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Features

Ethics of Extracorporeal Membrane Oxygenation under Conventional and Crisis Standards of Care

Gina M. Piscitello, Mark Siegler, and William F. Parker

ABSTRACT

Extracorporeal membrane oxygenation (ECMO) is a form of life support for cardiac and/or pulmonary failure with unique ethical challenges compared to other forms of life support. Ethical challenges with ECMO exist when conventional standards of care apply, and are exacerbated during periods of absolute ECMO scarcity when "crisis standards of care" are instituted. When conventional standards of care apply, we propose that it is ethically permissible to withhold placing patients on ECMO for reasons of technical futility or when patients have terminal, short-term prognoses that are untreatable

by ECMO. Under crisis standards of care, it is ethically permissible to broaden exclusionary criteria to also withhold ECMO from patients who have a low likelihood of recovery, to maximize the overall number of lives saved. Unilateral withdrawal of ECMO against a patient's preferences is unethical under conventional standards of care, but is ethical under crisis standards of care to increase access to ECMO to others in society. ECMO should only be rationed when true scarcity exists, and allocation protocols should be transparent to the public. When rationing must occur under crisis standards of care, it is imperative that oversight bodies assess for inequities in the allocation of ECMO and make frequent changes to improve any inequities.

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Extracorporeal membrane oxygenation (ECMO) is an increasingly utilized form of life support for cardiac or pulmonary failure, one that is used as a bridge to recovery, transplant, or mechanical assist device.¹ It is unique compared to other forms of life support, such as mechanical ventilation and dialysis, in that it can only be provided in acute care hospitals and requires specialized equipment and nursing care.² ECMO can completely replace the function of the permanently failed heart or lung, which may cause it to be a "bridge to nowhere," if a patient has contraindications to transplantation or a durable mechanical assist device. This can lead to patients who remain awake and alert who are unable to survive liberation from

ECMO, contributing to long hospital admissions and high costs.³

Even when ECMO circuits are not scarce, under conventional standards of care, significant ethical challenges exist. Examples include the use of exclusionary criteria to withhold a patient's candidacy for ECMO based upon clinicians' value judgments of the patient's quality of life, and unilateral withdrawal of ECMO, against a patient's preference, for a patient who remains on ECMO for long periods without hope for recovery. During the COVID-19 pandemic, surges in hospitalizations caused regions and health systems to institute "crisis standards of care."⁴ Much debate and focus have been placed on allocation schemes related to the scarcity of mechanical ventilation, which, in most circumstances in the United States, were not needed.⁵ It was ECMO and not mechanical ventilation, however, that became absolutely scarce, and it has been triaged throughout the U.S. during the COVID-19 pandemic. This scarcity was exacerbated by the lack of a unified system to allocate ECMO among hospitals in the U.S.⁶ The need to triage ECMO added ethical challenges on top of the normal challenges with ECMO under conventional standards of care, which are exacerbated by clinical uncertainty regarding patients' prognoses.⁷ The reported cases of triage of ECMO employed a first-come, first-served protocol, a system that ignores other relevant ethical principles and is inherently susceptible to manipulation by well-connected or well-resourced patients.⁸

This article evaluates fundamental ethical issues with ECMO in non-scarce settings and analyzes how these issues become more complicated when ECMO becomes truly scarce. After completing this foundational analysis, we use the insights gained to develop a coherent and equitable ECMO allocation framework to be used under crisis standards of care.

