J Extra Corpor Technol. 2019;51:12–9
The Journal of ExtraCorporeal Technology

Effects of ECMO Simulations and Protocols on Patient Safety

Fedelyne Thomas, BS, MS, CCP; Sunyoung Chung, BS, MS, CCP; David W. Holt, MA, CCT

Abstract: The use of extracorporeal membrane oxygenation (ECMO) has greatly increased over the years; however, the survival rate is only above 56%. There has been a drastic increase in ECMO centers and cases. ECMO has become a popular therapy route for patients with respiratory and cardiac complications; however, patient safety is a major concern. Perfusion and non-perfusion students from the University of Nebraska Medical Center were recruited to participate in three simulation trials. The trials consisted of five different tasks that are required for managing or preventing catastrophic events on ECMO. Students were evaluated for the time it took to complete each task, number of errors made, and protocol referencing. The data indicated that there was a decrease in time for the 1st vs. 2nd trial (p = .02) for perfusion students and a decrease from the 1st to 3rd trial (p = .001) for the circuit set-up simulation. There was a decrease in priming time from the 1st to 3rd trial (p = .02) and for the pump change (p = .0098) for the perfusion students as well. The non-perfusion students had a significant decrease in time for the circuit set-up in the 1st vs. 2nd (p = .004) and 1st vs. 3rd trial (p = .002). There was a decrease in time for priming (.004), pump change (p = .002), tubing change (p = .0098), and errors during the tubing change (p = .02) in the non-perfusion students. Both groups felt more confident after the simulations and the non-perfusion students specifically felt like they were more familiar with the purpose of ECMO after the simulation. ECMO simulations and protocols may improve patient safety by strengthening the skills needed for rapid management, fewer errors, and higher levels of confidence during the management of ECMO and catastrophic events. **Keywords:** cardiopulmonary bypass (CPB), extracorporeal membrane oxygenation (ECMO), education, simulation, protocols, patient care. *J Extra Corpor Technol. 2019;51:12–9*

Medical errors are the third leading cause of death and will continue to be without major improvements in patient safety (1). Although medical errors encompass many issues, they all have the potential to be fatal. One major area in need of attention is extracorporeal membrane oxygenation (ECMO). ECMO has become an increasingly popular therapy route for patients with respiratory and cardiac complications; however, patient safety is a major concern. Enhanced training for managing and assessing catastrophic events on ECMO is necessary, especially with the increase in ECMO centers and use over the years (2). In 1990, there were 83 registered ECMO centers internationally, but by 2017, the number increased to 379 centers. With the wide use of ECMO today, the survival rate for adult patients with pulmonary complications is 66%, and the rate for discontinuation of ECMO or transfer is only at 59% among the total cases reported in July 2018 by the Extracorporeal Life Support Organization (ELSO) registry. For adult patients with cardiac complications, the survival rate is 55% and the rate for discontinuation of ECMO or transfer is 42%. In the pediatric population, the survival rate for pulmonary complications is 67% and the rate for discontinuation or transfer is 58%. The survival rate of pediatric patients with cardiac complications is reported to be 68% and the rate for discontinuation or transfer is 52%. Although, poor patient selection and many other factors such as comorbidities play a role in the low survival rate, medical errors from improper management can also affect the outcome.

Common problems that arise with ECMO include bleeding, oxygenator failure, tubing rupture, and more (3). Resources that may aid in minimizing these problems from escalating into catastrophic events and producing major complications include enhancing ECMO training and the adoption of protocols. Studies have indicated that simulations demonstrate higher levels of short- and long-term memory skill performance compared with self-study modules (4).

Received for publication July 2, 2018; accepted January 25, 2019.
Address correspondence to: Fedelyne Thomas, BS, MS, CCP, Clinical Perfusion Education Program, University of Nebraska Medical Center, 42nd and Emile, Omaha, NE 68198. E-mail: fedelyne30@gmail.com
The senior author has stated that the authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

Many institutions have delegated the responsibilities of ECMO to perfusionists. An important aspect to becoming a competent perfusionist is learning the technical or psychomotor skills. In the past, perfusionists learned on the job in the operating room (5). Perfusion programs that do not incorporate ECMO simulations into their curriculum may not adequately train students for the clinical environment when the perfusion profession is so closely tied to ECMO. Because of the resources, volume of cases, and the number of registered nurses, many institutions have incorporated an ECMO specialist into their team, who may be a respiratory therapist or a nurse (6). According to the ELSO guidelines for training and continuing education of ECMO specialist, it is assumed that each ECMO center will develop their own specific guidelines and training (6). Darling & Searles, published a study stating that developing and practicing protocols enhances the performance of clinicians and that simulations equip perfusion students to conduct oxygenator change outs in a manner comparable with that of a certified perfusionist (7). In this proposed study, subjects with little to no previous ECMO experience are exposed to simulations and protocols to determine if those tools can strengthen the skills of ECMO management and ultimately lead to improvements in patient safety.

