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ECMO CHALLENGES 2017

ABSTRACTS

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Dear colleagues and friends,

This year's meeting, in the capital of Wielkopolska, is the second in the series of meetings of enthusiasts, experts and specialists who use the ECMO therapy for the patient requiring critical illness treatment.

First, last year's ECMO Conference aroused great interest among people from all over Poland. We hope that this year's meeting, enriched by interesting workshops, will indicate what challenges are posed by ECMO for us and for a patient. International Scientific Assembly, which takes part in the second Conference, emphasizes the significance of the scientific event, which will be included in the agenda of the scientific meetings related to emergency medicine, anaesthesia, intensive therapy, cardiology and cardiosurgery. Those who occupy themselves with rescue logistics, transport and mainly medical education will definitely find some interesting topics for themselves during the Conference. The development of the ECMO procedures is based on the highly accurate medical simulations, which met the challenge, but there is still a long way to go.

We are delighted to welcome you and share experience in creating ECMO programme for Greater Poland. We present you a special issue of Disaster and Emergency Medicine Journal, which includes the abstracts of all the presentations performed during this year's Conference.

We wish you a nice reading and invite you to active development of ECMO programme.

Łukasz Szarpak
Editor-In-Chief

ECMO CHALLENGES 2017 — "ECMO FOR GREATER POLAND"

Marek Jemielity

Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poland

It is with great pleasure that we to invite you to the "ECMO CHALLENGES 2017" conference in Poznan. The meeting will be held on October 14th, 2017 at the Congress Centre of Poznan University of Medical Sciences with workshops on October 15th, including simulation techniques applying extracorporeal therapy.

Bearing in mind the huge interest in last year's event which presented the "ECMO for Greater Poland" programme, the organizing committee has recognised the need for a national meeting to promote the consolidation of the medical community involved with management of life-threatening circulatory or respiratory insufficiency.

A group of medical staff in Poznan launched the first regional ECMO programme, namely "ECMO for Greater Poland" in 2016. "ECMO for Greater Poland" is a programme established to serve 3.5 million inhabitants of the Greater Poland region in Poland based on an approach already being implemented around the world. "ECMO for Greater Poland" allows the use of perfusion therapy to the benefit of the inhabitants of the Greater Poland region in a comprehensive manner, in all states of critical disease, by what appears to be a unique nationwide programme. This programme is complex and takes full advantage of ECMO perfusion therapy opportunities to promote health and save the life of patients in the Greater Poland region.

The main implementation areas are:
- Treatment of patients with hypothermia;
- Treatment of reversible severe respiratory failure;
- Treatment of acute intoxication resulting in cardiorespiratory failure or other critical states resulting in heart failure;
- A Donor after Circulatory Death (DCD) programme whereby, in the absence of a response to treatment and eventual death, and with donor authorization, there is the possibility of organ donation and transplantation from a DCD donor.

Moreover, an interactive e-learning platform has been created, bringing together current knowledge and establishing guidelines for perfusion therapy in different branches — (**www.ecmo.pl**). The final result was to build a strong procedural chain of treatment qualifications in order to identify potential candidates for treatment and for effective process coordination. During the last year, currently unavailable algorithms of ECMO therapy have been created in all branches. All branches of the programme regarding the use of ECMO were implemented simultaneously in order to maximize its positive impact.

ECMO (Extracorporeal Membrane Oxygenation) is both an art and dynamic technique, which through a wide range of implementation procedures, requires enormous attention and the necessity for the exchange of one's practical experience. This procedure is complex and one which leads to the multidisciplinary commitment of ECMO teams that will allow the use of current technology at the highest level in a safe and effective manner. Therefore, it seems natural to apply the modern techniques of simulation-based high-fidelity teaching. Indeed, its efficient implementation in Poznan has led to the success of the regional ECMO programme. Thus, part of this Educational Workshop and Conference will be devoted to medical simulation, a development that provides opportunities to achieve better and shorter preparation of medical staff than traditional methods.

We hope that this meeting will become a kind of scientific platform for the presentation and exchange of one's experience. Moreover, the conference is designed for physicians, perfusionists, nurses, emergency medical technicians and physiotherapists, as well as specialists in medical transport, thus for all those involved in the treatment of life-threatening circulatory or respiratory failure.

We invite you therefore to exchange your experience, share your knowledge and learn from each other. Your presence and experience will demonstrate the highest standards of teaching through high-fidelity simulations, an advance so essential and important in the development of regional ECMO programmes, especially in the implementation of perfusion techniques and patient transport.

KEY WORDS: "ECMO for Greater Poland", ECMO

ADDRESS FOR CORRESPONDENCE:
Marek Jemielity, Department of Cardiac Surgery
and Transplantology, Poznan University of Medical Sciences,
e-mail: mjemielity@poczta.onet.pl

Professor Marek Jemielity
President of Organizing Committee

ACC — UNDERESTIMATED AUTOMATED CHEST COMPRESSION (ACC)

Aleksander Pawlak[1], Paweł Nochowicz[2]

[1]Provincial Ambulance Service Station in Poznan, Poland
[2]SCAS (South Central Ambulance Service) Hightown Base Station, United Kingdom

In the Donor after Cardiac Death (DCD) procedures as outlined in Japan in 2008, the use of automated chest compression (ACC) was hailed as a breakthrough for use when transplanting organs from deceased patients [1].

The first uses of ACC were in the early 1960s [2]. However, despite this, the American Heart Association guidelines published in 2015, based on a number of research trials, did not highlight the use of ACC over manual chest compression [3].

Currently, EMS (Emergency Medical Service) teams mostly use ACC for patients who fit such criteria as;

- Cardiac arrest caused by reversible causes that can only be reversed in the emergency department;
- Cardiac arrest during pregnancy;
- Cardiac tamponade;
- Cardiodepressive intoxication.

As transporting patients during ACC might compromise the quality of the chest compressions and the safety of the ambulance crew [4], safety must be the first consideration.

In 2016, the Provincial Ambulance Service Station in Poznan was involved in 821 cardiac/respiratory arrest incidents. In 16 of these incidents, the ambulance crew were supported with ACC devices while, at the same time, being able to compare 3 different devices. The results of trials after several months highlighted the benefits of using ACC during transportation and improving the safety of the crew. However, the trials also highlighted a requirement for extra training for members of ambulance crews that will use ACC in their work.

Upgrading ambulances with devices for ACC provided one the ability to get involved in the regional ECMO programme ("ECMO for Greater Poland") and to carry out the DCD procedure, one which had never been used in Poland before. This resulted in upgrading 8 ambulance stations with ACC devices in order to increase the use of the devices, as well as optimize the time of arrival at the scene in the area that they currently cover. Once the ambulance station received "stand by" status, the device was delivered to the scene at an EMS team's request.

This program went live in February 2017 and within one month a 64-year-old woman received treatment involving ACC. This was the first time in this region that a patient had been transferred and successfully treated in a catherization laboratory with ACC having been used during the PCI (percutaneous coronary intervention).

Automated chest compression has become a necessary element for the ECMO project, being used in all appropriate procedures and used for training in high-fidelity medical procedure simulations (Fig. 1). All ECMO transportation, patients with cardiac arrest transfers for treatment or for potential donation, as well as transfers of patients with cardiopulmonary bypass (CPB) are now performed using ACC, or having ACC as a supporting device.

