

Establishing an ECMO program in a developing country: challenges and lessons learned

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Abstract

Aim: The ECMO (extracorporeal membrane oxygenation) Program at the American University of Beirut Medical Center was established in November 2015 as the first program serving adult and pediatric population in a low-resource setting. The aim of the study is to describe the challenges faced during the establishment of the program and factors leading to its success.

Methods: The program establishment is described. The preparation phase, included the strategic, financial, and clinical planning by administration, nursing, and a multidisciplinary team of physicians. The training and education phase included all the involved nurses, perfusionists, and physicians. Concerns were heard from various stakeholders, and the challenges were analyzed and discussed.

Results: The preparation committee chose the adequate equipment, responded to the concerns, defined roles and responsibilities through credentialing and privileging, wrote policies and protocols, and established a strategy to decide for the ECMO indication. Selected team of nurses, physicians, and perfusionists are identified and trained locally, and abroad. A full-time ECMO physician was recruited to launch the program. Twelve patients (6 adults, 3 children, and 3 neonates) were supported by ECMO, for cardiac and respiratory indications. Eleven patients were supported by veno-arterial ECMO, and 1 patient (a neonate) with veno-venous ECMO. Overall, 75% survived to decannulation and 41% survived to discharge.

Conclusion: With limited human and financial resources, new ECMO centers need to carefully establish selection criteria that may differ from those used in developed countries. Indications should be discussed on a case by case basis, taking into account clinical, social, and financial issues. This experience might help other institutions in developing countries to build their own program despite financial and human limitations.

Keywords

ECMO program; establishing; developing countries; recommendations; experience

Background

At the start of every new ECMO (extracorporeal membrane oxygenation) center, institutional resources are put under extreme and unprecedented pressure, in order to optimize patient care and outcome. In a developing country, planning for an ECMO program is challenging by itself, mainly because of the lack of resources. Centers in Saudi Arabia, Egypt, Pakistan, India, and others have reported their clinical experience, but recommendations about ECMO program initiation, specific to low- and middle-income countries, are still lacking in the literature. ELSO has published general

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guidelines to outline the ideal requirements, stating that these may be adapted according to country specificities and resource availability and highly recommends that new centers in developing countries benefit from the experience of developed countries.

In Pakistan and Saudi Arabia, ECMO experience started with the H1N1 epidemics in 2009. In most other developing countries, ECMO was used initially as a last resort to wean patients from cardiopulmonary bypass following cardiac surgery and then expanded to include other indications.

The American University of Beirut Medical Center (AUBMC) is one of the main tertiary care hospitals in Lebanon, serving a country of 4 million. It is the only ACGME and JCI accredited, Magnet certified hospital, and the only center to have established an ECMO program. Its 400 beds include 10 pediatric, 22 neonatal, and 32 adult critical care beds.

This report describes the establishment of the ECMO program in the institution and summarizes the initial experience with ECMO, discussing limitations, strengths, and challenges.

Methods

The establishment of the program was accomplished in two phases: the first phase entitled preparation, was the phase of discussing, reading, meeting, planning, and convincing the skeptical colleagues and other stakeholders of the importance of this technology. The second phase included education and training.

Phase 1: preparation

The process was triggered simultaneously by the cardiac surgeons and the pulmonologists with the argument that ECMO had to be part of the armamentarium of a tertiary medical center. A multidisciplinary committee was assigned to assess the need, establish policies, and select the adequate equipment. Sub-committees were designated to work on each of these aspects. The committee had the administration's full support and included clinicians, perfusionists, nurses, and administrators. The group was called to meet every 2 weeks to discuss, amend, and approve the work of the sub-committees. In addition to policies and equipment, the team had to discuss important questions and come up with decisions related to debatable matters, in order to avoid ethical or medico-legal dilemmas at the start of the ECMO program. These questions included who decides to put a patient on ECMO, indications, futility, financial coverage, when to turn off the ECMO, in addition to privileging and credentialing the physicians to cannulate for, and/or manage, an ECMO.

