Chapter 2

Simulation Training on Extracorporeal Membrane Oxygenation

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Additional information is available at the end of the chapter

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Abstract

Conventional extracorporeal membrane oxygenation (ECMO) training usually only consists of didactic lectures and water drill of ECMO circuit. However, learners cannot “experience” changes of clinical condition of patients. Simulation-based learning is a perfect answer to this by providing participantsauthentic, interactive, team-based training without risk to real patients. Hospital Authority (HA) of Hong Kong has implemented a corporatewide ECMO simulation-based training program since 2014. It aims to provide a structural and standardized training opportunity for clinical staff members to gain hands-on experience in ECMO circuit management and troubleshooting technique. In the program, participants will go through three categories of scenarios: (1) replicate common real patient clinical experience; (2) replicate incident that only happens infrequently; and (3) imitate clinical situation that is rarely happened but life threatening, and where prompt and correct actions are necessary. Every scenario has its own debriefing session that covers technical and human factor issues.Since 2014, 32 identical full-day courses were conducted and 285 doctors and nurses were trained. All participants were satisfied with the training and expressed that the simulation was an effective model for ECMO training. The training met their need and they could apply what they learned in real-life practice.

Keywords: crisis management, debriefing, extracorporeal membrane oxygenation, non-technical skill, simulation

1. Introduction

In this chapter, we will use extracorporeal membrane oxygenation (ECMO) simulation training organized by Hong Kong Hospital Authority (HA) as an example to illustrate how to develop and set up an ECMO simulation training. We will discuss overview of an ECMO training program in Hong Kong, goal and advantages of starting the ECMO simulation training, budgetary considerations, modification of old manikin and design of new manikin to facilitate ECMO training, set-up of high-fidelity-simulated environment, explanation on scenario design and flow, and what to debrief after every scenario.

2. Overview of the Hong Kong ECMO training program

Hong Kong experienced two large-scale infectious disease outbreaks, i.e., 2003 SARS outbreak and 2009 Swine H1N1 influenza outbreak. In 2003, SARS patients with severe respiratory failure were only supported by conventional mechanical ventilation [1]. In 2009, patients suffered from Swine H1N1 influenza were managed with ECMO when they were unlikely to survive by conventional mechanical ventilation [2, 3]. The use of ECMO in adult patients remained controversial until publication of the CESAR trial in 2009, which showed promising results with ECMO in terms of survival for patients with severe respiratory failure and ARDS after H1N1 pandemic [4].

HA is a statutory body established under the Hospital Authority Ordinance of Hong Kong in 1990. It is responsible to manage all Hong Kong's public hospitals services. Under the governance of HA, there are five ECMO centres in five different public hospitals. ECMO may be offered to the selected patients that have potentially reversible causes of cardiac and/or respiratory failure when the predicted mortality is high. As ECMO is a newly introduced, but complicated and high-risk procedure, it was suggested by head management that clinical staff of the ECMO centres should receive structural and comprehensive training to deal with routine management and emergency situations. In 2013, HA decided to develop a centralized simulation training program on ECMO for staff working in the five ECMO centres. The simulation training is free-of-charge. It composes a variety of learning objectives including ECMO knowledge, technical skills and crew resource management. It also allows the development of a standardized experience for all staff members. Instructors of the ECMO simulation training are intensive care specialists and senior nurses from the five ECMO centres. Most of the instructors are qualified by HA for using simulation to teach. Some of them received Train-the-trainer Courses of ECMO Simulation run by Extracorporeal Life Support Organization (ELSO).

3. Goaland advantages of starting the ECMO simulation training

ECMO is a complex technology that involves cannulation of big central vessels, operation of the ECMO console, circuit management and use of anticoagulation. Medical errors are not infrequent as ECMO patient is extremely critical and technology is complex. On the other hand, patients and their relatives become increasingly concerned that doctors are "practicing" on them, and clinical medicine is now more focusing on patient consent, safety and quality than on teaching and education. To solve this dilemma, clinical staff that take care of ECMO patients should receive proper and specialized training before they manage real patients.

ECMO is a extracorporeal life support system that has a pump to circulate blood through an oxygenator. VV ECMO has the return cannula placed in the venous system for lung support. VA ECMO has the return cannula placed in the arterial system for cardiac support. Different ECMO centres have different casemix due to geographic reason and specialization. Therefore, some ECMO centres have more VV ECMO cases, whereas other centres have more VA ECMO cases. And even within the same centre, the number of ECMO cases may vary from month to month. In Hong Kong, winter and summer are the peak seasons of influenza so we have higher number of VV ECMO cases in these seasons [5]. After the peak season, training is needed to keep our staff competent on managing this complex technology when there is no VV ECMO case in the unit.