ETHICAL CONCERNS WITH ECMO UNDER CONVENTIONAL STANDARDS OF CARE

Limitations on Candidacy for ECMO

ECMO clinicians place limits on candidacy for ECMO when conventional standards of care apply. These limits are often operationalized by withholding ECMO from patients who meet categorical exclusionary criteria. Currently there is significant risk for inequity in the allocation of ECMO with the use of categorical exclusion-

ary criteria such as age and medical comorbidities, as these exclusionary criteria are not uniform across hospitals and departments in the U.S.⁹

There are four main categories that may be used to limit candidacy for ECMO under conventional standards of care: (1) technical futility; (2) a terminal, short-term prognosis that is untreatable by ECMO; (3) a low probability of a successful bridge to recovery or transplantation; and (4) quality-of-life judgments. The first category, technical futility, places limits on ECMO candidacy when an adequate level of cardiopulmonary support cannot be provided with ECMO, such as in patients with uncontrolled bleeding. The second category, a terminal, short-term prognosis that is untreatable by ECMO, is present when adequate cardiopulmonary support can be provided, but another fatal diagnosis makes short-term survival impossible (for example, placement on ECMO for acute respiratory distress syndrome when a patient has concomitant acute liver failure or intracranial catastrophe) or when ECMO has no proven benefit (for example, refractory vasodilatory septic shock). The third category, a low probability of successful bridge to recovery or transplantation, occurs when the ECMO clinician or patient finds that the burden of a bridge to recovery by ECMO outweighs the potential benefits to the patient (for example, a patient with advanced age and multiple comorbidities who is not a transplant candidate is unlikely to survive, and may experience significant suffering on ECMO without an equal benefit as perceived by the patient). The final category of exclusionary criteria for ECMO is judgments regarding a low quality of life for a patient, when the treatment team makes a value judgment about the patient's comorbid conditions. For example, the Extracorporeal Life Support Organization (ELSO) lists as relative contraindications to ECMO "conditions incompatible with normal life if the patient recovers" and "preexisting conditions which affect the quality of life (central nervous system status, end-stage malignancy, risk of systemic bleeding with anticoagulation)" (see table 1).¹⁰

While the limitations on candidacy for ECMO that are based on technical futility and on a terminal, short-term prognosis that is untreatable by ECMO are less controversial, withholding ECMO based on a low probability of a successful bridge to recovery and transplant or based on quality-of-life criteria must be scru-

tinized, as they require value judgments by clinicians. Categorical exclusionary criteria that are based on these types of categories may deprioritize members of certain groups, such as elders and racial minorities, without allowing holistic evaluation of each patient's current medical status and history, which may lead to the discovery of additional factors that would influence the likelihood of a patient's surviving ECMO (see table 1).¹¹

ECMO centers, which can be motivated by factors outside direct patient care, may also seek to exclude patients, even when ECMO circuits are plentiful. Contextual features, such as the high cost to the hospital and the patient's ability to pay, may covertly influence decisions regarding candidacy for ECMO. Access to ECMO is often limited to tertiary or quaternary care centers and is associated with high healthcare costs. A disorganized U.S. health system has prevented patients who meet inclusion criteria for ECMO, but who are located in hospitals without ECMO, from transferring to locations that offer ECMO. ECMO cases with a low probability of success (but that are not strictly futile) may be turned down by hospitals, not for a valid, ethical reason, but instead due to concerns about financial margins; hospitals may prefer instead to maximize profits by focusing on procedures that will be more lucrative.

Another ethical concern is that the criteria used to exclude patients' access to ECMO may

be overly broad. Broad exclusionary criteria may incentivize the over treatment of patients who could survive without ECMO, as centers seek higher volumes of ECMO use and enjoy artificially inflated data on rates of survival. Incentives to inflate survival data may be minimal, however, as survival statistics are not required for applications to become an ELSO Center for Excellence.¹²

When ECMO circuits are not regionally scarce and standards of conventional care are in place, rationing ECMO is unethical. We support a centralized oversight system that allocates ECMO to patients who qualify by multidisciplinary evaluation, so that the rationing of ECMO does not occur when ECMO circuits are available elsewhere. When conventional standards of care are in place, we agree with the use of exclusionary criteria for technical futility when considering candidates for ECMO, which can help guide candidacy for ECMO with the intent of saving lives and minimizing harm to patients. We acknowledge that terminal, short-term prognoses can ethically be considered by clinicians to exclude a patient from candidacy for ECMO if, for example, it is determined that the burdens of ECMO outweigh the potential benefits for the patient. Under conventional standards of care, we disagree with the use of categorical exclusionary criteria for patients who have a low probability of survival with ECMO. Probability of survival must be generated from multiple vari-

