Improving Students' Knowledge and Skills Through a Tele-ICU Clinical Rotation

Karsten J Roberts, Karen K Zumstein, Thomas R Lamphere, Maria Williams, Susan A Powell, Alexa Moran, Brian Kellar, William R Solly, and Margarete Pierce

BACKGROUND: In the course of their education, respiratory therapy students participate in clinical rotations, which are essential to their education. Recently, the number of clinical sites has decreased as some have been eliminated. During the COVID-19 pandemic, schools were challenged to find hospitals to accommodate students due to the risk of infection. Tele-ICU has emerged as a means for staff therapists to assess and monitor patients via remote monitoring systems. We hypothesized that a clinical rotation at a tele-ICU would strengthen students' knowledge of mechanical ventilation, telemedicine, and COVID-19. METHODS: In this study, students completed clinical rotations in a tele-ICU. Students spent two 4-h clinical rotations rounding on 320 ICU beds at 5 hospitals. Under the supervision of experienced therapists, students performed remote patient-ventilator assessments, including review and interpretation of ventilator waveforms, patient-ventilator interaction, arterial blood gases, and chest x-rays. Students completed pre- and post-rotation surveys assessing their confidence managing mechanical ventilation, experience with telemedicine, ARDS, and patients with COVID-19. RESULTS: Mean self-confidence in mechanical ventilation ($P = .001$), assessing waveforms ($P = .001$), and knowledge of ARDS increased after the clinical rotation ($P = .001$). Similarly, reported knowledge related to spontaneous breathing trial protocols ($P = .009$), lung-protective ventilation ($P = .002$), patient care planning ($P = .001$), and use of Excel spreadsheets ($P = .002$) increased from the beginning to the end of the clinical rotation. Student confidence in interprofessional communication increased from 85 [69–98] to 95 [78–100]; $P = .03$). Overall, the largest change was students' ability to assess patients with COVID-19 (pre-rotation 50.0 [11.5–65.7], post-rotation 80.0 [58.5–100]; $P = .001$). Qualitative results revealed overwhelmingly positive results for both students and preceptors. CONCLUSIONS: Students' confidence in assessing patients via remote monitoring increased in a tele-ICU clinical rotation. Self-assessed knowledge related to COVID-19 also increased to statistical significance. *Key words: respiratory therapy; education; students; telemedicine; ICU; critical care.* [Respir Care 2022;67(7):789–794. © 2022 Daedalus Enterprises]

Introduction

Clinical practicums are foundational to students' learning in respiratory therapy (RT) school and are essential to RT students' learning objectives.[1-3] Lack of clinical sites has been cited as a reason for low enrollment in some RT programs.[4] The COVID-19 pandemic profoundly affected RT students' education by limiting their bedside, hands-on patient care, as they were prohibited from caring for patients with COVID-19. Many clinical affiliates canceled student rotations due to high rates of infection, risks of exposure, and limited personal protective equipment (PPE) availability. Even as students returned to the bedside, close supervision, contact tracing, and restrictions to hands-on patient care were required to mitigate the risk of infection.

Telemedicine emerged as a means for managing critical care patients during the COVID-19 pandemic.[5] Although tele-critical care has been utilized for over a decade, only recently have respiratory therapists been introduced to these care teams.[6] In April 2020, the University of Pennsylvania Health System introduced 24-hour, 7 days a week respiratory care under Penn E-lert, the tele-ICU program at the Center for Connected Care. The initial role of respiratory therapists in the tele-critical care environment included patient monitoring, ventilator assessment, and chart review, as a means to assist the COVID-19 ICUs with high patient volume, reduce

the use of PPE, and decrease the risk of infection to health care clinicians in the physical ICUs as well as those working remotely.[6]

As with other disciplines in medical education, there are limited options for student education within tele-critic-

SEE THE RELATED EDITORIAL ON PAGE 895

al care.[5] During the COVID-19 pandemic, we initiated a new clinical rotation for RT students at Penn E-lert. We hypothesized that a clinical rotation at a tele-ICU would increase students' knowledge of mechanical ventilation, telemedicine, and COVID-19. Our goal was to increase their knowledge of the disease process to better prepare them for the workforce. To our knowledge, this is the first study to evaluate respiratory therapy student clinical rotations in a tele-ICU setting.