All stakeholders (nursing, physicians, and administrators) expressed concerns about bringing ECMO to the hospital. Nursing leadership was concerned about the imposed patient acuity and workload. The physicians' skepticism was also valid: with the exception of cardiac surgeons, there were no physicians experienced in ECMO in our institution; during the past decade, surgical intensivists had unsuccessfully supported five patients, using improvised, obsolete equipment. Administration representatives expressed the same concern for the absence of a full-time ECMO physician. Since most ECMO cases would be life-saving situations, administrators expressed also concerns about the cost of the program, because ECMO therapy was not covered yet by the ministry of health and insurance companies in our "middle income" country.

Phase 2: education and training

Education and training were planned for all healthcare professionals expected to care for ECMO patients. Theoretical courses and practical hands-on sessions were prepared. Abroad training in different centers in Europe was also planned for a selected team of physicians and perfusionists. Medical and para-medical staff members were expected to earn official institutional training certificates, in order to be credentialed to participate in the management of patients on ECMO.

Continuous medical education was scheduled to take place every 4-6 months, to maintain competency until the volume load increased. Progressively, ECMO training would include new personnel, with the ultimate objective to train, over a period of 2 years, all existing staff, in all units involved in the care of an ECMO patient.

Data collection. All patients supported on ECMO were included. Data regarding patients' characteristics, indication for ECMO, type of cannulation, mode of support, complications, and survival to decannulation and discharge were retrieved from the medical records. The study was approved by the university institutional review board committee.

Results

Figure 1 summarizes the logic model we followed for the establishment of the ECMO program.

Execution of the preparation phase

The committee. The multidisciplinary committee was composed of key personnel from medical, nursing, and administration leaderships: a nurse clinical educator,

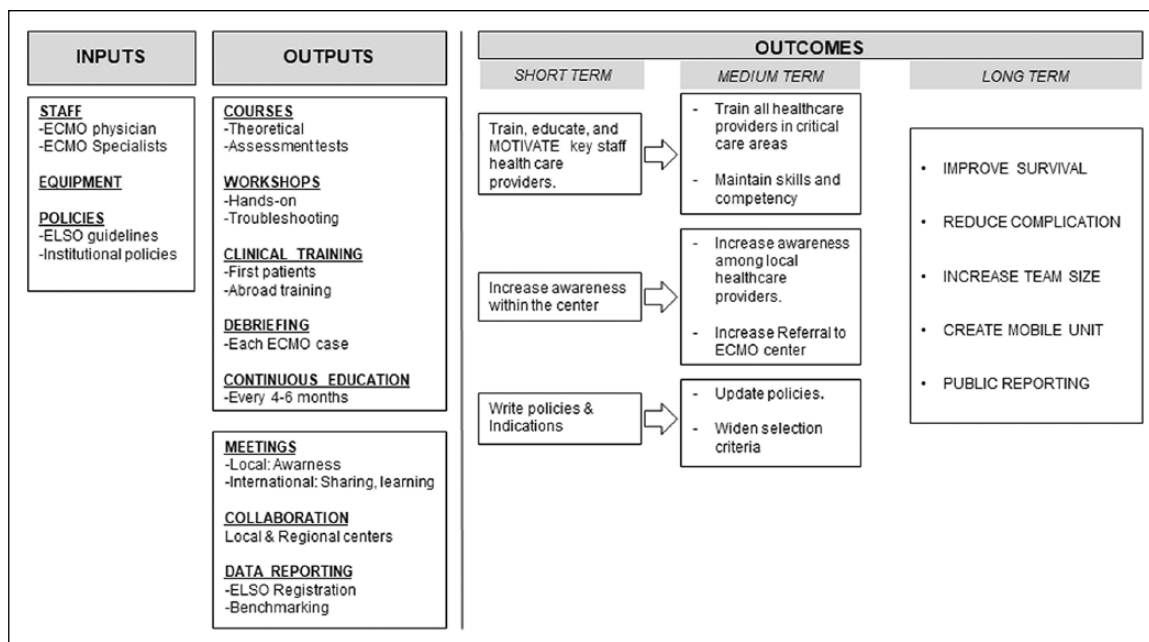


Figure 1. Logic model for the establishment of an ECMO program in a middle- to low-income country.

