Telepresent mechanical ventilation training versus traditional instruction: a simulation-based pilot study

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ABSTRACT

Background Mechanical ventilation is a complex topic that requires an in-depth understanding of the cardiopulmonary system, its associated pathophysiology and comprehensive knowledge of equipment capabilities.
Introduction The use of telepresent faculty to train providers in the use of mechanical ventilation using medical simulation as a teaching methodology is not well established. The aim of this study was to compare the efficacy of telepresent faculty versus traditional in-person instruction to teach mechanical ventilation to medical students.
Materials and methods Medical students for this small cohort pilot study were instructed using either in-person instruction or telementoring. Initiation and management of mechanical ventilation were reviewed. Effectiveness was evaluated by pre- and post-multiple choice tests, confidence surveys and summative simulation scenarios. Students evaluated faculty debriefing using the Debriefing Assessment for Simulation in Healthcare Student Version (DASH-SV).
Results A 3-day pilot curriculum demonstrated significant improvement in the confidence (in person $P<0.001$; telementoring $P=0.001$), knowledge (in person $P<0.001$; telementoring $P=0.022$) and performance (in person $P<0.001$; telementoring $P<0.002$) of medical students in their ability to manage a critically ill patient on mechanical ventilation. Participants favoured the in-person curriculum over telepresent education, however, resultant mean DASH-SV scores rated both approaches as consistently to extremely effective.
Discussion While in-person learners demonstrated larger confidence and knowledge gains than telementored learners, improvement was seen in both cases. Learners rated both methods to be effective. Technological issues may have contributed to students providing a more favourable rating of the in-person curriculum.
Conclusions Telementoring is a viable option to provide medical education to medical students on the fundamentals of ventilator management at institutions that may not have content experts readily available.

INTRODUCTION

Mechanical ventilation is a complex topic that requires an in-depth understanding of the cardiopulmonary system, its associated pathophysiology and a comprehensive knowledge of the capabilities of the mechanical ventilator.[1] If mechanically ventilated patients are mismanaged, iatrogenic complications may occur, including ventilator-associated pneumonia, barotrauma and pneumothorax.[2 3] As the US population ages, the incidence and duration of patients on mechanical ventilation is expected to increase.[4] Mechanical ventilation is taught in a variety of ways. This may include clinical training at the bedside, self-guided training, training on simulators and training in virtual environments.[5–7] There is no single well-established gold standard curriculum for the training of mechanical ventilation. Learners also face trainee work hour restrictions, medicolegal concerns, the significant shortage of intensivists in the USA,[8] and the increasing volume and complexity of critical care patients. This ultimately results in limited time at the bedside to learn key concepts and develop autonomy in mechanical ventilation management for many residents.[9]

Medical simulation is a proven training methodology in medical education, including in the instruction of mechanical ventilation.[10–13] Yee *et al* reported that a 12-hour simulation-based mechanical ventilation boot camp significantly improved the confidence, knowledge and performance of first-year residents in the management of the ventilated patient.[12] Similarly, Spadaro *et al* have demonstrated improved knowledge and skills of anaesthesia residents who were taught acute respiratory distress syndrome (ARDS) management with manikin-based simulation, in contrast to computer-based simulation. Their researchers found that the manikin-based learners had increased key action scores and global rating scores.[13] The use of telepresent faculty to train providers in the use of mechanical ventilation using medical simulation, however, is not well established. There is limited research exploring the use of mechanical ventilation training using telemedicine technology, especially in undergraduate medical education. Training at this level can help lessen the steep learning curve of new residents and could improve patient safety, as many interns call in the intensive care unit (ICU) and are potentially responsible for these patients.

The objective of this pilot curriculum was to familiarise medical students with common modes of ventilation, common aetiologies of ventilator alarms and subsequent management strategies, including using the ventilator as a diagnostic tool. The aim of this study was to compare the efficacy of telementoring versus traditional in-person instructions in the training of mechanical ventilation. Additionally, we sought to identify medical students' perceptions of the effectiveness of faculty instruction for each method of instruction.

