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GENERAL

A Novel Score to Predict Outcome in Patients Supported by Veno-Arterial Extracorporeal Membrane Oxygenator

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Introduction/Aim: High mortality remains a major complication of an increasingly used veno-arterial extracorporeal membrane oxygenation (VA-ECMO) for cardiogenic shock. The Sequential Organ Failure Assessment (SOFA) score is known to predict ICU mortality.
Methods: Multivariate logistic regression analysis was performed to investigate predictors of ICU mortality in all patients on VA-ECMO between 2004 and 2015 in our tertiary referral hospital. Variables included SOFA score, age, C-reactive protein (CRP), heart failure etiology, and persisting right heart failure (RHF) during VA-ECMO on echocardiography.
Results: The study comprised of 103 patients with a mean age of 49±16 years, 54% male. Causes of cardiogenic shock were: ischemic in 23 (22%), non-ischemic in 25 (24%), postcardiotomy in 25 (24%) and 30 (29%) of various etiology. During a median VA-ECMO support of 7 days [rage 0–52], 63 (61%) survived ICU, with 10 patients bridged to left ventricular assist device, 2 to heart transplant. Twenty-two (21%) patients had a persisting RV failure during VA-ECMO support with 86% mortality. A combined SOFA and a severe persisting RHF score has 4 fold (OR =27.2, 95% CI 6.5- 113.6) vs. (OR=7.1, 95% CI 2.2-23.3) more predictive value of ICU mortality compared with SOFA score alone.
Conclusions: Adding RHF to SOFA score better predicts ICU mortality in patients supported by VA-ECMO.

Recirculation in Venovenous Extracorporeal Membrane Oxygenation

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Introduction/Aim: Venovenous extracorporeal membrane oxygenation (ECMO) has the ability to support gas exchange in respiratory failure. VV ECMO has fewer vascular complications as compared pumpless interventional lung assist and veno-arterial ecmo. The effectiveness of ECMO is dependent on multiple factors such as the amount of blood flow, cardiac output, metabolic demand, sweep gas, diffusion and surface area of oxygenator and the amount of recirculation within the circuit. Other ontributing factors to recirculation include patient movement which may affect cannula position, volume status, high ECMO flow and the distance between the return and drainage cannula has been shown in multiple studies to increase recirculation. Higher recirculation many decrease the efficacy of VV ecmo and may lead to severe hypoxemia and multi-organ failure.
Methods: A literature review was conducted by using different electronic data bases such as MEDLINE, PubMed, CINAHL, Sage and Science Direct. The following terms were used such as recirculation, respiratory failure, extracorporeal membrane oxygenation (ECMO) as keywords or combined to guide the search.
Results: There is no routine method to measure the recirculation fraction. Two method such as use of bicaval double-lumen cannula and correct positioning can reduce significant recirculation. Studies have proposed a step wise approach/ algorithm to guide specific intervention to decrease the amount of recirculation in the circuit.
Conclusion: The combine echocardiography and ultrasound dilution may help to optimize cannula positioning. Advances in extracorporeal cannulation strategies, particularly the development of the dual-lumen cannula has lessen the amount of recirculation in VV ecmo.

Nursing and Interdisciplinary Challenges: Veno-Venous Extracorporeal Membrane Oxygenation

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Introduction/Aim: Daily nursing care such as positioning, sponge bath and mobilization impacts on the physiological parameters: desaturation, hypertension, reduction in ECMO blood flow and mixed venous oxygen saturation of the patients with veno-venous ECMO. These patients are unstable due to oxygenation, anticoagulation and possible risk for accidental decannulation. Cannula position displacements are highly reported with veno-venous ECMO. Patients on ECMO require higher doses of sedation and opioids, this increases the risk for significant physical impairments [4].
Methods: A systematic search was done in October 2016, to access research studies on nursing care, and challenges on patients undergoing veno-venous extracorporeal membrane oxygenation. Key words included: ECMO, nursing care, weakness, physical rehabilitation and sedation. Data bases: CINAHL, PubMed, Sage and Science Direct were used to guide the search. The search ranged from 2010 to 2016. A total of 90 articles appeared, only fifteen articles relevant to the study purpose. The aim of the study was to identify safe nursing care protocol and prevent challenges in caring for patients with veno-venous extracorporeal membrane oxygenation.
Results: No significant study discusses challenges during routine nursing care and increase in sedation requirements in patient with VV ECMO. One of the studies [2] showed a relationship between work of breathing and oxygen requirements during nursing care activities (bed baths, turning). Some studies recommended the evidence-based ´ABCDE´ bundle, an interdisciplinary approach for the management of ECMO patients [5].
Conclusion: Spontaneous awakening, breathing trials, choice of sedation and analgesia, delirium monitoring and early mobility exercises are recommended to decrease ICU and hospital length of stay and improving survival [1]. It is recommended to develop safe and practical interdisciplinary protocols. Multidisciplinary team should also involve during nursing care activities to adjust sedation plan, ECMO and ventilator settings to prevent or treat critical changes in vital signs or deterioration.

Native Heart Against ECLS – Numerical Simulation of the Competing Circulations and Their Impacts

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Introduction/Aim: Should manual resuscitation in the event of acute cardio-vascular failure be unsuccessful, technology needs to be used to restore the circulation. However, when the heart pump resumes, it competes in competition with the artificial circulatory system, which in turn impairs patient recovery.
Methods: A virtual 3D model was generated, based on CT data of a human aorta to include the influence of real human anatomy. Pressure in the aorta was 90mmHg. A geometrically standard cannula of 16Fr was positioned in the left superficial femoral artery. The volume flow fraction from the native heart and ECLS were systematically varied to produce aortic flow of 5l/min. The pressure boundary conditions at the arterial outlets were selected to demonstrate the downstream vascular system.

Results: At a flow fraction of 25% from the ECLS, the supply level in the branching arteries is largely the same as that when supply is provided exclusively by ECLS. A defined interface forms between the two opposing blood flows rather than a mixing zone. The range of ECLS blood flow depends on native cardiac flow. Even with 100% ECLS flow, the left ventricle and its coronary arteries are not reached.
Conclusion: In silicio modelling of the human circulatory system, as part of the EMPACs project, makes it possible to qualitatively and quantitatively simulate and analyse the effects of competing circulatory systems. The simulation model is currently being further developed to include the analysis of dynamic effects.

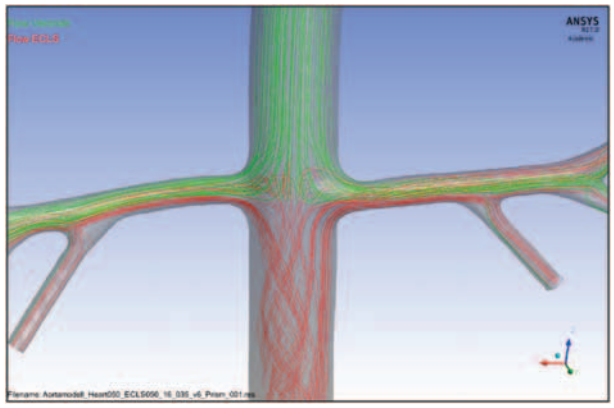

Figure 1: Shock front (Flow fraction: 0.5/0.5)

Double-Lumen Canula Better than Single-Lumen Canulas During a VV-ECMO? - An In-Silico Comparison

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Introduction: Clinical practice reveals that that oxygen supply to a patient receiving VV-ECMO is consistently less than optimal. The position and construction of the cannula influence flow within the vena cava and the right atrium.