one adult and one pediatric cardio-thoracic surgeons, one adult cardiologist, one adult and one pediatric medical intensivists, one perfusionist, one adult surgical intensivist, one inhalation therapist, and one biomedical engineer. The committee concluded that ECMO was definitely necessary for our institution and estimated the potential volume of patients between 6 and 10 yearly, based on the experience of intensivists, cardiologists, pulmonologists, and cardio-thoracic surgeons during the previous years. The committee's work and achievements described in detail below and in figure 1 were crucial for the initiation and development of the ECMO program. At the end of the preparation phase, the members of the ECMO committee became members of the ECMO program, with a director and a coordinator, as recommended by ELSO.^{1,2}

How the "concerns" were handled. To reduce nursing concerns, the education and training phase was planned with nursing, including the nurse educators in all the decisions, from the beginning. The active involvement of nursing in the preparation phase transformed concern into enthusiasm, and ECMO was set as an objective for nurses in critical care units. Concerning the absence of an experienced ECMO physician, the decision to recruit a full-time ECMO physician was taken, to launch the program successfully, and speed up the learning curve thereafter. The financial concerns of administration about the cost of this expensive therapy needed more strategic planning with the ministry of health, and the major insurance companies, in order to achieve acceptable coverage. In the meantime, it was

decided that the cost would be covered by the patients and their families, or through funds from the hospital.

The equipment. The sub-committee in charge of equipment attended presentations given by representatives of the two major ECMO vendors working in the Middle-East at that time: Maquet* (Getinge, Rastatt, Germany) and Levitronix* (Thoratec, Abbott Laboratories, Pleasanton, CA). Maquet was favored over Levitronix for the local availability of significant clinical and technical support; thus, one Cardiohelp and one Rotaflow ECMO consoles were acquired. Neonates and children below 20kg would have a 1/4-in Rotaflow circuit. Patients above 20kg would have either a 3/8-in Cardiohelp or Rotaflow circuit. In addition to standard ECMO circuits, 1/4-in and 3/8-in Rotaflow circuits without an oxygenator were ordered, for isolated left or right ventricular support.

Storage and inventory check of all ECMO equipments were left under the care of the perfusionists, being familiar with the management of cardiopulmonary bypass equipment. The perfusionists were asked to create an "ECMO Cart," similar to the crash cart used in case of cardiac arrest, with all what can be needed to put a patient on ECMO. The cart would be stored in the perfusion room, along with the ECMO consoles, and would be wheeled to the bedside of the patient by the perfusionist on call whenever needed.

To improve monitoring of ECMO patients, the equipment sub-committee introduced two new monitoring tools into intensive care clinical practice: near-infrared spectroscopy (NIRS), and anti-Xa level measurements.

Roles and responsibilities. The ECMO physicians were the cardiologists, surgeons, and intensivists who attended, and succeeded in the training courses, and were credentialed by the institution; they were responsible for the medical management. ECMO specialists were the credentialed bedside nurses; they were responsible for patient care and ECMO circuit management under the supervision of the ECMO physician. It was agreed initially on a 2/1 nurse-to-patient ratio for any ECMO, during the first 12 months. Both nurses would be at the same time, bedside nurses, and ECMO nurses. A young nurse, novice in ECMO, would always be scheduled to work with an experienced colleague. The perfusionist's role was limited to priming, and initiating ECMO, in addition to a technical circuit check every few hours during daytime. The ECMO program elected to rely on the credentialed nurses, rather than perfusionists, because of the reduced number of perfusionists, and their duties all day in two simultaneous operating rooms performing cardiac surgery.

