2023

Relationship Between Number of Mechanical Ventilation Days Prior to ECMO Initiation and Outcomes in COVID-19 Patients

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Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Nursing Practice at the University of Kentucky

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Lexington, Kentucky

Spring 2023

Abstract

Background: Since the start of the pandemic, there has been over 16,000 COVID-19 positive patients placed on Extracorporeal Membrane Oxygenation (ECMO). Little is known about the effect of long mechanical ventilation prior to ECMO initiation. **Purpose:** The first purpose of this project is to evaluate whether a longer mechanical ventilator time (ten or more days) prior to ECMO initiation is associated with increased mortality and longer total lengths of time on ECMO in patients with COVID-19, as opposed to being on a ventilator for under ten days prior to being placed on ECMO. The second purpose is to increase provider awareness and education of COVID-19 ECMO usage at UK Healthcare throughout the pandemic. **Methods:** A chart review was performed at University of Kentucky Healthcare on COVID-19 positive patients that were placed on ECMO between the dates of February 2020 and August 2022 with documented intubation and cannulation dates. Patients with long mechanical ventilator times (10 days or greater) were compared with patients placed on ECMO prior to their 10^{th} ventilator day. Total length of time on ECMO as well as discharge disposition were assessed and compared between the two groups. Results of the study and a three question pre and posttest were distributed to ECMO providers in the Cardiovascular Intensive Care Unit to evaluate their understanding of ventilator length of time prior to cannulation and the effect on outcomes in COVID-19 ECMO patients. **Results:** The chart review showed there was no significant difference in outcomes (discharged or deceased, p=.545) and total length of time on ECMO (p=.796) between the patients who were placed on ECMO prior to their tenth intubation day compared to ten or more days of mechanical ventilation. Education within the ECMO providers were significantly increased after the distribution of the results of the study in two of the three questions. Post-education results were increased to 86.4% and 90.9% (p=<0.001). **Conclusion**: These results

indicate that more research is still needed on the use of ECMO throughout the COVID-19 pandemic and the factors that affect mortality. Length of time on mechanical ventilation prior to ECMO initiation was not associated with significant effect on mortality or total length of time on ECMO, while there was a significant increase in provider education on the topic.

Acknowledgements

I would first like to thank my advisor, Dr. Sheila Melander, who assisted me throughout my time at the University of Kentucky. I'd also like to thank Dr. Melissa Czarapata and Dr. Candice Falls for all the advice given to me throughout this project the past year. Thank you to Dr. Aaron Harris for your mentorship, advice, and encouragement throughout this whole project. Thank you to Dr. Amanda Wiggins for your expertise in the statistical analysis of this project. Finally, thank you to Whitney Kurtz-Ogilvie who helped me edit this manuscript to make it the best it could be.

Dedication

I would like to dedicate this project first to my wonderful parents, Greg and Susan Bergman. Thank you for listening to me vent for countless hours throughout these last five years even when I wanted to give up. Your constant pride and words of encouragement gave me the strength to push through the difficult times. I'd also like to thank my fiancé, Zane, and all my closest friends who have listened to me doubt myself and stress throughout this whole process.

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Background and Significance

Extracorporeal membrane oxygenation (ECMO) has been utilized since the late 1960's in patients for whom severe acute respiratory distress syndrome is unresolved by mechanical ventilation support alone. The ECMO machine pumps blood from the patient's body to an "artificial lung," also known as an oxygenator. The oxygenator replaces the overall function of the body's lungs. This machine adds oxygen and removes carbon dioxide from the patient's blood (White et al., 2020). Since the beginning of the COVID-19 pandemic, ECMO has been used on COVID patients when their acute respiratory distress has reached maximum support and there is no further option. According to the Extracorporeal Life Support Organization (ELSO), longer mechanical ventilation days have been associated with worse patient outcomes in conventional ECMO patients; however, little is known about the effect of these factors in COVID-19 patients. Limited studies have been done on the effects of prolonged ventilator days on COVID-19 patients prior to ECMO cannulation and its effect on mortality. There is a need for increased COVID-19 specific evidence-based practice with regard to ECMO usage.

According to the World Health Organization (2022), as of January 2022, there had been 5,570,163 COVID-19 deaths globally. COVID-19 is a new disease caused by a virus known as SARS-CoV-2. This virus can cause a variety of symptoms from a minor cold to severe acute respiratory syndrome (SARS), respiratory failure, and even death (CDC, 2021). COVID-19 is causing severe respiratory failure requiring ECMO support across all populations. These patients have been shown to require longer ECMO total days on ECMO resulting in increased healthcare costs, and overall increased mortality (ELSO, 2022). According to the ELSO registry, since January 2023 there have been 16,393 COVID-19 positive patients placed on ECMO in the United States, with a 47% in-hospital mortality rate. Pre-pandemic ECMO data show a mortality

rate of approximately 40% (ELSO, 2023).