FIGURE 1. Automated Chest Compression device in use during medical simulation

KEY WORDS: automated chest compression device, ECMO, resuscitation

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ADDRESS FOR CORRESPONDENCE: Aleksander Pawlak, Provincial Ambulance Service Station in Poznan, e-mail: ratownik.ap@gmail.com

BUILDING QATAR'S ECMO PROGRAMME

Abdulsalam Saif Ibrahim

SRF-ECMO Program,
Hamad Medical Corporation, Qatar,
Medical Intensive Care Unit

Although discussions regarding the need for a Severe Respiratory Failure-Extracorporeal Membrane Oxygenation (SRF-ECMO) service in Qatar had started in 2010, the trigger to immediately establish the service was the response to the emerging MERS-Corona outbreak in 2013 [1]. The need to establish an SRF-ECMO centre with mobile ECMO retrieval capabilities was identified in order to anticipate and proactively deal with the situation. The main objective was to improve our patients' outcomes, while avoiding needless harm through the introduction of this service. Implementation was achieved by engaging in a strategic partnership with a UK-based academic healthcare system with a view to initially mirror the UK-based ECMO program, with subsequent tailoring to fit local needs in Qatar.

It took more than one year of comprehensive preparation to start our first case of ECMO in Qatar with the support of our partner team (Fig. 1). This involved the selection of team members and the appropriately structured and staged education and training for our staff in order to develop the required knowledge and skills, as well as an understanding of the challenges associated with ECMO (Tab. 1). Its clinical leaders realized that the only way to achieve a successful and safe program was to provide hands-on experience to all HMC staff involved in order that

Table 1. Qatar SRF-ECMO Team Members: Training requirements and function

Intensivist	ECMO Nurse Specialist	Perfusionist
Master the knowledge • Master the cannulation • Troubleshooting • Transport on ECMO • Replicate documents	ECMO nurse specialist • Checklists • Troubleshooting • Prone position	All technical aspects about the circuit • Understand circuit — patient interaction • Rehabilitation on ECMO
Respiratory Therapist	**Clinical Pharmacist**	**Physiotherapy**
Pre-ECMO management PEEP optimization Recruitment maneuvers Ventilation on ECMO Prone position	Understand ECMO-Patient interaction Review all drugs protocols	Exercise on ECMO Mobility on ECMO Prone position on ECMO Chest physiotherapy on ECMO
Nutritionist	**Critical Care Paramedics:**	**Supporting services appraisal**
Principles of entral feeding on ECMO TPN and circuit interaction	Transport on ECMO Retrieval checklist Trolley design Ambulance platform Team dynamics and Checklists	CT surgery Vascular surgery Blood bank Anesthesia/OR Surgery and Radiology

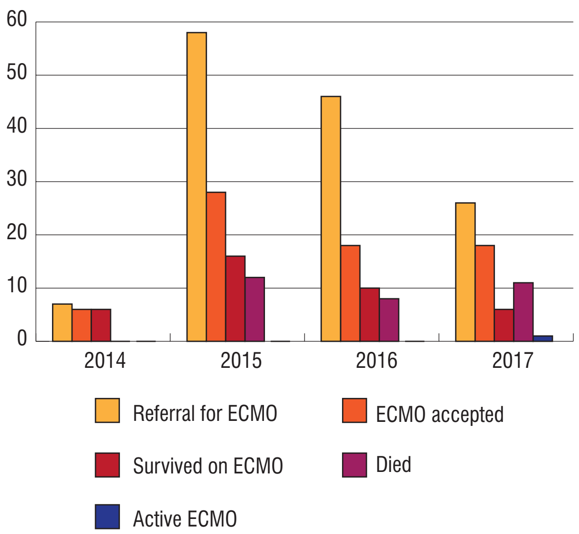

FIGURE 1. Hamad Medical Corporation SRF-ECMO center VV-ECMO activity

they could become a fully functional and highly efficient team [2]. We therefore defined each team member's functions, roles and responsibilities, and established an effective communication processes, thus inculcating a change towards a collaborative culture of multi-professional teamwork.

The service is designed to be intensivist led and centred on medical intensive care, as it is clear that specialist knowledge and experience is required in order to limit complications and improve results by ensuring a sufficient volume of patients [3]. Our centre believes that setting standards, appropriate selection criteria, accurate data collection, ongoing reflection in debriefing sessions, as well as gap analysis revision by local or international experts, are effective tools in order to maintain a high quality programme. We are investing in developing and running simulation-based training sessions that provide additional opportunities beyond traditional education tools [4].

In conclusion; intensive and comprehensive training of the multidisciplinary team members, clear objectives, quality standards, and an ongoing review process are important elements in building a successful ECMO programme.

KEY WORDS: ECMO, ECMO in Qatar, ECMO simulation, Intensivist-led ECMO, ECMO Team

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ADDRESS FOR CORRESPONDENCE:
Abdulsalam Saif Ibrahim, SRF-ECMO Program, Hamad Medical Corporation — Qatar, Medical Intensive Care Unit,
e-mail: Aibrahim1@hamad.qa

CAPNOMETRY — THE GUIDEPOST

Tomasz Kłosiewicz

Department of Medical Rescue, Chair of Emergency Medicine,
Poznan University of Medical Sciences, Poznan, Poland

Performing chest compressions in patients with sudden cardiac arrest comprises one of the basic emergency procedures. The high quality of early-delivered chest compressions is emphasized in the current guidelines of the European Resuscitation Council. The quality parameters are the appropriate rate and depth of the compression, the complete relaxation of the chest, and frequent switching of the compressors to avoid fatigue. Actions should be continuously assessed by the resuscitation team both visually and by additional tools that can provide real-time feedback.

The monitoring of end tidal carbon dioxide (ETCO2), also known as capnometry, is a method that consists of colorimetric or spectrophotometric analysis of the gas composition that exits the lungs during exhalation. This treatment should be routinely used during rescue procedures, *inter alia*, to evaluate the quality of chest compression and to confirm the correct position of an advanced airway. A relationship has been found between carbon dioxide content in exhaled air and the value of cardiac output generated by chest compressions, with constant minute ventilation. ETCO2 is now increasingly recognized as a prognostic factor in patients with cardiac arrest. Current resuscitation guidelines indicate specific values that may suggest poor CPR quality, as well as the possibility of a return of spontaneous circulation. Some devices additionally indicate the number of breaths per minute, which also helps to correct excessive ventilation and to minimize the resulting adverse effect on the quality of resuscitation.

The value of ETCO2 is not an ideal indicator as it is also influenced by the primary causes of arrest. A capnometer is now a mandatory piece of equipment in every emergency ambulance in Poland. It therefore is recommended to use this method during each resuscitation.

KEY WORDS: capnography, out-of-hospital cardiac arrest, cardiopulmonary resuscitation, Quality Improvement

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ADDRESS FOR CORRESPONDENCE:
Tomasz Kłosiewicz, Department of Medical Rescue, Chair of Emergency Medicine, University of Medical Sciences, Poznan, Poland,
e-mail: tomek.klosiewicz@gmail.com

CIRCUIT MONITORING DURING EXTRACORPOREAL LIFE SUPPORT PROCEDURE

Małgorzata Ładzińska[1], Piotr Ładziński[2], Mateusz Puślecki[3], Marcin Ligowski[1], Marek Jemielity[1]

[1]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland
[2]Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, Poznan, Poland
[3]Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland

Extracorporeal Life Support (ECLS) has become popular as a salvage strategy for the critically ill. ECLS indications have still progressed and could be used in the intensive care management of acute cardiopulmonary failure. ECLS also complements cardiac surgical and cardiology procedures, the implantation of long-term mechanical cardiac assist devices, heart and lung transplantation and cardiopulmonary resuscitation. ECLS provides and opportunity for recovery in patients who fail conventional treatment. Extracorporeal Life Support Organization data shows that ECLS increases survival to hospital discharge to 55% for patients with a risk of death of more than 80%.