Policies and protocols. A sub-committee drafted a policy based on ELSO recommendations and guidelines.^{1,2} It included indications and contraindications as well as management and monitoring guidelines. In-hospital and out-of-hospital cardiac arrest, as well as septic shock, were initially considered contraindications. Delaying "in-hospital cardiac arrest" as an ECMO indication would allow for more preparation and training of the ECMO team, to be able to quickly initiate ECMO support, in a setting where time plays a major role. However, during the following months, and with increased practice and experience, indications were broadened to include sepsis and in-hospital cardiac arrest.

A "3-Yes" strategy was agreed upon to initiate an ECMO. The call for ECMO was to be initiated by the primary care physician who would identify the patient as a potential candidate; the case would then be discussed with another physician from the same, or a related specialty, to secure a second "yes." The third "yes" must come from the ECMO program director or coordinator; the approval of all three would be required to start ECMO support.

Execution of education and training phase

Training. More than 60 selected key personnel attended the initial training organized over 3 days, and repeated three times, at monthly intervals. The attendees included 21 registered nurses and 31 physicians (from surgical, medical, and cardiac critical care units; from general, cardio-thoracic and vascular surgery departments; and from pediatric and neonatal critical care units), three perfusionists, three inhalation therapists, and three key staff from blood bank. The educational

material was based on the "ELSO Guidelines" published online, and in the "ELSO Red Book."² An ECMO physician was invited by the company to organize and supervise personally all three training sessions. Satisfactory results were achieved following the courses and the hands-on workshops. Pretest and posttest assessment questionnaires showed an increase in correct responses from an average of 60%, to an average of 90%, respectively. In the qualitative assessment, most attendees showed genuine interest and requested more case scenarios and discussions. Eight physicians were sent to renowned ECMO centers in Paris and Milano, for additional intensive ECMO training, with clinical bedside coaching; they were general surgeons, adult and pediatric intensivists, and pulmonologists.

Privileging. Training certificates were distributed to all attendees, and by policy, they were the only physicians and nurses privileged to care for ECMO patients. In addition, a full-time experienced ECMO physician was recruited to launch the program. Initially, and in order to improve the learning curve, all credentialed physicians, with the exception of the cardiac surgeons, had to discuss ECMO management with the recruited expert who had full authority for clinical decisions; only following experience with two ECMO cases, locally credentialed physicians would be privileged to manage ECMO without conferring with the recruited expert. Surgical cannulation was the privilege of the pediatric and adult cardiac and vascular surgeons only. Percutaneous cannulation could be performed by the surgeons, or by the intensivists who attended hands-on training sessions, and asked to be privileged for cannulation. A cardiac or vascular surgeon was always called to be ready to intervene in case of difficult vascular access, or complication.

Continued education and training. When the program started, all credentialed nurses, from all units, attended educational bedside training sessions in small groups, whenever there was an ECMO running anywhere in the hospital. Formal detailed debriefing sessions were held following each ECMO case, in the presence of all medical and para-medical staff involved in care or management. In addition, every 4 months, any staff member not involved in an ECMO run attended a 4-hour interactive training session, with pretest and posttest assessment questionnaires.

Patients results

The first application of ECMO was done prior to completion of the planned education and training sessions. The patient presented with refractory cardiogenic shock secondary to Pheochromocytoma. The patient was a 42-year-old female (patient #1, Table 1), previously healthy, wife and mother, and ECMO was her only chance

Table 1. Patients characteristics and outcomes.

