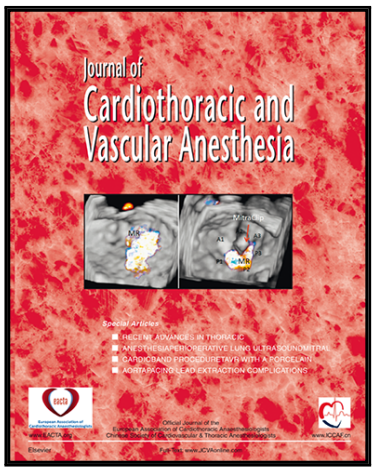

Transport and Retrieval on ECMO: Setup and Activities of an Immersive Transport and Retrieval on ECMO Workshop

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Special Article

Transport and Retrieval on ECMO: Setup and Activities of an Immersive Transport and Retrieval on ECMO Workshop

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Abstract

Extracorporeal Life Support (ECLS) and Extracorporeal Membrane Oxygenation (ECMO) are widely used for acute severe refractory cardiac and/or respiratory failure. An increasing number of patients are treated with ECMO worldwide. This can be attributed to technical and technological advancements, eased access to modern equipment, more regular and accessible training opportunities for practitioners to maintain current skills and develop new ones.

Typically, ECMO is provided at tertiary or regional centers which are often university affiliated. In a significant number of patients, ECMO may be initiated at a peripheral hospital before they are transported to a tertiary facility by a specialized multiprofessional ECMO team. The transport phase is however fraught with challenges and untoward events are not uncommon during ECMO transportation, so a robust education and training program is critical to ensure patient safety and optimum outcome. This article describes our experience of developing and running a simulation-based ECMO Transport and Retrieval workshop with multiple immersive scenarios and opportunities for participants to familiarize themselves with the process and the ambulance equipment and environment. Preparation is a key element to successfully run scenarios that are technically challenging to facilitate due to the environment and equipment involved. To date, 136 multidisciplinary ECMO providers have attended the workshop and no incidents have been reported by our teams during actual transfers and retrieval missions with patients on ECMO.

Keywords:

Transport, Retrieval, ECMO, Simulation, High-Fidelity, Workshop, Immersive

Introduction

The Extracorporeal Life Support Organization (ELSO) registry reported a total of 12,850 Extracorporeal Life Support (ECLS) runs in 2019.[1] ECLS and Extracorporeal Membrane Oxygenation (ECMO) are synonymous and refer to the extracorporeal circulation of blood with a mechanical device so it can be re-oxygenated before being returned to the patient, and hence is used for severe heart and lung failure.[2] The number of ECMO runs, number of centers as well as scientific publications related to ECMO have gone up steadily over the last few decades.[3, 4] Clinicians are increasingly becoming aware of the capability of ECMO to buy time for critically ill patients as a bridge to transplantation or if their heart or lungs are allowed to rest while they recover. To that effect there has been a growing number of instances when ECMO teams have mobilized to put patients on ECMO in facilities that do not have such capability.

The literature refers to primary ECMO transport as mobilizing a clinical team to attend to a patient at a referring facility for assessment, optimization, followed by implantation of the ECMO lines, and transportation of the patient on ECMO to the receiving facility.[5] In secondary transportation on ECMO, the patient is already on ECMO and transport is undertaken for specialized clinical and logistical reasons (such as accommodating a family request or a capacity issue).[6]

Transport of critically ill patients on multi-organ support could be hazardous and impact negatively on patient outcomes.[7] Untoward events are common during ECMO transportation and have been reported in up to 28% of transport missions.[8] In this particular report from Sweden, the majority of the events were patient-related (62%), whilst equipment, transport platform, and human error accounted respectively for 19%, 13%, and 5% of incidents. The literature emphasizes the holistic approach to patient transportation

on ECMO.[8, 9] Appreciative of this risk, professional and societal bodies have developed guidelines for transportation of the critically ill patient.[10, 11]