One of the conditions for these results is the correct monitoring and management of the ECLS circuit. Although the technology of the ECLS has evolved, it is not without potentially serious complications. Therefore, every day medical experts namely, perfusionists, are ready to intervene 24 hours a day and monitor the ECLS system in order to avoid potentially life-threatening adverse events. Basic circuit components, namely: the blood pump; the oxygenator (membrane lung); blood tubing; and venous and arterial cannulas may fail at any time due to mechanical or patient-related complications. Oxygenator gas transfer capability should be frequently monitored in order to record membrane lung performance.

The most common monitored circuit parameters are as follows: power supply; sweep gas flow; the difference between arterial and venous saturation; pressures across the system (pre and post-membrane, negative drainage pressure); blood flow; rotation per minute of the pump; transmembrane pressure; gas embolism; and blood temperature.

KEY WORDS: Extracorporeal Life Support, perfusionist, cardiopulmonary failure, mechanical cardiac assist devices, cardiopulmonary resuscitation, ECLS circuit, ECLS monitoring

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ADDRESS FOR CORRESPONDENCE:
Małgorzata Ładzińska,
Department of Cardiac Surgery and Transplantology,
e-mail: malgorzataladzinska@gmail.com

CONTEMPORARY PAEDIATRIC ECMO

Wojciech Mrówczyński

Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, Poznan, Poland

Extracorporeal life support therapies connected with ECMO technology continue to evolve. This phenomenon is also being observed in paediatric ECMO. Due to the popularity of this method and ever-growing numbers of performed procedures, the main question facing ECMO now is not whether to employ ECMO therapy at all, but when and in which group of patients.

On a national scale, similarly to other countries, paediatric ECMO is mainly applied in patients treated surgically due to congenital heart disease in the postoperative period. Nevertheless, many centres have introduced in-hospital programs of Rapid Response ECMO within the framework of local eCPR strategies. A widening of ECMO indications is presented to show how to treat intoxications, cases of near-drowning, complicated foreign body aspirations, as well as to perform tracheal reconstructions. ECMO is utilized more frequently in the treatment of non-cardiotomy heart failure – fulminant myocarditis.

ECMO is still used to treat respiratory insufficiency, more and more frequently as a bridge to lung transplant. The accumulation of experience has made the creation of score systems enabling treatment efficacy prognosis possible. Similar progress is noted in cases of postcardiotomy ECMO, thereby enabling the improvement of outcomes in patients with univentricular heart at different stages of treatment.

Outcomes of ECMO therapy are analysed from the point of view of health care system costs. Indeed, the cost of ECMO procedures can differ significantly between countries, as well as between centres within the same country, or even city. Still declining mortality and shortening hospital LOS are connected with higher expenditures per patient. This has resulted in a search for economization regarding this expensive treatment, namely from alternative hardware use to the elimination of continuous perfusion specialist supervision in the ICU's basic support model.

ELSO guidelines highlight the need for long term ECMO outcome evaluation. This stimulates many studies on different aspects of post-ECMO morbidity with special attention being paid to neurological outcomes in patients undergoing ECMO in the developmental age. The literature data points to the positive influence of centre expericence on short and long term results.

Despite tremendous progress in the domain of paediatric extracorporeal life support, many doubts remain that will have to be resolved, e.g. the problem of multiple ECMOs in the same patient, or bridging to heart or lung transplantation. Nevertheless, it is certain that the answer will finally come as ECMO is no longer an experimental therapy but has become reality in the treatment of the most severe paediatric conditions.

KEY WORDS: ECMO, children, circulatory and circulatory insufficiency, economy, outcomes

ADDRESS FOR CORRESPONDENCE:
Wojciech Mrówczyński, Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, Poznan, Poland,
e-mail: wjmrow@ump.edu.pl

DCD-ECMO ALGORITHM

Mateusz Puślecki[1, 2], Marek Karczewski[1, 3], Marcin Ligowski[2], Tomasz Małkiewicz[3], Marek Dąbrowski[1], Marcin Zieliński[1], Aleksander Pawlak[4], Małgorzata Ładzińska[2], Marek Jemielity[2]

[1]Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland
[2]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland
[3]Department of Transplantology, General, Vascular and Plastic Surgery, Poznan University of Medical Sciences
[4]Provincial Ambulance Service Station in Poznan, Poland

Maintaining the viability of organs from DCDs (donors after circulatory death) for transplantation is a complicated procedure from a time perspective in the absence of appropriate organizational capabilities that make such transplantation cases difficult. Although not yet widespread in Poland, (the procedure of organ donation from DCD-ECMO had not yet been performed in any hospital in Poland), this has been demonstrated as achievable in other countries.

It has been proved that use of normothermic extracorporeal oxygenation (nECMO) perfusion for "organ recovery" is associated with significantly better long-term organ transplant outcomes (kidney) and less delayed graft function (DGF) compared to donation after traditional management with automated chest compression (ACC) [1–3]. DCD donation has the potential to increase the number of organ donors by at least 10–30% and it is reported to increase the available organ pool supply by 20–25% [3].

The purpose of the high-fidelity simulation scenario was to verify the DCD-ECMO procedure algorithm created for the "ECMO for Greater Poland" programme. This algorithm was established for transplantation centres cooperating with the ECMO team and can be recommended as a model for all centres in Poland.

The critical time from SCA to organ perfusion start is less than 150 minutes, which is the standard for good outcomes in transplantation [1–3] The warm ischemia time, i.e. the time from the first contact with the potential donor to the cannulation of the artificial vessels and the commencement of *in-situ* organ perfusion on ECMO, including CPR (cardiopulmonary resuscitation), transplant coordination and donor authorisation, should not exceed 150 min. The nECMO regional perfusion for organ recovery should be conducted for a minimum of 90 minutes according to the algorithm architecture. The nECMO protocol is adopted according to the main DCD-ECMO centres (Maastricht, Madrid, Barcelona) whereas the applied ECMO priming solution is the "Spanish protocol" with the author's modification.

The best evidence of the success of creating an algorithm via medical simulation is reassuring. Soon after the simulated procedure, Maastricht category II (donor after unsuccessful CPR) DCD procedures were performed involving real patients and resulting in two successful double kidney transplantations for the first time in Poland [4–5].

KEY WORDS: DCD, donors after circulatory death, ECMO, extracorporeal membrane oxygenation

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ADDRESS FOR CORRESPONDENCE:
Mateusz Puślecki, Department of Medical Rescue, Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland, e-mail: mateuszpuslecki@o2.pl

ECMO — A BRIDGE TO WHERE?

Bartłomiej Perek

Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland

Introduction: Veno-arterial extracorporeal membrane oxygenation (VA ECMO) has been used for many years. However, at least in Poland, up to a few years ago this method of life support was applied exclusively in the best paediatric surgical centres. Currently, many adult cardiac surgical departments use VA ECMO with relatively favourable outcomes.

In order to understand the principles not only of ECMO applications, but also of other methods of supporting the failing heart, two crucial issues have to be addressed. Firstly, what is the underlying pathology (**indication**) that eventually led to heart failure? The second issue is the **purpose** of heart support. Although in theory they seem clear, in daily clinical practice, not uncommonly, the answers to the aforementioned questions are not obvious. However, correct answers require experience of the 'heart failure' team and ensure success in VA ECMO therapy, if they are addressed appropriately.

Indications: There are two groups of indications, namely acute and chronic heart failure. In case of the acute setting, in many patients myocardial function is normal, or at least relatively well preserved prior to the effects of culprit factors. The most prevalent are infarct, inflammation and surgery-related myocardial injury. In many of these factors, pre-existing, although clinically silent, myocardial pathologies make cardiomyocytes prone to being injured. The second group of indications comprises the significant deterioration of chronic heart failure (e.g., in the course of idiopathic dilated cardiomyopathy).