Selection and contraindication criteria for ECMO patients remained the same from pre-pandemic due to lack of supportive evidence needed for any practice changes. ECMO should be "potentially contraindicated" in patients who have had "long invasive mechanical duration of over 10 days," per ELSO guidelines (2021, p.489). The Selection Criteria Algorithm/Guidelines (see Figure 2.a) provided by ELSO state, "The impact of duration on high-flow nasal cannula and/or noninvasive mechanical ventilation in addition to invasive mechanical ventilation is unknown" (2021, p.489).

University of Kentucky Cardiothoracic Surgeons and ECMO Specialists are the main decision makers when it comes to ECMO patients at UK HealthCare. These decision makers have a goal of initiating ECMO in COVID-19 patients prior to their tenth day of mechanical ventilation, in hopes of improving outcomes and shortening ECMO runs in this population. The studies that have been conducted worldwide show overall increasing mortality in COVID-19 patients on ECMO, but little evidence on the effect of mechanical ventilation length on outcomes. There is a strong need to evaluate the effect of earlier cannulation in COVID-19 patients as well as evaluating and potentially increasing education for the providers who place patients on ECMO.

Purpose & Objectives

A retrospective chart review was performed to assess whether longer mechanical ventilation days prior to ECMO cannulation had more negative effects on outcomes in patients with ARDS due to COVID-19. Given the continued poor outcomes in ECMO patients due to ARDS from the novel Coronavirus, the purpose of this study is to determine whether there is any significant difference in outcomes between patients treated under ELSO selection guidelines

(less than ten days of mechanical ventilation prior to cannulation) and patients intubated for ten days or more prior to ECMO initiation. Furthermore, the specific aims of this study are:

1. Comparison of mortality and total length of time on ECMO in COVID-19 patients who were cannulated before and on/after ten days of mechanical ventilation.
2. Evaluation of selection criteria for COVID-19 patients and/or create new protocols for ECMO use in COVID-19 patients.
3. Evaluation and improvement of provider education on the effects of long mechanical ventilation on outcomes for COVID-19 ECMO patients.

Theoretical Framework

The Iowa Model of Evidence Based Practice to Promote Quality Care is the framework that was used to guide this project. This framework is a revision to the original 1994 Iowa Model. The Iowa Model of Evidence Based Practice to Promote Quality Care is a guide used to identify problems in healthcare and implement evidence-based strategies to improve patient outcomes.

Using this model, first a trigger was identified; the unknown risk for poorer outcomes due to long mechanical ventilation days prior to ECMO initiation in COVID-19 patients. This issue can be of significance since COVID-19 is a relatively new disease and the use of ECMO in these patients is still being researched and understood. ECMO patient outcomes are monitored and registered through ELSO, the Extracorporeal Life Support Organization. Using the revised Iowa Model, the effect of prolonged intubation prior to ECMO initiation on patient outcomes will be further assessed and may be used to increase education and awareness in ECMO providers at UK HealthCare.

Review of Literature

There is still little understanding of the factors that affect outcomes in COVID-19 ECMO patients, specifically prolonged mechanical ventilation. The PICOT question guiding this project was: *In patients on ECMO due to ARDS from COVID-19, does the length of mechanical ventilation prior to initiation of ECMO influence patient outcomes?*

Using the Iowa Model, a literature review was needed to evaluate the current evidence on the effect of ventilation days in COVID-19 ECMO patients. For this literature search, the electronic databases CINAHL and PubMed were used to find significant articles. The search terms used were *COVID-19* AND *ventilation* AND *ECMO* OR *extracorporeal membrane oxygenation.* Inclusion criteria encompassed articles in English, published in 2019 or later, and studies focusing on adults over the age of 18. Fifteen articles met the inclusion criteria for relevance to this research.

The studies analyzed included retrospective studies and meta-analyses of systematic reviews, providing levels III and V evidence. Of the ten patients reviewed by Giraud et al. (2020), all of those who received greater than seven days (150 hours) of mechanical ventilation prior to ECMO initiation ultimately died. Kunavarapu et al. (2021) evaluated 52 ECMO patients and found that pre-ECMO ventilator days were significantly associated with a higher risk of mortality at 31%; however, it was also found that there was a 75% survival rate when ECMO was initiated on patients prior to being intubated at all. Pranav et al. (2021) found similar outcomes stating ECMO was most successful in awake, non-intubated COVID-19 patients. The studies of Oliver et al. (2021) and Hermann et al. (2022) showed there was no significant association between the duration of mechanical ventilation prior to ECMO initiation and mortality. Mortality was 53% compared to 50% in cannulations prior to seven days and 60%

compared to 62%. Chong et al. (2022) analyzed multiple large observational studies and discovered that between COVID-19 ECMO survivors and non survivors, the duration of mechanical ventilation prior to initiation was similar (5.51 days compared to 6.68 days) but the mean was less than ten days.