In preparedness for the MERS-Corona outbreak, and as part of the government entity that provides secondary and tertiary healthcare, XXX established a severe respiratory failure (SRF)-ECMO center within its Medical Intensive Care Unit (MICU) at XXXXX Hospital in 2014 with mobile ECMO capability to cater for the whole state XXX.[12] Simulation played a key role in the establishment of the SRF_ECMO center from the onset and in all aspects. Over 160 transport and retrieval on ECMO missions have been undertaken since November 2014. Integral to safe service provision is education and training of staff members joining the team in addition to ensuring continuing medical education for the established multiprofessional team.[13-15] To accomplish this task, the SRF-ECMO service at XXX developed a comprehensive simulation-based ECMO Transport and Retrieval workshop comprising of several theoretical and immersive, high-fidelity, ECMO transport and retrieval scenarios.

The Transport and Retrieval on ECMO Workshop

Candidate selection

The workshop is designed for an inter-disciplinary ECMO transport and retrieval team (TRT) and accommodates a maximum of 20 participants representing all professions normally involved in such missions (critical care physician, nurse, perfusionist, respiratory therapist (RT), and critical care paramedic (CCP). The participants are selected based on their professional track record in the Intensive Care Unit, during conventional transport missions, and on their line manager's recommendation. A consent for participation, photo and video shooting is obtained from the selected participants. Taking part in the workshop does not guarantee participants that they will join the XXX ECMO TRT. On occasion, the workshop is

attended by ECMO providers from other institutions within XXXX and from overseas to support other centers develop their ECMO transfer and retrieval capabilities. The current number of participants by profession over the eight times the workshop has been facilitated is presented in Table 1.

Table 1:

The faculty

The workshop is delivered by an experienced multiprofessional team comprising an ECMO physician, a TRT physician, an ECMO nurse, a perfusionist, a critical care paramedic (CCP), a simulation educator, and a simulation operations specialist (SOS). Each one plays an important part in several aspects of the workshop from setting up and operating the equipment and patient simulator, the transmission of a live video feed of the scenario into the classroom, to debriefing the participants. Most of the faculty involved and participants recruited will have previously completed the high acuity patient retrieval training program run in collaboration with the National Ambulance Service to familiarize hospital clinicians with the ambulance setting and equipment.[16]

The workshop

Our educational package is an ELSO endorsed and XXXX Council for Health Professionals (XXXX CHP) accredited 8-hour Continuing Professional Development (CPD) activity. The workshop is composed of two components which are didactic and practical in nature (Table 2) but also includes some pre-workshop reading material which is circulated to participants a month in advance. The learning objectives of the didactic component are listed in Table 3.

The breadth of these topics offers candidates with the essential background knowledge related to the transport of sick patients and emphasizes the principles of a multiprofessional approach to safe patient care, use of checklists, and the concept of crisis resource management (CRM).[17, 18] For the practical component of the workshop, the candidates are split into 4 multiprofessional teams of 5members. Each team is assigned one clinical scenario, and remotely observes all the other scenarios. It is established that, for effective simulation-based learning, participants should be acquainted with the simulation environment and equipment used, be informed of the limitations of such experiential learning opportunity, and be reassured about the aspects of confidentiality.[19] To that effect, the participants are offered a hands-on introduction to the simulation environment and equipment in use, including the patient simulator and the intensive care ambulance. Aspects of that orientation are conducted in parallel and in small groups with an emphasis on the specialized transport equipment, the inside of the ambulance, and the safety measures to adhere to during transport (e.g. everyone to remain seated and with their seatbelt on while the vehicle is moving).