Purpose: ECMO can be used as a bridge to recovery, the most optimal scenario, although exclusively in the acute setting. Otherwise, in many patients, ECMO is considered as a bridge to ventricular assist device insertion or, in smaller groups, as a bridge to heart transplantation. In chronic failing heart individuals, one must not be naive and expect rapid recovery during ECMO therapy. When applying ECMO, one must be aware that this device may be employed just for a few days as a temporary support. In the literature, the usual duration of use with a successful outcome ranged between 4 and 7 days. This short period should provide the time necessary in order to improve the performance of other important organs and prepare them optimally for permanent and usually more invasive therapy.

To summarize, the qualification of using VA ECMO as a temporary method should take into account both the indications and the purpose of support. In practice, ECMO as bridge to recovery may be considered only in acute cases, whereas it may be a bridge to long-term assist device application in both acute and deteriorated chronic heart failure.

KEY WORDS: heart failure, veno-arterial extracorporeal life support, indications

ADDRESS FOR CORRESPONDENCE:
Bartłomiej Perek, Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poland, e-mail: bperek@yahoo.com

ECMO — A NURSE'S POINT OF VIEW — CASE STUDY

Sabina Krupa, Hanna Krukowska, Kazimierz Widenka

Department of Cardiac Surgery, Medical Faculty, University of Rzeszow

ECMO (Extracorporeal Membrane oxygenation) is a method of modern intensive care. Despite many advantages, it is an invasive treatment with many complications. ECMO is a method of extracorporeal blood support which, in many cases, is a last resort. It is based on the multidisciplinary effort of doctors, perfusionists and nurses. The patient described in the article is an example of such effort and commitment. The method used in this article was a case study. The material was collected during the daily work of nurses on the ward, while laboratory tests were also analysed.

During ECMO treatment in the Intensive Care Cardiac Surgery Clinic in Rzeszow, cooperation among the interdisciplinary team was very close. The patient, who was in a life-threatening state, needed special care. The nurse who was responsible for the patient on duty, showed a lot of empathy towards the patient, while also being conscientious and meticulous. Thanks to their training at a hospital in Leicester (UK), the team taking care of the patient had acquired theoretical and practical knowledge of how to cultivate a patient. An important role was played by the sharing of observations, remarks, and related experiences caring for patients undergoing highly specialized medical procedures, including the method of extracorporeal blood oxidation. Thanks to the introduction of innovative methods, treatment in intensive care units requires the continuous development of new standards for the management of patients at risk of losing health and life. Often doctors have different opinions on how to treat a patient with ECMO, as it may happen that a patient's condition deteriorates daily. The patient described in this article was also diagnosed with a tumour in the abdominal area. Each day the whole team was mobilized and ready for what the next day would bring. After completing the ECMO therapy, the patient had stable breathing and circulation. She was transferred to a rehabilitation unit where she participated actively in exercise, and with the support and assistance of her family and a psychologist, achieved a better mental condition. ECMO has proven effects in treating acute respiratory failure and heart failure. All successes and failures should be reported, as this is helpful to doctors from other hospitals units where treatment is provided. Thanks to such data, we provide each other with information about possible failures that may occur [1].

As ECMO systems are complex and expensive, there are only a few hospitals in Poland which are suitable for introducing such therapy. It is important to remember that although ECMO therapy is a great hope for patients who qualify for such treatment, at the same time ECMO is also a huge challenge for all interdisciplinary teams which work with this device [2].

KEY WORDS: ECMO, extracorporeal circulation, nursing care

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ADDRESS FOR CORRESPONDENCE:
Sabina Krupa, Department of Cardiac Surgery, Medical Faculty, University of Rzeszow, e-mail: sabinakrupa@o2.pl

ECMO — NEW TRENDS AND TECHNOLOGY

Piotr Ładziński, Marta Kilanowska, Tomasz Nałęcz, Michał Sobieraj, Andrzej Wodziński, Przemysław Westerski, Wojciech Mrówczyński, Michał Wojtalik

Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, Poznan, Poland

Extracorporeal membrane oxygenation (ECMO) indications and usage has progressed to a striking degree over recent years and has become an important tool in adult and paediatric intensive care. Contemporary ECMO includes patients that are extubated, awake and ambulatory, therefore reducing traditional deconditioning.

This paper examines novel applications and recent trends in the use of ECMO, namely: the employment of the ECMO procedure to facilitate the safe application of other treatments; changing the timing of ECMO initiation; newer equipment with better biocompatibility; new trends in anticoagulation; ICU management; methods of cannulation; as well as early mobilization and Intensive Care Unit rehabilitation. As ECMO evolves and diversifies in its applications, its safety is improved. This manifests itself in an increasing amount of ECMO centres and ECMO patients.

The future of ECMO depends on the emergence of new technology which is still being developed. ECMO circuits are continuously being simplified, with increased portability and automation, potentially allowing for their increased use outside the hospital setting. Such improvements are associated with a reduction in required anticoagulation parameters, decreased inflammatory response, increased safety, as well as decreased costs.

KEY WORDS: extracorporeal membrane oxygenation, extracorporeal life support, cardiac failure, pulmonary failure, mechanical circulatory support

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ADDRESS FOR CORRESPONDENCE:
Piotr Ładziński, Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, e-mail: pladzinski83@gmail.com

ECMO POSITION IN CONTEMPORARY ADULT INTENSIVE CARE

Marcin Ligowski

Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland

Veno-venous Extracorporeal Membrane Oxygenation (ECMO) for refractory acute respiratory distress syndrome (ARDS) has been used since the 1970s. Due to fatal outcomes in adults for many decades, it was mostly used in paediatric populations. This was changed in 2009 when in the CESAR study reported lower mortality in ECMO-treated patients [1] and due to the H1N1 influenza epidemic outbreak. Since then, ECMO has become more commonly used for severe respiratory failure treatment. Analysis of the International ELSO Registry shows the relationship between the number of treated patients and outcomes. Thus, a higher annual hospital ECMO volume is associated with lower mortality [2].

ECMO is a form of life support which can assist both the heart and lungs. In the veno-arterial configuration, it provides gas exchange and replaces systemic circulation. Its first application took place in cardiac surgery settings as a cardiopulmonary bypass modification in cases of a low cardiac output syndrome in the postoperative period. Currently, ECMO is applied most often percutaneously as a short-term circulatory assist device in different indications, such as deep hypothermia, refractory

cardiogenic shock, and even cardiac arrest during CPR. Such implantation stabilizes the circulatory system and prepares patients to receive specific treatment. Particularly encouraging outcomes are related with use ECMO as extracorporeal cardiopulmonary resuscitation (eCPR). In patients with in-hospital cardiac arrest of a cardiac origin, eCPR had a survival rate higher than conventional CPR by 20 to 40% [3]. ECPR should be considered in selected candidates with potentially reversible causes. Automated chest compression and capnometry should be available to maintain high-quality resuscitation.

Femoral cannulation in VA ECMO is linked to possible drawbacks. Non-physiological retrograde blood flow in the aorta increases afterload, deteriorates heart performance and overloads pulmonary circulation that eventually lead to cardiac abnormal dilatation and pulmonary oedema.

Although a heart supported by VA ECMO may generate some native output, if it is accompanied by poorly functioning lungs, upper body hypoxia, also termed Harlequin syndrome may appear. As femoral cannulation may result in leg ischaemia, additionally in this case, a shunt inserted peripherally is needed in order to preserve distal perfusion.

One of the approved clinical indications is the implementation of ECMO as a support for organ perfusion in donors after circulatory death (DCD) DCD-ECMO [4]. The use of normothermic extracorporeal oxygenation (nECMO) perfusion for "organ recovery" is associated with significantly better long-term organ transplants outcomes (kidney) and lowers the rate of delayed graft function compared to donation after DCD with automated chest compression.