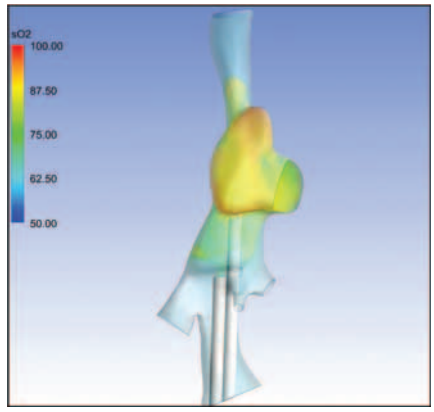

Figure 1: Double-Lumen-Canula (Oxygen Saturation)

Methods: MRI data was used in systematic in-silicio analysis to generate a virtual model of a native vena cava based on human anatomy.
Starting from conventional distances between inlet and outlet lumens, the distance was varied for both ECMO cannula. Static near-reality simulations within physiological boundaries limits were run, excluding the pulse.
Results: A femoral double-lumen cannula (DLC) with an ECMO flow rate of 3l/min resulted in an immediate increase in sO_2 of approx. 21% with a recirculation degree (GRC) of approx. 65%. This was recorded for the standard and all other positions, and all cannula tip distances. This value was only achieved at a maximum symmetrical inter-tip distance of 198 mm for a single lumen cannula cannula (SLC). The lowest GRC value of 60%, combined with a lower increase in oxygen saturation of approximately 8%, was achieved at all inter-tip distances for DLCs, whereas this was only achieved for SLC at a maximum inter-tip distance and a ECMO flow of 1l/min.
Conclusion: Oxygen saturation and recirculation degree in ECMO with a DLC was influenced by inter-tip distance and, as with the SLC, also by the positioning of both cannula tips. The resulting jet stream can be positively exploited using a double-lumen cannula.
In-silico studies are an ideal compliment to classical investigative techniques.

A New Application for Recording Extra-Corporeal Life Support Data

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Introduction/Aim: Extra-corporeal life support (ECLS) is used increasingly frequently, and standardisation of data collection could be useful for the creation and analysis of ECLS databases.
Methods: We developed an application (app) specifically for use with ECLS. Three common situations are covered, namely refractory out-of-hospital cardiac arrest, refractory in-hospital cardiac arrest, and cardiogenic shock. The app records data regarding initiation of ECLS, management, follow-up and discharge of patients. The main app interface presents 11 intuitive icons that each open the respective pages for data completion.
Results: The app is already available for free download on the Appstore (name: ECLS) for optimal use with iPad. After a learning curve, data entry is easy, and facilitated by a reminder of the number of missing data variables for each page, as well as shortcuts that allow the user to re-use the previous day's data if there has been no change. Numerous security features guarantee data safety.
Conclusions: This app is useful for recording ECLS data on large series of patients, and could be used for research purposes to study outstanding questions in this area.

D-Dimer and CO_2 Removal Capacity: Another Way To Evaluate Oxygenator Performance During ECMO?

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Introduction/Aim: Extracorporeal circuit non-biologic surface triggers activation and consumption of pro- and anti-coagulant blood components[1]. Increased plasma D-dimer levels could therefore reveal clot apposition on membrane lung (ML) fibers[2], as a marker of ML aging process[3]. The resulting dead space (DS)[4], with ventilated but not perfused ML units, reduces ML CO_2 removal ($V'_{ML}CO_2$) capacity[5]. We have already proposed a ML functional assessment based on $V'_{ML}CO_2$ ratio[6] (proportion of actual $V'_{ML}CO_2$ to corresponding bench reference value at given gas/blood flows ratio). The aim of our study was to combine D-dimer as additional parameter for ML assessment.
Methods: $V'_{ML}CO_2$ ratio, D-dimer, DS and P/F (blood-outlet O_2 partial pressure divided by gas-inlet O_2 fraction) values are expressed as medians; comparisons of variables between high and low $V'_{ML}CO_2$ ratio measurements were made by Mann–Whitney test.
Results: We divided $V'_{ML}CO_2$ ratio measurements in two groups according to $V'_{ML}CO_2$ ratio median value (0,83). Measurements above the median were associated with lower levels of D-dimer (4118 ng/ml vs 7435 ng/ml, p<0,001) and DS (0,24 vs 0,34, p<0,001), and higher levels of P/F (315 vs 278, p=0,027).
Conclusion: Our data confirm the value of $V'_{ML}CO_2$ ratio for ML performance assessment. Decreased $V'_{ML}CO_2$ ratio and increased DS correlates with increased D-dimer levels. Thus decreased $V'_{ML}CO_2$ ratio is confirmed to be due to partial clot apposition. CO_2 removal based indexes combined with D-dimer levels could represent early predictors of ML deterioration, to guide ML replacement decision-making.

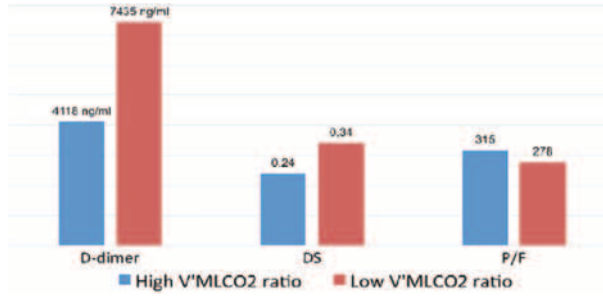

Figure: High $V'_{ML}CO_2$ ratio measurements were associated with lower levels of D-dimer (4118 ng/ml vs 7435 ng/ml, p<0,001) and DS (0,24 vs 0,34, p<0,001), and higher levels of P/F (315 vs 278, p=0,027).

Outcome of Inter-Hospital ECMO / ECLS Transport – the Zürich Experience

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Introduction / Aim: An ECMO – Transport Service (ETS) offers access to heart and lung support therapy for patients in peripheral hospitals that normally were too sick to transport.
Here we describe the Zurich experience of the last 4 years, where we built an ETS.
Methods: This is a retrospective analysis from 01/2013 to 12/2016 of our ECMO database. The patients, which received an ECMO - implantation in a peripheral hospital (transport group, n=51) and then thereafter were transported to the university hospital of Zurich (USZ) were compared to the patients receiving an ECMO implantation in USZ during the same period of time (control group, n=374). The primary endpoint of this analysis was 30 days mortality. Both groups were divided into different types of cannulation.
Results: The numbers of ECMO – runs and ECMO – transports done per year and the associated overall mortality are shown in figure 1. In V-V ECMO 30 days survival in the transport group vs. control group was 92% (n=25) vs. 71% (97) respectively; whereas in V-A ECMO it was 50% (n=13) vs. 49% (n=32). Among the survivors, the average number of days on ECMO therapy in the transport and control group were 8.0 days (+/– 6.8 days) and 6.0 days (+/– 11.8 days) respectively.
Conclusion: Our current data shows that the external ECMO – transport, while case numbers increased continuously, has no negative effects on the patient's outcome. The findings therefore suggest that ECMO – transport and implantation in a foreign setting seems to be safe. The treating physicians outside of ECMO centers should consider ECMO implantation and transport to the center a reliable therapeutic option in selected patients.