Analysis of Mustafa et al. (2021) showed in COVID-19 ECMO patients, mortality was significantly lower across all ages and BMI compared to mechanically ventilated patients alone, 68% of patients discharged from the hospital. Oshimo et al. (2022) and Urner et al. (2022) found that older age (over 65) and longer ventilator days prior to starting ECMO showed increased mortality. Hu et al. (2020) found an in-hospital mortality rate of 52.8% in COVID-19 ECMO patients. Ramanathan et al. (2021) conducted a metanalysis that showed an in-hospital mortality rate from 22 studies of 37.1% and the average length of time on ECMO was 15.1 days. Increased age was a risk factor to death in these patients as well. Drier et al. (2021) found that ECMO support for COVID-19-induced respiratory failure is justified if ECMO is initiated early and at an experienced ECMO center. The final study, Ahmad et al. (2022) was also a metanalysis that showed patients who received greater than three days of mechanical ventilation were less likely to be liberated from ECMO or discharged from the hospital.

The inconsistent outcomes of these studies indicate the need for further research of the effects of mechanical ventilation prior to ECMO initiation at UK Healthcare.

According to current ELSO selection guidelines for COVID-19, “long invasive mechanical duration of over ten days” is a potential contraindication for ECMO initiation (2021, p.489). Of course, each ECMO referral should be considered on a case-by-case basis but at the University of Kentucky, cardiothoracic surgeons typically try to rule out ECMO for patients who have been on the ventilator for over ten days. There is a huge gap in evidence and a lack of a set

regulatory protocol for initiation of ECMO in COVID-19 patients. Previous ECMO contraindications are being used for their choices in what patients to cannulate, but little evidence is out there to show what factors truly effect outcomes in this population. More research and evidence are needed to determine if COVID-19 ECMO selection criteria should be different and if prolonged ventilator days do actually have a negative effect on overall mortality. There is a need for an evidence-based selection protocol for initiation and contraindications of ECMO in COVID-19 patients. This project would provide research from a large ECMO-capable facility with multiple COVID-19 ECMO patients from 2020-2022 and illuminate whether a prolonged ventilator time of over ten days should be used as a contraindication when selecting patients for ECMO. This project will raise provider awareness of this facility's ECMO outcomes and increase provider awareness and knowledge when considering future use in this population.

Methods

Design

This project is a descriptive research study utilizing retrospective chart reviews to evaluate the effect of prolonged ventilator days prior to the initiation of ECMO in COVID-19 patients. Outcomes were compared in patients that were on mechanical ventilation ten days or greater prior to ECMO initiation with patients on mechanical ventilation less than ten days before ECMO initiation. Baseline health and demographic data were compared between all patients assessing for significant differences and effects on outcomes. Using the ELSO selection criteria, all patients considered for ECMO should meet universal standards of health prior to being cannulated, such as lack of cancer, immunosuppression, and advanced age. After data collection, results were shared with providers and a pre and posttest was used to evaluate understanding and improve education in this topic.

Setting

This project was conducted at the University of Kentucky Chandler Hospital in Lexington, Kentucky. This hospital is a large, academic medical center with a 945-bed capacity. University of Kentucky Hospital has 12 ECMO circuits with the potential to have 10 patients on ECMO concurrently in the Intensive Care Unit (ICU). COVID-19 ECMO patients were limited to the Cardiovascular ICU (8th floor) and the Medicine ICU (10th floor) in this hospital. Prior to 2021, COVID-19 ECMO patients were managed by the Medicine ICU team during their first 21 days after testing positive for COVID, then transferred to the Cardiovascular ICU to be managed by the Cardiothoracic (CT) surgeons and Anesthesia Critical Care team. As of 2021, all COVID-19 ECMO patients were cannulated and managed by CT surgeons, critical care anesthesia team, and the lung transplant team only.

UK HealthCare has five values leading their care: Diversity, Innovation, Respect, Compassion, and Teamwork. Their innovation value states, "We embrace continual learning and improvement to drive positive change". This project will inform UK Healthcare more about the care of COVID-19 patients placed on ECMO. COVID-19 ECMO patients are different than other ECMO patients and need individualized criteria and protocols. Continual research is needed to provide the best possible evidence-based care for these patients and improve outcomes, which aligns with UK HealthCare's overall mission.

Stakeholders in this project include the cardiothoracic surgeons who place these patients on ECMO, the mechanical circulatory support team (MCS team) who coordinates all the care, referrals, and transportation of ECMO patients at UK and surrounding hospitals, and the CVICU nurses who care for these patients. The ECMO specialists provided information regarding selection criteria for COVID-19 ECMO patients. Nurses in the Cardiovascular ICU highlighted

concerns regarding inconsistent COVID-19 ECMO patient care/decision making throughout the pandemic. This group also asked many questions regarding the selection criteria in place. The results of the chart review will be shared with these stakeholders to address the potential influence on the current practice at UK HealthCare in regard to ventilator days prior to ECMO initiation. COVID-19 ECMO patients are also important stakeholders to this project. The results of this project could influence and change criteria to improve the outcomes of COVID-19 ECMO patients or prevent future futile cannulations that may cause prolonged, inevitable death, familial emotional distress, and increased use of very limited and expensive resources.