KEY WORDS: ECMO, respiratory failure, eCPR, femoral cannulation, DCD, Necmo

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ADDRESS FOR CORRESPONDENCE:
Marcin Ligowski, Department of Cardiac Surgery
and Transplantology, Poznan University of Medical Sciences,
e-mail: mligowski@icloud.com

ECMO PROTOCOL IN DM-2 POZNAN

Marcin Zieliński

Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland
Provincial Ambulance Service Station in Poznan, Poland

Coordination of medical activities aimed at verifying a patient who is in immediate danger of dying for qualification to the ECMO program (ECMO for Greater Poland) involves a number of individual activities [1]. In order to achieve the desired effect, it is necessary to coordinate many elements into one cause-and-effect sequence.

The protocol implemented in the Concentrated Medical Dispatch Centre No. 2 in Poznan aimed at qualifying the patient for the ECMO procedure is based on two basic assumptions [2]. The first element of the whole procedure is the positive verification of the victim in terms of determining his or her current status for further treatment. The second main item is notification of the project coordinator by the main dispatcher. This person operating in the emergency mode checks the technical capacity and willingness of the appropriate hospital unit to introduce the procedure. Subsequently, feedback is given to the dispatcher as the medical rescue team concerned continues its actions. If the designated hospital unit is intended to take the injured person, then further action by the EMS and the coordinator is aimed at improving and introducing all treatment at the pre-hospital stage.

KEY WORDS: Concentrated Medical Dispatch Centre, No. 2, ECMO

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ADDRESS FOR CORRESPONDENCE:
Marcin Zieliński, Department of Medical Rescue, Poznan University of Medical Sciences, Provincial Ambulance Service Station in Poznan, Poland, e-mail: marcin.zielinski.1976@gmail.com

ECPR ALGORITHM — NEW CHALLENGE OF CARDIOPULMONARY RESUSCITATION

Łukasz Szarpak[1], Marek Dąbrowski[2]

[1]Department of Emergency Medicine, Medical University of Warsaw, Poland
[2]Department of Medical Rescue, Chair of Emergency Medicine, Poznan University of Medical Sciences, Poznań, Poland

Sudden cardiac arrest (SCA) is one of the leading causes of death in the world. Many authors have indicated that SCA occurs about 55–113 per 100 thousand inhabitants per year. In the adult population one of the most initiate heart rhythm during cardiac arrest is ventricular fibrillation [1]. The chances of survival after cardiac arrest are low. Only approximately 10% of patients with cardiac arrest treated by EMS Teams survive until hospital discharge. Aid may be provided by the procedure developed and first applied by Gibbon in 1953 when a heart-lung machine was first used during cardiac surgery operation.

Extracorporeal cardiopulmonary resuscitation (ECPR) is a method of CPR that passes the patient's blood through an external device, in a process carried out in order to oxygenate the blood supply. A portable extracorporeal membrane oxygenation (ECMO) device is used as an addition to standard CPR. A patient who is deemed to be in cardiac arrest, refractory to CPR, has percutaneous catheters inserted into the femoral vein and artery. Extracorporeal membrane oxygenation within CPR (ECPR) may improve survival for refractory out-of-hospital cardiac arrest (OHCA).

In the majority of centres employing ECPR procedures, among the inclusion criteria for commencing ECPR one may include the following: witnessed arrest; VF or VT as the initial rhythm; age (18–70); and presumed cardiac cause or minimal interruptions in CPR. In turn, among the most frequent contraindications for implementing ECPR one may include the following: irreversible causes; prolonged CPR/EMS transport; known cognitive impairment; DNR/DNI protocol; and evidence of multi-organ dysfunction.

The procedure itself of connecting ECMO during CPR may be implemented both at the SOR level and in pre-hospital medical aid conditions. Resuscitation based on the ECPR protocol is divided into three stages. The first stage is commencing standard resuscitation based on the ALS or ACLS algorithms. In the meantime, the team gains access to the vascular bed with the aid of a 17–21 F venous cannula and a 15–19 F arterial cannula. In order for resuscitation to be performed at this time with high-quality chest compressions, it is worth employing mechanical system for compressing the chest [2–3]. Following the connection of the previously prepared ECMO kit, the starting of the device and the gaining of adequate flow, CPR is discontinued. As many studies have shown including that by Ahn et al. [4], ECPR may be more effective than conventional CPR as an additional treatment for survival and good neurological outcomes in cardiac-origin and cardiac arrest patients.

KEY WORDS: ECMO, ECPR, Cardiopulmonary resuscitation

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ADDRESS FOR CORRESPONDENCE:
Łukasz Szarpak, Department of Emergency Medicine, Medical University of Warsaw, Department of Medical Rescue, Chair of Emergency Medicine Poland, Lindleya 4, 02–005 Warsaw, e-mail: lukasz.szarpak@gmail.com

MEDICAL SIMULATION CAPABILITIES

Marek Dąbrowski[1, 2], Michael Czekajlo[2, 3, 4], Agata Dąbrowska[1, 2], Mateusz Puślecki[1, 5], Tomasz Kłosiewicz[1, 2], Maciej Sip[1, 2], Łukasz Szarpak[2, 6]

[1]Department of Medical Rescue, Chair of Emergency Medicine,
Poznan University of Medical Sciences, Poznan, Poland
[2]Polish Society of Medical Simulation, Poland
[3]Hunter Holmes McGuire VA Medical Center, Department of Surgery, Richmond, United States of America
[4]Medical Simulation Centre, Lublin Medical University, Lublin, Poland
[5]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland
[6]Department of Emergency Medicine, Medical University of Warsaw, Poland

Medical Simulation is an educational technique used to enhance medical education and as an objective measure of competency assessment. Simulation is currently one of the best ideas to prepare the long and proper process of education. Medical Simulation is widely accepted as a tool in the education of health care providers. Medical education based on simulation includes several tools and approaches, namely: task trainers; simulators; specialised software; standardized patients; as well as many complex processes in order to create a high-fidelity environment. In medical training, sophisticated and complex mannequins are used [1]. These mannequins are computer-controlled so that the human patient simulators can imitate physiological functions such as breathing and circulation (pulse, blood pressure, ECG). Human Patient Simulators (HPS) possess pupils that react to light, skin colour changes, heart and lungs sounds, and are capable of physiologically reacting to drugs administered. A HPS can be connected to monitors and all medical basic and advanced equipment used in the emergency department (ED), intensive care unit (ICU) or operating room (OR) to portray all the same parameters as in real life [2]. Medical Simulation is an interdisciplinary project permitting one to create many brand new algorithms and protocols and use them before one's first contact with a real patient. Medical Simulation has many advantages, such as:

— Standardization of learning outcomes and individualization of the learning process;
— Integration of one's formal knowledge and clinical experience;
— Development of one's habits of inquiry and innovation;
— Focus on one's professional identity formation [3, 4].

Simulation is a methodology and should not be thought just of as requiring a manikin or exercise in resuscitation. This is not only process to train advanced life support (ALS) protocols. The whole process is a compromise between students and patients, education and medicine. Simulation allows us to guarantee that a student or resident will see and treat all pathologies they need in order to develop into a competent medical doctor, nurse or paramedic. However, simulation should not be thought of as an alternative to dealing with a real patient but rather as supplement to dealing with one. Simulation has also become an invaluable tool in order to improve logistics and workload. Before opening any new ward or hospital just simulation is the best tool and should be used to identify staffing needs, staff roles or logistical efficiency [1–4].

Correct and proper simulation training may be dissected into three parts, namely: preparation; scenario; and debriefing (analysis). This model helps maintain a logical and effective order in the process of improving one's medical education [4, 5]. High-fidelity simulation offers a real working environment and risk-free training. The important role of medical simulation is not only as a kind of skill tester or testing tool, but also as a mechanism for creating procedures which do not yet exist. Thus, the results of medical simulation lead to effectiveness in clinical situations [6–8].