QUICK LOOK

Current knowledge

Student clinical rotations are foundational to respiratory therapy education. Clinical sites have decreased over time, including during the COVID-19 pandemic. Telemedicine has emerged as a means to remotely monitor patients in an ICU setting.

What this paper contributes to our knowledge

Student respiratory therapists successfully completed clinical rotations in a tele-ICU. Students' self-reported knowledge of mechanical ventilation, ARDS, COVID-19, and patient-ventilator interactions increased significantly during the study period.

Methods

Students from 2 universities completed clinical rotations in a tele-ICU as a part of an institutional review board–approved observational study. Previous clinical rotations in the ICUs at the Hospital of the University of Pennsylvania or Penn Presbyterian Medical Center (Philadelphia, Pennsylvania) were required before students could attend clinical rotations in the tele-ICU. Learning objectives for the clinical rotation were based on discovering the benefits of telehealth in the observation, assessment, and treatment of patients in an intensive care setting. Students participated in incoming and outgoing shift report, discussing the various modes of ventilation and how changes in the ventilator parameters would affect arterial blood gas values. Students were graded by their individual institutions based on the completion of specific competencies developed and shared between the 2 school programs. Appendix 1 (see related supplemental material at http://rc.rcjournal.com). Throughout the semester, two 4-h shifts were spent in the tele-ICU with one student attending 11 AM–3 PM and one student 7 PM–11 PM. Seven preceptors were selected based on availability and the shifts worked. Preceptors had a median 14 y of experience (interquartile range [IQR] 10–24), and 5 had specialty credentials including Registered Respiratory Therapist-Adult Critical Care Specialist through the National Board for Respiratory Care. The preceptors all had previous experience leading students through clinical rotations.

The Penn E-lert suite is located approximately 2 miles from the main hospital campuses in urban Philadelphia. Therapists and students rounded on 320 ICU beds at 5 hospitals across the health system, including hospitals in Pennsylvania and New Jersey. Data collection occurred from February 2021–May 2021. Under the supervision of therapists, students performed remote patient assessments, which included review and interpretation of ventilator waveforms, patient-ventilator synchrony, arterial blood gases, and chest x-rays. Students received an introduction to lung protective ventilation, spontaneous breathing trials, bronchopulmonary hygiene protocols, and the relationship of evidence-based protocols for the management of critically ill patients. Other methods of monitoring patients' status were reviewed, including end-tidal carbon dioxide pressure, urine output, and hemodynamics.

Patient assessments were completed at the request of respiratory therapists in the ICUs, and clinical emergencies were addressed in real time via remote monitoring. During ventilator assessment rounds and regular patient monitoring, demographic surveys to identify the complexity and diversity of the patient population were completed. Students

Messrs Roberts and Lamphere and Dr Pierce and Ms Zumstein are affiliated with Department of Respiratory Care, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania. Ms Williams is affiliated with Center for Connected Care, University of Pennsylvania Health System, Philadelphia, Pennsylvania. Mss Powell and Moran and Mr Kellar are affiliated with Department of Respiratory Care, West Chester University-Bryn Mawr Hospital, Bryn Mawr, Pennsylvania. Mr Solly is affiliated with Department of Respiratory Care, Gwynedd Mercy University, Gwynedd Valley, Pennsylvania.

The authors have disclosed no conflicts of interest.

Mr Roberts presented a version of this paper as an Editors' Choice abstract at AARC Congress 2021 LIVE!, held virtually December 1, 2021.

Supplementary material related to this paper is available at http://rc.rcjournal.com.

Correspondence: Karsten J Roberts MSc RRT FAARC, Hospital of the University of Pennsylvania, Department of Respiratory Care Services, 3400 Spruce Street, Ground Floor, Founders Building, Philadelphia, PA 19104. E-mail: karsten.j.roberts@gmail.com.