Figure 1 Training environment displaying mechanical ventilator connected to the ASL 5000 breathing simulator and high-fidelity manikin simulator. Clinical monitor demonstrates vital signs, rhythm strip and arterial blood gas.

MATERIALS AND METHODS

Study location and equipment

This study was performed at a tertiary care university-affiliated teaching hospital simulation lab from September 2016 to April 2017. Human-patient simulators in ICU beds were intubated and connected to a mechanical ventilator (Covidien Puritan Bennett 840, Mansfield, Massachusetts, USA). The mechanical ventilators were connected to ASL 5000 Breathing Simulators (IngMar Medical, Pittsburgh, Pennsylvania, USA). The breathing simulators were used to modify the pulmonary mechanics in real time based on the actions of the students. Each of the human patient simulators were connected to a cardiopulmonary monitor to reflect real time changes in the patients' vital signs based on the actions of the medical student (figure 1). Chest X-rays, ECGs and arterial blood gas measurements were displayed in the monitor on request of the participants by the on-site simulation technician. For the telementoring set up, an iPad (Apple, Cupertino, California, USA) positioned in front of the instructor was connected via the FaceTime (Apple, Cupertino, California, USA) application to a second iPad mounted to the ceiling and suspended at an angle above the mechanical ventilator. This allowed the telepresent instructor to view changes made by the student to the ventilator. The ceiling-mounted iPad was hard-wired via HDMI to a wall-mounted television to facilitate both audio and visual communication between the instructor and the medical student. A camera (CAE Learning Space Saint-Laurent, Quebec, Canada) mounted to the wall adjacent to the mechanical ventilator was used to visualise the actions of the students.

Curriculum development and outline

A 3-day curriculum was developed to educate third-year and fourth-year medical students on the initiation and management of mechanical ventilation. Our study model used either traditional in-person instruction or telepresent faculty. This study required approximately 40 hours of initial preparation for the development of the curriculum, evaluation tools and simulation cases with accompanying didactic postsimulation lectures, as well as the establishment of a telecommunication system. After initial curriculum development, all participating staff performed a rehearsal simulation to ensure the cases were executed without difficulties and that all equipment was functioning appropriately. This required an additional 5 hours of preparation. This study was scheduled for 5 hours over 3 days. Overall, total preparation and execution of the curriculum took approximately 50 hours to execute the project for one single student session. This curriculum was offered six times over a 7-month period.

The curriculum consisted of four parts: preintervention evaluation, independent study, the intervention phase and postintervention evaluation. Cognitive tests, critical action checklists and confidence surveys were used to assess the students. These assessments were identical in the preintervention and postintervention evaluations. The faculty were evaluated after each formative simulation by students who individually completed a validated faculty debriefing assessment tool (Debriefing Assessment for Simulation in Healthcare Student Version, DASH-SV).[14] Below is the curriculum outline for the 3-day programme (table 1).

Participants, faculty and staff

Third-year and fourth-year medical students from two medical schools were invited to participate in the curriculum during their rotations as an enrichment opportunity at the institution from September 2016 to April 2017. Participants were given a letter of information and option to participate in the education and not the data collection. Students signed individual informed consent to participate. Each medical student was assigned to either in-person or telementoring cohorts based on their month of participation. One to two faculty members were assigned to each station for debriefing, which included attendings, chief residents and a respiratory therapist, depending on their availability. Each station required a simulation technician for all 3 days of the curriculum to operate the simulators, present clinical information and establish connections for tele-education when applicable.

Preintervention evaluation

The preintervention evaluations assessed baseline knowledge and confidence on two simulated scenarios, including AMS from a drug overdose and dynamic hyperinflation (also known as air trapping). Participants completed a pretest confidence survey and a 20-question multiple-choice test. Each station accommodated one medical student at a time. Students transitioned through the stations based on availability. The medical students were rated using a predetermined checklist of critical actions. Feedback was not given to the participants during the preintervention phase. The critical actions used for the dynamic hyperinflation are provided below.