Last year we attempted to create an entire Polish ECMO project in the province of Greater Poland. This preparation is a brand new idea regarding a new level of world simulation. We should bear in mind that the only limitation to simulation is our imagination.

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ADDRESS FOR CORRESPONDENCE:
Marek Dabrowski, Department of Medical Rescue, Chair of Emergency Medicine, Poznan University of Medical Sciences, Poznan, Poland, 79 Dabrowskiego St., 60–529 Poznan, Poland,
e-mail: maro.dabrowski@gmail.com

MEDICAL SIMULATION IN ALS — ARTIFICIAL LIFE SUPPORT

Marek Dąbrowski[1, 2], Mateusz Puślecki[1], Łukasz Szarpak[2, 4], Agata Dąbrowska[1, 2]

[1]Department of Medical Rescue, Chair of Emergency Medicine,
Poznan University of Medical Sciences, Poznan, Poland
[2]Polish Society of Medical Simulation, Poland
[3]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland
[4]Department of Emergency Medicine, Medical University of Warsaw, Poland

Medical Simulation, or Healthcare Simulation, is the future of healthcare training. Medical simulation is the modern day methodology for training healthcare professionals through the use of advanced educational technology [1, 2]. Simply put, medical simulation is the experiential learning every healthcare professional will need, but cannot always engage in during real-life patient care. Medical simulation has also been called healthcare simulation, simulation in healthcare, patient simulation, nursing simulation, surgical simulation and clinical simulation [2]. Simulation is a training and feedback method in which learners practice tasks and processes in lifelike circumstances using models or virtual reality, with feedback from observers, peers, actor-patients, and video cameras in order to assist improvement in skills. Medical simulation is a cross-disciplinary effort that brings together healthcare providers, including nurses, physicians, and allied health professionals across a variety of disciplines with computer scientists, researchers, educators, and human factors engineers. Medical Simulation is an interdisciplinary project permitting one to create brand new algorithms and protocols and check them before one's first contact with a real patient [3].

Artificial Life Support (ALS) comprises forms of medical technology used when one's vital organ systems are failing. Life support refers to a spectrum of techniques used to maintain life after the failure of one or more vital organs. ALS systems use medical technology to aid, support, or replace a vital function of the body that has been seriously damaged. Such techniques include artificial pacemakers, internal defibrillators, dialysis machines, and respirators. The use of life-support systems to prolong the life of a patient who has suffered apparently irreversible damage to a vital organ system may raise such ethical issues as the quality of life [4–6].

High-fidelity simulation offers a real working environment and risk-free training. The important role of medical simulation is not only as a kind of skill tester or testing tool, but also as a mechanism for creating procedures which do not yet exist. The results of medical simulation lead to effectiveness in clinical situations [1-3]. Last year we attempted to create an entire Polish ECMO project in the province Greater Poland. During the first 4 months (Sep-Dec 2016) of our programme, the following simulation scenarios with ECMO simulator were generated [1]:

— "ECMO for DCD" — for donors after circulatory death with veno-arterial (VA) cannulation of a mannequin's artificial vessels and initiating organ perfusion on-site;
— "ECMO for INTOXICATION" — for poisoned patients as extended extracorporeal life support with automated chest compression and VA cannulation for the implementation of ECMO therapy and transport to a reference hospital;
— "ECMO for RRF" — for reversible respiratory failure as ventilation support, with veno-venous cannulation for the initiation of perfusion therapy, including specialist transport (80 km) with ECMO to another hospital where the (VV) ECMO therapy was continued for the next 48 hours — *in situ* simulation;
— "ECMO for HYPOTHERMIA" for hypothermia treatment, as extended extracorporeal life support with automated chest compression and VA cannulation for the implementation of ECMO therapy and transport to areference hospital for whole body heating.

This preparation is a brand new idea regarding a new level of world simulation. We should bear in mind that the only limitation to simulation is our imagination.

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ADDRESS FOR CORRESPONDENCE:
Marek Dabrowski, Department of Medical Rescue, Chair of Emergency Medicine, Poznan University of Medical Sciences, Poznan, Poland, 79 Dabrowskiego Str, 60–529 Poznan, Poland,
e-mail: maro.dabrowski@gmail.com

PROPOSITION OF SOPS FOR ECMO PATIENT TRANSPORT IN POLAND

Konrad Baumgart

Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland

Specialist transport of critically ill patients requires planning and a high level of efficiency while being carried out under pressure of time with an awareness of the highest level of care. The Standard Operating Procedure (SOP) is a tool (schedule) which helps one execute processes consisting of many tasks. The aim of the SOP is achieving uniformity of the procedure while maintaining the best possible care quality, efficiency and decreasing the risk of errors.

A simplified version of an SOP is a checklist. There are three important parts that one should focus on: preparing the patient and their environment [1]; planning and transport organisation [2]; and, finally, the time before leaving the hospital with the patient on ECMO and time during transport (on board). After the patient is qualified to undergo ECMO therapy, the notifying hospital receives a checklist with treatment and organisational advice which made the transfer process possible. During "preparation for the journey" phase, the transport team carries out mode of transport selection (by road, by air combined), then route planning (i.e. detours, other hospitals, escort car etc.) while the patient is deemed ready-to-transfer once an equipment checklist has been checked. The aim of these actions is to achieve easier decision-making processes, increasing the patient's and medical team's safety while reducing risk.

KEY WORDS: ECMO, patient safety, risk management, patient transfer, life support care, transportation of patients, critical care

ADDRESS FOR CORRESPONDENCE:
Konrad Baumgart, Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences,
e-mail: kbaumgart@o2.pl

PROTOTYPE OF ECMO SIMULATOR

Michał Kiel[1], Mateusz Puślecki[2, 3], Marcin Ligowski[3]

[1]IT Works, Wroclaw, Poland
[2]Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland
[3]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland

We present a prototype of a new extracorporeal membrane oxygenation (ECMO) simulator prepared for high-fidelity medical simulation in extracorporeal life support for Poland's first unique regional program — "ECMO for Greater Poland". Due to the complexity and cost of implementing ECMO in patient care, we have prepared an advanced ECMO simulator prototype, which can be used for medical training. It can be incorporated into any commercially available full-body patient simulator.

This tool is designed to imitate the physiological circulatory system and is able to simulate an implemented dysfunction scenario (i.e. bleeding, low pressure, occlusion, reaction to proper and incorrect pharmacological treatment). Moreover, it can work well with ECMO system therapy devices and can take necessary actions as in the human body during an ECMO intervention. An electronic core control unit (CCU) with silicone tubes, artificial vessels (modified polyethylene) and electronic components can be implanted into the basic manikin. Regarding maintenance, each part can be replaced easily. The total expected cost of the simulator is approximately $450 USD, with replaceable parts costing $50 USD.

A major function of the CCU is to stabilize the system in order to achieve scenario conditions. An algorithm coded into the CCU collects the information from hydro pumps and pressure sensors. These can adapt liquid flow, mean and peak pressures to imitate the human circulatory system. A device based on microcontroller can be further developed to cover all the customer's expectations, i.e. additional peripherals to manage given scenarios, monitor the system or report the results in order to find out the weak points of trained staff. The importance of ECMO simulation-based learning in medicine has a twofold importance. Firstly, it is a mechanism for recreating rare or non-existent procedures and, secondly, it is a tool for testing users in various clinical scenarios.

The advantages of simulation as an educational tool are invaluable. Medical simulation allows for standardized training, the testing of new or commonly used procedures, skills upgrading but also to practice very rare case scenarios. The economic result of the training simulation is optimized at the expense of improving theoretical and practical skills. On the basis of our experience in the Greater Poland region, full responsibility we confirm the effectiveness of training activities based on simulation, practical and theoretical training developed within the programme. These have a direct impact on the effectiveness of implementing such sophisticated procedures as perfusion therapy at the highest level in a well-prepared manner, and which has a direct impact on the safety of the patients being treated.

