Simulation training for extracorporeal membrane oxygenation

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ABSTRACT

Background: Extracorporeal membrane oxygenation (ECMO) is a complex treatment. Despite this, there are a lack of training programs designed to develop relevant clinical and nonclinical skills required for ECMO specialists. The aim of the current study was to describe the design, implementation and evaluation of a 1-day simulation course for delivering training in ECMO. Methods: A 1-day simulation course was developed with educational and intensive care experts. First, the delegates received a lecture on the principles of simulation training and the importance of human factors. This was, followed by a practical demonstration and discussion of the ECMO circuit, console components, circuit interactions effects and potential complications. There were then five ECMO simulation scenarios with debriefing that covered technical and nontechnical issues. The course culminated in a knowledge-based assessment. Course outcomes were assessed using purpose-designed questionnaires. Results: We held 3 courses with a total of 14 delegates (9 intensive care nurses, 3 adult intensive care consultants and 2 ECMO technicians). Following the course, 8 (57%) gained familiarity in troubleshooting an ECMO circuit, 6 (43%) increased their familiarity with the ECMO pump and circuit, 8 (57%) perceived an improvement in their communication skills and 7 (50%) perceived an improvement in their leadership skills. At the end of the course, 13 (93%) delegates agreed that they felt more confident in dealing with ECMO. Conclusions: Simulation-training courses may increase knowledge and confidence in dealing with ECMO emergencies. Further studies are indicated to determine whether simulation training improves clinical outcomes and translates to reduced complication rates in patients receiving ECMO.

Key words: Extracorporeal membrane oxygenation; simulation; training

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) provides support to patients with life threatening forms of respiratory and/or cardiac failure, which are unresponsive to conventional therapy.¹ Despite being arguably one of the most complex treatments available in the Intensive Care environment, there is a distinct lack of recognized training programs designed to facilitate ECMO training. With standard training usually being focused on acquiring the relevant theoretical knowledge along with direct practical training, there is an implicit need for training in the additional skills of communication, teamwork and leadership that are required to be an ECMO specialist. An integration of both these clinical and nonclinical skills is vital to minimize mortality and complications in the high risk and complex patients that require ECMO.

The aim of the current study was to describe the design, implementation and evaluation of a 1-day simulation course for delivering training in ECMO.

METHODS

The ECMO Faculty at King’s College Hospital designed and developed a 1-day course in
conjunction with simulation experts from the Weston Education Centre. In order to integrate both the clinical and nonclinical training components required for successful ECMO delivery, we elected to incorporate 7 key components. The first component required delegates to read purpose-designed precourse material and to complete a precourse self-assessment. During the course itself 6 hierarchical sequential training modules were delivered. This began with a seminar on the principles of simulation training and relevant human factors. Following this, there was an introduction to the manikin and the simulated ECMO circuit, a troubleshooting workshop, ECMO scenario training and cases-based discussion. The course concluded with an informal assessment and the completion of evaluation questionnaires.

Precourse material
All participants were given purpose-designed precourse material. This was comprised of a 52 page “ECMO workbook” that had been created by specialists at King’s College Hospital, London. In this, relevant information pertinent to ECMO was included along with definitions, indications and technical details. In addition, troubleshooting tips, treatment and emergency response algorithms were included. The “ECMO workbook” concluded with 29 questions to aid self-assessment. It was a mandatory requirement for course delegates to complete the manual and self-assessment prior to the practical component of the course.

Practical course

Principles of simulation training and relevant human factors
A medical education expert delivered a 15-min seminar, which explored the principles of simulation training and definitions of human factors. This also included a discussion on the application of relevant human factors in the clinical environment.

Simulation and manikin introduction
For the practical component of the course, the delegates were then introduced to the high fidelity simulation room at King’s College Hospital. This room was specifically configured to mimic the intensive care environment. In order to suspend the disbelief associated to simulation training, relevant observation charts, clamps, ventilators and monitors were made available alongside the manikin. The ECMO sessions themselves were driven by a Gaumard Hal 3201 high fidelity manikin (Gaumard, Miami, USA). This fully automated patient simulator permitted the emulation of a wide spectrum of physical and medical parameters required for ECMO relevant scenarios. The simulator was operated remotely via a wireless tablet device, and on a “pallet items mode” (complete or partial group of settings preprogrammed), rather than “on-the-fly” operations (reduced preprogramming and response to real-time actions), to best reflect immediate changes to vital parameters scripted for the ECMO scenarios. For the simulation of hydrodynamics, a liquid filled reservoir attached to the ECMO machine was used. This permitted the control of fluid pressure, movement and flow. There were no physical connections to or from the ECMO machine.