Some site-specific factors that helped facilitate this project are the ECMO specialists at UK HealthCare. The MCS team was very willing to offer advice and help facilitate the data collection process, as well as increase communication with the Cardiothoracic surgeons throughout this project. Some factors that served as barriers to this data collection were that UK HealthCare switched electronic medical record systems in 2021. UK is one of the few ECMO-capable facilities in Kentucky and surrounding states, UK HealthCare frequently accepts ECMO patients from outside hospitals. This results in documentation errors such as unknown and undocumented mechanical ventilation or cannulation start dates, which caused us to exclude multiple patients from the sample.

Sample

This study included COVID-19 positive patients that were on ECMO due to severe acute respiratory distress at UK Chandler Hospital between the dates of February 1, 2020 and August 31, 2022. This sample included adult patients over the age of 18 of varying genders, races, and ages from Kentucky as well as surrounding states. Following previous ELSO selection criteria, patients should be of similar underlying health such as absence of cancer, immunocompromise,

advanced age, and significant comorbidities. Criteria for inclusion were patients over 18 and placed on ECMO due to COVID-19 with positive COVID test, documented intubation, cannulation, and decannulation dates. This included patients that were placed on ECMO at outside hospitals and transferred to UK for further care. Patients were excluded if they did not have a documented intubation or cannulation date, were never placed on mechanical ventilation, or were under the age of 18.

Procedure

IRB Approval

Submission to the University of Kentucky's Medical Institutional Review Board where the project was performed was completed and approved in the Fall of 2022 before conducting this project. On September 8, 2022 the IRB determined this project met criteria to qualify as an exempt study. A "Waiver of Authorization", "Waiver of Documentation of Informed Consent" and Form K "Waiver of HIPAA Documentation" were approved by the University of Kentucky IRB and Office of Research Integrity (ORI). These waivers also applied to providers who would receive the educational materials and pre/posttests created. After approval in the Fall of 2022, we began the data collection.

Measures and Instruments

Demographic measures including age, race, gender, comorbid burden, and BMI were collected through chart review and used to evaluate, compare, and describe our sample. Outcome measures of this project were in-hospital mortality and total length of time on ECMO in comparison to their number of ventilator days prior to ECMO cannulation. ECMO canulation and decannulation dates were collected, as well as intubation dates and discharge disposition of

the patient. Providers' answers to a 3- questionnaire pre and posttest (Appendix 3) were collected anonymously via Qualtrics and sent through UK email.

Data collection

Medical record numbers (MRN) were obtained for patients who were placed on ECMO due to acute respiratory distress syndrome (ARDS) caused by COVID-19 at UK Hospital from the dates listed above from UK's Center for Clinical and Translational Science (CCTS) and given to the Primary Investigator. A chart review of data from patients' electronic and paper medical records was performed to find ECMO cannulation, decannulation, and intubation dates. Body mass index (BMI), age, comorbid burden, race, and discharge disposition were provided with the patient's MRN from CCTS. The data were transferred to a data analysis software, SPSS, with the help of Dr Amanda Wiggins and results were made into two tables. The provider education, which included the results of this study, pretests, and posttests, were sent out using the University of Kentucky Qualtrics system via e-mail. The list of ECMO providers to distribute the education to was provided by the MCS team and Dr Kevin Hatton from Anesthesia Critical Care Management at UK. Pre and Posttest answers were anonymous. Comparison of pre and post test results were also analyzed using SPSS.

Data analysis

Data retrieved from medical records for this project were entered into SPSS Statistics Software, version 25 with an alpha of .05. Descriptive statistics was used to describe the demographic distributions of the sample. Means with standard deviations were used for age, weight, and BMI and frequencies with percentages were used for race and gender. Two sample t-tests were used for age, continuous and normally distributed samples. Gender and race are categorical and used the chi square test of association. Comorbid conditions and total ECMO

days are continuous but skewed so a Mann-Whitney U test was used. Differences in mortality rates between mechanical ventilation lengths prior to ECMO placement were analyzed using chi-square tests. Provider knowledge was evaluated with the pre and post tests using McNemars paired categorical data test.

Results

Sample Characteristics

Utilizing records from the MCS Coordinators, there were 124 COVID-19 ECMO patients in this time frame of study. 107 patients met inclusion criteria; 81 who were cannulated prior to their tenth ventilator day and 26 who were cannulated on their tenth or more day on the ventilator. Demographics of this population were analyzed and demonstrated the average age to be 46.4 years old. There were 71 (66.4%) males and 36 (33.6%) females. 82 (83.7%) were white, 7 (7.1%) Black, 5 (5.1%) Hispanics, 3 (3.1%) Asian, and 1 (1%) multiracial. The average comorbid burden in these patients was 2. There were 9 (8.4%) patients with a normal BMI, 18 (16.8%) patients with an overweight BMI, and 80 (74.8%) of the 107 patients were in the obese BMI category. Of the 107 patients, 48 (44.9%) were discharged home or to long term care and 59 (55.1%) died in hospital, with an average length of time on ECMO of 24 days (11-37).

The provider education and pre/post tests were sent to 10 ECMO specialists, 2 cardiothoracic surgeons, and all the Critical Care Anesthesia providers who manage these patients in the CVICU at UK (80 providers). Out of the 80 providers who were sent the pre/posttest, 22 anonymous responses were obtained via Qualtrics.

