Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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EDITORIAL

Extracorporeal Membrane Oxygenation in Acute Respiratory Distress Syndrome: How Do We Expand Capacity in the COVID-19 Era?

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Despite advances in medical technology, the mortality rate for severe acute respiratory distress syndrome (ARDS) remains high at around 40% [1]. In recent years, multiple studies, systematic reviews, and meta-analyses [2–5], including the study in this issue of *Heart, Lung and Circulation* published by Wang and colleagues [4], have indicated that treatment with veno-venous extracorporeal membrane oxygenation (VV-ECMO) may be associated with better outcomes in severe ARDS than conventional mechanical ventilation. Increasing evidence will likely lead to an increase in the use of VV-ECMO in the treatment of ARDS in the coming years [6].

ARDS is an acute inflammatory lung injury resulting in widespread alveolar injury and hypoxaemia [4,7]. There is no gold standard to diagnose ARDS, and each ARDS case can have a multitude of causes [7]. Many providers diagnose ARDS based on the Berlin criteria which take into account the timing of symptoms, chest imaging, the presence of other possible explanations for pulmonary oedema, and oxygenation requirements [8]. In their article, Wang and colleagues perform a comprehensive literature review and meta-analysis of research examining the utility of ECMO in the treatment of ARDS [4]. They found that ECMO treatment was associated with improved 60-day and 1-year mortality but increased intensive care unit (ICU) mortality [4]. Applying these findings within the complex ecosystem of the ICU requires a consideration of patient, provider, and systems-level issues.

Most often, authors cite a lack of high-quality randomised controlled trials (RCTs) as a limitation in definitively determining whether ECMO or conventional mechanical ventilation is more effective in treating ARDS [2,7,9]. As discussed by Wang and colleagues, the two most definitive RCTs examining outcomes in those treated with ECMO for ARDS, the Conventional ventilation or ECMO for Severe Adult Respiratory Failure (CESAR) study and the ECMO to Rescue Lung Injury in Severe ARDS (EOLIA) study showed conflicting results [3,10]. CESAR showed a significantly better likelihood of survival and an improvement in quality-adjusted life-years with ECMO treatment versus conventional mechanical ventilation [3]. EOLIA found an 11% decrease in mortality in the ECMO group but failed to reach statistical significance [10]. Though some argue that results have been inconclusive, others assert that there is sufficient evidence to question the ethics of withholding ECMO treatment from patients with severe ARDS to conduct other RCTs [11]. This makes a confirmatory RCT unlikely and underscores the importance of registry data.

While more research is needed to definitively determine which patients would most benefit from the use of ECMO,

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improvements in technology and survivability in recent years has made ECMO a more reasonable treatment for patients with severe ARDS [6]. In the United States, adult respiratory ECMO "runs" increased from 92 cases in 2008 to 3,133 in 2019, and the survival rate has increased from 39% to 65% within the same time period [12]. In the coming years, results like those published by Wang and colleagues will continue to encourage clinicians to consider ECMO therapy for their patients with severe ARDS, particularly in the post COVID era [4]. The increasing use of ECMO for respiratory failure and ARDS treatment raises questions about how to increase capacity to safely and effectively deliver ECMO. ECMO requires significantly more providers and resources to operate compared to those with mechanical ventilation only, so how do medical centres scale up to accommodate more ECMO therapy?

The most commonly used strategy to expand capacity of ECMO treatment and improve outcomes over the past decade has been risk stratification and mortality prediction models [1,13–15]. Because ECMO is not only invasive but also very resource-intensive, it is often reserved for the sickest patients and only considered when other, less extreme treatment options have been exhausted [1,11]. First line treatments for ARDS include lung protective-ventilation, prone positioning, and neuromuscular blockade with heavy sedation [1,7]. For patients who do not respond to these less invasive options, ECMO allows for sufficient oxygenation without the use of potentially harmful ventilation volumes or peak pressures, and therefore helps decrease the risk for ventilator-associated lung injury [7].

Determining which patients would most benefit from ECMO support and which require less invasive strategies can be difficult. Several risk stratification models exist to aid clinicians in making this determination [15]. The PREdiction of Survival on ECMO Therapy-Score, Predicting death for severe ARDS on VV-ECMO score, and the ECMOnet score have all shown moderate predictive value in determining which patients will benefit most from ECMO therapy [13–15]. Further research is needed to refine these prediction models and to determine which best predicts ECMO outcomes.

