormal</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Severely abnormal</td>
<td>51 (78%)</td>
</tr>
<tr>
<td>No effect</td>
<td>7 (10%)</td>
</tr>
<tr>
<td>Posture</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Flexion</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Decerebrate</td>
<td>49 (71%)</td>
</tr>
<tr>
<td>No effect</td>
<td>15 (22%)</td>
</tr>
<tr>
<td>Activity</td>
<td></td>
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<tr>
<td>Normal</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Decreased</td>
<td>5 (7%)</td>
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<tr>
<td>No activity</td>
<td>47 (68%)</td>
</tr>
<tr>
<td>No effect</td>
<td>12 (17%)</td>
</tr>
<tr>
<td>Cord pH</td>
<td></td>
</tr>
<tr>
<td>&gt;7.00</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>6.70-7.00</td>
<td>10 (15%)</td>
</tr>
<tr>
<td>≤6.70</td>
<td>29 (43%)</td>
</tr>
<tr>
<td>No effect</td>
<td>6 (9%)</td>
</tr>
</tbody>
</table>

Figure. How often would you offer ECMO if the following conditions were present? Compared to Chapman et al, *J Perinatology*, 2008.

Hitesh S Sandhu, 50 N Dunlap, Suite 380R, Memphis TN, 38103, 862 596 7121, hsandhu@uthsc.edu.