Table 2:

Table 3:

The scenarios

Different scenarios have been developed to reflect common ECMO emergencies. A summary of these scenarios, covering both veno-venous (VV) and veno-arterial (VA) ECMO is provided in Table 4 along with their respective learning objectives. Each scenario is

allocated one hour in the program but the majority of the time (40 minutes) is actually spent in the facilitation of the debriefing of the participants. Most scenarios involve at some point an embedded participant in the form of a faculty acting as a confederate within the transport team or as a member of the referring hospital team. That person contributes to making some of the human factor issues emerge so the corresponding learning objective can be addressed.[20, 21] Each scenario is only undertaken once by one of the teams, while the other workshop participants remotely watch the scenarios from the classroom on a large screen (Figure 1). Live streaming is set up so they can see the patient monitor as well as the ECMO display screen at all times; when the patient is being moved on the stretcher within the facility as well as inside the ambulance. During the scenarios, participants are expected to play their own professional role, but depending on the number of candidates from each profession some participants sometimes take part in two scenarios. On occasion, a physician or nurse is required to take part in an additional scenario in the capacity of a perfusionist as they represent a small professional group in most institutions and hence are underrepresented in most courses due to their clinical duties.

Figure 1:

The simulation environment

All scenarios take place in a combination of real or simulated settings such as in the ward immediately before transport is initiated, while the patient is being moved on a stretcher through the hospital corridor or inside the ambulance. A real intensive care ambulance with its custom-designed ECMO stretcher is always utilized for this workshop (Figures 2 and 3), whereas the realism of the other settings is less important and might be either in a

simulated patient room within a simulation center or a room in a conference venue with only the essential pieces of medical equipment so it represents the corresponding clinical environment.

A Laerdal SimMan® 3G patient simulator is used in this workshop, but any other model preferably with interactive physiological monitoring capability could be used. It is prepared with the typical femoro-femoral ECMO configuration used at XXX and cannulas are attached to the patient simulator with a functional ECMO circuit. Due to infection risks, the use of human or animal blood is not permitted, so instead a red coloring agent is added to distilled water but it does not allow for color differentiation of the oxygenated and deoxygenated blood. Although we have developed a prototype solution to realistically simulate blood oxygenation [22] we do not use it during this workshop as it is not currently portable. Mechanical ventilation, hemodynamic monitoring, infusion pumps, vascular access devices, a nasogastric tube and a Foley catheter are attached and secured onto the patient simulator as would be the case on a real patient (Figure 4).

The aim is to offer a realistic learning experience so that pertinent technical and non-technical skills of transport and retrieval can be addressed. This workshop does not include the ECMO cannulation procedure as it is an aspect addressed in another workshop using a different patient simulator.[23]

Figure 2:

Figure 3:

Figure 4:

Educational Foundations

Immersive learning experience

The simulation component of the workshop is very immersive in nature as is the scenarios are run like real-life cases in a mobile ambulance at variable speed, driving through regular traffic on various roads. At the start of each scenario, participants are provided with the information they would receive with a standard transport and retrieval call for service and are asked if they need any further information before they arrive at the patient side. A scenario typically lasts a maximum of 20 minutes including briefing. To maximize the learning opportunity for all participants, real-time live streaming of the complete scenario is established and broadcast in a classroom. Taking advantage of modern technology including 4G network and different mobile apps, the technical team is able to establish a stable connection with clear images and voice from the rear of the moving ambulance to the training venue observation room. This allows the observers to subsequently contribute to the debriefing.[24] To maximize realism, the occurrence of the potential emergency varies and might be before, during, or after the ambulance transport phase. This is done in order to avoid having participants anticipating when something might happen.

A clinical faculty member sits next to the ambulance driver and manipulates the patient simulator physiological parameters, and depending on the scenario may inject air into the ECMO circuit, alter circuit pressures, or perform other interventions according to the emergency that needs to be created during the scenario. If such type of intervention needs to be performed at an earlier or later stage in the scenario, the action required will be done discretely by a confederate.