TABLE 1. Limitations to candidacy for ECMO

Exclusion category	Example
1. Technical futility ¹	Patients with abdominal aortic rupture that cannot be repaired.
2. Terminal, short-term prognosis untreatable by ECMO ²	Patients considered for ECMO with acute respiratory distress syndrome who have concomitant end-stage liver disease with no further treatment options, who are not candidates for a liver transplant, and for whom the harms of ECMO would outweigh the potential benefits.
3. Low probability of successful bridge to recovery or transplantation ³	Patients of advanced age with multiple comorbidities, who are ineligible for transplantation, who have a low probability of surviving a prolonged bridge to recovery on ECMO.
4. Quality-of-life judgments ⁴	Patients with dementia, clinician-determined poor quality of life, or categorical age exclusions.

NOTES

1. A strong ethical foundation to consider as exclusionary criteria under conventional standards of care and crisis standards of care.
2. Ibid.
3. Can be considered as exclusionary criteria during periods of absolute scarcity of ECMO to maximize the number of lives saved.
4. Should not be used as categorical exclusionary criteria under conventional standards of care or crisis standards of care.

ables rather than the use of categorical clinical cutoffs (for example, body mass index >40). Patients' preferences regarding the potential benefits and burdens of ECMO should be incorporated into decision making. Strict quality-of-life exclusions for illnesses such as dementia, which may be subjectively and broadly defined, and that lack uniform criteria regarding disease progression and patients' outcomes, are ethically problematic, as they do not allow multidisciplinary evaluation of each patient. Evaluation for ECMO must be holistic and include patients' likelihood of survival, patients' and clinicians' perceptions of possible benefit from ECMO, and patients' preferences regarding a trial of ECMO.

Unilateral Withdrawal of ECMO for Patients Who Are on a "Bridge to Nowhere"

Ethical, legal, and clinician practice encourage withdrawal of life support when a patient does not want it, including ECMO. There is less support for unilateral withdrawal of ECMO under conventional standards of care, when ECMO is not scarce.¹³ Unilateral withdrawal of ECMO against the wishes of a patient or surrogate is controversial, especially for patients who are on a "bridge to nowhere" (that is, for whom recovery, transplant, or transition to another form of mechanical life support are not available), who remain awake and alert on ECMO, request to remain on ECMO support, and are unable to survive liberation from it.¹⁴ ECMO that constitutes a "bridge to nowhere" for these patients can be harmful, as it prolongs their suffering and increases the risk of complications from ECMO, including neurologic catastrophe or exsanguination, which can be traumatic for patients, families, and medical staff. Sustained ECMO in these situations is also not desirable from the perspective of a benevolent social planner, as "bridge to nowhere" ECMO is orders of magnitude less cost effective than expanding society's access to health insurance and medications.¹⁵

Although discussion of a time-limited trial during the informed consent process may be one way to plan for withdrawal of ECMO in the future if a patient cannot be liberated from it, this is a challenge to pursue, as informed consent discussions for ECMO are often brief and, even when patients have previously consented to a time-limited trial, they may change their mind at any time while on ECMO.¹⁶ If this occurs, their preferences should be honored by clinicians to the best of their ability. In addition, there is con-

cern that patients may feel implicitly or explicitly coerced into accepting a clinician-recommended time-limited trial, as they may view agreement with these recommendations to be necessary to receive potentially life-prolonging care with ECMO.

On the other hand, there are often many ethical reasons to support maintaining patients on ECMO who are not able to survive liberation from it. Clinicians have an obligation to provide care to patients that is available, is medically beneficial to them based upon the clinician's and patients' preferences for care, and is consistent with other life support measures such as mechanical ventilation and dialysis, which are routinely provided to patients in the U.S.