Close collaboration among clinical staff members is mandatory for both daily ECMO care and crisis management. Appropriate team behaviour and clear communication are of utmost importance in caring for ECMO patient. Therefore, staff members that take care of ECMO patient should receive training on non-technical skills, namely, communication, situational awareness, assertiveness, leadership and teamwork.

In addition, medical crisis on ECMO occurs very rarely in real situation. Clinical staff members normally do not have the chance to experience or deal with this kind of situation. However, making correct decision depends upon understanding the situation under short time pressure. Therefore, simulation training can provide a standardized opportunity for staff members to experience and gain confidence in managing ECMO emergency.

4. Budgetary considerations

After the H1N1 pandemic in Hong Kong in 2009 and publication of CESAR trail in 2009, ECMO has been recognized as an option to patients that failed conventional mechanical ventilator support. However, there was insufficient formal and structural ECMO training locally. There were just didactic lectures supplemented with ECMO circuit priming hands-on training. Clinical staff members had to go overseas for receiving hands-on practice such as crisis management and troubleshooting. As there has been an increasing demand of ECMO service, a corporate wide ECMO simulation training was first proposed in 2013 by clinical expertise working group and local simulation training unit development group to the simulation training committee of HA. The goal of the training is to let clinical staff members acquire clinical competencies of handling ECMO patients. The funding consideration of the proposal was screened and prioritized by the Service and Budget Planning Committee and approved by the HA board for resource allocation. Every year the training has to undergo a service and budget planning review process at the corporate level. It serves to secure consensus of the policy direction and program's service model.

4.1. Equipment

Only circuit and cannulae that are for training purpose were purchased. We usually changed a new set of ECMO circuit and console in every six sessions. The simulation centres provide manikin and help to modify the manikin so the ECMO circuit can be incorporated inside. Other essential items that the simulation centres will provide include mechanical ventilator, infusion devices, resuscitation cart and monitoring devices (**Table 1**). There was a list of consumables that need to purchase and replace after use. **Table 2** shows the number of items that we used in the past two years.

Items that are provided by the simulation centre	Items that needed to be purchased by the training program
Manikin	HLS Set (non-sterile)
Mechanical ventilator	PLS Set (non-sterile)
Portable ventilator	HG0291 Straight Connector 3/8 × 1/4 LL
Physiological monitor	HY0263 Y Connectors 3/8 × 3/8 × 3/8 LL (non-coating)
Infusion pump and tubing	BE-S 2085 Back Flow Tubing Line
Resuscitation cart	Tubing Line 3/8 × 3/32 × 150cm
Defibrillator	Tubing Line 1/4 × 1/16 × 50cm
Syringes	Arterial HLS Cannulae Fr 19 (non-sterile)
Clamp	Venous HLS Cannulae Fr 23 (non-sterile)
Intravenous access	BE-S 2086 High Flow Tubing Line (with Bioline Coating)
Wall oxygen	PIK 100 Percutaneous Insertion Kit
Portable oxygen cylinder	PIK 150 Percutaneous Insertion Kit
Wall suction	HG0285 Straight Connector 3/8 ×3/8
Endotracheal tube	Ultrasound Contact Cream
Computer	SU2855 Tubing Clamp Forceps w/guard
	PIK Guidewire 100cm
	PIK Guidewire 150cm
	Cordis 504608 (Vascular sheath)
	Bladder reservoir

Table 1. Essential items and consumables required for the ECMO training course.

4.2. Personnel

Instructors are all qualified ECMO specialists that are properly credentialed by the training units. We have two doctor instructors and two nurse instructors in each class. They come to conduct the training either by applying official release from their departments or being financially compensated for their time if they take leave for the teaching. Instructors are paid by the hours according to the class duration and their HA payroll. Participants are arranged to attend the training on the day of their compensation off or during their duty shift while their clinical duties are covered by other clinical staff members. We also employ an executive assistant to provide administrative work that involves instructor and participant recruitment process and communication.