	Age	ECMO indication (underlying disease)	Mode of ECMO Cannulation site Days on ECMO	Backflow femoral cannula	LV venting	Circuit change Dialysis	Survival to	
							Decannulation	Discharge
<i>Adult patients</i>								
1	42 years	Cardiogenic shock (pheochromocytoma crisis)	Peripheral VA Femoral vessels 5 days	Yes	No	No CRRT	Yes	Yes
2	82 years	Unable to wean from CPB (pulmonary embolectomy)	Central VA 2 days	No	No	No No	No	No
3	56 years	Unable to wean from CPB (CABG + mitral valve repair)	Central VA 2 days	No	IABP	No CRRT	No	No
4	63 years	ECPR during cardiac catheterization (ischemic heart disease)	Peripheral VA Femoral vessels 5 days	Yes	IABP	No CRRT	Yes	No
5	65 years	ECPR during cardiac catheterization (aortic valve stenosis)	Peripheral VA Femoral vessels 1 day	Yes	IABP	No No	Yes	No
6	72 years	RV failure following LVAD implantation (dilated cardiomyopathy)	Peripheral VA Femoral vessels 3 days	Yes	No	No No	Yes	No
<i>Children and neonates</i>								
7	15 years	Subacute myocarditis	Peripheral VA Femoral vessels 7 days	Yes	LV can- nula	Yes No	Yes	Yes
8	2 years	Septic shock (acute lymphocytic leukemia)	Peripheral VA Carotid—jugular 3 days	–	No	No Hemofilter	No	No
9	7 years	Low cardiac output 1 week following Fontan with mitral valve replacement	Peripheral VA Carotid—jugular 19 days	–	No	Yes Hemofilter and peritoneal	Yes	No
10	30 days	Respiratory failure (pulmonary infection)	Peripheral VA Carotid—jugular 10 days	–	No	No No	Yes	No
11	2 days	Respiratory failure (no diagnosis)	Peripheral VV Dual lumen cannula 13 days	–	–	Yes Peritoneal	Yes	Yes
12	1 day	Respiratory failure (congenital diaphragmatic hernia)	Peripheral VA Carotid—jugular 17 days	–	No	Yes No	Yes	Yes

ECMO: extracorporeal membrane oxygenation; CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; CRRT: continuous renal replacement therapy; ECPR: extracorporeal cardiopulmonary resuscitation; IABP: intra-aortic balloon pump; LV: left ventricle; LVAD: left ventricular assist device; RV: right ventricle; VA: veno-arterial; VV: veno-venous.

for survival. The ECMO equipment was already in the hospital, but no one felt comfortable enough to engage yet in the first ECMO run. We asked the company to provide, as promised, technical and clinical support. The invited ECMO physician responsible for training the team was thus given clinical privileges and asked to manage this first unexpected ECMO case. This ECMO physician was later recruited by our institution as a full-time intensivist and ECMO expert to launch the program.

A total of 12 patients from all age groups, with different indications, were supported with ECMO over a period of 26 months. Patients' characteristics are described in Table 1.

There were six adults, three children, and three neonates. Eleven patients were supported with veno-arterial (VA) ECMO and one patient (a neonate) with veno-venous (VV) ECMO. A backflow cannula to the lower limb was systematically inserted in all patients with femo-

ral artery cannulation, as part of the policy. In case of left ventricular distension and stunning, an intra-aortic balloon pump was used in adults. When necessary, an additional apical decompression cannula was inserted through a small left thoracotomy. ECMO circuit was changed in four patients, (two children, and two neonates), when significant clots were spotted in the circuit. Six patients required renal support therapy for fluid overload, and/or kidney injury, using the continuous renal replacement therapy (CRRT) machine, a hemofilter inserted in the ECMO circuit, or a peritoneal drain. Overall, nine patients (75%) survived to decannulation, and five patients (41%) survived to discharge from the hospital.

Among the adult population, two patients died on ECMO, four patients survived to decannulation, and only one survived to discharge. Patients' outcomes are also described in Table 1. The two adult patients who died while on ECMO were supported for inability to come off cardiopulmonary bypass following cardiac surgery (patients 2 and 3): one of them was an 80-year old man with cancer, rushed to the operating room with the diagnosis of massive pulmonary embolus. The patient was put on ECMO just to prepare the family for the bad news. The second patient was transferred from another hospital for acute massive myocardial infarction complicated with papillary muscle rupture; he had suffered multiple cardiac arrests before arrival. In both these patients, ECMO was turned off in ICU on day 2, to declare the patients dead. Two of the three adults who died following decannulation were supported for extracorporeal cardiopulmonary resuscitation (ECPR) and died from malignant arrhythmias (patient 4) and overwhelming sepsis (patient 5). The third patient who died after decannulation was put on ECMO for right ventricular failure following left ventricular assist device (LVAD) implantation (patient 6) and died from sepsis.