Confidence survey

1. Very uncomfortable
2. Somewhat uncomfortable
3. Neutral
4. Somewhat comfortable
5. Very comfortable

1. How comfortable do you feel distinguishing between the different modes of ventilation?
2. How comfortable do you feel initially choosing a mode of ventilation?
3. How comfortable do you feel addressing an alarming ventilator?
4. How comfortable do you feel identifying causes of an elevated peak airway pressure?

Table 1 Curriculum outline

Study day	Activity	Details	Time (min)
1	Pretesting evaluation	Pretest confidence survey	5
		Pretest cognitive multiple-choice exam	25
		Simulated cases and evaluation using critical actions checklist Case #1: AMS secondary to overdose Case #2: Dynamic hyperinflation (auto-PEEP)	10 (5 per case)
	Intervention phase	Bedside debriefing (in person or telementoring) by faculty and respiratory therapist	45
		DASH-SV completed by students	5
	Independent study (take-home)	Scholarly articles assigned for asynchronous education	90
2	Additional curriculum and educational intervention	Participation in two cases by medical students	20 (10 per case)
		Debriefing by faculty and respiratory therapist which included review of the topics: ► Assessment of the intubated patient ► Applying initial ventilator settings ► Interpreting and correcting ventilator alarms ► Understanding the pathology of dynamic hyperinflation	60 (30 per case)
		DASH-SV completed by students	5
3	Post-testing evaluation	Post-testing confidence survey	5
		Post-testing cognitive multiple-choice exam	25
		Postcurriculum survey	5
		Simulated cases and evaluation using critical actions checklist Case #1: AMS secondary to overdose Case #2: Dynamic hyperinflation (auto-PEEP)	

AMS, altered mental status; DASH-SV, Debriefing Assessment for Simulation in Healthcare Student Version; PEEP, positive end expiratory pressure.

5. How comfortable do you feel identifying causes of an elevated plateau pressure?
6. How comfortable do you feel managing the mechanical ventilation of a patient with ARDS?
7. How comfortable do you feel managing the mechanical ventilation of a patient with an acute exacerbation of chronic obstructive pulmonary disease (COPD)?
8. How comfortable do you feel managing the mechanical ventilation of a patient with an acute exacerbation of asthma?

Critical actions checklist for dynamic hyperinflation

1. Identifying air trapping: yes or no
2. Identify decreased lung compliance by increased plateau pressure: yes or no
3. Taking at least two corrective actions to decrease air trapping (decrease respiratory rate, decrease inspiratory time, bronchodilators, increase extrinsic positive end expiratory pressure): yes or no
4. Re-evaluate the patient after vent changes: yes or no
5. Document ventilator setting changes: yes or no

After the initial assessment, medical students were provided with reading material for independent study. The material consisted of three review articles that took approximately 90 min to complete.

Educational intervention

The intervention phase comprised two 40-min scenarios that occurred on two separate occasions: the same day immediately following pretesting evaluation and 7 days after pretesting. As noted above, the students were assigned to receive the intervention phase in person or via tele-education. The curriculum covered in each session did not vary between the two modalities. Medical students were divided into groups of two to four participants for each station. Participants were given a brief clinical description and expected to manage the ventilated patient for the first 5 min. Telepresent faculty were not able to manipulate the ventilator, and instead relied on verbal instruction to instruct students how to assess peak and plateau pressures, as well as how to make changes on the ventilator's interface. Afterwards, faculty had approximately 30 min to conduct an in-person or tele-education debriefing. The debriefing included individualised assessment and feedback, as well as summation of clinical teaching points. At the conclusion of each formative debriefing, students anonymously completed a DASH-SV form evaluating the quality of faculty instruction.

Postintervention evaluation

During the postintervention stage, participants individually underwent the same two scenarios as the preintervention stage, with faculty grading their performance using the same predetermined critical action checklists. This occurred 14 days after the initial preintervention evaluation. At the conclusion of the scenarios, participants completed the postintervention cognitive multiple-choice test and confidence survey, as well as a postcurriculum survey. This survey was administered soliciting feedback on areas of strength and potential improvement of the curriculum using a 5-point Likert Scale.