Items that purchased and replaced	Item used from 2014 to 2016	
1	HLS Set (non-sterile)	13
2	PLS Set (non-sterile)	13
3	HG0291 Straight Connector 3/8 × 1/4 LL (Box of 20s)	1
4	HY0263 Y Connectors 3/8 × 3/8 × 3/8 LL (non-coating) (20s)	1
5	BE-S 2085 Back Flow Tubing Line (with Bioline Coating)	12
6	Tubing Line 3/8 × 3/32 × 150cm	2
7	Tubing Line 1/4 × 1/16 × 50cm	2
8	Arterial HLS Cannulae Fr 19 (non-sterile)	23
9	Venous HLS Cannulae Fr 23 (non-sterile)	23
10	BE-S 2086 High Flow Tubing Line (with Bioline Coating)	6
11	PIK 100 Percutaneous Insertion Kit (sterile)	8
12	PIK 150 Percutaneous Insertion Kit (sterile)	9
13	HG0285 Straight Connector 3/8 ×3/8 (non-coating) (20s)	1
14	Ultrasound Contact Cream	11
15	SU2855 Tubing Clamp Forceps w/guard	10
16	PIK Guidewire 100cm (Box of 5s)	2
17	PIK Guidewire 150cm (Box of 5s)	2
18	Cordis 504608 (Vascular sheath) Box of 5 pc	2
19	Bladder	2

Table 2. Items that are consumed and replaced from 2014 to 2016.

5. Modification of old manikin to facilitate the ECMO training

An ideal manikin for the ECMO simulation training should possess realistic anatomical features for clinical assessment and intervention yet inexpensive and durable. However, there is no such manikin in the commercial market. Therefore, modification of an old manikin was done for facilitating hydrodynamic simulation. We drilled holes in our old manikin "Nursing Kelly" so that tubing can be incorporated into the manikin. Inside the manikin, a closed-loop system was made by connecting tubing with a plastic reservoir (bladder). There are two openings on the "bladder." Each of these is connected to a syringe with a long tubing. In scenario of hypovolaemia, we would draw "blood" from the circuit with the syringe. In scenario of air embolism, we would inject "air" from the syringe into the circuit (**Figures 1–3**).

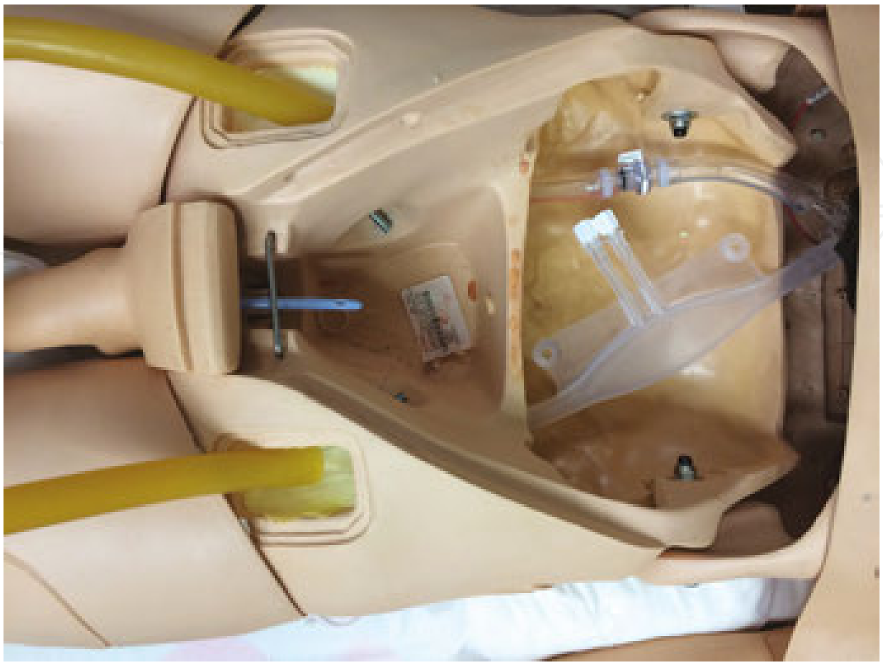

Figure 1. Modification of old manikin—forming a closed loop with a "bladder" reservoir and using a latex tube to pretend central vein.

Figure 2. Modification of old manikin—inserting an ECMO cannula into the pretended vessel.