Under conventional standards of care, we recommend that patients who request continued ECMO support be allowed to remain on it, even if significant costs arise. We disagree with the consideration of unilateral withdrawal of ECMO, under conventional standards of care, due to cost concerns. Rather than reallocate care from patients on ECMO for extended periods to others in society who have medical needs—which is unlikely to happen in our current medical system due to political barriers—we recommend that efforts be focused on expanding access to medical care, including medical insurance and affordable medication coverage, to those in society who do not have them, to improve health equity across society.

ETHICAL CONCERNS WITH ECMO UNDER CRISIS STANDARDS OF CARE

Ethical values that can guide the allocation of scarce healthcare resources include saving the greatest number of lives overall, saving the greatest number life-years by prioritizing younger patients, random allocation, and giving priority to those who can benefit others during a pandemic such as healthcare workers.¹⁷ Variation in use of these allocation principles will contribute to differences in the allocation of ECMO in practice. Studies that have assessed current policies in the U.S. regarding the allocation of scarce resources report that there is significant variability in allocation guidelines for ECMO and mechanical ventilation across individual hospitals and states.¹⁸ Even if these differences in allocation guidelines across hospitals could be controlled, variability in allocation within hospitals will likely exist. There is evidence that

triage officers who use a single ventilator allocation protocol have different outcomes when they rank the same patients for allocation. This is likely related to the high rate of “tie breakers” to determine allocation in these protocols.¹⁹ For example, when 49 triage officers in Chicago-area hospitals were asked to rank hypothetical patients in need of mechanical ventilation using their hospital’s ventilator allocation protocol, 47 percent reported the use of at least one tie breaker to rank patients, as clinical indicators alone were not enough to distinguish one patient from another.

Protocols for the Allocation of Scarce Resources in Practice—Lessons Learned from Protocols for Mechanical Ventilation

The use of allocation methods for ECMO to prioritize saving the most lives or the most life-years may be too complex to be used in practice, as seen with the allocation of mechanical ventilation, and may contribute to inequity in allocation by race/ethnicity and age, as outlined below.²⁰ One multicenter retrospective simulation study that assessed allocation policies that had been designed to save the most overall lives using both short-term prognosis (for example, Sequential Organ Failure Assessment—SOFA) and long-term prognosis (for example, medical comorbidities) found that racial inequity would occur in the allocation of ventilators.²¹ Importantly, another retrospective cohort study that also used short- and long-term prognosis for the allocation of scarce resources did not find racial inequities in allocation.²² Allocation protocols that use SOFA as a short-term prognosis factor increase the risk for racial inequity in allocation, as the same SOFA score has been found to be associated with an overestimated mortality risk for Black patients when compared to White patients.²³ This may be related to differences in kidney and hematologic SOFA scores among races, as the range of lab values chosen to meet each score may give higher scores to Black patients that are not clinically associated with higher overall mortality. Allocating scarce resources to save the most life-years by prioritizing the youngest to receive allocation first may lead to overall better survival for all patients. However, this approach likely will also contribute to age inequity in allocation and risk for racial/ethnic inequity.²⁴ A random lottery may likely have the lowest risk of racial/ethnic and age inequity in allocation and be the least time-

intensive allocation method to pursue. The random lottery method could, however, lead to lower overall rates of survival.²⁵

Simulation of ECMO allocation protocols using patients’ data has not yet been done. It is possible that outcomes for ECMO allocation protocols may be similar to that of outcomes for ventilator allocation protocols, which were described above. For these reasons, the use of a random lottery to allocate ECMO for all patients who meet candidacy criteria for ECMO may be the best choice to pursue currently. The use of a random lottery is quick to implement and may have the lowest risks of inequity in allocation and of bias from numerical scoring scales. Once empirical scales are created that can accurately reflect patients’ severity of illness and likelihood of survival and equitably allocate ECMO, we recommend that the random allocation of ECMO be replaced for patients who meet the criteria for ECMO based on these new empirical scales.