Statistical analysis

Demographic data were summarised by intervention group (in person or tele-education) using percentages. Study assessments were measured as a mean score with SD for all students in each study group. Study outcomes (multiple-choice knowledge test scores, summed confidence score and case study scores) were assessed at pre-education and posteducation intervention time points and the change was determined as postintervention outcome value minus preintervention outcome value. Confidence scores were calculated as the sum of 12 ordinally measured questions. The primary study objective was to estimate the mean change in knowledge attainment for each teaching group as determined by the difference in the number of correct answers out of 20 knowledge-based questions pretraining and

Table 2 Baseline characteristics and outcomes

	Study group						
	In person			Tele			
	n	Mean (SD)	P value	n	Mean (SD)	P value	P value*
Demographics and experience							
Gender							
Female	5 (29.4%)			4 (25.0%)			
Male	12 (70.6%)			12 (75.0%)			
Age (years)		25.8 (3.8)			26.0 (3.56)		
Education level							
MS3 - Third-year medical student	8 (47.1%)			10 (62.5%)			
MS4 - Fourth-year medical student	9 (52.9%)			6 (37.5%)			
Previous ventilator course	2 (11.8%)			3 (18.8%)			
Multiple-choice test							
Preintervention score (out of 20)	17	7.7 (1.84)		16	8.0 (1.93)		
Postintervention score (out of 20)	17	12.5 (3.04)		15	10.5 (3.07)		
Change in score	17	4.8 (3.88)	<0.001	15	2.6 (3.54)	0.022	0.203
Confidence survey							
Preintervention confidence (out of 8)	17	14.8 (3.77)		16	15.4 (3.61)		
Postintervention confidence (out of 8)	17	40.2 (6.98)		15	40.9 (7.26)		
Change in confidence	17	25.4 (6.96)	<0.001	15	25.2 (8.65)	0.001	0.845
AMS case							
Preintervention score (out of 5)	17	0.8 (0.83)		16	1.1 (0.44)		
Postintervention score (out of 5)	17	4.4 (0.61)		15	3.8 (1.01)		
Change in score	17	3.6 (1.28)	<0.001	15	2.7 (1.03)	0.001	0.049
The instructor set the stage for an engaging learning experience		6.7 (0.46)			6.1 (0.93)		0.001
The instructor maintained an engaging context for learning		6.9 (0.36)			6.3 (0.75)		0.001
The instructor structured the debriefing in an organised way		6.7 (0.52)			6.3 (0.79)		0.039
The instructor provoked in-depth discussions that led me to reflect on my performance		6.8 (0.59)			5.8 (1.09)		<0.001
The instructor identified what I did well or poorly and why		6.6 (0.70)			5.8 (1.22)		0.001
The instructor helped me see how to improve or how to sustain good performance		6.9 (0.29)			6.0 (0.84)		<0.001
Auto PEEP case							
Preintervention score (out of 5)	17	0.2 (0.53)		16	0.1 (0.34)		
Postintervention score (out of 5)	17	3.9 (1.45)		15	2.9 (2.0)		
Change in score	17	3.7 (1.45)	<0.001	15	2.7 (1.87)	0.002	0.142
The instructor set the stage for an engaging learning experience		6.7 (0.52)			6.0 (0.91)		0.001
The instructor maintained an engaging context for learning		6.8 (0.43)			6.1 (0.81)		<0.001
The instructor structured the debriefing in an organised way		6.7 (0.52)			6.2 (0.84)		0.016
The instructor provoked in-depth discussions that led me to reflect on my performance		6.5 (0.90)			6.0 (0.98)		0.008
The instructor identified what I did well or poorly and why		6.3 (0.93)			5.7 (1.19)		0.022
The instructor helped me see how to improve or how to sustain good performance		6.7 (0.63)			6.2 (0.80)		0.004