We hypothesized that simulations and protocols for catastrophic events for ECMO management will strengthen the skills of practitioners while enhancing patient safety.

ETHICS

Institutional Review Board (IRB) approval was obtained from the University of Nebraska Medical Center (UNMC) Office of Regulatory Affairs. IRB #402-17-EX. Written informed consent was obtained from each participant.

MATERIALS AND METHODS

Recruitment

Students enrolled at the UNMC Clinical Perfusion Program class of 2018 and other health programs were recruited in the month of July 2017. The subjects were recruited via their UNMC student email. Eleven perfusion students were recruited and 10 non-perfusion students were recruited. The 10 non-perfusion students consisted of seven physician assistant students, two pharmacy students, and one physical therapy student.

Exclusion Criteria

The exclusion criteria consisted of any student enrolled at the UNMC who had more than 1 year of experience managing patients on ECMO.

Study Design

Every participant scheduled a 1- to 2-hour period in the month of July 2017 to come into the Clinical Perfusion Simulation Laboratory located in the UNMC Eppley Science Hall. At arrival, a pre-simulation confidential paper survey was distributed (Figure 1). This pre-survey consisted of basic questions about their health-care experience and ECMO. After completion, each student was presented and instructed to watch a 14-minute video created by the researchers on how to construct and prime an ECMO circuit, change an oxygenator, change a roller head pump, and change and remove a ruptured tubing piece. After the video, they were reminded of how the rest of the simulation would be conducted and were shown where all the materials for the simulation were located.

Effects of ECMO simulations and protocols on patient safety pre-survey

1. I am a:
   a. Perfusion student
   b. Non-perfusion student
   c. Clinical perfusionist
2. Years of clinical experience:
   a. <1
   b. 1-2
   c. 3-4
   d. >4
3. Years since last traditional ECMO training:
   a. <1
   b. 1-2
   c. 3-4
   d. >4
4. Years of ECMO experience:
   a. <1
   b. 1-2
   c. 3-4
   d. >4
5. I have participated in an ECMO simulation before:
   a. True
   b. False
6. I have experience with the use of protocols:
   a. True
   b. False
7. I have experience using ECMO-specific protocols:
   a. True
   b. False

Subjective data

0 = Strongly disagree
5 = Strongly agree

1. I am familiar with the purpose of ECMO:
   0 1 2 3 4 5
2. I believe the use of simulations are necessary for ECMO management
   0 1 2 3 4 5
3. I believe the use of protocols are necessary for ECMO management
   0 1 2 3 4 5
4. I feel confident managing a patient on ECMO
   0 1 2 3 4 5

Figure 1. Pre-Simulation Survey.

All participants were exposed to three different simulation trials. Within each trial, they were required to complete all five tasks shown in the video. Each task was presented via PowerPoint slides that provided a case scenario directing them to complete a specific task. All three trials started with a circuit set-up and priming PowerPoint slide, but the remaining tasks were presented randomly. The subjects were timed on how long it took them to complete each task, evaluated for errors, and the number of times they referred to the protocols was also documented. Participants were evaluated by two researchers who were perfusion students.

The circuit used in the simulation consisted of a Maquet Quadrox I adult oxygenator (Maquet Cardiopulmonary GmbH, Rastatt, Germany), roller head pump, and 3/8-inch polyvinyl chloride tubing. Plastic stop-cocks to place on 3/8 × 3/8 luer connectors, non-luer tubing connectors, oxygen filters, soft-shell collection bags, Plasmalyte prime bags filled with water, and a "Y" spike line were used for the circuit design (Figure 2). Extra safety devices were not used for simplicity purposes. A mannequin was also incorporated to simulate a real patient. An arterial and venous line was connected by a 3/8″ × 3/8″ connector and was tucked inside the mannequin's chest.

During the first simulation trial, the participants were given the basic circuit design to reference (Figure 2). The various tasks were shown via PowerPoint and the researchers guided the perfusion and non-perfusion participants through the tasks when asked for. After completing the 1st trial, they were given five separate protocols to look over outside of the room for 5 minutes, while the researchers cleaned the laboratory in preparation for the 2nd trial (Figure 3).