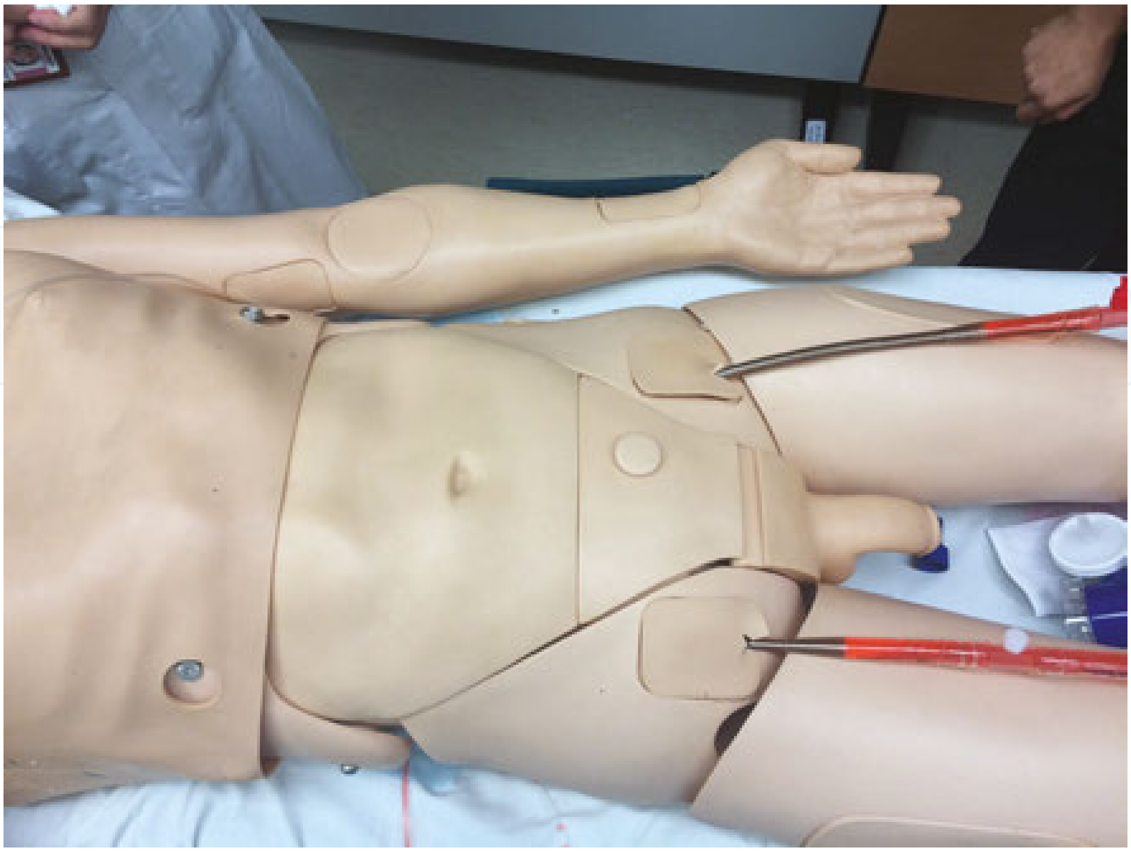

Figure 3. Modification of old manikin—finished model with cannulae placed.

6. Set-up of high-fidelity-simulated environment

Simulation refers to the artificial imitation of a real-life scenario or process with sufficient fidelity to achieve a particular goal, such as training or assessment [6]. A well-designed simulation program, complemented with high-fidelity simulator, allows learners to engage in the scenarios and immerse in the teamwork dynamic in the scenario play. It would provide learners with an environment to learn not only technical skills (theoretical knowledgeand procedures skills), but also non-technical aspects (teamwork, leadershipand communication).

Our training is conducted in two simulation training centres under HA. The simulation rooms are configured to mimic the intensive care environment. The manikins are intubated and put on mechanical ventilation. They have intravenous access that is connected to inotrope and sedative infusing agent. Participants can read the vital signs (i.e., arterial blood pressure, pulse rate, ECG, $O_2$and saturation) of the "patient" on a physiological monitor that is at the head of the patient bed. The parameters are controlled remotely by a simulation technician that is sitting behind a one-way mirror. The simulation technician can change the parameters at any time according to the scenario flow or instructor's instruction. Participants can get the relevant laboratory results, ECG, CXR, or echocardiography findings of the patient on request (**Figure 4**).