KEY WORDS: ECMO, extracorporeal life support, simulator, high-fidelity simulation, education, training

ADDRESS FOR CORRESPONDENCE:
Michał Kiel, IT Works, Wroclaw,
e-mail: michalkiel@gmail.com

REFERRAL TO AN EXTRACORPOREAL MEMBRANE OXYGENATION CENTRE FROM RURAL HOSPITALS — ORGANIZATION, LOGISTICS, PROCEDURE

Mirosław Czuczwar, Justyna Sysiak

Department of Anaesthesiology and Intensive Care, Medical University of Lublin, Poland

Despite accumulating evidence on the potential usefulness of veno-venous extracorporeal membrane oxygenation (ECMO) in treating refractory acute respiratory failure, its availability in Polish hospitals is still limited to specialized centres, which are mainly located in cardio-surgical wards. Recently published guidelines, endorsed by the Polish Society of Anaesthesiology and Intensive Care, provide useful information on the main issues associated with conducting ECMO treatment. However, the potential problems associated with patients' referral from distant hospitals are only briefly discussed, due to limited data. The MEDLINE data base comprises very few well-conducted studies on the subject of inter-hospital transport of patients requiring ECMO support in a specialized centre, with most of the available evidence coming from single centres or case reports. To the best of our knowledge, the pooled survival rate of adult and paediatric patients transported on ECMO support, obtained from data on 1,481 patients, was 62–68%, while only two deaths were reported during transportation. It is noteworthy that the complication rates were low in this study. Here, we report single-centre data regarding the procedures, complications, and mortality associated with the transportation of patients on ECMO support. The data was gathered from January 2016 until August 2017 and comprises 12 cases, with a mean transport distance of 100 km of ground transport, no complications or side effects during ambulance transport, and an average mortality rate of 25% at discharge. Based on our experience, it seems that patients' referral to a distant ECMO centre while on extracorporeal support appears to be safe, even at significant distances using a ground transport system.

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ADDRESS FOR CORRESPONDENCE:
Mirosław Czuczwar,
Department of Anaesthesiology
and Intensive Care, Medical University of Lublin,
e-mail: czuczwarm@gmail.com

SAFEGUARDS, PITFALLS AND CHALLENGES IN ECMO THERAPY FROM THE PERSPECTIVE OF A CARDIAC SURGEON AND ANAESTHETIST — THE EXPERIENCE OF THE WARSAW INSTITUTE OF CARDIOLOGY

Paweł Litwiński, Barbara Nicińska

Warsaw Institute of Cardiology, Warsaw, Poland

BACKGROUND: Extracorporeal membrane oxygenation (ECMO) is a technology expanding worldwide for patients in severe cardiogenic shock that can be used as a "bridge to recovery", a "bridge to a bridge" until a long-term biventricular or left ventricular assist device can be implanted, or as a "bridge to transplantation" if there is neither a possibility for heart recovery nor contraindications for transplantation.

AIM: A cohort of 168 consecutive patients received ECMO in our institution during the last 5 years. The aim of the presentation is to review our experience in ECMO therapy applied to a heterogeneous group of patients suffering from severe heart failure usually presented as cardiogenic shock, pulmonary oedema and single or double ventricle congestive heart failure.

RESULTS: Hemodynamic instability refractory to conventional medical treatment was attributable mainly to postcardiotomy low cardiac output syndrome (75%), exacerbation of chronic heart failure or myocardial infarction. Decisions regarding ECMO implantation should be made by a multidisciplinary team, based on prior experience and hospital resources. The prognosis depends significantly on the time between haemodynamic destabilization and the reestablishment of adequate end-organ perfusion. Qualification for ECMO therapy is accompanied by many challenges in managing and preventing complications. Bleeding and thrombotic complications remain a leading cause of morbidity and mortality in patients on ECMO support. Inadequate left ventricular decompression and pulmonary oedema are other recognized limitations of ECMO. Modern ECMO therapy also presents a multitude of ethical problems. An ECMO weaning protocol is applied at our institution. Daily heart function assessment on ECMO allows for treatment optimalization and decision making, including explantation. In cases of protracted ineffective maintenance of organ function, a futile therapy protocol is applied.

CONCLUSIONS: ECMO is a complex form of therapy that facilitates treating severe refractory cardiogenic shock and combined heart-respiratory failure. Although it poses many advantages, it also carries a high risk of serious complications. The team-work of involved and qualified specialists and consultants seems to be crucial for successful ECMO therapy.

KEY WORDS: ECMO, mechanical circulatory support, cardiogenic shock, postcardiotomy low cardiac output syndrome

ADDRESS FOR CORRESPONDENCE:
Barbara Nicińska, Warsaw Institute of Cardiology,
e-mail: baska.nicinska@gmail.com; open4cor@gmail.com

SIMULATION IN EDUCATION

Guillaume Alinier

Hamad Medical Corporation Ambulance Service, Qatar
University of Hertfordshire, United Kingdom,
Northumbria University, United Kingdom

The importance of offering effective simulation-based training opportunities to multiprofessional teams of students and qualified healthcare professionals is becoming increasingly recognized. However, a recently emerging focus has been on quality education and low-cost and *in situ* simulation, rather than promoting the use of prohibitively expensive technology [1–3]. Although many studies have been conducted proving the benefits of technology-enhanced simulation [4, 5], perceived cost constraints sometimes unnecessarily hinder the adoption of the "approach" which gets mistaken for the "tool" or "technology".

Professional societies dedicated to the use of simulation to complement the education of healthcare students and professionals are trying to address quality issues by publishing simulation standards [6, 7], accrediting centres and programmes [8], as well as offering certifications to educators and technologists, or operation specialists [8, 9]. The development of simulation facilitators is expected to significantly contribute to improving the quality of simulation-based training opportunities, as well as providing a framework to standardize the language and terminology used [10].

Once the appropriate facilitation aspect of the learning experience is guaranteed, it remains to ensure that the skills practiced and acquired by the "participants" or "learners" are transferable to the real patient care environment. This means that at some point, the level of fidelity or "verisimilitude" is carefully taken into consideration in order that the simulation experience adequately bridges with real patient care [11]. The level of fidelity of the various aspects of a simulation can be adapted depending on how close they are from the session's learning objectives, whether it is for team training, procedural skills training, or "systems testing" of a new clinical environment.

Although simulation is a valued training and testing modality for Extracorporeal Membrane Oxygenation (ECMO) centres, it is still not implemented everywhere [12]. As ECMO is still a niche area with a limited market from an industry perspective, simulation developments are very limited and there is currently no simulator that provides a complete high-fidelity experience. Ideally such simulator should allow for skin incision through to cannula placement with ultrasound or fluoroscopy, along with running the ECMO machine in order to achieve optimal oxygenation with the expected blood colour change [13].

Ultimately, pedagogical understanding coupled with wise technological implementation may contribute to democratizing the use of simulation of various modalities, increase the frequency of access to students and clinicians, and facilitate research opportunities, not only for ECMO, but for all acute and non-acute specialties.