For the 2nd trial, the student was presented with case scenarios via PowerPoint in a random order with the exception of the circuit set-up and priming, which were shown first. The participants could reference the protocols at any given time throughout the trial. After completing all five tasks, they were led out of the room for 5 minutes and were given the option to look over the protocols again while the researchers cleaned the laboratory for the next trial. The 3rd trial was a repeat of the 2nd trial.

The statistical analysis was completed with a statistician and the Wilcoxon signed-rank test. The test was used to compare the different simulation trials based on how long it took them to complete each task, the number of errors, the number of times subjects referred to the protocols, and the survey questions. Perfusion students and non-perfusion students were also compared. A p-value of $<.05$ indicates significant data for a power of 85%.

RESULTS

All 21 participants completed the study. None of the participants were excluded from the study because of the exclusion criteria. The results for the perfusion and non-perfusion students are included in the tables. The median for each variable was used because of extreme scores included in the data. For the perfusion student's circuit set-up

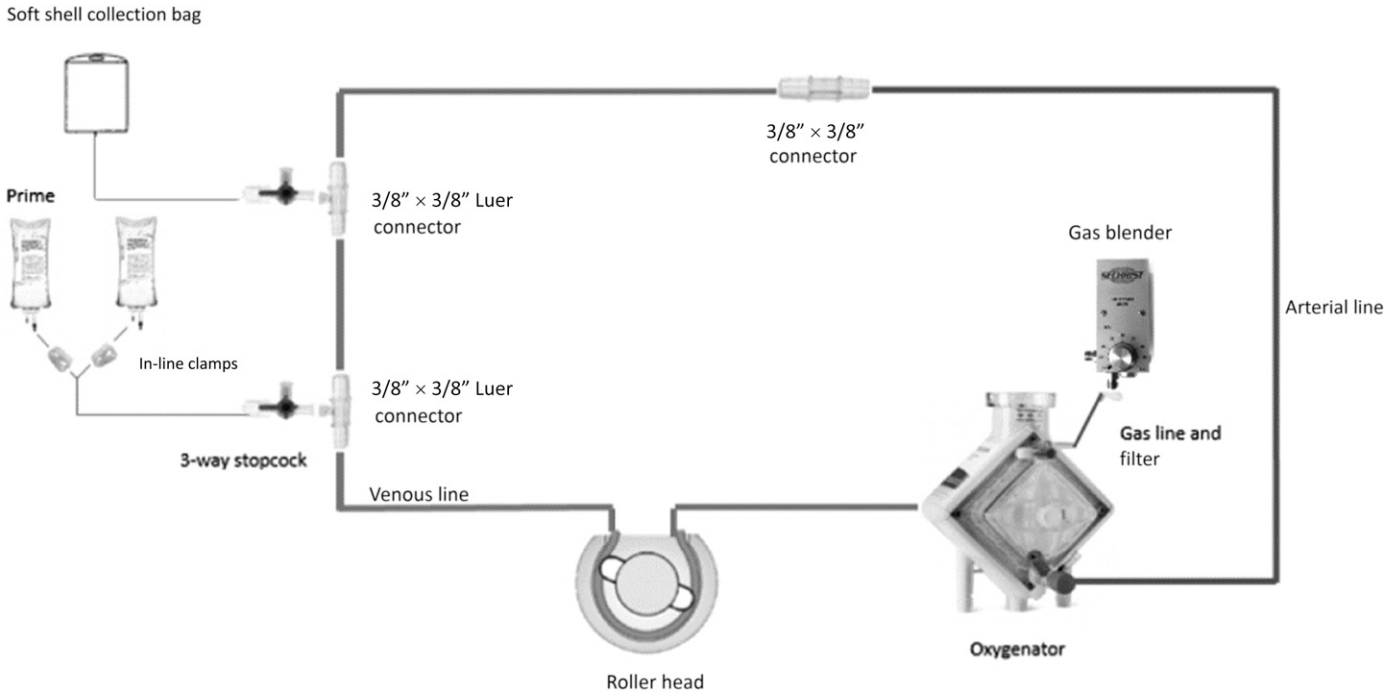

Figure 2. Circuit Design.