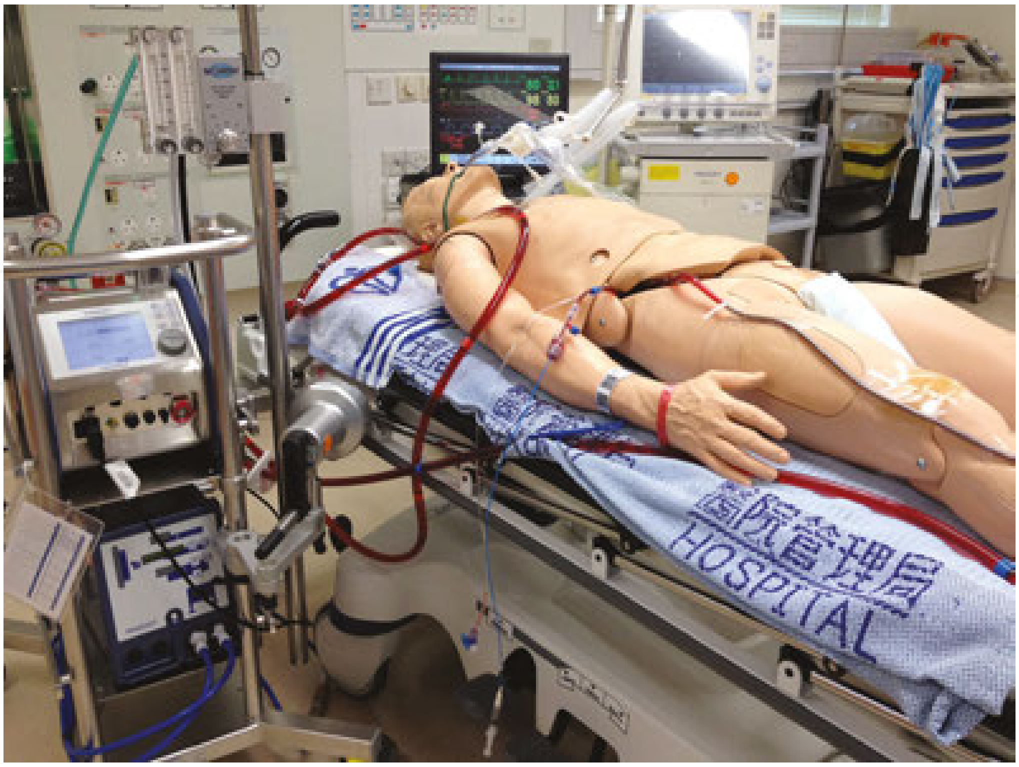

Figure 4. High-fidelity simulation environment for the ECMO simulation training.

7. Explanation on scenario design and flow

"See one, do one and teach one" has been the classical method in learning, when the trainees are exposed to patients in the clinical environment. However, this mode of education may expose patients to harm because participants may have inadequate initial experience, knowledge and technical skills necessary to manage the patient in a safe manner. Medical simulation provides a solution by providing a safe environment for both the learners and patients, especially for high-risk procedure like ECMO. Moreover, the use of simulation in our training can let us provide three categories of scenarios: (1) replicate common real patient clinical experience; (2) replicate incident that only happens infrequentlyand (3) imitate clinical situation that is rarely happened but life threatening, and where prompt and correct actions are necessary.

In the first category of scenario, scenarios are designed such that participants can acquaint basic ECMO concepts, circuit components, relevant parameters and alarms. The second category contains scenarios that are rarely happened. This kind of scenario serves to develop and maintain competency of skills and decision making for troubleshooting emergencies. The third category consists of life-threatening emergencies. These provide participants immersive and experiential opportunity to manage as in real life. Participants need to troubleshoot the crisis in a team-based approach with the use of both technical and non-technical skills (**Table 3**).

Category	Training scenarios
Replicate common real patient clinical experience	• Pinched return tubing • Recirculation due to femoral drainage cannula is shifted in accidentally • Transportation to CT suite • Differential hypoxia • Retrieval transportation to another hospital
Replicate incident that only happens infrequently	• Hypovolaemia due to blood leak from a broken pigtail • Forget to switch on water heater leading to hypothermia • Progressive oxygenator failure with increasing delta pressure, minor clot in oxygenator • O_2 supply failure due to disconnection of O_2 tubing • Limb ischaemia due to kinked reperfusion cannula of a peripheral VA ECMO
Imitate clinical situation that is rarely happened but life threatening, and where prompt and correct actions are necessary	• Air bubbles were inside theaccess side of the ECMO circuit (pre-oxygenator) • Console failure due to short circuit • Accidental decannulation of the femoral access catheter • VT/VF arrest in a patient on VV ECMO

Table 3. Categories of training scenario.