*P value comparing the two study groups.
AMS, altered mental status, PEEP, positive end expiratory pressure.

post-training interventions. The ranked changes in knowledge attainment were tested within each study group for equality to zero via Wilcoxon signed-rank tests. Between-group comparisons for equality in rank change were determined via exact Mann-Whitney U tests. Finally, curriculum assessments measured ordinally from 1 (extremely ineffective) to 7 (extremely effective) were summarised by study group and question using mean and SD descriptive statistics. Exact Mann-Whitney U tests were employed to compare each study group for rank equality. All statistical testing was two-sided with P<0.05 considered statistically significant. Statistical analyses were performed using SPSS V.24.0 (IBM, Armonk, New York, USA) software.

RESULTS

Demographics

Thirty-three medical students participated in this study. Eighteen were third-year medical students (54.5%), and 15 were in their fourth year (45.4%). Nine students were female, and 24 were male. The mean and median ages of the students were 25.8 years and 25 years for the in-person group and 26.0 years and 25.5 years for the telementored group, respectively. Five students (15%) had prior exposure to ventilator management education, including two students in the in-person curriculum and three students in the telementored groups. All students were present for the entirety of the study. Seventeen students participated in the in-person sessions and 16 students participated in the telementoring (table 2).

Confidence assessment

Participants felt more confident with ventilator management, regardless of education modality, based on their preintervention and postintervention confidence surveys (table 2).

There was a statistically significant confidence increase for all questions, with a mean preintervention score of 14.8 (in person) and 15.4 (telementored), and a postintervention score of 40.2 (in person) with a respective P value of <0.001 and 40.9 (telementoring) with a respective P value of 0.001. Mean confidence gain was 25.4 (in person) and 25.2 (tele-education) with a P value of 0.845, indicating that there was no statistically significant difference between the groups.

Cognitive knowledge assessment

Cognitive knowledge between the identical preintervention and postintervention 20-question multiple-choice tests increased significantly in both the telementored (P value 0.022) and in-person teaching modalities (P value <0.001) (table 2). The preintervention scores were 38.5% (9.20%) and 40% (9.65%) in the in-person and telementored groups, respectively. The postintervention mean (SD) was 62.5% (15.20%) for the in-person group and 52.5% (15.35%) in the telementored group. The mean (SD) change in test score was 24% (19.40%) (in person) and 13% (17.70%) (telementored) with a P value of 0.203, which indicated that there was no statistically significant difference between the teaching modalities.

Clinical performance and critical actions assessment

The increase in critical actions performed after intervention was significantly higher for the in-person and telementored groups, for both AMS (P<0.001 in person, P=0.001 telementored) and the dynamic hyperinflation cases (P<0.001 in person, P<0.002 telementored)(table 2).

The AMS case had a mean of 0.8 (in person) and 1.1 (telementored) critical actions met during preintervention. Postintervention scores were 4.4 and 3.8 for the in-person and tele-education groups, respectively. The mean (SD) change in test scores was 3.6 (1.28) (in person) and 2.7 (1.03) (telementored) with a P value of 0.049, indicating that there was a statistically significant difference between the teaching modalities, favouring in-person instruction.

In the preintervention dynamic hyperinflation case, the mean critical actions met for the in-person group was 0.2 and for the telementored group 0.1, with mean postintervention critical actions scores of 3.9 and 2.9 for in person and telementored groups, respectively. The mean (SD) change in test scores was 3.7 (1.45) (in person) and 2.7 (1.87) (telementored) with a P value of 0.142, indicating that there was no statistically significant difference between the teaching modalities.

Curriculum assessment

The faculty debriefing assessment was significantly higher for the in-person group for each question for each ventilation scenario, however, both methods were deemed effective via median scoring (table 2).

Technical problems

The telementored group occasionally encountered technological issues, such as freezing of the livestream video, students standing in front of the monitor and dropped calls due to poor internet connectivity. These instances were not counted or recorded.