The debriefing

A structured debriefing immediately follows each scenario and lasts approximately 40 minutes. It is facilitated by a simulation educator and an experienced clinical faculty with more than 3 years of ECMO and transport experience. Our most commonly adopted approach follows the RUST model of debriefing. [25] Its components are four distinctive debriefing phases which cover the participants' *Reaction*, *Understanding* their mental frames, decisions, and actions, getting them to *Summarize* what happened and what could have been other outcomes depending on their actions, and finally asking each of them to verbalize a *Take home message* from the scenario. [26] It is conducted using an inquisitive approach with good judgement encouraging participants to actively contribute their thoughts and perceptions about what happened, primarily focusing on the actual scenario participants, and later also seeking input from the observers. It is facilitated in a way that helps address performance gaps but also makes everyone realize the commendable aspects of their performance. [27]

The points explored during the debriefing mainly relate to the key issues and learning objectives listed in Table 4. It contributes to emphasizing aspects presented during the didactic component of the workshop, for example in relation to ergonomics and CRM, both of which linked to human factors.

Table 4:

Participants and workshop evaluation

The XXX- CHP categorization of this CPD activity is such that it includes two forms of evaluation. The workshop does not incorporate a pre/post-intervention assessment component to measure the knowledge acquisition of participants, however there is an element of ongoing formative assessment made by the faculty. It is done throughout the

course of the workshop as participants are observed taking part in their own scenario and based on their contribution during the overall workshop. At the end of the day, the workshop facilitators meet to discuss each participant's performance and to recommend them or not to join the ECMO-TRT. In addition, all workshop participants are required to complete an evaluation form to appraise the quality of the educational activities (didactic and practical components), the facilitators, and the training venue in order to receive the workshop certificate of attendance.

Discussion

To date the Transport and Retrieval on ECMO workshop, covering both VV and VA ECMO has been delivered 8 times for a total of 136 ECMO multidisciplinary providers. Due to clinical commitments, some participants have sometimes sent last minute apologies, hence the workshop was conducted with 17 participants per day on average. From a patient care point of view, the value of the workshop has been demonstrated at our facility thanks to over 160 transport and retrieval ECMO missions without adverse events. In addition, the post-event feedback from participants confirmed increased confidence, improved knowledge, and better preparedness to transport patients on ECMO.

The mixed composition of the faculty team enabled this to not affect the quality of the learning experience for the participants. Although primarily developed for XXX staff, the workshop has attracted participants from other countries and has also been delivered at international conferences. The feedback from participants revealed that, as for most simulation-based workshops, it is found to be highly valuable and informative. The participants' take-home messages from taking part or observing scenarios generally relate to human factor aspects and the importance of decision making and communication.

By the very nature of mobilizing the equipment, patient simulator, and audio-video recording equipment, technical failures are prone to occur so the faculty team members need to be well experienced and readily identify and troubleshoot potential issues before they can impact on the participants' learning experience. Issues we could sometimes face during a scenario are poor internet connectivity for the audio and video streaming, loss of control of the patient simulator's physiological parameters, and inability to alter the ECMO circuitry pressures as required for the scenario. Meticulous preparation, attention to detail and testing of the scenarios in-situ (i.e. where the scenario will be conducted) the day before the workshop have been key in identifying problems, finding solutions, ensuring all required resources are available, and preventing issues on the day of the actual workshop. This has been especially critical with regards to the video streaming aspect of the workshop while the ambulance is being driven during some scenarios. The video recording quality had to be optimized from a bandwidth point of view while adopting a stable online streaming platform that is accessible from the training venue. The security measures on the hospital network pose a challenge that pushed us to explore several solutions and always having a backup plan in place. Exploring this aspect in details is not the objective of the present article.

Conclusion

Joint training is a critical element for a multiprofessional team to function optimally, especially when a crisis situation arises. This immersive scenario-based workshop has been developed to ensure that patients who are already very vulnerable due to their precarious health condition can benefit from the best possible care during inter-facility transportation.