Extracorporeal membrane oxygenation troubleshooting
This session was a one and half hours practical demonstration of the ECMO circuit led by senior ECMO specialists. In this interactive session, the delegates had the opportunity to (1) name and review circuit components and (2) name and review the console, its components and relevant circuit interactions. In addition, delegates had the opportunity to discuss the effects and emergency response to complications.

Extracorporeal membrane oxygenation simulation scenario training
The ECMO simulation training commenced with the demonstration of a scenario. This first scenario was acted out by some faculty members and was used to demonstrate what was expected of the course attendees. Participants were then given the opportunity to participate in at least one of four different ECMO simulation scenarios. These were designed to highlight relevant problems that may occur in the ECMO context. The first scenario dealt with the “sweep gas” (the process of gas exchange in the membrane oxygenator) not being turned on. The second scenario dealt with the accidental disconnection of a circuit. The third scenario dealt with “rattling of the lines” caused by a mismatch between circuit volume and pump circuit pressure resulting in turbulence in the system. Finally, the forth scenario dealt with air in the circuit.

For the simulation practice, the delegates were briefed on the clinical scenario and were then led into the simulation room in pairs. Throughout the scenario, there was an “acting” nurse to assist with any practical aspects and to provide additional information where required.
In order to maximize the learning experience, the remaining delegates were able to observe the scenario unfold via a live video feed in an adjacent room. At the end of each scenario, a debriefing session was led by an education expert and ECMO expert. During this, both clinical and nonclinical skills related to the scenario were addressed in an interactive manner.

**Interactive extracorporeal membrane oxygenation case-based discussion**

Following the simulation training, the delegates participated in a ½-h discussion of clinical cases in a seminar-based format. The ECMO expert initially presented a brief clinical case along with the relevant physiological and ECMO parameters. This was, followed by an interactive discussion that addressed the salient issues. The principal aim of this session was to encourage delegates to apply the skills they had acquired in the preceding session in more complex clinical scenarios. The cases discussed included issues related to venous-arterial and venous-venous ECMO.

**Assessment and evaluation**

At the end of the course, the delegates were required to complete a 1-h formal assessment to consolidate the factual learning delivered on the course. This assessment was comprised of 14 multiple-choice questions and 16 questions based on short scenarios and pictures where free text responses were permitted.

Part of the course also required the delegates to complete an evaluation form to capture their precourse expectations and to determine whether their learning objectives had been met. A Likert five-point scale was used to assess the responses regarding the ECMO simulation experience. The questionnaire also contained open-ended questions about specific aspects of the course and addressed both clinical and nonclinical skills.

**RESULTS**

The ECMO simulation course was successfully delivered on three separate occasions at Kings College Hospital, Weston Education Centre, from June 2013 to July 2013. During this time, 14 delegates attended the course and successfully completed all seven components. There were 9 (64%) intensive care nurses, 3 (21%) adult intensive care consultants and 2 (14%) ECMO technicians.

**Postcourse knowledge assessment**

The paper-based assessments (14 multiple choice questions) were marked by one of the ECMO experts. The overall average score was 89%. The range of scores was between 70% and 98%.

**Course evaluation**

**Precourse expectations – clinical and nonclinical skills**

All 14 delegates responded the precourse evaluation questionnaire at the end of the course. There was a bias for the delegates wishing to develop their technical skills when compared to their nontechnical skills [Table 1]. For the technical skills, 7 (50%) delegates expected to learn how to troubleshoot an ECMO circuit, 6 (43%) how to manage common circuit problems, 4 (29%) to increase their familiarity with the ECMO pump/circuit and 4 (29%) to understand patient physiology and respective changes on ECMO. For the nontechnical skills, 5 (36%) expected to improve their general confidence with ECMO and 3 (21%) to improve their communication skills.

**Postcourse perceptions – clinical and nonclinical skills (open-ended questions)**

All 14 delegates responded to the postcourse evaluation questionnaire at the end of the course. In contrast to the precourse expectations, the course was successful in that the delegates perceived a development in both their technical and nontechnical skills [Table 2]. For the technical skills, 8 (57%) gained familiarity in troubleshooting an ECMO circuit, 6 (43%) increased their familiarity with the ECMO pump and circuit and 3 (21%) improved their understanding of patient physiology and respective changes on ECMO. For the nontechnical skills, 8 (57%) perceived an improvement in their communication skills, 7 (50%) an improvement in their leadership skills and 5 (36%) an improvement in their delegation skills.

**Simulation training feedback**

Table 3 gives the results of the simulation training feedback using a Likert five-point scale.[2] Prior to the course attendance, 7 (50%) of the delegates did not feel confident in dealing with ECMO patients and 5 (36%) were neutral in their response. At the end of the course 6 (43%) felt “very confident” in managing ECMO patients and 13 (93%) agreed that they felt more confident in dealing with ECMO patients following the course.