Limitations on Candidacy for Access to ECMO under Crisis Standards of Care

Limitations on candidacy for ECMO by the use of exclusionary criteria have the potential to maximize the number of lives saved by allocating ECMO circuits to patients who have the highest likelihood of future improvement and liberation from ECMO.²⁶ If these exclusionary criteria are uniform across hospitals and departments, they have the potential to increase the equitable allocation of ECMO independent of a patient’s geographic location. However, exclusionary criteria for ECMO during the COVID-19 pandemic became more strict and more likely to lead to inequities in the allocation of ECMO. During the COVID-19 pandemic, ELSO recommended the following absolute contraindications for placing patients on ECMO with cardiopulmonary failure from COVID-19: advanced age, chronic kidney disease stage three or greater, dementia, and an inability to accept blood products.²⁷ These absolute exclusionary criteria contributed to inequity in allocation that deprioritized elders; groups with higher rates of kidney disease, including Black and Hispanic patients; and Jehovah’s Witnesses patients, who cannot receive blood products.²⁸ Relative contraindications for ECMO by ELSO’s guidelines also included situations when no legal medical decision makers were available. This increased the risk that patients without family support would have less access to ECMO.

Currently existing criteria for ECMO under crisis standards of care are inequitable and categorically exclude members of vulnerable groups without holistic evaluation. We disagree with the use of categorical exclusionary criteria for this reason, except in cases of true physiologic futility and terminal, short-term prognosis untreatable by ECMO, consistent with our recommendation for the criteria to be used under conventional standards of care. We believe it is ethical to also consider the exclusion of patients who have a low probability of a successful bridge to recovery or transplantation, to maximize the number of lives saved under crisis standards of care. We disagree with use of categorical exclusionary criteria that are related to quality-of-life judgments, even under crisis standards of care, and instead recommend holistic, multidisciplinary evaluation of each candidate who is considered for access to ECMO.

Unilateral Withdrawal of ECMO under Crisis Standards of Care

Ethical and legal support exist for withdrawing life support during periods of true scarcity, in order to provide care for other patients with medical indications for that resource who are more likely to survive.²⁹ It would be difficult for

clinicians, patients, and families to undergo unilateral withdrawal of ECMO support in these settings. The alternative—to allow patients who are not recovering to remain on ECMO for significant time periods³⁰—could result in prioritizing patients who arrive first to the hospital and inequitably deprioritizing patients who arrive later.

Under crisis standards of care, we agree it is ethical for clinicians to unilaterally withdraw ECMO from one patient who is not recovering and provide ECMO to another patient who has a better chance of recovery. When crisis standards of care are enacted, we believe that all patients admitted to the hospital should be informed that unilateral withdrawal of life support may occur, with the intent to most equitably allocate life support among all patients who meet medical indications for this support. We also recommend that special training and support be provided to medical teams to aid in their communication with patients and families about potential, unilateral withdrawal of life support in a transparent and empathetic manner. This recommendation is different from our recommendations regarding withdrawal of ECMO under conventional standards of care, when we do not believe that unilateral withdrawal of ECMO

TABLE 2. Withholding and withdrawing ECMO under conventional standards of care and crisis standards of care

Conventional standards of care	Crisis standards of care
Ethically acceptable to withhold ECMO	
<ul style="list-style-type: none"> • Technical futility • Terminal, short-term prognosis is untreatable by ECMO 	<ul style="list-style-type: none"> • Technical futility • Terminal, short-term prognosis is untreatable by ECMO • Consider excluding patients with low probability of a successful bridge to recovery or transplantation
Not ethically acceptable to withhold ECMO	
<ul style="list-style-type: none"> • Patients with low probability of a successful bridge to recovery or transplantation • Categorical, clinician-defined quality-of-life judgments 	<ul style="list-style-type: none"> • Categorical, clinician-defined quality-of-life judgments
Withdrawing ECMO	
Unethical to unilaterally withdraw ECMO against patient's preferences	Ethical to consider unilateral withdrawal of ECMO against patient's preferences when ECMO scarcity exists, to allow access to ECMO for other patients who meet medical indications for it

is ethically appropriate for patients who request to remain on ECMO (see table 2).