It requires a lot of preparation and is more demanding to organize and run than a static or simulation center-based workshop It is recommended that the key simulation team members be well rehearsed and experienced in facilitating this workshop and troubleshooting potential issues without delay. All phases of the workshop are equally important as they complement one another to provide participants with an enriching and valuable learning experience. For the participants, the key learning points generally relate to human factor aspects and the importance of decision making and communication. This demonstrates that scenario design and the immersive nature of the simulation component of the workshop are critical points. They will directly affect what will be discussed during the debriefing and help identify behaviors, decisions, or actions that need to be remedied or commended.

References:

1. ELSO. ECLS Registry Report International Summary; January 2020. Extracorporeal Life Support Organization, Ann Arbor, MI 2020.
2. Bartlett R. ECLS: Past, present, and future. *Qatar Medical Journal*. 2017; 4th Annual ELSO-SWAC Conference Proceedings 2017, 1:8 https://doi.org/10.5339/qmj.2017.swacelso.8.
3. Makdisi G and Wang I-w. Extra Corporeal Membrane Oxygenation (ECMO) review of a lifesaving technology. *Journal of thoracic disease*. 2015; 7: E166.
4. Mao J, Paul S and Sedrakyan A. The evolving use of ECMO: The impact of the CESAR trial. *International Journal of Surgery*. 2016; 35: 95-9.
5. Puślecki M, Ligowski M, Dąbrowski M, et al. Development of regional extracorporeal life support system: The importance of innovative simulation training. *The American journal of emergency medicine*. 2019; 37: 19-26.
6. Burgueño P, González C, Sarralde A and Gordo F. Issues to resolve with the use of extracorporeal membrane oxygenation during interfacility transportation. *Medicina Intensiva (English Edition)*. 2019; 43: 90-102.
7. Blakeman TC and Branson RD. Inter-and intra-hospital transport of the critically ill. *Respiratory care*. 2013; 58: 1008-23.

8. Fletcher-Sandersjöö A, Frenckner B and Broman M. A single-center experience of 900 interhospital transports on extracorporeal membrane oxygenation. *The Annals of thoracic surgery*. 2019; 107: 119-27.
9. Broman LM, Holzgraefe B, Palmér K and Frenckner B. The Stockholm experience: interhospital transports on extracorporeal membrane oxygenation. *Critical Care*. 2015; 19: 278.
10. Warren J, Fromm RE, Orr RA, Rotello LC and Horst HM. Guidelines for the inter-and intrahospital transport of critically ill patients. *Critical care medicine*. 2004; 32: 256-62.
11. Dirnberger D, Fiser R and Harvey C. Extracorporeal Life Support Organization (ELSO) guidelines for ECMO transport. 2015.
12. Hassan IMF and Al Shaikh L. Building Qatar severe respiratory failure ECMO program. *Qatar Medical Journal*. 2017; SWACELSO: 2.
13. Labib A. Road transport on ECMO: The key elements. *Qatar Medical Journal*. 2017; 4th Annual ELSO-SWAC Conference Proceedings 2017, 1:50: https://doi.org/10.5339/qmj.2017.swacelso.50.
14. Ibrahim AS. How to maintain a quality ECMO program? *Qatar Medical Journal*. 2017; SWACELSO: 12.
15. Alinier G, Hamed A and Racela B. ECMO transport simulation. *Qatar Medical Journal*. 2017; SWACELSO: 60.
16. Alinier G, Al Shaikh L, Campbell C, Fawzy I and Meyer J. Board #200 - Program Innovation Development of a Multi-disciplinary Simulation-based Training Course for the Safe High Acuity Adult Retrieval Programme (SHAARP) (Submission #9978). *Simulation in Healthcare*. 2014; 9: 439.
17. Logarajah S and Alinier G. An integrated ABCDE approach to managing medical emergencies using CRM principles. *Journal of Paramedic Practice*. 2014; 6: 620-5.
18. Fung L, Boet S, Bould MD, et al. Impact of crisis resource management simulation-based training for interprofessional and interdisciplinary teams: a systematic review. *Journal of interprofessional care*. 2015; 29: 433-44.
19. Der Sahakian G, Alinier G, Savoldelli G, Oriot D, Jaffrelot M and Lecomte F. Setting Conditions for Productive Debriefing. *Simulation & Gaming*. 2015; 46: 197-208.
20. Dieckmann P, Lippert A, Glavin R and Rall M. When things do not go as expected: scenario life savers. *Simulation in Healthcare*. 2010; 5: 219-25.
21. Alinier G. Developing High-Fidelity Health Care Simulation Scenarios: A Guide for Educators and Professionals. *Simulation & Gaming*. 2011; 42: 9-26.
22. Al Disi M, Alsalemi A, Alhomsi Y, Bensaali F, Amira A and Alinier G. Using thermochromism to simulate blood oxygenation in extracorporeal membrane oxygenation. *Perfusion*. 2019; 34: 106-15.
23. Al Disi M, Alsalemi A, Alhomsi Y, Bensaali F, Amira A and Alinier G. Extracorporeal membrane oxygenation simulation-based training: methods, drawbacks and a novel solution. *Perfusion*. 2019; 34: 183-94.
24. O'Regan S, Molloy E, Watterson L and Nestel D. Observer roles that optimise learning in healthcare simulation education: A systematic review. *Advances in Simulation*. 2016; 1: 4.
25. Karlsen R. Stable Program. Adaptation of the RUS model. Original work from the Center for Medical Simulation (D.R.), Cambridge, MA, USA. 2013.
26. Oriot D and Alinier G. *Pocket Book for Simulation Debriefing in Healthcare*. Springer, 2018.