DOI: 10.4187/respcare.09896

Table 1. Student Demographics

Sex	
Female	22 (67)
Male	11 (33)
Highest degree earned	
High school	22 (67)
Associate degree	8 (24)
Baccalaureate degree	3 (9)
Degree (in progress)	
Associate degree	3 (9)
Baccalaureate degree	30 (91)
Knowledge of telemedicine	
Yes	18 (55)
No	15 (45)
Prior experience with telemedicine	
Yes	17 (52)
No	16 (48)

Data are presented as *n* (%). $N = 33$ participants.

were given the opportunity to communicate with patients and bedside staff during these assessments using Penn Medicine's audiovisual platform.

Students voluntarily completed a pre-rotation survey assessing their confidence managing mechanical ventilation, experience with telemedicine and technology, ARDS, and patients with COVID-19 on the first day of their clinical rotation. Randomized universally unique identifier numbers were assigned to track participant data. This number was used to fill out both the pre- and post-rotation surveys. At the end of the rotation, students completed a second survey assessing self-confidence related to the same concepts (see related supplementary materials at http://www.rc.rcjournal.com).

Statistical Analysis

Statistical analysis was completed using SPSS Statistics for Mac 26 (IBM, Armonk, New York). Descriptive statistics were reported as medians and IQR. Categorical data were reported as percentages. Ordinal responses were considered nonparametric. Qualitative data were analyzed and triangulated by 3 of the authors (KJR, KKZ, MP) using an open-coding method. A Wilcoxon signed-rank test was applied to compare pre– and post–clinical rotation and self-confidence surveys (Likert scale 1–100). Descriptive data are reported as percentages or median (IQR). Statistical significance was set to $P < .05$.

Results

Of the 37 students that rotated through the virtual ICU, 33 (89%) completed pre– and post–clinical rotation surveys. Of those, 67% ($n = 22$) were female. Fifty-five percent of students reported prior knowledge of telemedicine and 52% had observed interactions with the tele-ICU in previous clinical rotations, Table 1. Mean self-confidence in mechanical ventilation ($P = .001$), assessing waveforms ($P = .001$), and knowledge of ARDS increased after the clinical rotation ($P = .001$). Similarly, reported self-confidence related to spontaneous breathing trial protocols ($P = .001$), lung-protective ventilation ($P = .002$), patient care planning ($P = .001$), and use of Excel spreadsheets ($P = .002$) increased from the beginning to the end of the clinical rotation. Student confidence in interprofessional communication increased from 85 [69–98] to 95 [78–100]; $P = .03$). Overall, the largest change was students' ability to assess patients with COVID-19 (pre-rotation 50.0 [11.5–65.7], post-rotation 80.0 [58.5–100], $P = .001$), Table 2.

Students rounded on a total of 370 subjects during their remote clinical rotations. Of the subjects RT students interacted with, 57% ($n = 211$) identified as male. Mean age of the population was 52.5 ± 18.0. Racial makeup closely resembled the diversity in Philadelphia with 39% ($n = 145$) Black and 50% ($n = 183$) white subjects (Table 3). Ninety-two percent of the subjects were mechanically ventilated, and RT students completed 239 patient-ventilator

Table 2. Students' Comfort With Tele-ICU Competencies

	Pre-Rotation	Post-Rotation	*P*
Comfort with mechanical ventilation	80.0 (69.5–90.0)	95.0 (84.5–100)	.001
Comfort with waveforms	70 (50–85)	95(83–100)	.001
Knowledge of ARDS	71 (55–85)	87 (80–100)	.001
Knowledge of COVID-19	50.0 (11.5–65.7)	80.0 (58.5–100)	.001
Comfort with Excel	65 (50–90)	91 (75–100)	.002
Knowledge of SBTs	83.0 (75.0–95.0)	99.0 (80.5–100)	.009
Knowledge of protocols	75.0 (50.0–86.0)	88.0 (76.5–100)	.002
Care plan skills	79.0 (60.5–89.0)	90.0 (77.5–100)	.001
Interprofessional communication skills	85 (69–97.5)	95 (77.5–100)	.03

Student knowledge changes presented in median (IQR). Comparisons preformed with Wilcoxon signed-ranks test. Statistical significance set to $P < .05$.
SBT = spontaneous breathing trial

Table 3. Subject Demographics

Sex	
Male	211 (57)
Female	158 (43)
Transgender	1 (< 1)
Race	
Asian	11 (3)
Black	145 (39)
White	183 (50)
Hispanic	16 (4)
Other	15 (4)
Age, y	
16–34	67 (18)
35–51	102 (28)
52–68	129 (35)
69–88	72 (19)

Data are presented as *n* (%). *n* = 370 subjects.