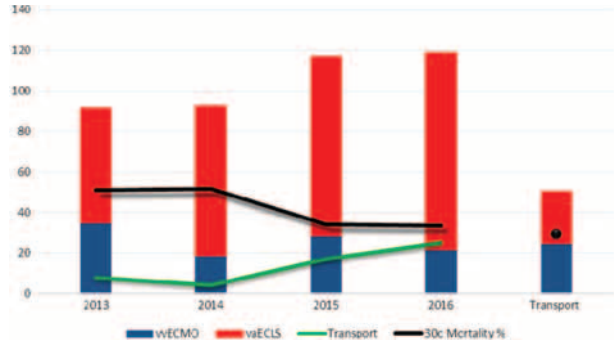

Figure 1. Overview of the data collected from 2013 to 2016. The numbers of ECMO (blue) and ECLS (red) done per year are shown in columns. As lines are depicted the number of transports (green) during the same period and the overall 30 days mortality (black). On the right side the column aggregates the overall numbers of transports done from 2013 to 2016 – again in blue ECMO and red ECLS; the black dot shows the overall mortality on transport.

Quality Improvement Project. Cardiohelp Device Incident Analysis and Response: The Experience of a Regional ECMO Centre

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Introduction/Aim: Extracorporeal membrane oxygenation (ECMO) enables the provision of prolonged extracorporeal respiratory and cardiac support
International recognition as rescue therapy for refractory cardiac arrest[1]
Recent introduction of Cardiohelp platform, an 'intelligent' miniaturised ECMO device offering a sophisticated system of patient safety functions comprising warning limits, alarms and intervention settings. Device offers significant advantages but its use demands a change in clinical practice therefore device incidents have been closely monitored To analyse Cardiohelp device critical incidents. To develop strategies to improve processes of care delivery
Methods: Analysis of all incidents 01/10/2015 – 30/09/2016
Device data extracted from Cardiohelp internal auditing device which records cyclic and asynchronous data (data logging). Data decoded to determine sequence of events.
Actions taken compared with Standard Operating Procedures (SOPs) which detail correct use of intervention settings and appropriate response. Decoded data compared with corresponding incident report forms (Datix) to gain better understanding of interplay of human factors contributing to incident.
Result: Common theme errors emerged from the analysis: Bubble intervention incorrectly on in VV-ECMO mode. Identified that urgent action needed to raise awareness of intervention settings and correct response.
Conclusion: Incident analysis enabled a specific knowledge and skills gap to be identified and targeted interventions to be put in place.
This study highlights the importance of constant review and analysis when using cutting edge technology.

VAD Development Techniques Applied on ECMO Oxygenators

The Hidden Improvement Potential

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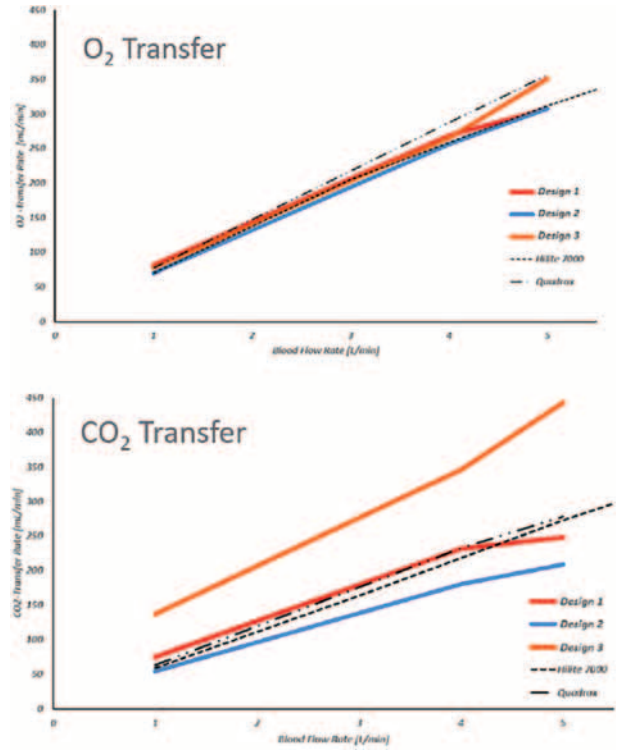
Introduction/Aim: In the past two decades, implantable blood pumps have undergone a continuous improvement process which results in a significant technology shift. The same engineering principles can be applied to oxygenators which have seen little innovation in the same time period.
Methods: Hemolysis is mainly caused by negative pressure and too high shear stress. Thrombus formation is triggered by foreign surfaces contact and insufficient wash out zones which lead to stagnant flow areas. In addition, hemodilution by high priming volumes is disadvantageous for the patient per se.
Fluid dynamic based design principles have been used to developed a novel gas exchanger for longer term usage focussed on the above-mentioned parameters. In addition, homogenous flow patterns result in higher gas exchanger efficiency. Initial prototypes have been optimized during multiple design iterations and have been tested in terms of pressure loss and flow patterns in water glycerol with 3.6 cPoise. Gas exchange rates have been determined according to EN ISO 7199:2014 using porcine blood (Hb=12,7g/dL±0,2g/dL) with sO_2=63,5%±2,2% and pCO_2=46,4 mmHg±1,9mmHg prior to the oxygenator entry and a 1 to 1 sweep gas flow ratio to the blood flow.
Results: The best oxygenator prototype shows low pressure loss (50mmHg at 5L/min), excellent wash out and provides a significantly reduced surface (1.3m^2) area and priming volume (170mL). At the same time gas exchange properties were at least comparable or better than currently available devices. The O_2 transfer rate is 300 mL/min and CO_2 transfer rate is 280 mL/min at 5 L/min of blood flow.
Conclusion: The consequent application of development methods proven to be successful in VAD blood pump design have led to a promising device prototype as a basis for a next generation ECMO/ECLS systems.



Extracorporeal Membrane Oxygenation for Neuroprotection. A Case Report

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Introduction/Aim: Hypoxemia and hypercapnia in cases with severe cerebral vasospasm (CV) and acute respiratory distress syndrome (ARDS) lead to brain damage. Extracorporeal membrane oxygenation (ECMO) can be neuroprotective, but its usage is extremely rare in neurosurgical practice.
Case report.: A 42-years-old gentleman with subarachnoid hemorrhage due to rupture of an aneurysm of the left ACA (Hunt-Hess IV; Fisher IV) was transferred to our center on day 2 after bleeding. The aneurysm was coiled. CV was revealed on day 5, and invasive multimodal neuromonitoring (ICP, PbrO2) was started with a Licox/Camino probe (Integra, USA). Vasospasm progressed during the next 5 days. On day 10 the clinical picture of panhypopituitarism appeared. On the next day ARDS developed. In spite of protective ventilation both arterial hypoxemia and hypercapnia persisted. These abnormalities resulted in intracranial hypertension and a decreased PbrO2. Coma and hemiparesis developed. V-V ECMO was started. Heparin was administrated for anticoagulation in spite of a high risk of intracranial hemorrhage. Our strategy was to use low-dose heparin with maintenance of the activated clotting time (ACT) between 120–140 seconds. After ECMO starting, parameters of neuromonitoring stabilized, and the patient's neurological status gradually improved. ECMO support lasted for 5 days. The patient´s Glasgow Outcome Scale at hospital discharge was 4, and improved within 6 months to 5.
Conclusion.: ECMO can be an effective method for neuroprotection in neurocritical patients with severe CV and ARDS. Meticulous surveillance of hemostasis parameters with maintenance of ACT between 120 – 140 second may allow to avoid hemorrhagic complications.

High-Fdelity Simulation Creating DCD-ECMO Procedure in Poland

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Introduction/Aim: Maintaining the viability of organs from non-heart beating donors (NHBD) for transplantation is a complicated procedure from a time perspective in the absence of appropriate organizational capabilities that make such transplantation cases difficult and not yet widespread in Poland.