27. Rudolph J, Raemer D, Arnold J, Allan C, Remke D and Reid J. Debriefing as a Tool for Closing Performance Gaps. *International Pediatric Simulation Symposia and Workshop (IPSSW)*. 1-3 June 2017, Boston, MA, USA2017.

Acronyms

CCP: Critical Care Paramedic

CPD: Continuing Professional Development

CRM : Crisis Resource Management

ECLS: Extracorporeal Life Support

ECMO: Extracorporeal Membrane Oxygenation

ELSO: Extracorporeal Life Support Organization

XXX: XXX

XXXX CHP: XXXX Council for Health Professionals

RUST: Reaction, Understanding, Summarize, Take home message

RT: Respiratory Therapist

SOS: Simulation Operations Specialist

TRT: Transfer and Retrieval Team

VA: veno-arterial

VV: veno-venous

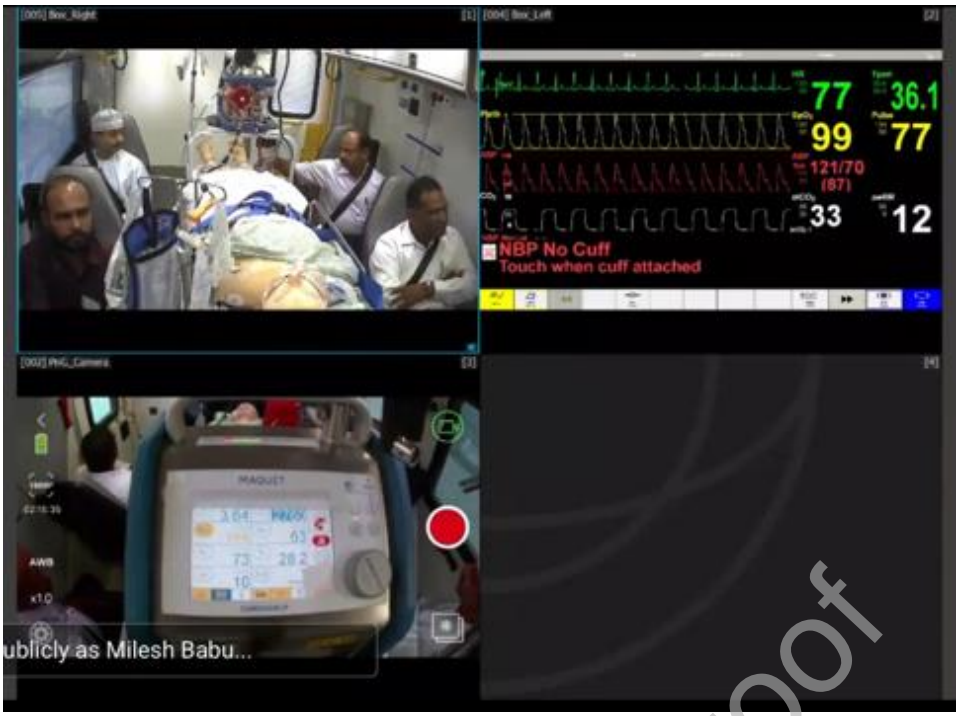

Figure 1: Live streaming display of a scenario in the classroom for the workshop participants

Figure 2: Custom-designed ECMO stretcher used at HMC with patient simulator on ECMO

Figure 3: Intensive care ambulance used at HMC for ECMO patients transfers and retrievals and during the workshops

Figure 4: Mechanically ventilated and fully monitored patient simulator on ECMO inside the intensive care ambulance during a scenario

Table 1: Number of workshop participants by professional group over the last 8 workshops

Profession	Number	Institutional affiliation
Nurses	34	Local and international
Physicians	47	Local and international
Respiratory Therapists	20	Local and international
Critical Care Paramedics	18	Local
Perfusionists	17	Local and international
Total	**136**	

Local: Participant based in XXXX – International: Participant based overseas

Table 2: Transport and Retrieval on ECMO Workshop timetable

Time	Workshop Program
08:00-08:30	Registration
08:30-08:50	Road Transportation on ECMO: What Do You Have to Have? *Senior CCP, Ambulance Service*
08:50-09:10	Human Factors in ECMO Transportation: What are the Essential Requirements? *ECMO consultant, MICU/Consultant Ambulance Service*