Table 4. Ventilatory Status and Disease Process

Invasive ventilation	
Pressure support ventilation	97 (26)
Volume control ventilation	175 (48)
Pressure control ventilation	68 (18)
Manual ventilation	1 (< 1)
Non-intubated	29 (8)
ARDS	178 (48)
COVID-19	145 (39)
Subject decompensated	73 (20)

Data are presented as *n* (%). *n* = 370 subjects.

assessments. The primary disease processes of subjects seen were ARDS ($n = 178$) and COVID-19 ($n = 145$). In subjects with ARDS, 36% ($n = 65$) required follow-up with the ICU respiratory therapist due to issues related to adherence to a protocol. Volume-targeted modes of ventilation were most commonly used, 47% ($n = 175$). Patient interventions included 73 instances of worsening symptoms in mechanically ventilated subjects, Table 4. The most commonly completed interventions were basic patient-ventilator assessments ($n = 239$). Students and preceptors assessed 65 (18%) issues related to ARDS management. Additionally, there were 28 instances of airways deemed as high risk that required increased surveillance, Table 5.

Students' survey comments stated e-respiratory therapists provided guidance and created a comfortable learning environment that students would recommend to others. Interaction with tele-ICU registered nurses was described as friendly, and tele-ICU nurses were noted to be knowledgeable and helpful. Students noted the high level of teamwork in the tele-ICU and that they observed quality patient care provided. Students stated that interactions with

Table 5. Types of Interventions Completed

High-risk airway evaluation	28 (8)
Patient-ventilator assessment	239 (65)
ABCDE bundle	6 (2)
Quality and safety	26 (7)
ARDS management	65 (18)
Other interventions, as needed	37 (10)

Data are presented as *n* (%). *n* = 370 subjects.

tele-ICU medical doctors were educational; however, 40% of students reported not interacting with tele-ICU physicians during their clinical rotations. Whereas some of the students did not interact with staff at the bedside, in the physical ICU, others noted that interactions via telecommunication platforms were positive and friendly. The biggest difference noted between this rotation and in-person rotations was that it is not hands-on; however, students stated they were able to focus on technology and learning about ventilator waveforms and mechanics. When asked what it takes to be an effective e-respiratory therapist, a willingness to learn and be involved was described. Students felt it was important to be knowledgeable about technology, modes of mechanical ventilation, and waveforms. Additionally, the students noted it was important to be knowledgeable about diseases and patient-ventilator synchrony. Appendix 2 highlights exemplar quotes from students (see related supplemental material at http://rc.rcjournal.com).

Discussion

During a newly implemented clinical rotation, students experienced an increase in their baseline self-assessed knowledge of telemedicine and mechanical ventilation. Telemedicine, particularly in critical care, is a relatively nascent competency for RT students. For instance, only 2% of respiratory therapists working in the Commonwealth of Pennsylvania reported working in telemedicine.[7]

One potential benefit to this type of clinical rotation is the volume of patients to which students are exposed. Penn E-lert covers 320 ICU beds in 5 hospitals throughout our health system.[6] This clinical rotation provided the opportunity for students to assess a total of 239 mechanically ventilated subjects, as noted in Table 5. This was an important aspect of the rotation due to the decrease in clinical sites during the first wave of COVID-19. Furthermore, providing a telemedicine curriculum to RT students may contribute favorably to the future of the respiratory care profession. As noted in the student comments, the tele-ICU clinical rotation gave them an opportunity to focus on waveform analysis and technology. Appendix 2 (see related supplemental material at http://rc.rcjournal.com). With the emergence of telemedicine as a means to assess patients, new

competencies are necessary for helping respiratory therapists work at the top of their license.[8]