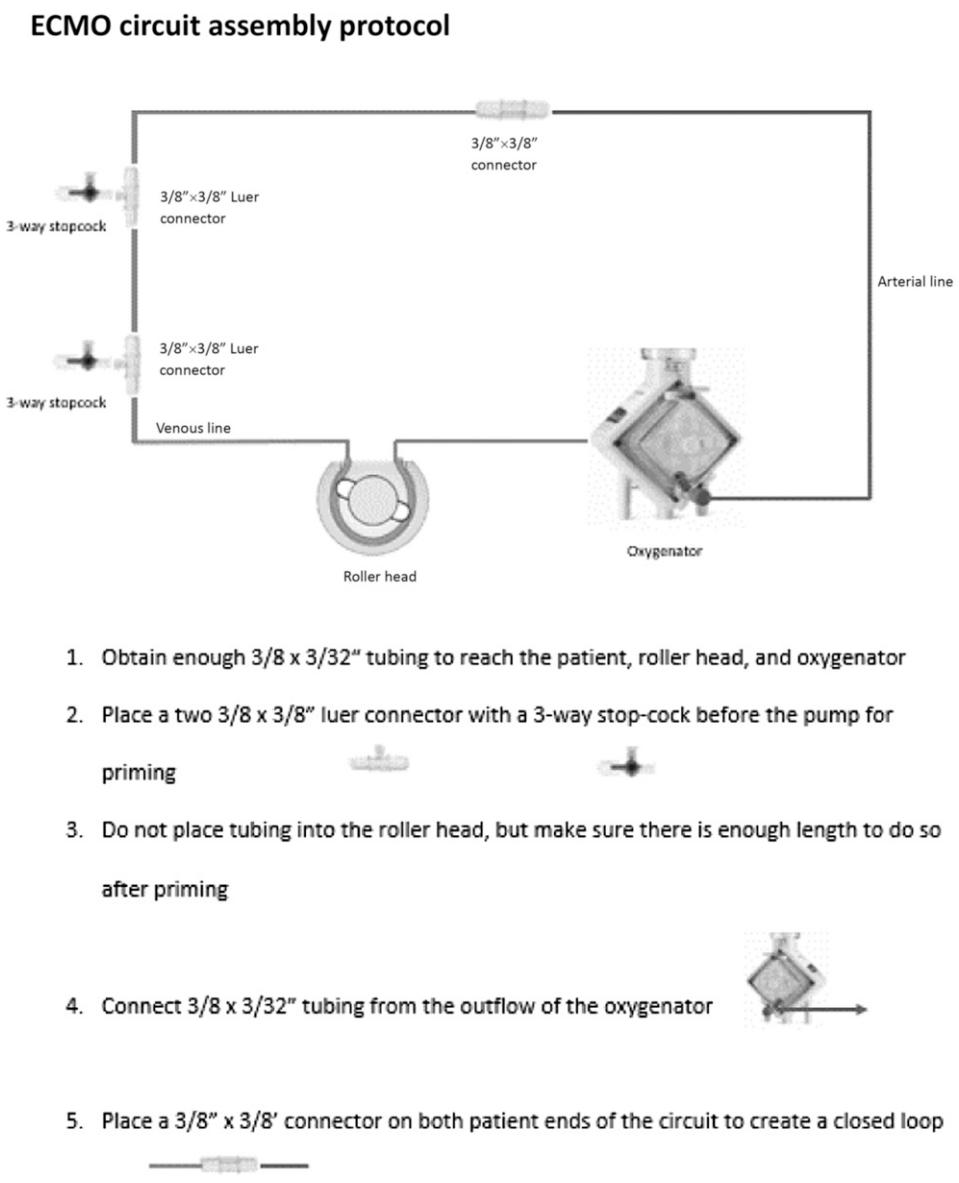

Figure 3. ECMO Circuit-Assembly Protocol.

(Table 1), the data indicated significant results when comparing the 1st and 2nd trial with a *p*-value of .02. When comparing the two trials for errors, there were no significant results, but there was a slight decrease in errors with a *p*-value of .28. The 2nd and 3rd trials were also compared with respect to time and provided significant results with a *p*-value of .001.

The data may suggest that simulations can minimize the time it takes to set-up an ECMO circuit with fewer errors. To analyze the effectiveness of protocols, the number of times participants referred to the protocols was recorded. No significant results were produced; however, having protocols may have played a role in the decrease in time and errors participants displayed during the 2nd and 3rd trials.