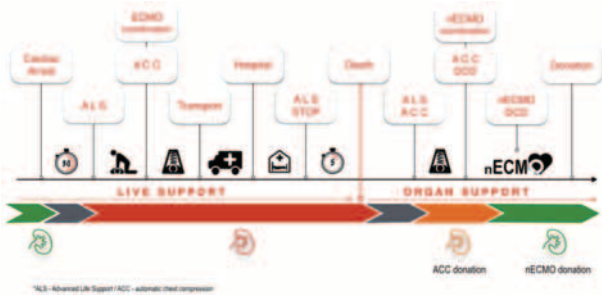

Figure 1. The "rescue chain" DCD-ECMO algorithm in Poland (ACC DCD – donation after circulatory death on automatic chest compression).

Methods: We present the procedural preparation for Poland's first case of organ (kidney) transplantation from a donor after circulatory death (DCD) in which perfusion was supported by Extracorporeal Membran Oxygenation (ECMO). Because this organizational model is complex and expensive, we used advanced high-fidelity medical simulation to prepare for the real-life implementation. The system uses silicone loop to simulate blood vessels, filled with pressurized red-dyed liquid and embedded into the groin of a mannequin. The real time scenario included all crucial steps: prehospital identification, cardiopulmonary resuscitation (CPR), Advanced Life Support (ALS); perfusion therapy (CPR-ECMO or DCD-ECMO) inclusion and exclusion criteria matching, suitability for mechanical chest compression; DCD confirmation and donor authorization.
Results: Warm ischemia time, i.e. time - first contact of mannequin to the vessel cannulation and in-situ organ ECMO perfusion, did not exceed two hours. The success of our first simulated DCD-ECMO procedure in Poland is reassuring. Soon after this simulation, Maastricht category II DCD procedures were performed involving real patients and resulting in two double successful kidney transplantations.
Conclusion: During debriefing, it was found that the previous simulation-based training allowed to build a successful procedural chain, to eliminate errors at the stage of identification, notification, transportation, donor qualifications, and ECMO organs perfusion (Figure 1).

High-Fidelity ECMO Simulation Scenarios

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Introduction: We present procedural preparation using high-fidelity medical simulation for the Poland's first unique regional program – "ECMO for GreaterPoland", for 3.5 million inhabitants of region (Wielkopolska).
Methods: Because ECMO therapy organizational model is complex and expensive, we used advanced high-fidelity medical simulation tests to prepare for real-life experiences.
Results:

- Scenario "ECMO for DCD" (donors after circulatory death) included steps: prehospital identification, CPR ALS (cardiopulmonary resuscitation Advanced Life Support); perfusion therapy inclusion and exclusion criteria, mechanical chest compression; transport; DCD confirmation and donor authorization; the veno-arterial cannulation of mannequin artificial vessels and starting in situ organ perfusion.
- Scenario "ECMO for INTOXICATION" included steps: hospital identification (in Department of Toxicology), poisoning treatment, CPR ALS; mechanical chest compression; the veno-arterial cannulation of mannequin artificial vessels and implementation of perfusion therapy using CARDIOHELP (Maquet) and qualified transport with ECMO to the another hospital (Department of Cardiac Surgery).
- Scenario "ECMO for RRF" (reversible respiratory failure) included steps: hospital identification (Regional Department of Intensive Care) - inclusion and exclusion criteria; "ECMO team" transport (80 km); therapy confirmation; the veno-venous cannulation of mannequin artificial vessels and implementation of perfusion therapy using CARDIOHELP (Maquet) and qualified transport (80 km) with ECMO to the provincial city (Clinical Department of Intensive Care), where the VV ECMO therapy was performed next 48 hours.

Conclusions: Advantages of simulation as an educational tool is invaluable. Medical simulation allows for standardized training, testing of new or commonly used procedures, skills upgrading but also to exercise the very rare cases.

Holistic Sedation for Emergency ECMO Cannulation: A New Paradigm?

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Introduction/Aim: We present an emergency veno-venous ECMO (VV-ECMO) cannulation in an awake patient with critical hypoxaemia using a multi-modal sedation technique including the presence of a psychologist.
Methods: 32 year old lady with end stage pulmonary fibrosis and severe secondary pulmonary arterial hypertension was admitted with a lower respiratory tract infection requiring emergency VV-ECMO for severe acute on chronic respiratory failure, planned as bridge to lung transplantation. Conscious sedation was administered (remifentanil and dexmedetomidine) by continuous infusion. Patient specific psychological strategies, including talking about her pleasurable activities and head massage kept the patient calm while lying flat. Saturations were measured between 60-80% throughout the procedure. VV-ECMO was established via bi-femoral cannulation with local anaesthetic infiltration. The psychologist and the patient had agreed that she wanted to be informed throughout of events. The psychologist liaised with the team throughout to ensure the patient was informed and calm.
Results: A 25 French multistage drainage cannula and long 23 French single stage return cannula were inserted and patient commenced on VV-ECMO. General anaesthesia was avoided despite critical hypoxaemia throughout the procedure. The

patient was calm and cooperative and returned to the intensive care unit with no dyspnoea and normal arterial blood gases.
Conclusion: Conscious sedation for ECMO cannulation can be used even in the context of severe hypoxaemia with peri-procedural psychological intervention being a useful adjunct. Patient specific strategies promote the patient's ability to cope with physical and psychological symptoms during ECMO initiation. Psychological support should be considered in awake ECMO initiation.

Wet Pre-Primed Circuits for ECMO: Circuit-Related Infections During a 6-Year Clinical Experience

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Introduction/Aim: ECMO-related infection is a culture proven infection from any site acquired during extracorporeal support not believed to be preexisting. Aim of the study was to investigate the safety of pre-primed wet ECMO circuits, that has never been clinically evaluated. Circuit-related infection was defined as culture proven blood stream infection during the first seven days of support, as a surrogate of the ECMO-related infections.

Table 1 Microorganisms isolated in circuit-related infections and concomitant antibiotic regimen.

Patient	Pathogen	Antibiotics
1	Klebsiella Pneumoniae	Meropenem
2	Candida Tropicalis	Broad spectrum*
3	Serratia Marcescens Pseudomonas Aeruginosa	Cefazolin
4	Candida Lusitaniae	Vancomicin, Meropenem
5	Staphylococcus Haemoliticus	Broad spectrum* + fluconazole
6	Klebsiella Pneumoniae	Vancomicin, Meropenem, Gentamycin, Colistin, Ecalta
7	Staphylococcus Hominis	Piperacillin - tazobactam
8	Staphylococcus Hominis	Broad spectrum* + fluconazole
9	Staphylococcus Hominis	Vancomicin
10	Staphylococcus Hominis	Broad spectrum* + fluconazole
11	Pseudomonas Aeruginosa	Broad spectrum* + fluconazole
12	Enterococcus Faecalis	Broad spectrum*
13	Staphilococcus epidermidis	Vancomicin
14	Candida Tropicalis	Broad spectrum*
15	Staphylococcus cohnii	Ceftriaxone

* Broad spectrum antibiotic therapy includes vancomycin, ceftazidime and levofloxacin.