09:10-09:30	ECMO Patient Transportation: Current Recommendations and Practice. *ECMO consultant, MICU*
09:30-10:00	Panel Qs & As
10:00-10:15	Coffee Break
10:15-10:30	Introduction to Simulation and Equipment *Simulation educator*
10:30-11:00	Demonstration of Scenario and Debriefing *TRT Course Faculty*
11:00-11:50	First Scenario and Debriefing
11:50-12:50	Lunch
12:50-13:40	Second Scenario and Debriefing
13:40-14:30	Third Scenario and Debriefing
14:30-15:20	Fourth Scenario and Debriefing
15:20-16:00	Group Discussion: Lessons Learnt and Closure *Course Director, MICU*

Table 3: Learning objectives of the didactic components of the workshop

Road Transportation on ECMO: What Do You Have to Have? • To review the clinical and logistical requirements for ECMO retrieval. • To describe the planning and preparations required before retrieval of an ECMO patient. • To illustrate the logistical requirements for a road based ECMO retrieval. • To provide an overview of the risk management processes required for ECMO retrieval.
Human Factors in ECMO Transportation: What are the Essential Requirements • Describe the non-technical (non-clinical) skills required for the successful conduct of effective clinical practice. • Able to list practical tools and strategies to compensate for the limitations of cognitive human performance. • Gain knowledge about the practical applications of non-technical (non-clinical) skills to maximize team performance.
ECMO Patient Transportation: Current Recommendations and Practice • Describe the risks associated with road transportation of adult patients on ECMO and how to mitigate them. • Review the multidisciplinary management of road transportation of patients on ECMO. • To illustrate the role of checklists and human factors. • Demonstrate current recommendations and guidelines. • Discuss how to develop a transportation service for ECMO.