RECOMMENDATIONS FOR THE ALLOCATION OF ECMO UNDER CRISIS STANDARDS OF CARE

Utilizing the discussion about the ethics of ECMO in practice, we propose a framework for allocation of ECMO during periods of true scarcity that is presented in table 3.

Limitations

Although inequitable allocation of ECMO may still exist even with our proposed model for allocation under crisis standards of care, we intend to minimize this risk. Instituting the recommendations we make in table 3 will reduce the inequitable allocation of ECMO by providing a centralized source for the allocation ECMO and by only rationing ECMO when true scarcity exists. This centralized oversight will limit the potential for patients who have more resources to have the ability to succeed in receiving ECMO at higher rates than other groups.³¹ We do acknowledge that without significant support from individual states and/or the U.S. government to create centralized oversight for the allocation of ECMO, our proposed method to minimize rationing will be difficult to implement in practice. At this time we do not recommend the use of an area deprivation index in our allocation framework, as past data from simulations of ventilator allocation protocols suggest that the random allocation strategy in our model should not contribute to racial inequity.³² These simulated studies are limited, however, as they evaluated patients who met criteria for mechanical ventilation, which included patients who were medically different than those who meet clinical criteria for ECMO. Thus, the outcomes observed from the ventilator allocation simulations may be different than if an ECMO allocation simulation was performed. We are open to considering the integration of an area deprivation index if socioeconomic allocation disparities are found to exist in practice, once the framework is used.³³

CONCLUSIONS

There are unique ethical concerns regarding the care of patients who receive ECMO compared to other forms of life support. These ethical concerns are exacerbated during periods of

absolute scarcity such as during the COVID-19 pandemic. We have provided a framework for the allocation of ECMO that we believe will minimize inequities in the allocation of ECMO under crisis standards of care.

NOTES

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7. MacLaren, Fisher, and Brodie, "Treating the

TABLE 3. Allocation of ECMO under crisis standards of care

Minimize triage of access to ECMO
<ul style="list-style-type: none">• Create a nationwide ECMO allocation network.• Create a nationwide database to identify all open ECMO circuits with adequate staffing for use across the U.S.• Create a centralized process to transfer patients who have medical indications for ECMO to hospitals with availability, if stable, or transfer ECMO circuits and staffing to patients in need. This move should be utilized before considering whether to ration ECMO.• If a true scarcity of ECMO circuits and/or clinical staffing exist even after the measures above are completed, we propose allocating access to ECMO as outlined below.
Allocation protocol if true scarcity of ECMO exists
<ol style="list-style-type: none">1. <i>Create a triage committee.</i> Create an institutional triage committee to aid in oversight for equitable allocation of ECMO. Triage committee members should not be involved in direct patient care of the patients considered for allocation to reduce bias in allocation. Members of the triage committee may include physicians (cardiothoracic surgeons, intensivists, etc.), nurses, ethicists, and patient representatives/advocates from the community. The triage committee should include at least two members at any one time to increase the ability of the committee to respond to questions and potential appeals about the decisions that have been made.2. <i>Use exclusionary criteria for cases with true physiologic futility and terminal, short-term prognoses that are untreatable by ECMO, with consideration of the exclusion of patients who have a low probability of successful bridge to recovery or transplantation, to maximize lives saved.</i> Avoid the use of categorical exclusionary criteria and priority groups in the allocation of ECMO, which may disproportionately deprioritize groups such as elders and populations who have been disproportionately affected by medical comorbidities.¹ Encourage clinicians to holistically assess each patient for medical indications for ECMO and include all patients who meet medical indications for ECMO in the pool for potential allocation. Holistic assessment can include evaluation of current medical conditions, medical comorbidities, patients' preferences to pursue aggressive interventions, etc.3. <i>Utilize a random lottery for allocation.</i> For patients who meet medical indications for ECMO, utilize a random lottery to allocate ECMO circuits when they become available, to reduce inequity in allocation by age and race/ethnicity.4. <i>Create a withdrawal mechanism.</i> Create a unified mechanism to withdraw ECMO support from a patient after a time-limited trial of support (based on the best available data relating to the patient's disease processes, which evolve over time²) to equitably provide other patients a chance to benefit from ECMO. One potential example could be to recommend withdrawal of ECMO once ECMO survival rates reach a plateau.³ Recommend institutional support for patients, families, and staff who care for patients on ECMO when withdrawal is considered. Recommend training for staff who will discuss ECMO withdrawal with patients and families.5. <i>Integrate palliative medicine.</i> Recommend providing assistance by palliative medicine to aid in the management of patients' symptoms and clinical discussions to all patients who receive ECMO, due to the high risk of mortality and potential withdrawal of ECMO support if the patients do not improve.
Procedural principles
<ol style="list-style-type: none">1. <i>Retrospective oversight.</i> Recommend that institutions create a process for retrospective oversight of allocation decisions to assess for disparities in allocation (including race, ethnicity, age, etc.) and take action to reduce them when they occur. If there is concern that socioeconomic inequities are occurring, consider the use of adding an area deprivation index into a weighted lottery allocation strategy to reduce these disparities.2. <i>Transparency.</i> Allocation criteria should be transparent to the public and include criteria to exclude patients from consideration for ECMO and to withdraw patients from ECMO who have a lower chance of recovery.3. <i>Appeals process.</i> An appeals process should be created to allow bedside clinicians to advocate to the triage committee if a true error has been made regarding ECMO eligibility or withdrawal. This appeals process must not allow triage decisions to be swayed by subjective judgments or coercion.