Ventilator Comparison

After chart review and data analysis performed by SPSS between the two groups (patients intubated ten days or greater compared with patients intubated less than ten days), there

was no significant difference found in outcomes (discharged or deceased, p=.545) and total length of time on ECMO (p=.796) between the patients who were placed on ECMO prior to their tenth mechanical ventilator day and patients who placed on ECMO after ten or more days of mechanical ventilation.

Between the two groups, demographics were similar. The average age for the shorter ventilation time (less than 10 days) was 46 years old compared to 47.8 in the prolonged ventilator group (p=0.48). There were 55 (67.9%) males and 26 (32.1%) females who were placed on ECMO in less than 10 days, and 16 (61.5%) males and 10 (38.5%) females placed on ECMO after 10 or more days (p=.55). BMI comparisons between the two groups were similar resulting in a p value of .086, with 61.5% and 79% of patients in each group being "Obese". While exact comorbidities were not assessed in this study, the Charlson Comorbidity Index Score between the two groups was an average of 2 (p=0.688). The only significant piece of data provided from this statistical analysis is a comparison of races between the two groups, resulting in a p value of 0.23, showing that 3 (12.0%) of the 26 patients placed on ECMO after ten or more days were Hispanic.

For the 81 patients that were placed on ECMO before their tenth ventilator day, the average length of time on ECMO was 24 days; 35 (43.2%) patients were discharged while 46 (56.8%) died in the hospital. Of the 26 patients that were placed on ECMO on their tenth or greater day on the ventilator, the average length of time on ECMO was 21 days; 13 (50%) patients were discharged, while 13 (50%) patients died during hospitalization. Comparison of discharge disposition between the two groups resulted in a p value of .545, and comparison of total ECMO days between the two groups resulted in a p value of .796, making neither result significant.

Provider Education

A three-question-questionnaire (Appendix C) was sent to providers who care for or place patients on ECMO at UK HealthCare, including MCS Coordinators, CT Surgeons, and Critical Care Providers in the CVICU. The pretest was given to providers prior to receiving education or results of this study (Table 2). After reviewing the study results, the same repeat posttest was provided to providers.

The first question was related to ELSO (Extracorporeal Life Support Organization) guidelines: True or false, "ELSO guidelines define 'long invasive mechanical ventilation' as over 10 days?" Of the 22 providers who answered, 21 (95.5%) got it correct on the pre and posttest. The one provider who answered incorrectly on the pretest also answered incorrectly on the post test. Since 95.5% of providers answered this question correctly with and without education, the p value is 1.00, and the results are statistically insignificant.

The second question required providers to review the education and results of the study. It asked, "Does shorter ventilator time before ECMO cannulation correlate with increased survival in COVID-19 patients?" As found in the results of the study, ventilator time has no significant effect on outcomes. The results were statistically significant with a p value of <0.001. Only 9.1% of providers got it correct pre-education, thinking shorter ventilation time would increase outcomes and survival in this population. Seventeen of the 20 providers who got it wrong, got it right after education, increasing from 9.1% to 86.4%. Two of the providers answered incorrectly even after education was provided.

The last question stated, "Does shorter ventilator time before ECMO cannulation correlate with shorter total ECMO days in COVID-19 patients?" 36.4% of providers answered correctly without education. 12 of the 14 providers changed their answer to false on the posttest, increasing

results to 90.9% of providers answering correctly after education was provided. The results were statistically significant with a p value of <0.001 as well.

Discussion

Ventilator Length

This study showed that ventilator length of time prior to ECMO initiation was not as significant as previously thought. According to literature reviews and ELSO guidelines, ECMO on or after ten days of mechanical ventilation should be potentially contraindicated and was linked to increased mortality. Increased ventilator length prior to ECMO has always thought to have resulted in longer ECMO runs and worse outcomes; however, the results of this study conflict with that hypothesis. This study shows that the length of time a patient has been on the ventilator prior to ECMO initiation has no significant effect on their chance of survival. ECMO considerations should be based on other factors, not just mechanical ventilation.

Provider Education

While this study did not yield significant results on the factors that increase survival in COVID-19 ECMO patients, it did show lack of provider awareness of ECMO usage in this population. The pre/posttest showed a significant increase in education in two of the three questions. The only non-significant result was question one, which ECMO providers should already be aware of prior to this study's education. A significant number of providers thought that longer ventilation days would result in longer ECMO runs and worse mortality. While this isn't necessarily true, providers should be aware of the outcomes in their previous ECMO usage. Being aware of the results from this study could help future patients who would have previously been turned down due to long ventilation days, get reconsidered for this life saving measure.

Cost Analysis

Information for cost analysis was gathered from the MCS team at UK Healthcare. To place a patient on ECMO it costs $17,805.00 with a daily ECMO charge of $12,165.00. Each additional circuit exchange is $5,185.00. Assuming these patients are on ECMO for an average of 24 days, multiple circuit exchanges are inevitable driving up the costs for these patients. It's reported that it costs an average of $1,500 per day just being on the ventilator alone. This is in addition to the daily ICU charge of approximately $10,000 per day while they are on ECMO and weaned off the ventilator.