Table 4: Key issues and learning objectives of the scenarios

Demonstration Scenario key issues:	Clinical/Medical: Hypovolemia on ECMO	Human Factors: Managing a panicking colleague.
Demonstration scenario Intended Learning Objectives and Debriefing Points:	Clinical/Medical: • Recognizing the effect of hypovolemia on ECMO patient (access insufficiency causing line shattering, low pressures). • Demonstrate how to perform a full circuit check. • Demonstrate how to manage haemorrhage control through volume expansion on a VV ECMO patient.	Human Factors: • Assertiveness on the part of the ECMO consultant to guide the team. • Teamwork in managing the time-critical situation. • Performing SBAR handover over the phone with the surgeon.
Scenario 1 key issues:	Clinical/Medical: Air in the ECMO circuit due.	Human Factors: Time critical procedure of de-airing process once initiated.
Scenario 1 Intended Learning Objectives and Debriefing Points:	Clinical/Medical: • To recognize air in the ECMO circuit. • To identify and resolve the source of air entry by performing a systematic review of circuit and patient. • To perform ECMO circuit de-airing. • To manage the patient off circuit during de-airing.	Human Factors: • Leadership and communication skills during ECMO patient de-airing process (distributing workload, explaining process, ensuring presence of CPR backup).
Scenario2 key issues:	Clinical/Medical: • Power failure on VV ECMO (flat battery) • Use of hand crank. • Potential cardiac arrest.	Human Factors: • Managing a crisis situation in a coordinated manner with the rest of the team to re-establish blood circulation. • Leadership skills for rapid team activation and briefing as to what is happening and needs to be done. • Methodical troubleshooting of ECMO circuit to resolve issue (Flat battery) • - Practice infection control measures with H1N1 patient.

Scenario 2 Intended Learning Objectives and Debriefing Points:	Clinical/Medical: Recognizing pump failure due to power failure. • Disconnecting and moving the oxygenator from the rotor system to the hand crank to allow for pump replacement or troubleshooting and maintain appropriate blood flow using the hand crank over a period of time. • Putting patient on full ventilator support during pump failure. • Placing the oxygenator back onto the pump once it is again operational. • (Possible) Managing cardiac arrest on ECMO patient.	Human Factors • Quick action and decision making to overcome sudden stop of blood flow through the oxygenator. • Coordination between staff performing hand crank to maintain appropriate and constant flow. • (Possible) Team coordination in managing ECMO patient cardiac arrest. • Demonstrate methodical approach to troubleshooting of ECMO circuit to resolve issue. • Demonstrate use of PPE for infection control measures with H1N1 patient.
Scenario 3 key issues:	Clinical/Medical: Persistent hypoxemia on VV ECMO. Patient under-sedated.	Human Factors: Panicked nurse.
Scenario 3 Intended Learning Objectives and Debriefing Points:	Clinical/Medical: • Systematic approach to assessing ECMO patient and checking the circuit. • Recognizing the increased oxygen consumption due to increased cardiac output related to several factors (Fever, tachycardia, patient not well sedated, shivering). • Demonstrate how to recalibrate the SvO_2 sensor.	Human Factors: - Managing panicked colleague. - Communication skills. - Leadership and teamwork in a multidisciplinary team.
Scenario 4 key issues:	Clinical/Medical: • Ventricular fibrillation cardiac arrest on VA ECMO. • AMI causing cardiogenic shock and VF arrest during transportation	Human Factors: • Communication skills. • Leadership and teamwork in a multidisciplinary team.
Scenario 4 Intended Learning Objectives and Debriefing Points:	Clinical/Medical: • Prompt recognition of cardiac arrest and need for DC shock	Human Factors: • Assignment of roles during crisis • Communication • Assertiveness and decision making

	• Delivery of DC shock • Safety of DC shock delivery on ECMO/CPR on ECMO/ CPR in moving vehicle • Other management strategies, Amiodarone, Magnesium	• Resource and team management