All 14 (100%) delegates agreed that the simulation training sessions raised their awareness of the importance of effective team working, delegating tasks and good communication skills. There was a consensus among 12 (86%) delegates that simulation training was
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a good learning experience for communication and team working. The majority of delegates (93%) found the feedback session to be useful and 12 delegates (86%) agreed or strongly agreed that they had learnt new concepts important for patient safety during the day. All delegates agreed that simulation training would be a good means to assess competency when dealing with ECMO patients although 2 (14%) remarked that “some individuals may not be comfortable with simulation training” and that “there were limitations as to how real a simulated ECMO scenario could be.”

DISCUSSION

In the current study, we demonstrate the successful design and delivery of a 1-day simulation-based training course in ECMO. We also show that using simulation training it is possible to deliver both clinical and nonclinical relevant skills that are important for the safe delivery and practice of ECMO in an intensive care environment.

Extracorporeal membrane oxygenation is one of the most complex treatments available in the intensive care environment, and it requires a high level of technical skill and nontechnical skills such as communication, teamwork, and leadership. Simulation training can provide a realistic and controlled environment for healthcare professionals to practice and improve these skills, ultimately leading to better patient outcomes.

Table 1: Technical skills and nontechnical skills hoped to be gained during the course

| Technical skills | n (%) | Nontechnical skills | n (%) |
|------------------|-------|---------------------|-------|
| Troubleshooting  | 7 (50)| Confidence in general | 5 (36) |
| Management of common circuit problems and failures | 6 (43) | Improved communication skills | 3 (22) |
| Increased familiarity with pump and circuit (ECMO machine) | 4 (29) | Improved situation awareness | 1 (7) |
| Understand patients physiology and physiology changes on ECMO | 4 (29) | Improved teamwork | 1 (7) |
| Improve clinical management of patient on ECMO | 3 (21) | Improved leadership | 1 (7) |
| Improve timing skills from diagnosis of failure to action | 1 (7) | Improved understanding of human factors in complex ECMO situations | 1 (7) |

ECMO: Extracorporeal membrane oxygenation

Table 2: Perception of technical and nontechnical skills gained during the course

| Technical skills | n (%) | Nontechnical skills | n (%) |
|------------------|-------|---------------------|-------|
| Improved familiarity with troubleshooting | 8 (57)| Improved effective communication | 8 (57) |
| Increased familiarity with pump and circuit (ECMO machine) | 6 (43) | Effective leadership | 7 (50) |
| Improved clinical management of patient on ECMO | 4 (29) | Improved delegation skills | 5 (36) |
| Improved practical experience/practical skills | 3 (22) | Increased confidence | 2 (14) |
| Increased understanding of patients’ physiology and physiology changes on ECMO | 3 (22) | Better understanding of human factors | 2 (14) |
| Good recap in a realistic environment | 2 (14) | Anticipation, planning, role definition, prioritization | 1 (7) |
| Improved knowledge | 1 (7) | Teamwork | 1 (7) |

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Table 3: Feedback questions on simulation

| After the simulation experience | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---------------------------------|------------------|----------|---------|-------|----------------|
| I feel more confident in managing a ECMO patient | 1 | 9 | 4 |
| I now feel very confident in managing a ECMO patient | 2 | 6 | 6 |
| The debriefing sessions were useful | 1 | 6 | 7 |
| The session raised my awareness of the importance of effective teamwork and delegating tasks | 4 | 10 |
| The session highlighted the importance of good communication skills | 4 | 10 |
| Simulation is a good learning experience for teamwork and communication | 3 | 11 |
| I have learnt new concepts important for patient safety | 3 | 5 | 6 |
| I am now more aware of my leadership skills in a resuscitation scenario | 1 | 1 | 6 | 6 |
| Simulation is a valuable tool in my training as a doctor/nurse | 4 | 10 |
| Simulation is a good learning experience for clinical skills and knowledge | 4 | 10 |
| I would benefit from annual simulation courses | 3 | 1 | 10 |
| Simulation are useful adjuncts to learning from real-life | 2 | 4 | 8 |

ECMO: Extracorporeal membrane oxygenation
care setting. It requires a unique skill set of both technical and nontechnical abilities to deal with unforeseen events and also complications.\[10\] Despite the growing need for ECMO specialists and the demands on existing services, training opportunities in ECMO are limited. Experience is usually gained either by a period of mentorship or at the bedside in patients whom are critically unwell. Although attempts have been made to deliver training courses in ECMO, these seem to be insufficiently equipped to provide both technical and nontechnical skills across an array of varied ECMO clinical scenarios. In order to achieve this, we developed a unique course that utilized the skills of both experts in teaching and ECMO. Our course was comprised of a number of key components. These varied from precourse material and self-directed learning, to didactic lectures, interactive seminars, practical demonstration, simulation-based training and case-based discussions. Our initial results demonstrate that this approach facilitates learning of technical issues related to ECMO and also fosters the desirable skills of effective communication and team leadership. One additional key component of our course was that our scenarios were drafted in consultation with medical education experts in order to maximize the potential to deliver specific learning outcomes relevant to ECMO emergency situations. We therefore included problems that might arise in a crisis situation so that the participants would have a chance to practice the skills required to troubleshoot these problems.