The priming trials (Table 2) indicated significant results when the 1st trial was compared with the 3rd trial (.02). This may suggest that the repeated simulations may decrease the time to manage ECMO. The participants completed the 1st trial in less time compared with the 2nd trial; however, it did not produce significant results. The number of times participants referenced the protocols slightly decreased from the 2nd to the 3rd trial, which may indicate that they could rely on them less by the 3rd.

There were no significant results associated with the time it took to complete the oxygenator change between the different trials, but there was a slight decrease by the 3rd trial (Table 3). There were also no significance results pertaining to the number of errors and protocol references in the data. Most participants expressed the oxygenator change task was the most difficult of all the tasks.

The pump change (Table 4) provided significant results when comparing the 1st vs. 3rd trial (.0098). There was a

Table 1. Perfusion student's circuit set-up data.

Circuit Set-up Variables	Median	Standard Deviation	*p*-Value
1st trial time	218 seconds	52.95	–
2nd trial time	127 seconds	51.81	–
3rd trial time	101 seconds	45.99	–
2nd vs. 1st time	−74 seconds	71.31	.02
3rd vs. 1st time	−88 seconds	52.88	.001
1 st trial errors	1	.94	–
2nd trial errors	0	.69	–
3rd trial errors	0	.4	–
2nd vs. 1st errors	−1	1.04	.28
3rd vs. 1st errors	−1	1.1	0
2nd trial protocols	1	1.78	–
3rd trial protocols	0	2.15	–
3rd vs. 2nd trial protocols	0	1.75	.45

Table 2. Perfusion student's priming data.

Priming Variables	Median	Standard Deviation	*p*-Value
1st trial time	450 seconds	186.15	–
2nd trial time	356 seconds	259.55	–
3rd trial time	354	145.06	–
2nd vs. 1st time	−92	232.24	.28
3rd vs. 1st time	−182	205.58	.02
1st trial errors	1	1.13	–
2nd trial errors	1	1.22	–
3rd trial errors	1	1.01	–
2nd vs. 1st errors	0	1.36	.53
3rd vs. 1st errors	0	.87	.75
2nd trial protocols	1	3.1	–
3rd trial protocols	1	2.17	–
3rd vs. 2nd trial protocols	−1	1.83	.24

Table 3. Perfusion student's oxygenator change data.

Oxygenator Change Variables	Median	Standard Deviation	*p*-Value
1st trial time	262	135.55	–
2nd trial time	262	82.65	–
3rd trial time	227	67.21	–
2nd vs. 1st time	0	158.95	.98
3rd vs. 1st time	−25	189.34	.41
1st trial errors	1	1.29	–
2nd trial errors	1	1.01	–
3rd trial errors	1	1.08	–
2nd vs. 1st errors	0	1.22	.99
3rd vs. 1st errors	0	1.72	.94
2nd trial protocols	1	2.45	–
3rd trial protocols	0	2.5	–
3rd vs. 2nd trial protocols	0	1.5	.66

Table 4. Perfusion student's tubing change data.

Tubing Change Variables	Median	Standard Deviation	*p*-Value
1st trial time	196	30.52	–
2nd trial time	175	96.15	–
3rd trial time	139	74.69	–
2nd vs. 1st time	−26	97.31	.32
3rd vs. 1st time	−55	80.64	.07
1 st trial errors	1	1.17	–
2nd trial errors	0	.5	–
3rd trial errors	0	1.19	–
2nd vs. 1st errors	−1	1.54	.12
3rd vs. 1st errors	0	1.29	.39
2nd trial protocols	0	2.58	–
3rd trial protocols	0	2.4	–
3rd vs. 2nd trial protocols	0	1.47	.99

Table 5. Perfusion student's pump change data.

Pump Change Variables	Median	Standard Deviation	*p* Value
1st trial time	113	133.2	–
2nd trial time	105	24.41	–
3rd trial time	75	27.63	–
2nd vs. 1st time	−27	130.82	.15
3rd vs. 1st time	−38	120.48	.0098
1st trial errors	1	1.22	–
2nd trial errors	0	.52	–
3rd trial errors	0	.48	–
2nd vs. 1st errors	0	1.04	.31
3rd vs. 1st errors	0	.48	.25
2nd trial protocols	0	1.4	–
3rd trial protocols	0	1.21	–
3rd vs. 2nd trial protocols	0	.47	.25

Table 6. Non-perfusion student's circuit set-up data.