In the neonatal and pediatric age group, one patient died on ECMO, five patients survived to decannulation, and three patients survived to discharge. The patient who died while on ECMO (patient 8) was a 2-year-old girl treated for leukemia, supported for septic shock, which is still a debatable indication today. The two patients who died following decannulation were a 9-year-old boy with single ventricle, supported following complex cardiac surgery; he died 1 week following LVAD implantation from multiple organ failure (patient 9). The second one was a neonate supported for acute respiratory distress syndrome due to pulmonary infection; he died 2 weeks after decannulation from recurrent sepsis (patient 10).

Discussion

Over the past 20 years, ECMO has emerged as a powerful and effective life-saving technique for refractory cardiopulmonary compromise. According to the international

report of ELSO in January 2018, there are more than 300 active ECMO centers worldwide.¹ ECMO allowed for the survival of some patients not retrievable by the usual cardiac or pulmonary intensive care methods; this gratifying reality has been witnessed by all ECMO physicians, and clinicians experienced in intensive care, although not firmly confirmed by clinical comparative studies. ECMO is now practically a must in tertiary care centers and is discussed often unofficially among teams and physicians as an elective support before the catastrophic deterioration of the patients. This is precisely why AUBMC ECMO team elected to present its experience. The experience of a center is of great help for other centers; thus, the above described way of creating an ECMO center when the resources are limited is suggested. ECMO is often compared to cardiopulmonary bypass by many groups experienced in cardiac surgery; hence, in countries like Lebanon where ECMO culture is still lacking, cardiac surgeons, intensivists, and perfusionists in non-academic regional hospitals have used ECMO on patients, without any significant ECMO experience, and without the presence of an ECMO physician or ECMO expert. Dramatic failures have been witnessed in those hospitals due to the absence of a structured ECMO program.

When launching an ECMO center, a well-structured program should be implemented with an assigned director, a coordinator and a multidisciplinary team. AUBMC ECMO center was developed following guidelines and recommendations from the ELSO² and other international perspectives.^{3,4} Guerguerian et al.³ proposed six comprehensive steps for the development of a new ECMO center: planning, developing, implementing, sustaining, evaluating, and moving forward. Before the first ECMO patient, Guerguerian insisted on the first three steps being achieved. The first step, "planning" requires the identification of key personnel, and the conception of a strategic plan. The second step is developing the program, with the clear designation of human and organizational resources, as well as the listing of the needed equipment, with emphasis on safety and monitoring tools. Implementing the service is then done through education and training and setting of care models. The author emphasizes the importance of identifying the "key personnel" for proper training, but neither this author nor others gave specific recommendations on the need to initially start training small groups and expand later on to train more staff; most agreed that this decision needs to be taken according to specific institutional and demographic needs.³⁻⁵

Another field for discussion is staffing design, especially the ECMO specialist. At AUBMC, a model where the ICU nurse would be the ECMO specialist was selected because of the limited number of perfusionists and the need to perform cardiac surgery on daily basis. This lack of qualified human resources like perfusionists

and experienced ECMO physicians is another limitation in middle- and low-income countries. Different designs were reported in the literature, where the ECMO specialist could be a trained ICU nurse, respiratory therapist, or perfusionist,^{2,3,5} approved by the ECMO program director. The ECMO specialist provides care to the patient and is responsible for monitoring and troubleshooting the ECMO circuit. A recent cross-sectional survey conducted in 2017 by Daly et al., including 177 ECMO centers worldwide, showed that ECMO specialists are nurses in 59% of the centers, perfusionists in 30%, and inhalation therapists in 23%. They also showed that in the configuration where the nurse is the ECMO specialist, perfusionists were only responsible for the technical aspects of circuit management.⁶ With continuous training and increased experience, the model where the nurse is the ECMO specialist, worked well at AUBMC. The 2-to-1 nurse to patient ratio not only allowed for nurses to be thorough in patients care, circuit check, and documentation but also to benefit from each other's experience; most experienced nurses were always scheduled to work with the most novice, as an additional training strategy.