DISCUSSION

This study demonstrates that the use of telementoring is an effective conduit to impart the basics of mechanical ventilation on medical students. This 3-day simulation curriculum resulted in an overall increase in competency, knowledge and confidence of medical students who participated in either the in-person or tele-education group. Formal instruction on mechanical ventilation and the pathologies associated with ventilator alarms is profoundly absent and lacks standardisation in medical school curricula. As a result, medical students are entering residency without the knowledge base required to care for critically ill patient populations. With the utilisation of medical simulation and telementoring, many of the obstacles that exist to establish uniform training in these subject matters may be overcome.[15,16] Telementoring allows for content experts to remotely connect to students, saving both time and cost without sacrificing the quality of education. Community hospitals may only have one intensivist in-house at a time, and their clinical duties may preclude teaching. Alternatively, there are also international opportunities for both learning and teaching, and all learners may benefit from reviewing mechanical ventilation management. Developing areas with basic ventilators may still be used diagnostically in patient management with peak and plateau pressure interpretations.

Our goal was to impart knowledge of initiating mechanical ventilation, as well as using the ventilator as a diagnostic tool to critically reason through why the ventilator alarm has been activated. This is in contrast to having students memorise a ventilator's façade, as each ventilator model will have different knobs and buttons. Faculty were able to assess the students' baseline management skills before providing live instruction, which was personalised to their level of existing knowledge and performance. Learning occurred in a safe environment where students were encouraged to ask questions and perform hands-on tasks.

The participant's confidence scores significantly increased after the intervention phase. Interestingly, there was no significant difference between the in-person and tele-education groups. This is likely a result of the minimal knowledge base of the students on entering the study. Therefore, any type of education provided on this subject matter would expectantly increase their level of confidence, regardless of the instructional modality.

Similarly, the participant's knowledge, as assessed with a 20-question multiple-choice test, demonstrated a statistically significant increase in both groups. However, the in-person group participants scored a mean of 2.2 questions higher in post-testing when compared with the tele-education group. Given that the tested material was identical for both groups, one possible explanation is that students from the in-person group had more time to ask questions related to asynchronous reading to ensure understanding because the physically present instructor was able to manipulate the ventilator and demonstrate appropriate management more quickly compared with the telepresent faculty who required a longer time to explain to the students how to manipulate the ventilator.

The performance of the students to manage a simulated mechanically ventilated patient also significantly improved as a result of this study. Students had a statistically significant increase in critical actions for both the AMS and dynamic hyperinflation cases in both the in-person and telementored groups. Overall, the participants met more critical actions during the in-person curriculum versus tele-education. This is likely due to increased efficiency for both the faculty and students in the in-person curriculum. Students were able to directly visualise what modifications should be made on the ventilator and how to interpret subsequent waveforms. This is in contrast to the telementored students, who required additional time to find the appropriate buttons necessary to manipulate the ventilator while the faculty provided verbal instructions on the needed modifications. This improved efficiency for the traditional in-person cohort of students provided additional time for faculty and students to discuss remaining questions to ensure understanding.

There was a statistically significant difference in critical actions met between telementored and in-person students for the AMS case. It was during this case that students were taught mechanical ventilator fundamentals, while the dynamic hyperinflation case focused on pathology identification and management. We postulate that the greatest conceptual learning occurred during the AMS case. As mentioned above, students had additional opportunities to ask questions about basic ventilator operations in an in-person setting. Once fundamental knowledge was established, students were able to apply that knowledge to the more advanced dynamic hyperinflation case.

Students rated the in-person curriculum significantly higher than tele-education using the DASH-SV tool. Similar results have been illustrated in other studies.[17] We postulate this may be multifactorial. It may be more difficult to maintain engagement during telementoring if both teacher and learner are not sharing the same physical space. Debriefers standing beside their students could engage those who appeared to be more withdrawn or hesitant to ensure that global understanding and comprehension were achieved. In comparison, subtle non-verbal cues of confusion or hesitancy may be missed by a telepresent faculty who are only able to see a limited amount of the participant or if the faculty member is trying to visualise multiple learners simultaneously. Additionally, connectivity issues may be frustrating for all parties involved.