The rundown of this whole day training is listed in **Table 4**. Participants are welcomed and registered before the starting of the training. They will be introduced to one another and briefed about the simulation environment. They will be informed that the training is only for learning purpose and will not be used for assessment or punitive purposes. The training will be videotaped for debriefing and future education use.

08:45–09:00	**Registration**	
	HLS circuit and Cardiohelp	PLS circuit and Rotaflow pump
09:00–09:30	Pinched return tubing	O_2 supply failure due to disconnection of O_2 tubing
09:30–10:00	Hypovolaemia due to blood leak from a broken pigtail	Console failure due to short circuit
10:00–10:30	Forget to switch on water heater leading to hypothermia	Accidental decannulation of the femoral access catheter
10:30–10:45	Recirculation due to femoral drainage cannula is shifted in accidentally	VT/VF arrest in a patient on VV ECMO
10:45–11:15	Air bubbles were inside the access side of the ECMO circuit (pre-oxygenator)	Differential hypoxia
11:15–11:45	Progressive oxygenator failure with increasing delta pressure, minor clot in oxygenator	Limb ischaemia due to kinked reperfusion cannula of a peripheral VA ECMO
11:45–12:15	Transportation to CT suite	Retrieval transportation to another hospital
12:15–13:15	**Lunch break**	
	PLS circuit and Rotaflow pump	HLS circuit and Cardiohelp
13:15–13:45	O_2 supply failure due to disconnection of O_2 tubing	Pinched return tubing
13:45–14:15	Console failure due to short circuit	Hypovolaemia due to blood leak from a broken pigtail
14:15–14:45	Accidental decannulation of the femoral access catheter	Forget to switch on water heater leading to hypothermia
14:45–15:00	**Tea break**	
15:00–15:30	VT/VF arrest in a patient on VV ECMO	Recirculation due to femoral drainage cannula is shifted in accidentally
15:30–16:00	Differential hypoxia	Air bubbles were inside the access side of the ECMO circuit (pre-oxygenator)
16:00–16:30	Limb ischaemia due to kinked reperfusion cannula of a peripheral VA ECMO	Progressive oxygenator failure with increasing delta pressure, minor clot in oxygenator

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16:30–17:30	Retrieval transportation to another hospital	Transportation to CT suite
17:30–18:00	Q&A Closure of training Evaluation	

Table 4. Rundown of the simulation training.

Participants are split into two groups such that one group has 5–6 participants. In the morning session, group A will undergo seven scenarios that use MAQUET PLS circuit system and Rotaflow pump, whereas group B will undergo seven scenarios that use HLS circuit and Cardiohelp as the ECMO system. In the afternoon, group A will swap with group B and go through the scenarios that group B had in the morning.

The participants are brought into the simulation rooms. The group instructors orientate the participants the simulation environment inside the simulation room. Instructors explain what can the simulator do, and what are the limitations of the simulator, what equipment is available, where is the physiological monitor and what parameters will be shown. Participants are told that they can manage the ECMO circuit and adjust the parameter freely according to their clinical judgement and decision. One of the instructors will serve as a confederate in the scenario to facilitate scenario flow.

Figure 5. Instructor is briefing participants the simulation environment.

When the scenario starts, the instructor will introduce the patient's case history, present clinical status and issues, IV access, medications and laboratory results (e.g., arterial blood gas, plasma-free haemoglobinleveland post-oxygenator PO_2 level). On request, relevant imaging studies result will be provided (e.g., X-ray, CT scan and echocardiography). In each scenario, participants in the group haveto appoint one leader to lead the team. After the scenario training is complete, participants move to a separate cubicle for debriefing. Instructors have to debrief according to the manual with preset teaching objectives and debriefing notes. All learners are expected to actively participate in the discussion, and the facilitator serves as a guide for the discussion rather than a "lecturer." If there is any technical issues that participants want to go back and practice again, instructors will arrange the practice at the end of the debriefing session. At the end of the training course, there is a question and answer session that allows participants to further reinforce the learning. Participants are invited to fill in the feedback survey that helps to evaluate the course and guide future direction (**Figure 5**).