Set-up Change Variables	Median	Standard Deviation	*p*-Value
1st trial time	298	92.08	–
2nd trial time	199	34.1	–
3rd trial time	163	43.39	–
2nd vs. 1st time	−105	83.84	.004
3rd vs. 1st time	−144.5	88.01	.002
1st trial errors	2	1.65	–
2nd trial errors	.5	.7	–
3rd trial errors	0	.7	–
2nd vs. 1st errors	−.5	1.41	.06
3rd vs. 1st errors	−i	1.75	.06
2nd trial protocols	3	1.55	–
3rd trial protocols	2	1.94	–
3rd vs. 2nd trial protocols	−2	2.7	.17

decrease in time when comparing the 1st vs. 2nd trial; it was not statistically significant (.15).

As for the perfusion students, the time it took to complete the tubing change decreased after each trial but did not indicate significant results (Table 5). The students made more errors during the 3rd vs. 2nd trial with little difference in the amount of times the protocols were referenced.

The results for the non-perfusion students also provided significant results throughout the trials. During the circuit set-up (Table 6), the non-perfusion students had a significant decrease in time when comparing the 1st vs. 2nd trial (.004) and 1st vs. 3rd trial (.002). This may indicate that repeated simulation practice decreases the overall time to complete necessary tasks such as setting up the ECMO circuit, which is especially critical for emergent ECMO cases.

For the priming trials (Table 7), the non-perfusion students had shorter times when comparing the 1st vs. 3rd trials (.004). There was also a slight decrease in the amount of errors made during the 2nd and 3rd trials, but were insignificant.

Similar to the perfusion students, the non-perfusion students did not generate any significant results from the oxygenator change trial (Table 8).

There was a significant decrease in time during the pump change (Table 9) when comparing the 1st vs. 3rd trial (.002). There were no significant results associated with the number of errors made, or the times the students referred to the protocols.

During the tubing change (Table 10), the non-perfusion students had two statistically significant results. When comparing the time it took to complete the tubing change, the 1st vs. 3rd trial indicated a significant difference (.0098). Also, there was a significant difference when comparing the errors between the 1st and 3rd trial (.02).

The errors made by the perfusion and non-perfusion students were also evaluated. The perfusion students had significantly less median priming errors during the 1st trial and tubing change errors during the 2nd trial compared with the non-perfusion students (p = .03 and .03, respectively). This may indicate that perfusion students may be better equipped to manage patients on ECMO with their background in perfusion.

The pre- and post-survey from both groups generated significant results from the simulations and use of protocols. The perfusion group (Table 11) had an increase in confidence managing patients on ECMO after the simulations (p = .047). The non-perfusion students (Table 12) had an

Table 7. Non-perfusion student's priming data.

Priming Variables	Median	Standard Deviation	p-Value
1st trial time	606.5	235.18	–
2nd trial time	544.5	136.06	–
3rd trial time	398	151.81	–
2nd vs. 1st time	−44.5	247.23	.19
3rd vs. 1st time	−201	275.09	.004
1st trial errors	2.5	1.62	–
2nd trial errors	2	1.2	–
3rd trial errors	2	2.06	–
2nd vs. 1st errors	−.5	1.1	.06
3rd vs. 1st errors	−.5	1.72	.47
2nd trial protocols	5	2.78	–
3rd trial protocols	3	3.06	–
3rd vs. 2nd trial protocols	−.5	3.41	.30

Table 8. Non-perfusion student's oxygenator change data.

Oxygenator Change Variables	Median	Standard Deviation	p-Value
1st trial time	425.5	144.67	–
2nd trial time	306	141.25	–
3rd trial time	266	117.4	–
2nd vs. 1st time	−100.5	151.22	.19
3rd vs. 1st time	−150	202.78	.11
1st trial errors	2.5	1.4	–
2nd trial errors	2	1.14	–
3rd trial errors	1.5	1.35	–
2nd vs. 1st errors	0	1.15	.99
3rd vs. 1st errors	−.5	1.34	.62
2nd trial protocols	3	2.46	–
3rd trial protocols	1.5	3.27	–
3rd vs. 2nd trial protocols	0	2.27	.94

Table 9. Non-perfusion student's pump change data.

Pump Change Variables	Median	Standard Deviation	p-Value
1st trial time	192	64.27	–
2nd trial time	145	80.21	–
3rd trial time	115	26.05	–
2nd vs. 1st time	−30	90.36	.19
3rd vs. 1st time	−50.5	63.59	.002
1 st trial errors	0	1.07	–
2nd trial errors	0	.48	–
3rd trial errors	0	.42	–
2nd vs. 1st errors	0	1.16	.75
3rd vs. 1st errors	0	1.26	.5
2nd trial protocols	1.5	2.38	–
3rd trial protocols	.5	1.78	–
3rd vs. 2nd trial protocols	−.5	1.65	.47

Table 10. Non-perfusion student's tubing change data.