Simulation training represents an ideal platform to deliver ECMO training. Firstly it permits the safe development of relevant clinical skills away from a direct clinical setting where errors may contribute to mortality and morbidity. Secondly, it allows the rehearsal of key skills related to ECMO and also fosters the desirable skills of effective communication and team leadership. One additional key component of our course was that our scenarios were drafted in consultation with medical education experts in order to maximize the potential to deliver specific learning outcomes relevant to ECMO emergency situations. We therefore included problems that might arise in a crisis situation so that the participants would have a chance to practice the skills required to troubleshoot these problems.

As well as the permitting the development of technical skills, simulation training has also been shown to help individuals achieve fundamental cognitive, technical and behavioral skills when compared to didactic teaching.\[6\] It also facilitates an improvement in team working attributes and safety.\[7\] The benefit of using simulation training for ECMO has been demonstrated in a number of previous studies. Anderson et al. showed a decreased number of errors in ECMO emergencies in those individuals receiving simulation training.\[6\] Similarly, Burkhart et al. showed an improvement in confidence in individuals using ECMO by incorporating simulation training.\[3\] Our results are consistent with these prior studies in that we show an improvement in both technical and nontechnical skills for those delegates attending our course.

LIMITATIONS

There are a number of limitations to the current study. The principal aim of the current study was to design and deliver an ECMO course that would encompass both training in technical and nontechnical skills. We recognize that the number of the attendees to our course was small and accordingly the results of the feedback need to be interpreted with caution. Although we are able to demonstrate an improvement in perceived knowledge, confidence, leadership and communication skills when dealing with ECMO scenarios, no long-term clinical outcome data were available from our course. It is, therefore, unknown whether attendance at our course resulted in improved patient outcomes. The authors acknowledge that there is only limited data suggesting that simulation training aids the transference of skills into the clinical domain.\[8\] Further work is indicated to determine the longer-term effects of simulation training in ECMO and to whether our course has achieved Level 4 of Kirkpatrick evaluating training programs results.\[9\]

CONCLUSIONS

We successfully designed and delivered a 1-day simulation-training course in ECMO using expertise from specialists in medical education and intensive care. Our results suggest that training in ECMO can be delivered in a safe environment without compromising patient safety and that such an approach can increase knowledge and confidence among ECMO practitioners. Further studies are indicated to determine whether such training results in improved outcomes for patients receiving ECMO.

REFERENCES

1. Zanerillo A, Landoni G, Biondi-Zoccai G, Greco M, Greco T, Frati G, et al. A meta-analysis of complications and mortality of extracorporeal membrane oxygenation. Crit Care Resusc 2013;15:172-8.
2. Likert R. A technique for the measurement of attitudes. Arch Pyschol 1932;140:1-55.
3. Burkhart HM, Riley JB, Lynch JJ, Suri RM, Greason KL, Joyce LD, et al. Simulation-based postcardiotomy
extracorporeal membrane oxygenation crisis training for thoracic surgery residents. Ann Thorac Surg 2013;95:901-6.

4. Nimmo GR, Wylie G, Scarth J, Simpson J, Gracie E, Torrance, et al. Critical events simulation for neonatal and paediatric ECMO. Infant 2008;4:160-2.

5. Available from: http://www.elso.org/Portals/0/IGD/Archive/FileManager/97000963d6cuserssmyerdocumentselsoguidelinesfortrainingandcontinuingeducationofecmospecialists.pdf. [Last accessed on 2014 Oct 14].

6. Anderson JM, Murphy AA, Boyle KB, Yaeger KA, Halamek LP. Simulating extracorporeal membrane oxygenation emergencies to improve human performance. Part II: Assessment of technical and behavioral skills. Simul Healthc 2006;1:228-32.

7. Burton KS, Pendergrass TL, Byczkowski TL, Taylor RG, Moyer MR, Falcone RA, et al. Impact of simulation-based extracorporeal membrane oxygenation training in the simulation laboratory and clinical environment. Simul Healthc 2011;6:284-91.

8. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. Med Educ 2010;44:50-63.

9. Kirkpatrick DL. Techniques for evaluating training programs. J Am Soc Train Dir 1959;13:21-6.

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