The design of our curriculum was based on a similar module as previously reported medical school curriculum. In a 4-week curriculum, piloted by the Perelman School of Medicine during the pandemic, fourth-year medical students completed clinical rotations in April 2020.[5] The primary goal of the medical school curriculum described by Ho et al was to give students an opportunity to strengthen patient care skills within the context of telemedicine.[5] Medical students were assigned to 5-h shifts working under the direct supervision of third-year residents. Whereas RT students were exposed to patients in 320 beds across the health system, medical students cared for patients in one, 20-bed medical-surgical ICU. As a part of the pilot curriculum, physician trainees followed 16 patients, completed 73 patient care notes, and made a total of 70 contributions to patient care. Similar to respiratory care students, medical students were involved in ventilator management, which included changing orders for low-stretch ventilation protocol. Unlike our curriculum, medical students completed debriefing sessions, case presentations, reviewed relevant journal articles, and capstone essays.[5] Whereas we intended to give respiratory care students as robust a clinical experience as possible, they were not assigned extra work beyond attending the rotation and participating in patient care.

Communication skills are noted to be key in the development of teamwork and patient care.[9,10] Of the 18 student participants in a 2019 study by Oppermann and colleagues,[9] a background in customer service lead to higher proficiency in communication competencies. Although self-assessment scores did not meet statistical significance, overall communication scores did increase. Qualitative data from faculty trended toward improved communication among participants. Whereas our study did not evaluate specific communication competencies such as listening skills or verbal communication, our participants reported increased confidence in their ability to communicate within the interdisciplinary team.

As noted by Kacmarek,[11] for clinicians to adequately function in critical care they must possess good communication and teamwork. Additionally, it is imperative that new graduates be proficient in graphic waveform interpretation and possess the ability to recommend alternative modes to improve patient-ventilator synchrony.[8] This clinical rotation gave students an introduction to how these skills are merged with new technology available through patient care in telemedicine, and our results suggest that students' knowledge and abilities of these skills increased during the rotations. A potential benefit of this clinical rotation to participants may be, at minimum, the ability to be "conversant in new monitoring technology," as established by Barnes et al.[8]

As telemedicine continues to evolve into the future, it is important to consider the importance of including this modality as a part of respiratory care curricula. Increasing the knowledge base and skills needed for RT students was first noted by the American Association for Respiratory Care as part of the 2015 and Beyond project.[8,12] In the review of the first conference, Kacmarek et al[12] recognized the increased complexity of patient care requiring the need for better communication. As predicted by the authors, health care continues to emphasize the coordination of care throughout systems. Barnes and colleagues also discussed the incorporation of new technology into respiratory care with the advent of advanced monitoring.[8,13] This includes the ability of respiratory therapists to recommend changes to patient care based on protocols. Indeed, our tele-ICU incorporates evidence-based protocols while allowing therapists to think critically and problem-solve in real time. In the final conference paper, Barnes et al[13] reviewed the increased skills required by respiratory therapists to care for patients in diverse settings. Interestingly, the authors predicted an increase in manpower issues. In the post-COVID era of health care, more than ever, telemedicine has the potential to assist with ever-increasing workloads and responsibilities of respiratory therapists. Whereas the COVID-19 pandemic limited the ability of some schools to continue clinical rotations, we were able to leverage the technology available in our health system to provide a much-needed introduction to telemedicine for our students.

Future research should focus on validating student competencies within the tele-ICU environment. These competencies should include not only telemedicine and other technological advances but should also focus on assuring the clinical rotations meet the needs of RT students. Although these types of clinical rotations are unlikely to replace bedside, hands-on experience of traditional RT education, efforts should be made to compare the differences between the 2 experiences.