As in every new ECMO center, it was necessary to define selection criteria with considerations to ELSO guidelines, CESAR and EOLIA trials, and other international experiences.^{2,4,5,7,8} Initially, because of the small number of trained ECMO staff and the highly demanding service required, "in" and "out-of-hospital cardiac arrests" were not considered as ECMO indications and sepsis was listed as a contraindication. After 12 months of practice and a few successful outcomes in children, AUBMC ECMO program started considering ECMO support for patients with sepsis and with "in-hospital cardiac arrest." We are not sure today that the program was ready for these indications at that time, because the two patients managed with ECPR were resuscitated for more than 60 minutes before ECMO, and both did not survive. However, with the availability of the technique, and the witnessed unexpected cardiac arrest in the catheterization laboratory, it was extremely difficult for this young ECMO program to refuse support for these two patients. Without these two mortalities, the early experience would have had an overall survival rate of 40%, instead of 33%.

In addition, in both cardiac surgical patients in whom support was turned off in ICU on day 2, ECMO was a debatable indication; one patient was 80 years old, with a malignancy, supported just to prepare the family for the bad news. The second patient had a questionable neurologic status, following multiple cardiac arrests. Both decisions to go on ECMO were taken by the cardiac surgeons alone. Had we avoided only one of these two cases following a thorough multidisciplinary discussion, in addition to both ECPR patients, the overall survival would have increased to 55%, and the survival

of adults to 33%. Other young ECMO programs will undoubtedly face such dilemmas when ECMO becomes available and should benefit from this experience.

Following these four successive mortalities, AUBMC ECMO program decided to adopt the model described by Moll et al.⁵ The authors attribute the success of program to a formal consultative service to evaluate ECMO candidates, in order to ensure safe use of ECMO and avoid abuse in indications.⁵ Hence, the three "yes" procedure described above in results was adopted. Relative contraindications included an age above 70 years, preexisting renal failure, multiple organ failure, or preexisting significant heart failure if transplantation or LVAD was not indicated.

Our small series included only 1 VV, and 11 VA ECMO, which exposed the program very early, to the most difficult ECMO runs and their complications. The ECMO circuit was changed in four patients, all from the pediatric and neonatal age groups, because of the appearance, and progression of clots in the tubing and/or oxygenator: One patient developed clots in the circuit following an error in anticoagulation management. As consequence, anti-Xa was introduced for multimodal coagulation monitoring, in addition to the use of activated partial thromboplastin time (aPTT) and activated clotting time (ACT). In two other patients, the clots appeared following cessation of anticoagulation for a few hours, because the patients needed major surgical interventions on ECMO: diaphragmatic hernia repair and thoracotomy for left ventricular vent insertion.

A Backflow cannula to the lower limb was systematically inserted in all patients with femoral artery cannulation as part of the policy established, and no limb ischemia was noted. Continuous NIRS reading on the limb allowed for the detection of a malpositioned backflow cannula in one patient; limb hypoperfusion was corrected following the cannula's readjustment, avoiding further injury and ischemia. This clearly shows that the use of the optimal monitoring tools is important to anticipate and prevent catastrophic events by early recognition, thus minimizing the impact of life-threatening complications.

During the development of this program, and in agreement with the logic model shown in Figure 1, regular benchmarking with other centers and with ELSO data was performed, along with data reporting to the ELSO registry.¹ In addition, all cases were routinely and critically reviewed after each ECMO run, a practice that proved to be attended with enthusiasm. The other recommendations, including meetings and collaboration, were followed through the organization of the first Lebanese ECMO meeting in Beirut, chaired by the ECMO pioneer Robert Bartlett. This meeting facilitated the sharing of clinical data and helped increase awareness among local invited healthcare professionals, to encourage timely patient referral for ECMO.

Finally, in developing countries, the cost of this therapy is of utmost importance and carries significant consequences. Several reports have shown that ECMO is favorable when considering cost/life-year calculation and is justified on cost-utility basis.^{9–12} The ELSO registry stated that the cost effectiveness of ECMO support for fewer than six patients per year should be taken into consideration. In AUBMC, 12 patients were supported with ECMO within a period of 26 months.