Methods: Observational study on all the adult patients receiving ECMO>48 hours at our institution between May 1st, 2010 and March 31st, 2016.
Results: 266 ECMO procedures performed during the study period lasted more than 48 hours:188 VA-ECMO and 78 VV-ECMO.
Standby time was <7 days in 178 patients, between 7 and 14 days in 57 patients and >14 days in 31 cases: median standby was 3 (1–8) days, maximum value 81 days. 76(29%) patients had ECMO-related infections. Circuit-related infection rate was 5.6% (15 cases) and duration of the circuit standby was not associated with the circuit infection rate: standby time was < 7 gg in 9 patients (5%), 7–14 days in 5 cases (9%), >14 days in 1 (3.2%). All the patients were on antibiotic treatment. Candida spp and Staphylococcus spp were the most frequently isolated pathogens.
Conclusion: Circuit related infection is a severe complication of ECMO treatment. In modern era, early ECMO support should be available 24hours/day, 7/7. We showed that pre-primed circuits might be stored for several days without increasing the infection risk.

Haptoglobin Can Substitute Free Hemoglobin as a Hemolysis Marker?

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Introduction/Aim: Detecting hemolysis is crucial for the management of VA or VV ECMO. Mesuring free-hemoglobin is the gold standard for this purpose. In places without this laboratory support, we studied if haptoglobin, another laboratorial hemolysis marker, is able to help in the management of this patients.
Methods: We studied a small five cases series of patients in ECMO, three in ECMO VA and two in VV. All of patients were monitored for hemolysis with haptoglobin, bilirubin and hemogram, as we don't have (yet), free hemoglobin assay in our laboratory.
Results: We found no use of haptoglobin as a vigilance tool for hemolysis. All patients presented with haptoglobin below the detectable value, with no difference between VA or VV ECMO. Although the very low value, no clinical significant hemolysis was detected.
Conclusion: Haptoglobin is not a useful laboratory tool to search hemolysis. In places where free-hemoglobin is not available, we must find another marker to manage this complication from ECMO.

Starting an ECMO Program in a Private Hospital in Brazil

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Introduction/Aim: ECMO is a life-saving strategy to ARDS and cardiogenic shock patients. However, in developing countries with scarce resources, even in private system, start an ECMO program can face many challenges.
Methods: We present an experience of a single ICU center in a private Hospital in Rio de Janeiro (a city with the second biggest economy in Brazil) in implementing and develop an ECMO program with a year of working.
Results: Some steps must be followed to develop an efficient ECMO program, from the bottom to the top. We describe the steps to make it work from the formation of the team to reimbursement negotiation with health insurance companies using some business tools.
Conclusion: Creating an ECMO program is possible even in places with medium resources using some learnings from business tolls. This paper exhibits our experience on it, showing our strategies and expectations.

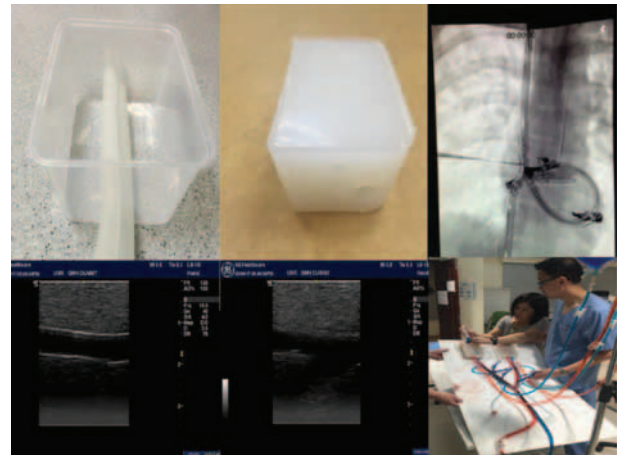
An ELSO/APELSO Developed ECMO Cannulation Model: An Overview of the Cannulation Workshop and the Evaluation of a Cannulation Course

Sin WC, Ngai CW, Mok YT, ChanWK, Lai CK, Graeme McLaren, Mark Ogino

ELSO/APELSO Organizations

Introduction/Aim: ECMO cannulation is of high risk and simulation plays an important role in acquiring cannulation skill and increase safety awareness.
A cannulation simulator (silicone ,ultrasound compatible) jointly developed by ELSO, APELSO and Queen Mary Hospital, Hong Kong was used for cannulation simulation.
Course Curriculum

1. ultrasound workshop in a health volunteer on vascular anatomy
2. TOE simulator for essential ultrasound view during cannulation
3. Cannulation practice on silicone model
    i. ultrasound guided seldinger technique, guidewire manipulation, serial dilatation, insertion of ECMO cannula , proper positioning of the cannula (bicaval cannula) and connection of cannula to ECMO circuit



Method: A retrospective analysis of a questionnaire
Results: 38 participants were recruited and all complete the questionnaire
The key findings were as follow:

1. Curriculum design (4.45 +/– 0.65, 0–5 point).
2. Cannulation model design (4.43+/– 0.69, 0–5 point).
3. Cannulation skill practicality (4.32+/– 0.72, 0–5 point).

4. Improve in cannulation safety awareness (4.48+/ 0.65, 0–5 point).
5. The self-reported confidence score before workshop was (4.34+/–2.39, 0–10 point). It was increased by 2.93 +/–1.57 points afterwards.
6. The self-rated cannulation skills score before workshop was (4.40+/– 2.84, 0–10 point). It was increased by 2.58+/– 2.02 points afterwards

Conclusion: The participants' feedback is encouraging. There is a significant gain in participants' cannulation skill, confidence and safety awareness after attending the workshop.

Experimental Study on Intra-Circuit Pressures of Continuous Blood Purification Circuit Directly Connected to ECMO Device

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Introduction: It is not uncommon that continuous blood purification (CBP) is required in patients undergoing long-term ECMO therapy, not only when acute renal failure developed but also when inflammatory cytokine removal is required. Connection of the CBP circuit to the access circuit is not recommended because of the risk of sucking air. In view of this, we conducted a study to evaluate intra-circuit pressures at varied blood flow rates, in the condition that the CBP circuit is directly connected between the centrifugal pump and the membrane oxygenator, in which intra-circuit pressure is always positive and membrane oxygenator can function as a filter.
Methods: Study Protocol
ECMO Flow Rate:1ℓ/min ~5ℓ/min (Per 0.5ℓ/min)
Blood Flow Rate (Qb): 60mℓ/min ~200mℓ/min (Per 20mℓ/min)
Simulated Blood:Glycerin 50%*20 °C ≒ HCT 33% level
Measurement Point
P1:Post-oxygenator P2:Pre-oxygenator P3:Return circuit
PHILIPS, IntelliVue MX800
Results:

Condition : Temp : 20℃ (Viscosity : Glycerin 50%≒ HCT33% level)

B/P Flow Rate (l/min)	1	1.5	2	2.5	3	3.5	4	4.5	5
RPM of centrifugal pump (rpm)	1420	1720	2040	2330	2611	2910	3170	3420	3690
P1: Blood transmission (mmHg)	66	80	97	116	140	166	194	220	250
P2 Pre-oxygenator (mmHg)	79	100	126	153	186	223	260	298	341
P3 Return blood pressure (Qb 60ml/min)	103	124	152	180	209	240	270	320	330?
P3 Return blood pressure (Qb 80ml/min)	112	137	159	188	219	254	289	323	330?
P3 Return blood pressure (Qb 100ml/min)	121	144	169	195	229	264	300	340	330?
P3 Return blood pressure (Qb 120ml/min)	131	153	180	209	240	273	310	346	330?
P3 Return blood pressure (Qb 140ml/min)	141	162	190	216	251	285	322	330?	
P3 Return blood pressure (Qb 160ml/min)	150	172	199	229	260	294	332	330?	
P3 Return blood pressure (Qb 180ml/min)	160	183	209	238	270	304	340		
P3 Return blood pressure (Qb 200ml/min)	170	193	219	247	280	311	330?		