A more in-depth study is needed regarding cost analysis. While we can look at the ECMO costs in the hospital, indirect costs should be considered as well. Most of these patients, and family members, are off work for extended periods of time, end up on disability, or spend multiple months in rehab or long-term care which also increases costs.

Limitations

This study had some limitations. Some patients had to be eliminated from the sample due to no recorded intubation dates. UK is a regional medical center that gets numerous transfers from outside hospitals in Kentucky and from nine surrounding states. Therefore, the intubation date was not always transferred over in the charting. This study did not separate and compare the different types of ECMO, which include veno-veno (VV), veno-arterial (VA), or an oxyRVAD. The sample size also favored patients who were intubated for shorter periods of time with the two groups being 81 compared to 26 patients in the other. Another limitation was short education viewing time from providers who took the pre/posttests. Qualtrics shows how long each provider who answered the survey took reviewing the education. There were multiple providers contributing to incorrect results that only viewed the education for under one minute, not fully

looking at the results of the study but just answering the questions. Finally, chart review studies are based on medical records and rely on correct documentation of events, making this also a limitation.

Impact on Site and Next Steps

This study brought up many questions that could be used in future research regarding ECMO usage in COVID-19 patients or future pandemics that may develop. While long mechanical ventilation days are sometimes the reason patients are denied ECMO, these results suggest that other factors may be more significant and need further investigating. This study showed that nearly 75% of COVID-19 ECMO patients were obese as well as the ELSO registry confirming that the average BMI for COVID-19 ECMO patients was 32 and 49% of patients had a BMI of >30. 31% of patients had underlying hypertension and 24% had diabetes. There were no underlying comorbidities in 26% of all COVID-19 ECMO patients. While this research study only looked at comorbid index scores and did not look at separate comorbidities and their specific effect on outcomes, it may be beneficial to further this research and assess specific comorbidities such as heart failure, diabetes, or renal failure and the effects on ECMO. While performing my literature review, I found data that linked increased age defined as over 65 years old and ventilator induced injuries to higher mortality in this population. UK's COVID 19 ECMO patients had an 8% higher in-hospital mortality rate than the recorded average. In future research, it may be beneficial to look at BMI and patient's that were placed on ECMO at outside facilities and transferred to UK for further care. I noticed that ECMO patients from outside hospitals were usually in worse condition than patients that were originally placed on ECMO at UK. This may be due to the fact that UK is a transfer center that accepts patients from all over Kentucky and nine surrounding states, often obtaining the sickest patients in the region. The

delay in obtaining an ECMO circuit and transferring the patient results in continued decline at outside hospitals. It may also be beneficial to conduct further research comparing the effect of veno-veno (VV) ECMO to oxyRVAD use in this population.

Conclusion

In conclusion, this study produced different results than what was thought prior to investigation. The objectives of this study were met by comparing mortality and total length of time on ECMO in COVID-19 ECMO patients that were cannulated before and on/after ten days of mechanical ventilation and showed no significant association. Evaluation of and improvement of provider education on effects of long mechanical ventilation on COVID-19 ECMO patient outcomes was performed. Providers who place patients on ECMO and care for them also had a poor understanding of the effect of ventilator length in this population. While the chart review provided insignificant results, provider awareness and education were significantly improved and will cause more discussion and investigation within this population. Patients should not be ruled out for ECMO based solely on pre-ECMO mechanical ventilator days. Providers should use their new knowledge to make case by case decisions on COVID-19 ECMO prospects. It would be beneficial to broaden this study and look at other factors such as BMI, age, or certain comorbidities in the future.

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Table 1. Descriptive summary of total COVID-19 ECMO patients (*N* = 107)

	Mean (SD); range, n (%) or mean (IQR)
Age	46.4 (11.5); 21-70
Gender Male Female	 71 (66.4%) 36 (33.6%)
Race White Black Hispanic Asian Multiracial	 82 (83.7%) 7 (7.1%) 5 (5.1%) 3 (3.1%) 1 (1.0%)
BMI Normal Overweight Obese	 9 (8.4%) 18 (16.8%) 80 (74.8%)
Comorbid Burden	2; 0-4
Ventilator days prior to ECMO Less than 10 days 10 or more days	 81 (75.7%) 26 (24.3%)
Total Days on ECMO	24; 11-37
Discharge Disposition Discharged Deceased	 48 (44.9%) 59 (55.1%)