Limitations

This study is limited by its retrospective aspect and the small number of patients. However, this small series reports the initiation phase of an ECMO program and is a good start in a small, low-to middle-income country.

Conclusion

In developing countries where human and financial resources are limited, establishing an ECMO program is challenging. However, if the program is structured and caters for institutional and local needs, outcomes can become progressively comparable to those in developed countries.

The following guidelines, recommended by ELSO, play a key role in the success of a young program: the presence of at least one ECMO physician, the designation and training of specific ECMO specialists, patients' selection early in the program, and continuous training in low-volume areas.

Most critical care units worldwide have witnessed patients surviving against all odds, thanks to ECMO support. In addition, patients who survive an episode of acute respiratory insufficiency should not be permanent respiratory cripples. Infants and children recover normal lung function quickly. Even in the most severe instances of acute respiratory insufficiency in adults who have survived, lung function has improved slowly over many months and permanent disability is quite rare. Thus, ECMO is here to stay, and centers in middle- and low-income countries might as well benefit from each other's experience while building ECMO programs.

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References

1. ELSO: ELSO Registry, international Summary, <https://www.else.org/Registry/Statistics/InternationalSummary.aspx> (January 2018, accessed June 2018).
2. ELSO: Guidelines for ECMO Centers, Version 1.8 (2014), and ELSO Guidelines for the training and continuing education of ECMO Specialists, Version 1.5 (2012), <https://www.else.org/portals/0/igd/archive/filemanager/97000963d6cusersshyerdocumentselsoguidelinesfortrainingandcontinuingeducationofecmospecialists.pdf> (accessed June 2018).
3. Guerguerian AM, Ogino M, Dalton H, et al. Setup and maintenance of extracorporeal life support programs. *Pediatr Crit Care Med* 2013; 14(5 Suppl 1): S84–S93.
4. Ogino MT, Chuo J and Short BL. ECMO administrative and training issues, and sustaining quality. In: Annich GM, Lynch W, MacLaren G, et al (eds) *ECMO: extracorporeal cardiopulmonary support in critical care*. 4th ed. Ann Arbor, MI: Extracorporeal Life Support Organization, 2012, pp. 479–497.
5. Mullany DV, Bull TN, Hunt W, et al. Outcomes of the first 30 cases of an adult extracorporeal membrane oxygenation program: strategies to manage the “learning curve” and implications for intensive care unit risk adjustment models. *Crit Care Resusc* 2012; 14: 119–129.
6. Daly KJ, Camporota L and Barrett NA. An international survey: the role of specialist nurses in adult respiratory extracorporeal membrane oxygenation. *Nurs Crit Care* 2017; 22: 305–311.
7. Moll V, Teo EY, Grenda D, et al. Rapid development and implementation of an ECMO program. *ASAIO J* 2016; 62: 354–358.
8. Swol J, Belohlavek J, Haft JW, et al. Conditions and procedures for in-hospital extracorporeal life support in cardiopulmonary resuscitation of adult patients. *Perfusion* 2016; 31: 182–188.
9. Peek GJ, Mugford M, Tiruvoipati R, et al. CESAR trial collaboration: efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. *Lancet* 2009; 374: 1351–1363.
10. Park M, Vitale Mendes P, Zampieri F, et al. The economic effect of extracorporeal membrane oxygenation to support adults with severe respiratory failure in Brazil: a hypothetical analysis. *Rev Bras Ter Intensiva* 2014; 26: 253–262.
11. Mahle W, Forbess J and Kirshbom et al. Cost-utility analysis of salvage cardiac extracorporeal membrane oxygenation in children. *J Thorac Cardiovasc Surg* 2005; 129: 1084–1090.
12. Vats A, Pettignano R, Culler S, et al. Cost of extracorporeal life support in pediatric patients with acute respiratory failure. *Crit Care Med* 1998; 26: 1587–1592.