Conclusion: Direct connection of the CBP circuit to the ECMO circuit at the pre-oxigenator part is supposed to be clinically dangerous, when ECMO flow rate exceeds 4 L/min.

Surgical Safety Checklist Implementation in the Extracorporeal Membrane Oxygenation (ECMO) Therapy

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Introduction: ECMO is a surgical procedure that requires a special level of compulsiveness and thoroughness, so it is associated with a significant number of adverse effects and complications.
World Health Organization (WHO) established in 2008 a tool to improve safety and reduce preventable adverse events: The Checklist of Surgery or Surgical Checklist. In order to help minimize errors and safety risks during shift change, a detailed ECMO checklist was developed to help facilitate communication and ensure that all equipment is functioning well.
The aim of this work is:

- To avoid inadequate clinical practices that put on risk the safety patient.
- To reduce surgical infection prevalence during the ECMO therapy.
- To improve communication among ECMO team members.

Method: A literature search was carried out using MEDLINE, EMBASE and PsycINFO databases. Relevant information was extracted relating to ECMO therapy, compliance with the checklist, effects of checklist use on patient outcomes, and staff perceptions of the checklist.
Results: The ECMO checklist is divided in two parts:

- First phase: This involves communicating the patient's condition and the review of the data. A lot of detailed and technical information needs to be conveyed as efficiently as possible.
- Second phase: This consists of a detailed inspection of the patient and equipment performed at the bedside by both the out-going and in-coming person together.

Conclusion: We have changed the original WHO surgical safety checklist, adapting it for ECMO practice. This reflects the natural evolution of this tool, representing a relatively simple and promising strategy for addressing ECMO patient safety worldwide.

Nursing Cares During the Interhospital Transport of the ECMO Patients

Borja Violant Gómez, Ferrán Oller Sánchez, Ricard Condal Sanmartín, Victor Gómez Simón, Jesús Cabañas Fernández, Joaquim Rios Sambernardo, Jorge Arnulfo Morales Álvarez, Candelaria de Haro López, Ramon Garrido Massana, Jordi Carbonell Garcia

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Introduction/Aim: Over the last few years, extracorporeal membrane oxygenation (ECMO) has proved its effectiveness as treatment in severe respiratory and/or circulatory failure. However, this procedure is only available in specialized centers, where patients often have to be transferred. A mobile team able to implant an ECMO device in situ, in order to stabilize and transfer the patients to an ECMO center, can mean a chance of survival. Nursing staff plays a key role, so in this sense, an adequate care plan is essential to improve the quality healthcare.
The aim of this work is:

- To describe the ECMO therapy and its effects over the patient.
- To identify and analyse real and potential nursing problems during the transport.
- To establish priorities and goals to achieve through nursing interventions.

Method: We conducted a bibliographic review of several literature sources using MEDLINE, EMBASE and PsycINFO databases. A care plan was designed to promote safety and quality of the nursing cares.
Results: In accordance with the several stages of the healthcare process, we have performed a nursing activities classification:

- Establishment of ECMO: Patient checking, material check-list, vital signs surveillance, bleeding control.
- Transport: Hemodynamic surveillance, respiratory support control, anaesthesia monitoring, drawn of blood samples, distal perfusion checking.
- Hospital transfer: Use of a checklist register, mechanical attachment of the ECMO device, families psychological support.

Conclusion: This work responds to the need for standardization in nursing cares for ECMO patients during interhospital transfer. A nursing care plan is a fundamental tool to guarantee patient safety and quality healthcare.

The Impact of a Two-Day Simulation-Based ECMO Course for ECMO Practitioners

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Introductio/Aim: While extra corporeal membrane oxygenation (ECMO) has grown in utility, the management of patients requiring ECMO support remains technically challenging. Simulation-based training has emerged as a valuable tool in medical education and may be ideally suited for ECMO training. We evaluated the impact of a simulation-based course in training ECMO practitioners in ECMO management.
Methods: A Laerdal SimMan 3G was connected to a running ECMO circuit. Participants attended a two-day simulation-based ECMO course Pre- and post-course, participants completed self-assessments and knowledge tests. A simulated case of pump failure was performed early and late in the course and the time taken to switch to the backup pump and restore ECMO flow was pre-identified for timing. Statistical analyses were performed via Wilcoxon signed-rank test.
Results: Results reported as Median [IQR]. Self- assessments (on a 5-point Likert scale) regarding ECMO knowledge and clinical management improved from 3.2 [2.8-3.4] and 2.1 [1.6-2.5] to 4.4 [4.-4.8] and 4.0 [3.6-4.4] ($p < 0.0001$ for both), respectively. Written exam scores also improved from 47 [33–60]% to 73 [67–87]% ($p < 0.0001$). During the simulated case of pump failure, average time to restore

ECMO flow improved between the early and late sessions from 201 [175–217]s to 104 [81–121]s (p = 0.016) (Figure 1).
Conclusion: A two-day simulation based ECMO course targeting various learner groups is effective with improvements in self-confidence, written knowledge, and clinical abilities. Further studies evaluating the role of simulation for ECMO credentialing and for maintenance of proficiency are required.

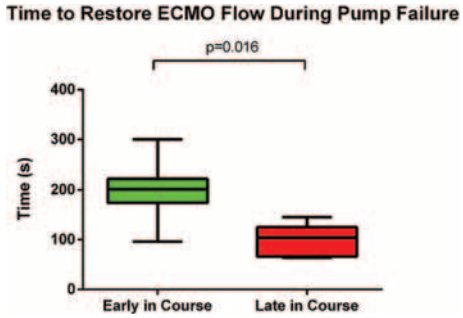

Figure 1. Time to restore ECMO flow during a simulated case of pump failure. Pump failure was performed early and late in the course and the time taken to switch to the backup pump and restore ECMO flow was timed.

"Single or a Double? A Service Evaluation on Single Care; A Gold Standard Practice at the Glenfield ECMO centre"

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Introduction/Aim: Due to reduction in complexity of the ECMO circuit a major change in nursing practice was implemented where by a single care model was adopted. A service evaluation was performed to review staff satisfaction identifying areas for practice improvement.
Method: Data was collected using an anonymous questionnaire this was distributed to all ECMO specialists. Supporting data was collated from the Quality and Safety department to ascertain a correlation between single care and critical incident reporting. 71 questionnaires were distributed to ECMO specialists with a response rate of 66%.
Results: The main identified areas in need of improvement were; less paperwork repetition, when able, cohort patients, assess daily whether patients are cared for in a 'single' or 'double' care capacity and to develop the role of the ECMO nurse float. Quality and safety is also discussed – with incident reports supporting data that more errors occur when 'double caring'.
Conclusion: Staff opinions will always impact on the delivery of single care and affect staff morale but to provide safe and quality care, single care must be considered as gold standard practice.