8. What to debrief after every scenario

There is a debriefing session after each scenario. Each debriefing session lasts about 15 min. Debriefing is the most important part in simulation training. To ensure a fruitful debriefing process and learning experience, instructors should create a supportive environment so that participants feel valued and respected, and are willing to share their experiences in an open and honest manner. Participants are encouraged to recall and reflect the experience in the scenarios they have just participated and observe the gap between desire and actual. Instructors will help participants to clarify thinking, clear misunderstanding and reinforce specific defined teaching objectives.

8.1. Technical aspect

Tables 5 and **6** illustrate technical issues for discussion in debriefing session.

Scenario	Technical issues to debrief
Pinched return tubing	Always check systematically on three areas: ECMO circuit and console, O2 source and patient. Understand the concept of PVen, PArt, PDelta, Pint. Identification of flow drop and trigger of the flow and pressure alarms. Reasons of flow drop.
Hypovolaemia due to blood leak from a broken pigtail	Identification of very negative venous pressure and possible reasons behind. Blood leak from a broken pigtail if after-pump, air embolism will happen if the broken pigtail is pre-pump. Reinforce to check systematically on three areas: ECMO circuit (the three-way Stop-cocks) and console, O_2 source, and patient (any physical signs of bleeding) Increase RPM will further impede the blood flow. Treatment to correct very negative venous pressure.
Forget to switch on water heater leading to hypothermia	Recognition of hypothermia. Importance of systematic circuit check, including the water tank and heater. How to recognize the water heater is working. Find out other possible causes of bradycardia. Pharmacological causes (e.g., beta-blocker, dexmedetomidine, propofol, high dose alpha agonist). Endocrine causes (e.g., hypothyroidism). Cardiac causes (e.g., heart block after contusion). CNS causes (e.g., Cushing reflex after bleeding).
Recirculation due to femoral drainage	Clinical features of recirculation (e.g., low SpO_2 with high SvO_2 readings) Return Red + Access Blue → Normal. Return Red + Access Red → Recirculation. Return Blue + Access Blue → Oxygenation failure. Optimal distance between the return and access ECMO cannula tips,

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Scenario	Technical issues to debrief
cannula is shifted accidentally	and how to appreciate the distance with X-ray and/or USG. Recognize recirculation is not a major problem as long as enough blood flow for oxygen delivery. Recirculation only happens in VV ECMO.
Air bubbles were inside the access side of the ECMO circuit (pre-oxygenator)	Identification of venous bubbles in the circuit and trigger of the gas bubble alarm. Air embolism is a major crisis and need to speak out immediately. When, where and how to clamp the circuit. Methods to de-air micro-bubbles. Systematic circuit check to look for leak site. Risk of air embolism is higher at pre-pump. Cracked three-way is always a possible source. Management of air embolism pre-oxygenator and post-oxygenator is different.
Progressive oxygenator failure with increasing delta pressure, minor clot in oxygenator	Hints that suggest a failing oxygenator:Elevating delta pressure; presence of clots on oxygenator membrane; post-oxygenator PO_2<200 mmHg; elevated plasma-free Hb. Oxygenators of HLS (Cardiohelp) and BLS (Rotaflow) have different lifespan. How to examine the circuit and oxygenator to find clot. In Cardiohelp only the post-oxygenator membrane can be seen. Can go through the technical aspect of changing oxygenator if time allows.

Table 5. Technical issues for discussion in debriefing session—when using HLS and Cardiohelp system.

Scenario	Technical issues to debrief
O_2 supply failure due to disconnection of O_2 tubing	Always check systematically on three areas: ECMO circuit and console, O_2 source and patient. Recognize disconnected O_2 supply has no alarm.
Console failure due to short circuit	Recognize pump failure is an emergency condition and need immediate reaction. Technique of switching to hand crank. Logistic of getting a new ECMO machine. Procedure of resuming the ECMO flow with the new ECMO machine.
Accidental decannulation of the femoral access catheter	Recognition of accidental decannulation can lead to massive bleeding. Immediate management of the massive bleeding. Recognition of accidental decannulation can lead to massive air embolism. Immediate management of the massive air embolism. Crisis management when ECMO is off accidentally (e.g., ventilator setting, inotropic support)
VT/VF arrest in a patient on VV ECMO	Perform CPR as usual as VV ECMO does not provide circulatory support. Adjustment of ECMO flow during CPR. When to decide switching VV ECMO to VA ECMO.
Differential hypoxia	Possible causes of O2 desaturation and check the three areas of ECMO circuit i.e. console and tubing, O2 source, and patient systematically. Pathophysiology of differential hypoxia (e.g., bad lungs and a recovering heart). Only happened in peripheral VA ECMO with femoral artery as return cannula. Features of differential hypoxia (e.g., right hand finger has a lower SpO2 reading than the left hand finger). Decision to switch VA ECMO to V-AV ECMO
Limb ischaemia due to kinked reperfusion cannula of a peripheral VA ECMO	Features of limb ischaemia (6 "P"). Method to check flow/patency/position of reperfusion cannula. When checking the cannula avoid flushing the cannula. Technique of line secure and dressing is important to avoid kinking of cannula.