Table 3 is continued on the next page.

Most Critically Ill Patients,” see note 2 above; G. MacLaren, D. Fisher, and D. Brodie, “Preparing for the Most Critically Ill Patients With COVID-19: The Potential Role of Extracorporeal Membrane Oxygenation,” *Journal of the American Medical Association* 323, no. 13 (22 December 2020): 1245-6, <https://doi.org/10.1001/jama.2020.2342>; M. Schmidt et al., “Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome associated with COVID-19: A retrospective cohort study,” *Lancet Respiratory Medicine* 8, no. 1 (2020): 1121-31; R.A. Diaz, et al., “Extracorporeal Membrane Oxygenation for COVID-19-associated Severe Acute Respiratory Distress Syndrome in Chile: A Nationwide Incidence and Cohort Study,” *American Journal of Respiratory Critical Care Medicine* 204, no. 1 (2021): 34-43; R.P. Barbaro et al., “Extracorporeal membrane oxygenation support in COVID-19: An international cohort study of the Extracorporeal Life Support Organization registry,” *Lancet* 396, no. 10257 (2020): 1071-8; R.P. Barbaro et al., “Extracorporeal membrane oxygenation for COVID-19: Evolving outcomes from the international Extracorporeal Life Support Organization Registry,” *Lancet* 398, no. 10307 (2021): 1230-8; ELSO, “Registry Dashboard of ECMO-Supported COVID-19 Patient Data,” 5 January 2021, <https://www.else.org/Registry/FullCOVID-19RegistryDashboard.aspx>; C. Karagiannidis et al., “Complete countrywide mortality in COVID patients receiving ECMO in Germany throughout the first three waves of the pandemic,” *Critical Care* 25, no. 1 (2021): 413; G. Lebreton et al., “Extracorporeal membrane oxygenation network organisation and clinical outcomes during the COVID-19 pandemic in Greater Paris, France: A multicentre cohort study,” *Lancet Respiratory Medicine* 9, no. 8 (2021): 851-62; A.A. Rabie et al., “Implementation of new ECMO centers during the COVID-19 pandemic: Experience and results from the Middle East and India,” *Intensive Care Medicine* 47, no. 8 (2021): 887-95.

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