Limitations

Several limitations to the results of our study exist. Whereas we had the opportunity to create a new clinical rotation in the tele-ICU, we recognize the limited resources in other health care systems. Schools in other parts of the country may not be near enough to health systems providing integrated patient care to justify sending students to clinical rotations. Despite a dearth of telemedicine clinical sites, we suggest RT programs investigate affiliation agreements with health systems offering telemedicine or work with third-party vendors on opportunities for students to get exposure to this type of clinical experience. Another limitation was that we did not draw comparisons between a standard, in-person clinical rotation and the tele-ICU rotations. Furthermore, students did not receive any didactic

education related to telemedicine before, during, or after their clinical rotation. They also did not have any specific competency testing; therefore, we were unable to quantify students' understanding and knowledge of the competencies reviewed.

Conclusions

Students' self-assessed knowledge and skills in assessing patients via remote monitoring increased in a tele-ICU clinical rotation. Statistically, self-confidence in knowledge related to COVID-19 also increased significantly. Students' experience in a virtual ICU was overwhelmingly positive, providing new perspectives on patient care. During this remote clinical rotation, RT students had the opportunity to interact with and complete assessments on patients diagnosed with COVID-19. This rotation prepared RT students to care for a diverse patient population via the tele-ICU and increase their knowledge and experience with patients with COVID-19, despite a lack of traditional hands-on experience.

ACKNOWLEDGMENTS

We appreciate the work of the respiratory therapists, nurses, advanced practice providers, and attending physicians at Penn E-lert, Center for Connected Care, and the University of Pennsylvania Health System.

REFERENCES

1. Alghamdi SM, Siraj RA, Ari A. Evaluation of the clinical learning environment in respiratory therapy education: student perceptions. Respir Care 2019;64(2):161-168.
2. Douce FH. Bachelor of science degree education programs: organization, structure, and curriculum. Respir Care Clin N Am 2005;11(3):401-415.
3. Koster MS, Wing TJ. Admission criteria and course performance in an undergraduate respiratory care program: a case for non–cognitive measures. Respir Care Educ Annu;28:3-17.
4. Goodfellow LT. Bachelor's and master's respiratory therapy educational programs and their relation to the AARC's 80% goal: recruitment and enrollment capacity challenges. Respir Care Educ Annu 2019;28:18-25.
5. Ho J, Susser P, Christian CW, DeLisser H, Scott MJ, Pauls LA, et al. Developing the eMedical student (eMS)—A pilot project integrating medical students into the tele-ICU during the COVID-19 pandemic and beyond. Healthcare 2021;9(1):73.
6. Pierce M, Gudowski SW, Roberts KJ, Scott MJ, Laudanski K. Establishing a telemedicine respiratory therapy service (eRT) in the COVID-19 pandemic. J Cardiothorac Vasc Anesth 2021;35(4):1268-1269.
7. Armaghan R, Geesey B, Juby J, Amador-Castaneda J, Bollinger A, Roberts KJ, et al; for the Pennsylvania Respiratory Research Collaborative Investigators. Practice of respiratory therapists in Pennsylvania: a statewide survey. Respir Care 2020;65(7):972-976.
8. Barnes TA, Gale DD, Kacmarek RM, Kageler WV. Competencies needed by graduate respiratory therapists in 2015 and beyond. Respir Care 2010;55(5):601-616.
9. Opperman RE, Divens CJ, Sturbleng EK, Rohaley HJE, Toh XL, Bailey ZJ, Varekojis SM. A descriptive study on the communication skills of first-year undergraduate respiratory therapy students. Respir Care Educ Annu 2019;28:44-52.
10. Shelledy DC, Wiezalis CP. Education and credentialing in respiratory care: where are we and where should we be headed? Respir Care Clin N Am 2005;11(3):517-530.
11. Kacmarek RM. Mechanical ventilation competencies of the respiratory therapist in 2015 and beyond. Respir Care 2013;58(6):1087-1096.
12. Kacmarek RM, Durbin CG, Barnes TA, Kageler WV, Walton JR, O'Neil EH. Creating a vision for respiratory care in 2015 and beyond. Respir Care 2009;54(3):375-389.
13. Barnes TA, Kacmarek RM, Kageler WV, Morris MJ, Durbin CG. Transitioning the respiratory therapy workforce for 2015 and beyond. Respir Care 2011;56(5):681-690.