Scenario	Technical issues to debrief
Transportation	Know what equipment and experienced personnel to assemble for ECMO transportation. Know the logistic of the whole transportation process. To recognize common potential problems in ECMO transportation. To troubleshoot during transportation if problems arise

Table 6. Technical issues for discussion in debriefing session—when using PLS and Rotaflow system.

8.2. Non-technical aspect

Appropriate team behaviours and clear communication are of utmost importance in caring for ECMO patients. Therefore, staff members that take care of ECMO patient should possess both technical (medical knowledge and technical skills) andnon-technical skills. Non-technical skills include situation awareness, communication, teamwork, leadership and decisionmaking. The importance of non-technical skills is to increase the work safety and ensure effective working environment, with a minimum of technical errors.

No.	Description	2014	2015
		Score of the item	
1	This program has achieved its stated objective(s).	4.43	4.47
2	This program meets my training needs.	4.47	4.25
3	The program content that I learned can be applied to my real practice.	4.51	4.49
4	The program is organized.	4.48	4.56
5	Length of the course is appropriate.	4.23	4.28
6	Scenarios are able to facilitate participation and learning.	4.51	4.49
7	Debriefing session is useful.	4.55	4.53
8	Trainer is effective in facilitating my learning.	4.55	4.57
9	Trainer helped me understand my performance.	4.42	4.54
10	I am overall satisfied with this training program.	4.5	4.49
11	For the learning objective of this course, I find that simulation is an effective mode of education.	4.55	4.49
12	Would you recommend this program to other colleagues?	Yes 86.2% No 0% Not answer 13.8%	Yes 94.1% No 0.05% Not answer 0.54%

*Strongly disagree: 1; disagree: 2; neutral: 3; agree: 4; strongly agree: 5.

Table 7. Questions of the course evaluation form and summary of the participants' comments.

In each scenario, troubleshoot the ECMO-related problem and stabilize the patient is the common goal. Participants are requested to select a leader and demonstrate teamwork. During the scenario, a team member is expected to maintain dynamic awareness of the situation based on assembling data from the environment, understanding what they mean and thinking ahead what might happen next [7]. Every team member should speak out when they have identified abnormality (situation awareness) so that other team members have the same shared picture of the situation (communication) and can react accordingly. The team leader after collecting the information will make decision (leadership) and act accordingly (decision making).

Besides discussing technical skills knowledge, instructors would also encourage group discussion on their non-technical skill performance. They would be encouraged to express their views on issues such as any performance gaps, the reasons behind such gaps, what could have improved and the relevance to their real-life experience. During the process, the instructors, apart from encouraging the participants to speak out, have to assist the participants to clarify issues, correct misunderstanding and reinforce certain pre-defined teaching objectives.

Table 7 shows the post-course evaluation form and the summary of the participants' comments. Participants expressed that the course is very organized and meets the training objectives. They agreed that scenario-based teaching can facilitate participation and learning and the debriefing session is very useful. However, we do not have data to show how our simulation training can improve patient outcomes. Further research is needed to study the effect of simulation training on outcomes of the ECMO patients.

9. Conclusion

ECMO is a complex and high-risk procedure that requires a high level of training to acquire and maintain proficiency. Non-technical factors such asteamwork, communication, situation awareness and decision making are equally important factors for keeping ECMO patients safe. Since the development of the ECMO simulation training in 2014, 32 identical full-day courses were conducted and 285 doctors and nurses from fiveECMO centres of Hong Kong were trained. All participants were satisfied with the training and expressed that the simulation was an effective model for ECMO training. The training met their need and they could apply what they learned in real-life practice.

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