There are inherent challenges associated with telementoring, namely technical issues associated with wireless internet utilisation. There were occasional periods where the screens would freeze or there would be a lag in connectivity.

We tried to minimise confounding factors by having one educator assigned to a case. Although additional faculty were used based on availability, the majority of the medical students was taught by the same two educators throughout the duration of the study. Additionally, a respiratory therapist was present during all educational sessions to provide additional feedback. The students were debriefed via tele-education or an in-person faculty member, during which they received feedback and remaining questions were answered. Asynchronous reading material was discussed with the students as time permitted.

Despite these potential downfalls, both methods were deemed effective by learners via mean scoring, with raters giving scores of 6 (consistently effective/very good) and 7 (extremely effective/outstanding). Both confidence and knowledge gains increased in both cases, regardless of the medium used. These results are similar to findings of our previous study, which assessed telementoring versus in-person teaching of emergency medicine residents.[17] This study demonstrated that the conventional curriculum was rated higher, however, both were rated at least 'consistently effective/very good'. These points illustrate that despite internet connectivity issues and potential loss of interpretation of non-verbal cues, telementoring may serve as an efficient and practical method of allowing learners to engage with geographically distant content experts.

Few studies exist in the medical literature that assess mechanical ventilation education for medical students. Even fewer have examined the role of telementoring in this setting. There are several potential causes for this void. The cost of the lung simulator and required associated technology are likely primary limiting factors. Furthermore, there is a significant time commitment for curriculum development and the necessary equipment training.

This study provides the framework for creating a mechanical ventilation curriculum for medical students that integrates the use of telementoring. Telementoring could be a viable option at facilities that lack access to expert faculty. Future study directions may include a curriculum that reviews additional aspects of mechanical ventilation using a randomised design with a control group of traditionally trained students compared with students who have completed a study similar to this to provide more data to support such intensive care curricula.

LIMITATIONS

This was a small pilot cohort from one institution that used a non-validated confidence survey, critical action checklists and multiple-choice tests. We did not survey participants to determine details of their past mechanical ventilation exposure, if they completed the provided reading materials or if they used other sources as supplementation. Some medical students may have been more motivated if mechanical ventilation was relevant to their future desired specialties. Also, as the curriculum progressed, the teaching became more polished and efficient with repetition. We occasionally experienced technical difficulties during the telementoring component as mentioned in the results section; this may have contributed to a lower evaluation from the participants. Statistical testing has the potential for type II error due to reduced sample sizes often encountered in non-confirmatory studies. There was no formal sample size calculation performed due to the pilot nature of the study; hence the potential for underpowering especially in the presence of non-parametrical testing. Lastly, this study demonstrated a short-term learning benefit. Knowledge and skill retention over time is critical, and further studies to evaluate this are required.

CONCLUSION

A 3-day pilot curriculum demonstrated significant improvement in the confidence, knowledge and performance of medical students in their ability to manage a patient on mechanical ventilation using in-person instruction or telementoring. Participants favoured the in-person curriculum over telementoring, however, resultant mean DASH-SV scores rated both approaches as consistently to extremely effective. Telementoring is a viable option to provide medical education to medical students on the fundamentals of ventilator management at institutions that may not have content experts readily available.

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Contributors AC monitored data collection, analysed the data, and drafted and revised the paper. JY designed data collection tools, monitored data collection, analysed the data, and drafted and revised the paper. She is guarantor. JAF cleaned the data, drafted and revised the paper. MDG wrote the statistical analysis plan, cleaned and analysed the data, and revised the paper. AB monitored data collection and revised the paper. JH monitored data collection and revised the paper. DB monitored data collection and drafted and revised the paper. RAA designed data collection tools, analysed the data, and drafted and revised the paper. AC, JY, AB, JH, DB and RAA implemented the trial in the USA.

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