Tubing Change Variables	Median	Standard Deviation	p-Value
1st trial time	321.5	124.52	–
2nd trial time	276.5	68.31	–
3rd trial time	213.5	46.94	–
2nd vs. 1st time	−3	124.3	.70
3rd vs. 1st time	−92	129.47	.0098
1st trial errors	1	1.27	–
2nd trial errors	1.5	1.27	–
3rd trial errors	0	.71	–
2nd vs. 1st errors	0	.67	.99
3rd vs. 1st errors	−1	1.15	.02
2nd trial protocols	3	2.25	–
3rd trial protocols	1	3.1	–
3rd vs. 2nd trial protocols	−.5	2.55	.47

Table 11. Perfusion student's survey data.

Variables	Median	Standard Deviation	p-Value
Pre-familiar purpose	5	.69	–
Post-familiar purpose	5	1.21	–
Post vs. pre-purpose	0	.7	.99
Pre-simulation necessary	5	.47	–
Post-simulation necessary	5	.4	–
Post vs. pre-simulation	0	.54	.99
Pre-protocol necessary	5	.4	–
Post-protocol necessary	5	.4	–
Post vs. pre-protocol	0	.63	.99
Pre-confident	2	1.33	–
Post-confident	3	1.54	–
Post vs. pre-confident	1	1.26	.04

Table 12. Non-perfusion student's survey data.

Variables	Median	Standard Deviation	*p*-Value
Pre-familiar purpose	.5	1.65	–
Post-familiar purpose	3.5	1.07	–
Post vs. pre-purpose	3	2.16	.04
Pre-simulation necessary	4	.88	–
Post-simulation necessary	5	.67	–
Post vs. pre-simulation	1	1.03	.08
Pre-protocol necessary	3.5	.99	–
Post-protocol necessary	5	.84	–
Post vs. pre-protocol	1.5	1.64	.29
Pre-confident	0	1.23	–
Post-confident	3	1.34	–
Post vs. pre-confident	2	1.79	.02

increase in feeling more familiar with the purpose of ECMO after the simulations ($p = .04$) and an increase in confidence for managing patients on ECMO ($p = .02$).

DISCUSSION

With the data, it can be concluded that ECMO simulations and protocols improve patient safety by strengthening the skills required for rapid management, fewer errors, and higher levels of confidence during the management of ECMO and catastrophic events. There was a decrease in time from the 1st to the 2nd trial ($p = .02$) for perfusion students and a decrease from the 1st to the 3rd ($p = .001$) for the circuit set-up simulation. There was a decrease in priming time from the 1st to the 3rd trial ($p = .02$) and for the pump change ($p = .0098$) for the perfusion students as well. The non-perfusion students had a significant decrease in time for the circuit set-up from the 1st to the 2nd ($p = .004$) and the 1st to the 3rd trials ($p = .002$). There was a decrease in time for priming ($p = .004$), the pump change ($p = .002$), and tubing change ($p = .0098$), and errors during the tubing change ($p = .02$) for the non-perfusion students. When comparing the groups, the perfusion students had fewer errors when priming during the 1st trial and the 2nd trial for the tubing change. Both groups felt more confident after the simulations and the non-perfusion students specifically felt that they were more familiar with the purpose of ECMO after the simulations.

There were several limitations in this study. During the 2nd and 3rd trials when the protocols were given, a few participants barely used them, which may not accurately assess the strength of having protocols for ECMO. This may be because of participants relying on their own memory from the previous trials, or the fact that they could depend on the researchers for help. The researchers knew which group each participant was categorized in, and there may have been a bias with how much help was offered to non-perfusion students vs perfusion students. The perfusion students have a basic understanding of extracorporeal circulation and the researchers may have provided less help to them by knowing that.

Also, all three trials were performed immediately after one another, which may have made it easier to improve because the tasks were still fresh in their minds by the 3rd trial. It may be possible that with greater time between the simulation trials, the participants may show slight improvement when having to do them again.

The circuit design was basic without the safety devices for simplicity purposes, but typically, circuits in the clinical setting can be more complex. The study did not take into account sterility as well, which is very important in avoiding infection.