Effects on Oxygenator Performance During Pulsatile Blood Flow

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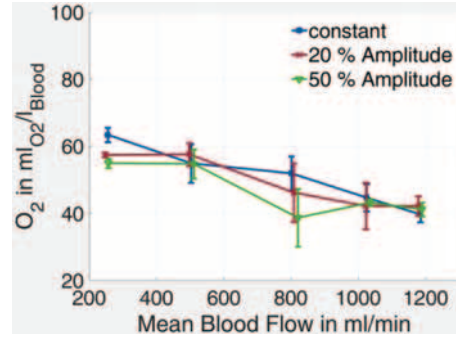
Introduction/Aim: Extracorporeal circulation systems (ECLA), especially the oxygenator in the long-term use still show thrombus formation, poor hemocompatibility, and inefficient gas exchange. To overcome these constraints, we performed a systematic study according to the hypothesis, that pulsatile blood flow in ECLA provokes a better blood mixing, therefore a higher gas exchange, and lower thrombus formation, and thus a better hemocompatibility. We compared the effects of pulsatile and continuous blood flow on gas exchange and hemolysis.
Methods: In-vitro tests were performed according to DIN EN ISO 7199. An externally controlled rotary pump realized both pulsatile and continuous blood flow through a small test-oxygenator. During the tests for gas exchange performance the operating points were varied systematically in frequency, amplitude, and mean flow. As reference, the same measurements were repeated in non-pulsatile mode. In order to investigate the influence of pulsatile blood flow on hemolysis two separate loops were operated for six hours at a mean flow of 500 ml/min, one with constant and the other with pulsatile sinus flow.
Results: The results of gas exchange and hemolysis showed minimal, but not statistically significant variations between all measurements of pulsatile and constant blood flow.
Conclusion: The systematic testing of pulsatile blood flow in oxygenators revealed no enhanced gas exchange. Additionally, it has no positive nor adverse effect on hemolysis. However, it is still a partly unanswered question what detailed consequences the pulsatility of an extracorporeal circulation has on the perfusion of the patient.



Implementation of ECMO System

Zvi Adler, Zvi Peled, Roi Glam, Keren Bitton-Worms and Gil Bolotin

Cardiac Surgery Department, RAMBAM Health Care Campus, Haifa, Israel

Introduction/Aim: ECMO (extracorporeal membranous oxygenation) is gaining ground as a rescue bridge therapy for patients with refractory respiratory or cardiac failure. Until March 2014 the ECMO service was not available in northern Israel. RAMBAM Health Care Campus is the largest medical center in northern Israel serving the over 2 million residents. We report our single-center experience with ECMO system implementation.
Methods: The ECMO unit was established in 2014 under responsibility of the Cardiac Surgery Department. The system is used to treat both adult and pediatric patients. The program was initiate by intensive formal and practical training in other hospitals carried out by the surgeons, nurses and perfusionists. We started with one available Maquet system, a second system was purchased soon after and a third system is on its way.
Results: From March 2014 to December 2016 ECMO was required for 29 patients in our center, including venous-venous (9/29) and venous-arterial (20/29) ECMO. Most of the patients were adult patients (17/29) who were treated in the cardiac surgery ICU and the rest were neonatal and pediatric patients (12/29) that were treated in the pediatric ICU. Nineteen patients were weaned from ECMO with an average duration of 6 days. The mortality was 15 patients. Table 1 describe our experience according to type of ECMO.
Conclusion: Our single-center experience presented a good learning curve together with the following good results of treated patients who were weaned from the ECMO. (1) A 18 years old student transferred from the Palestinian authority for VV ECMO after severe lung contusion, (2) A 40 years female in anaphylactic and cardiogenic shock after a bee sting transferred from the city of Tiberias, (3) 16 years old Druse student from the Golan heights referred for VV ECMO after organic Sulphur intoxication. The three cases and all other cases represent dramatic cases in extreme life threatening condition that were rescue by the use of the ECMO system.

Table 1: Number op Patients/ECMO type

	National	Pediatric	Adult
Cardiac	2	4	11
Respiratory	2	4	6

Left Ventricle Unloading in Veno-Arterial ECMO Support: Literature Review for an Unanswered Dilemma

Paolo Meani[2], Eshan Natour[1], Federico Pappalardo[4], Elham Bidar[1], Maged Makhoul[1], Giuseppe Raffa[1], Samuel Heuts[1], Sandro Gelsomino[1], Pieter Lozekoot[1], Dan Johnson[1], Susanne Kats[1], Niels Stuijpers[1], Rick Schreurs[1], Martijn Gilbers[1], Thijs Delnoij[2,3], Alice Montalti[3], Jan Willem Sels[2,3], Marcel van de Poll[3], Paul Roekaerts[3], Patrick Weerwind[1], Yuri Ganushchak[1], Erik Körver [1], Zaheer Babar[1], Jos Maessen[1], Roberto Lorusso[1]

Table 1 Published studies on LV venting in adult, pediatric, or mixed ECMO patients

	Year	Author	Experience	Approach	Location	Patient(s)	Access	Mechanism of unloading	Technique
Pediatrics									
	2013	Kotani	Retrospective Study	Surg	LA venting	23	LA	right-side LA cannula	Open chest
	2015	Hacking	Retrospective Study	Surg	LA venting	51*	LA	dissected Waterston groove	Open chest***
	2014	Sandrio	Case series	Surg	LV venting	8	LV	right superior V cannula	Open chest
	2013	Kimura	Case report	Surg	LV venting	1	LV	PA and LV drainage	Open chest
	2010	Guirgis	Case report	Surg	LV venting	1	LV	Catheter in the cardiac apex	Minimally Invasive
	2011	Fouilloux	Case report	Perc	PA	1	PA	Drainage PA	PA drainage
	2003	Cheung	Case report	Perc	LA venting	1	LA	Trans-septal	BBAS
	1993	Connor	Case report	Perc	LA venting	1	LA	Trans-septal	Balloon Atrial Septostomy
	1999	Johnston	Case report	Perc	LA venting	1	LA	Trans-septal	Balloon Dilation Atrial Septostomy
	2012	Swartz	Case report	Perc	LA venting	1	LA	Trans-septal	Trans-septal puncture
	1993	Koenig	Case report	Perc	LA venting	1	LA	Trans-septal	Balloon(3) and blade(1) atrial septostomy
	2006	Vlasselaers	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Impella
Adults									
	2014	Weymann	Prospective Study	Surg	LV venting	12	LV	right superior V cannula	Open chest
	2015	Eudailey	Case report	Surg	LV venting	1	LV	Catheter in the cardiac apex	Minimally Invasive
	2013	Dahdouh	Case report	Perc	LA venting	1	LA	Trans-septal	BBAS
	2016	Alkhouli	Case series	Perc	LA venting	4	LA	Trans-septal	Transseptal puncture ± balloon dilatation
	2011	Avalli	Case report	Perc	PA	1	PA	Drainage PA	PA drainage
	2011	Barbone	Case report	Perc	LV venting	1**	Trans-AO	LV unloading	Trans-AO catheter
	2016	Hong	Retrospective Study	Perc	LV venting	7	Trans-AO	LV unloading	Trans-AO catheter
	2011	Anastasiadis	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Trans-AO catheter
	2004	Fumagalli	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Trans-AO catheter
	2004	Doll	Prospective Study	Perc	Aorta	144	IABP	Reduced LV afterload and LVEDP	IABP
	2014	Ma	Retrospective Study	Perc	Aorta	54	IABP	Reduced LV afterload and LVEDP	IABP
	2014	Park	Retrospective Study	Perc	Aorta	41	IABP	Reduced LV afterload and LVEDP	IABP
	2014	Santise	Retrospective Study	Perc	Aorta	13	IABP	Reduced LV afterload and LVEDP	IABP
	2014	Yang	Prospective Study	Perc	Aorta	12	IABP	Reduced LV afterload and LVEDP	IABP
	2015	Cheng	Meta-Analysis	Perc	Aorta	1517	IABP	Reduced LV afterload and LVEDP	IABP
	2015	Gass	Retrospective Study	Perc	Aorta	56	IABP	Reduced LV afterload and LVEDP	IABP
	2014	Petroni	Prospective Study	Perc	Aorta	12	IABP	Reduced LV afterload and LVEDP	IABP
	2015	Samadi	Retrospective Study	Perc	Aorta	3	IABP	Reduced LV afterload and LVEDP	IABP
	2016	Lin	Retrospective Study	Perc	Aorta	302	IABP	Reduced LV afterload and LVEDP	IABP
	1997	Ko	Case report	Perc	Aorta	1	IABP	Reduced LV afterload and LVEDP	IABP
	2013	Cheng	Retrospective Study	Perc	LV venting	5	Trans-AO	LV unloading	Impella
	2016	Pappalardo	Retrospective Study	Perc	LV venting	34	Trans-AO	LV unloading	Impella
	2015	Abu Saleh	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Impella
	2012	Beurtheret	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Impella
	2012	Chaparro	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Impella
	2011	Koeckert	Case report	Perc	LV venting	1	Trans-AO	LV unloading	Impella
	2013	Li	Case series	Perc	LA venting	5	LA	Left atrial unloading	TandemHeart
Mixed									
	1999	Seib	Retrospective Study	Perc	LA venting	10	LA	Trans-septal	BBAS***
	2006	Aiyagari	Case series	Perc	LA venting	7	LA	Trans-septal	Transseptal puncture, incorporeted cannula