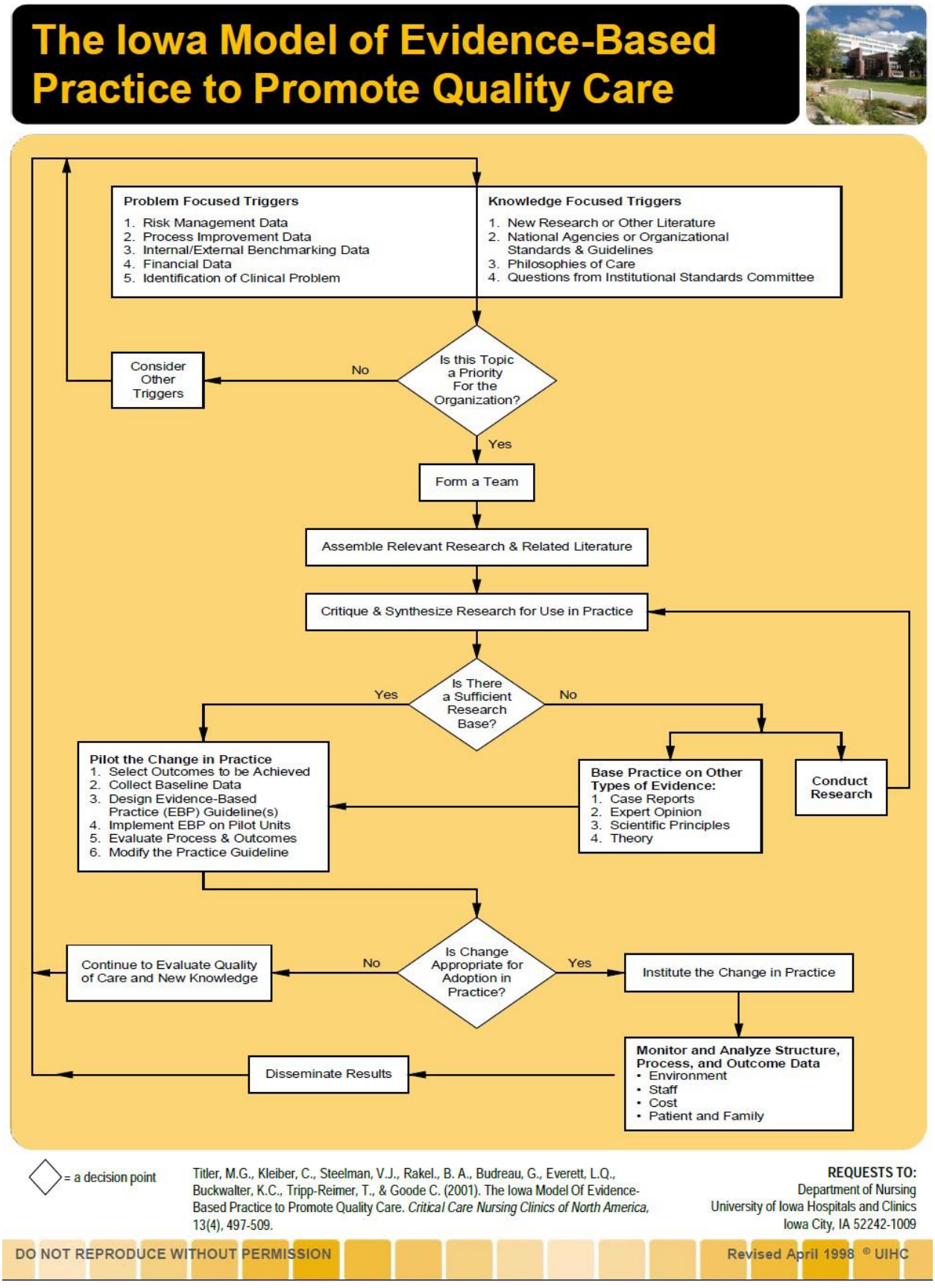
Table 2. Comparison of clinical characteristics by ventilation days

	Ventilation days		*p*
	Less than 10 days	10 or more days	
Age, mean (SD)	46.0 (11.0)	47.8 (13.1)	.48
Gender, n (%)			.55
Male	55 (67.9%)	16 (61.5%)	
Female	26 (32.1%)	10 (38.5%)	
Race/ethnicity, n (%)			.023
White	63 (86.3%)	19 (76.0%)	
Black	7 (9.6%)	0 (0.0%)	
Hispanic	2 (2.7%)	3 (12.0%)	
Asian	1 (1.4%)	2 (8.0%)	
Multiracial	0 (0.0%)	1 (4.0%)	
BMI, n (%)			.086
Normal	6 (7.4%)	3 (11.5%)	
Overweight	11 (13.6%)	7 (26.9%)	
Obese	64 (79.0%)	16 (61.5%)	
Comorbid conditions, median (IQR)	2; 1-4	2; 0-4	.688
Total days on ECMO, median (IQR)	24; 11.5-36.5	21; 8.75-38.5	.796
Discharge disposition, n (%)			.545
Discharged	35 (43.2%)	13 (50%)	
Deceased	46 (56.8%)	13 (50%)	

Table 3. Provider Education Pre/Post Test Results (*N* = 22)

	Pre-education: % Correct	Post-education: % Correct	*P value*
ELSO guidelines define "long invasive mechanical ventilation" as over 10 days	95.5%	95.5%	1.00
Shorter ventilator time before ECMO cannulation does not correlate with increased survival in COVID-19 patients	9.1%	86.4%	<.001
Shorter ventilator time before ECMO cannulation does not correlate with shorter total ECMO days in COVID-19 patients	36.4%	90.9%	<.001