Last, the simulation was performed in the UNMC perfusion simulation laboratory, a low-pressure environment, which is unrealistic when managing catastrophic events on a patient on ECMO (8). A simulation environment similar to the hospital setting with many other health-care professionals may provide the greater sense of urgency needed during high-risk events that require an oxygenator, tubing, and pump changes to save a patient's life.

There were several common errors that were made by the participants in this study. Errors that were made included overpressurizing the circuit, not priming the oxygenator correctly, forgetting to connect the gas filter to the gas line, and not understanding the orientation of stopcocks.

After conducting this study, it was identified that a few key factors should be addressed in future studies: having a selective study that assesses the strengths of ECMO simulations separate from the protocols to understand the value of each individually; conducting the study in a more realistic environment with more materials and having a team of people present in the room; spacing out the trials to incorporate time as a major factor in how simulations should be conducted; and designing the study as a double-blind study may alleviate any bias associated with the researchers knowing which groups the participants were in.

In conclusion, the results demonstrated that simulations and written protocols have a positive effect on patient safety. There were several purposes to this study, which included determining how protocols affect the outcome of patient safety, determining how simulation practice affects the outcome of patient safety, determining whether protocols and simulation practice can reduce the amount of time to correct a catastrophic event, emphasizing the importance of incorporating simulation practice in perfusion education and other allied health professional education, and determining the necessity of ECMO protocols at every practicing institution.

It is fair to say that simulation-based medical education is increasingly recommended as an educational strategy and for improving patient safety. Preventable adverse events is the leading cause of death in the United States. High-risk fields require intensive training that prepares practitioners

to handle any challenging situation. In comparison, the aviation industry has decades of safety challenges using simulation based training. This method has been adapted for anesthesiology; other high-risk fields such as nuclear power and the military; and various medical fields including emergency and trauma medicine, intensive care, and cardiac arrest response teams (9). Didactic training alone is not adequate for any perfusionist, respiratory therapist, nurse, or health-care professional to manage a patient on ECMO, let alone a catastrophic event that can be fatal to a patient.

ECMO indications and usage has progressed over the years and has become a valuable tool in care for not just pediatrics but also for adults. Incorporating simulations and protocols as a standard practice not only enhances confidence in health-care professionals but also enables overall better patient care.

ACKNOWLEDGMENTS

We would like to thank our Program Director, David W. Holt, MA, CCT, for providing us with the tools and education for cardiopulmonary bypass (CPB) and extracorporeal membrane oxygenation (ECMO); Benjamin Greenfield, MPS, CCP, LLP, our Adjunct Assistant Professor and Clinical Coordinator; Michael J. Huckabee, MPAS, PhD, PA-C; Christine Swets, our Clinical Perfusion Education Program Coordinator; the Clinical Perfusion Education Program Class of 2018; and the other allied health programs at the University of Nebraska (Physician Assistant Program, Pharmaceutical Sciences Graduate Program, and Physical Therapy Program).

REFERENCES

1. Makary MA, Daniel M. Medical error—the third leading cause of death in the US. BMJ. 2016;353:I2139. doi:10.1136/bmj.i2139.
2. Extracorporeal Life Support Organization Registry Report. 2017. Available at: https://www.elso.org/Portals/0/Files/Reports/2017/International Summary January 2017.pdf.
3. Kim G, Koh Y, Lim C, et al. The effects of an improvement of experience and training in extracorporeal membrane oxygenation management on clinical outcomes. Korean J Intern Med. 2018;33:121–9.
4. Rutherford-Hemming T, Kelsey N, Grenig DL, et al. Multisite single-blinded randomized control study of transfer and retention of knowledge and skill between nurses using simulation and online self-study module. Simul Healthc. 2016;11:264–70.
5. Sistino JJ. The case for a single entry level into the perfusion profession by 2020. J Extra Corpor Technol. 2014;46:127–9.
6. Extracorporeal Life Support Organization. Extracorporeal Life Support Organization Adult Respiratory Failure Guidelines, 1.4. 2017: 1–32.
7. Darling E, Searles B. Oxygenator change-out times: The value of a written protocol and simulation exercises. Perfusion. 2010;25:141–3.
8. Aggarwal R, Mytton OT, Derbrew M, et al. Training and simulation for patient safety. Qual Saf Health Care. 2010;19(Suppl 2):I34–43.
9. Bilotta FF, Werner SM, Bergese SD, et al. Impact and implementation of simulation-based training for safety. Scientific World J. 2013;2013:6.