Perc: percutaneous; Surg, surgical; LV: left ventricle; LA: left atrium; AO: aorta; IABP: intra-aortic balloon pump; PA: pulmonary artery; LVEDP: left ventricle end-diastolic pressure; BBAS: blade and balloon septostomy.
* 51 cases, 49 patients; ** the Authors treated 3 patients, only one was described; ***Mixed techniques.

Table 1

4. Knowledge Management	Does not meet	Somewhat Meets	Meets	Somewhat Exceeds	Exceeds
4.1 Initial MD Education *Elements: Course, test, water drills/simulation, pt care proctoring, min pt care requirements, prior ECMO experience, achieve credentialing*	no requirement	1 element or education only required of fellows, not attendings	2 elements	3 elements	greater than 3 elements

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Introduction/Aim: VA ECMO support is increasingly used in refractory cardiogenic shock and cardiac arrest, but characterized by increased afterload of left ventricle (LV). The aim of this study was to provide a comprehensive overview regarding the different LV venting techniques and results available in the literature.
Methods: A systematic literature search was performed in the PubMed database: 207 articles published between 1993 and 2016 were included. Papers dealing with pre-clinical studies, overlapping series, and association with other assist devices were excluded from the review, with 41 published papers finally selected. Heterogeneous indications for LV unloading were reported. The selected literature was divided in subgroups, according to the location or the performed procedure for LV venting.
Results: Case reports or case series were present in 59% of the papers, while retrospective study represented 29% of them. Adult series were present in 65%, pediatric patients in 30%, and mixed population in 5%. LV unloading was performed percutaneously in 83% of the cases. The most common locations of unloading was left atrium (29%), followed by indirect unloading (IABP)(27%), trans-aortic (27%), LV (12%), and pulmonary artery (5%). Percutaneous trans-septal approach was reported in 22%. Finally, the unloading was conducted surgically in 17%(with open chest surgery in 71%, and minimally invasive surgery in 29%).
Conclusion: Nowadays, a few data are available about left heart unloading in VA ECMO support. Despite the well-known controversy, IABP remains widely used in combination with VA ECMO. Percutaneous approach with unloading devices seems to become an increasing option. However, further studies are necessary to establish the best LV unloading method.

Description of the ELSO Excellence in Life Support Award: Scoring Rubric

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Introduction: The ELSO Excellence in Life Support Award broadens that recognizes ECLS programs worldwide that distinguish themselves by having processes, procedures and systems in place that promote excellence and exceptional care in ECMO. A scoring rubric was developed to standardize the scoring process for award applicants between ELSO Award committee members.
Method: The Excellence in Life Support Award scores for individual questions are reviewed annually to ensure clarity and consistency. Each question is scored based on a 5 point Likert scale (does not meet, somewhat meets, meets, somewhat exceeds, exceeds) based on specific, defined criteria for each question. Rubric scoring criteria were developed for each question based on ELSO guidelines.
Results: 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 application question.
Conclusion: A defined rubric for scoring ELSO Award for Excellence applications has made scoring between committee members consistent. The average score difference of a center reviewed by 2 award reviewers is now 25 points. This is less than 2% of the total possible score and cannot impact the resulting award status. The use of a robust scoring rubric is necessary to ensure standardization in the review process.

Prototype of High-Fidelity ECMO Simulator

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Introduction: Because ECMO is being a complex and expensive procedure, we prepared an advanced ECMO simulator prototype which can be used for

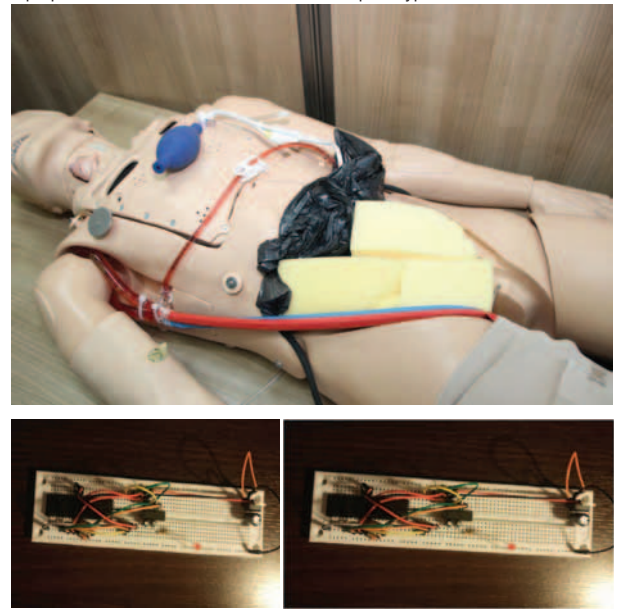

Figure 1. The artificial loop implanted in to mannequin groin and CCU.

high-fidelity medical simulation training to prepare for real-life experiences by altering any types of full-body patient simulator.

Methods: The system is equipped with an electronic core control unit (CCU) (Figure 1), a set of synthetic valves, pressure sensors, and hydraulic pumps. The major functions of the CCU is to stabilize the hydraulic system (flow of simulated blood, differential pressures in the arterial and venous lines), providing instant informations about the system to the user via a display, and in the future it will be remotely controlled through the internet. Electric valves and sensors provide 'on-the-fly' informations to the CCU about the actual system's status and it can be made to respond to specific instructions imitating the physiological circulatory system and simulating several scenarios (i.e. bleeding, low pressure, occlusion, reaction for proper and incorrect pharmacological treatment). It can be connected to an ECMO machine to act like the human body during ECMO run. All components can be integrated to customize any mannequin (Figure 1).

Result: Every components used can be easily replaced. The total cost of the simulator modification is approximately 500 € and the consumables parts cost about 500 €. It has been used to help simulate successfully a range of scenarios.

Conclusions: Advanced simulator allows unlimited possibilities with creating scenarios - implantation, conducting perfusion and patient transport with ECMO, but simulation as an educational tool is still invaluable.