KEY WORDS: ECMO, patient safety, teamwork, skills acquisition, human factors

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ADDRESS FOR CORRESPONDENCE:
Guillaume Alinier, Hamad Medical Corporation Ambulance Service, Qatar, University of Hertfordshire, UK, Northumbria University, UK, e-mail: Galinier@hamad.qa

SIMULATION-BASED EDUCATION IN ECMO AS A TOOL FOR EDUCATION AND ASSESSMENT — PRELIMINARY REPORT

Łukasz Gąsiorowski[1, 2], Piotr Ładziński[3], Mateusz Puślecki[4, 5], Marcin Ligowski[5], Małgorzata Ładzińska[5], Wojciech Mrówczyński[3]

[1]Medical Simulation Center Director, Poznan University of Medical Sciences, Poznan, Poland
[2]Thoracic Surgery Department at Wielkopolska Centre of Pulmonology and Thoracic Surgrery, Poznan, Poland
[3]Department of Paediatric Cardiac Surgery, Poznan University of Medical Sciences, Poznan, Poland
[4]Department of Medical Rescue, Poznan University of Medical Sciences, Poznan, Poland
[5]Department of Cardiac Surgery and Transplantology, Poznan University of Medical Sciences, Poznan, Poland

INTRODUCTION: Mechanical circulatory support using ECMO technology has become more available and utilized. With more awareness among physicians and society, there is a constantly increasing demand for this form of ECLS. As this procedure is very complex and comes with a high risk of morbidity, one of the integral parts of programme development is a structured education program. Recently, simulation-based teaching and assessment also has been in use with ECMO procedures.

AIM: The aim of the paper is a preliminary report on ECMO multidisciplinary team-training using simulation-based learning.

METHODS: A SimMan 3G (Laerdal, Norway) patient simulator was adapted to simulate both ECMO VV and VA procedures (single and dual vein cannulation) using a Rotaflow ECMO unit (Maquet, Germany), a non-sterile pump set, an oxygenator, vascular lines, cannulation catheters and a proprietary elastic container consistent with the venous reservoir. The container was connected to a set of syringes enabling the mimicking of volume changes, line obstruction and airing. The patient simulator was programmed with scenarios simulating typical clinical situations (hypothermia, hypovolemia, oxygenator failure, etc.), requiring prompt interventions from the students. The interdisciplinary workshop (two nursing staff and two physicians) comprised 16 hours over 2 days and was preceded by a mandatory e-learning course with the pre-test. The participants were inexperienced regarding ECMO technology. The course was evaluated by an anonymous survey filled out by all participants.

RESULTS: The workshop was evaluated extremely positively with 100% of all responders supporting the concept of an on-line pre-test as a prerequisite of joining the workshop. All the participants stated that this course would help in introducing ECMO therapy into the ICU. Moreover, the students evaluated the hands-on experience gained during this workshop very highly, particularly the cannulation training.

CONCLUSIONS: Simulation-based teaching is an effective tool in introducing ECMO technology to interdisciplinary teams inexperienced in such methods. It enables the boosting of one's self-confidence in management of the system, as well as the decreasing of stress levels when troubleshooting.

KEY WORDS: ECMO simulation, education, simulation-based teaching

ADDRESS FOR CORRESPONDENCE:
Łukasz Gąsiorowski, Medical Simulation Center Director; Thoracic Surgery Department at Wielkopolska Centre of Pulmonology and Thoracic Surgery, e-mail: lgasior@ump.edu.pl

TECHNICAL CHALLENGES OF SIMULATION IN ECMO EDUCATION

Guillaume Alinier

Hamad Medical Corporation Ambulance Service, Qatar
University of Hertfordshire, United Kingdom,
Northumbria University, United Kingdom

As Extracorporeal Membrane Oxygenation (ECMO) is gaining in popularity due to general improvements in patient outcomes, the demand for well-trained ECMO staff has risen over the last few years. ECMO therapy, however, comes with its own challenges as it can be a very high-risk procedure and requires the constant attention of an ECMO team ready to react quickly to a number of potential issues [1]. The safest approach for clinicians to gain experience regarding ECMO is by using various modalities of simulation of different levels of complexity and realism for them to acquire each of the required individual skills [2–5]. Once they are ready to demonstrate their level of preparedness, they can be exposed to more comprehensive and longitudinal simulated situations that may start from initial patient referral and assessment through to ECMO cannulation and performing a circuit change, followed by a facilitated debriefing that promotes reflection and helps deepen their knowledge [6].

Simulating this patient's journey is, however, riddled with technical and physiological challenges that current simulation technology has not yet fully replicated realistically into a single simulator. Although current ECMO simulators only meet some of the expected requirements and often rely on operator tricks to overcome simulator limitations in an attempt to render the simulations more realistic, some scenarios are still too complex to simulate with full fidelity in a reproducible and cost-effective manner. For example, transiting a patient from VV ECMO to VVA ECMO pauses cannulation challenges with regards to the mannequin circuit that needs to allow the flow of the same fluid from its pulsatile arterial tubing system into its venous one which should have a laminar flow and a much lower pressure. The system also needs to enable the clinician to check cannula placement near the heart using the expected form of medical imaging. Blood oxygenation ideally needs to be accompanied by the expected blood colour change in the return part of the ECMO circuit in a way that is economically viable (reusable membrane and circuit) and safe (no contamination risks or biohazards). Our team is working on such developments and making great progress that will allow for increased simulation realism and subsequently further enhance the clinical team learning experience and competence in managing ECMO patients [7, 8].

KEY WORDS: ECMO, patient safety, teamwork, skills acquisition, procedures, cannulation, troubleshooting, realism

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ADDRESS FOR CORRESPONDENCE:
Guillaume Alinier, Hamad Medical Corporation Ambulance Service, Qatar, University of Hertfordshire, UK, Northumbria University, UK,
e-mail: Galinier@hamad.qa

ULTRASOUND-GUIDED ECMO CANNULATION — A NECESSARY PROCEDURE

Sebastian Stefaniak[1], Marcin Ligowski[1], Mateusz Puślecki[1, 2], Marek Jemielity[1]

[1]Department of Cardiac Surgery and Transplantology, University of Medical Sciences, Poznan, Poland
[2]Department of Medical Rescue, University of Medical Services, Poznan, Poland

Ultrasound examination, as a safe and widespread method, plays a key role in the safe delivery of ECMO [1, 2].

It is not only a guide for the implanting person but a tool which helps to detect and prevent complications associated with the ECMO procedure. The importance of the use of this technique led to the creation of "Ultrasound ELSO Guidelines for ECMO" in 2015 [3].

Looking beyond guidelines, the use of ultrasound can be considered under three broad categories, namely: pre-ECMO, during ECMO and post-ECMO initiation [3, 4].

In the pre-ECMO initiation, real-time ultrasound evaluation of a patient may be helpful to diagnose of the site of cannulation, the size of cannulae to be used, possible pathology at the site, or anatomical variation among vessels. All the above-mentioned factors may influence the management of the safe practice of the ECMO procedure.

The rule of measuring the diameter of the vessel to determine the appropriate and safe size of the cannula should be always use before preparation; (3x diameter of the vessel in millimetres is the French Gauge size of a cannula) [3–5]. Vascular real time ultrasound during ECMO initiation helps to identify and puncture the vessel without causing any local complications. Keeping in mind the impossibility to differentiate between the arterial and venous vessels using the palpation method in CPR or other different pathologies, we must remember that femoral vascular anatomy is very varied.

After the introduction of the cannula into the vessel, the final desired position of the venous cannula should be guided by echocardiography. It is difficult to visualise the radiolucent distal end of the ECMO cannula in radiography. A malpositioned cannula tip may be identified and appropriate interventions put in place to prevent low-flow.

The post-ECMO initiation ultrasound is performed to deliver sufficient distal limb perfusion and prevent upcoming possible implantation site complications [3, 6].

KEY WORDS: ECMO, ultrasound-guided cannulation, echocardiography

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ADDRESS FOR CORRESPONDENCE:
Sebastian Stefaniak, Department of Cardiac Surgery and Transplantology, University of Medical Sciences, Poznan, Poland,
e-mail: sebkos@gmail.com