Appendix A: Iowa Model



Appendix B: ELSO Selection Guidelines

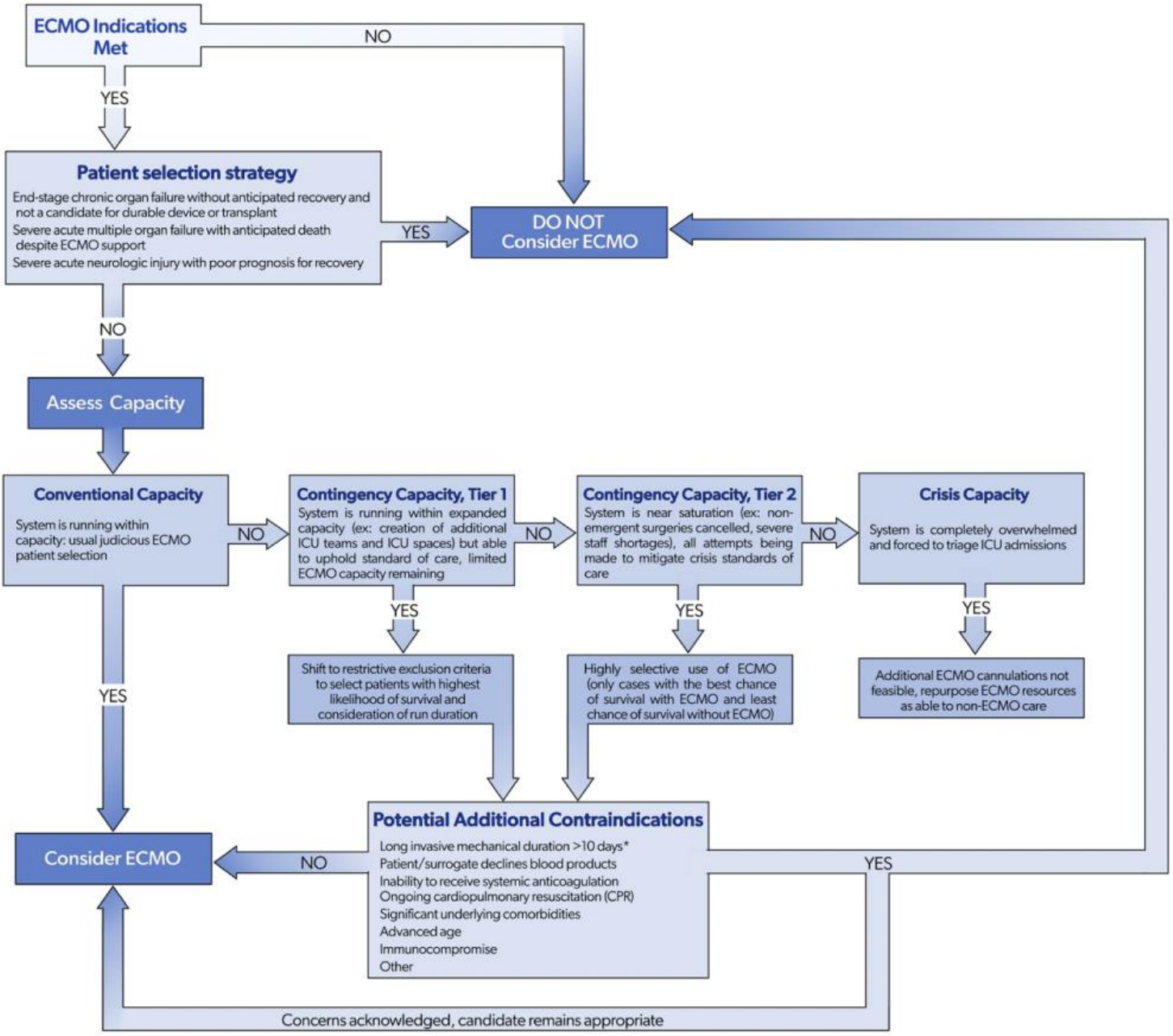


Figure 2. Contraindications algorithm for V-A and V-V ECMO use (COVID-19 and non-COVID-19) during a pandemic based on system capacity. *The impact of duration on high-flow nasal cannula and/or noninvasive mechanical ventilation in addition to invasive mechanical ventilation is unknown. COVID-19, coronavirus disease 2019; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; $PaCO_2$, partial pressure of carbon dioxide in arterial blood; PaO_2:FiO_2, ratio of partial pressure of oxygen in arterial blood to the fractional concentration of oxygen in inspired air; PEEP, positive end-expiratory pressure; V-A, venoarterial; V-V, venovenous.

Appendix C: Provider Pre/Post Test

ECMO Usage in COVID-19 Patients: A Clinical Evaluation Provider Test

1. ELSO guidelines define “long invasive mechanical ventilation” as over 10 days?
    1. True
    2. False

2. Does a shorter ventilator time of under 10 days before ECMO cannulation correlate with increased survival in COVID-19 patients?
    1. Yes
    2. No

3. Does shorter ventilator time of under 10 days before ECMO cannulation correlate with shorter total time on ECMO in COVID-19 patients?
    1. Yes
    2. No