Even with accurate prediction models helping clinicians choose which patients would most benefit from ECMO therapy, limited resources can prevent access to ECMO [16]. The H1N1 influenza pandemic highlighted how these resource limitations, particularly in trained personnel, could prevent those who might have benefitted from ECMO therapy from receiving the treatment [17]. Similarly to the H1N1 pandemic, ECMO usage has increased with the influx of patients suffering from severe ARDS secondary to COVID-19 infection [5,16]. It is critical during this time to reevaluate staffing and resource utilisation models, to maximise the number of patients who can be cared for safely [5]. Expanding the role of nurses to supplement perfusionists is one possible solution to increase capacity to care for patients requiring ECMO support without sacrificing quality [18].

Bedside nurses with special training in ECMO management are capable of fulfilling many of the roles that have traditionally been performed by perfusionists [18,19]. Following the H1N1 pandemic, the international Extracorporeal Life Support Organization (ELSO) created new guidelines for the training of ECMO specialists, allowing nurses with at least a year of critical care experience to be trained to fill the role [20]. Expanding the responsibilities of nurses in the management of the ECMO circuit allows for larger perfusionist-to-patient ratios and reduces costs without sacrificing patient safety [18,20]. Though perfusionists should still be available for major events like cannulation, decannulation, and emergencies, these critical care nurses, directed by intensivists and standards of care algorithms, can manage the ECMO circuit in addition to the typical level of care provided to patients in the ICU.

In addition to implementing risk stratification models and expanding nursing roles, consolidating patients requiring ECMO support to high volume medical centres or specialised lung recovery units when possible has the potential to increase capacity for ECMO treatments while also improving patient outcomes [21,22]. Maintaining an ECMO program requires a sophisticated network of nurses, perfusionists, respiratory therapists, emergency medicine physicians, respiratory physicians, cardiologists, and intensivists, all specially trained in ECMO management [22]. Particularly in hospitals where ECMO cases are rare, maintaining an ECMO program can be expensive and inefficient [22]. High volume centres have the resources and case volume to not only financially justify an ECMO program but also maintain a staff of trained, competent clinicians with ample experience caring for patients requiring ECMO support.

Beyond triaging patients requiring ECMO support to high volume medical centres, further specialisation into dedicated ECMO units has proven to be effective. A lung rescue unit (LRU) at the University of Maryland Shock Trauma Center is one of the first units of its kind. Opened in 2015, the LRU is an ICU exclusively reserved for adult patients requiring VV-ECMO for respiratory failure [21]. The incredibly specialised nature of this unit allows the clinicians that work there to quickly develop and maintain competencies in caring for patients on VV-ECMO. In its first year, the LRU improved the hospital's survival rate from 50% to 71% [21]. While this model is not sustainable for all hospitals, large, academic medical centres with steady streams of patients requiring VV-ECMO support could more efficiently manage staff and resources without sacrificing quality of care by adopting this model.

Especially in the context of the COVID-19 pandemic, expanding capacity for ECMO usage is of critical importance. Current World Health Organization recommendations include the use of ECMO in the treatment of COVID-19 associated ARDS when conventional mechanical ventilation is insufficient [5]. While there is no up-to-date, published data regarding the number of patients who have received VV-ECMO during the COVID pandemic, the data shared through the ELSO COVID dashboard suggests that nearly

5,000 adults have received VV-ECMO support as a result of COVID-19 infection world-wide [23]. This increased usage highlights the importance of expanding capacity to meet the needs of the world's population and demands attention to workforce and procedural volume issues [16]. As cases soar, more people require ECMO support, and triaged resource allocation becomes a reality: strategies to expand capacity are even more necessary [24].

Wang and colleagues make a useful contribution to the literature, particularly in the context of the COVID-19 pandemic [4]. Increases in ECMO for the treatment of ARDS will require clinicians and medical centres to develop strategies to maximise patient safety and quality of care [20]. Risk stratification, skill enhancement of all health workers, expanding nurses' roles, and specialised ECMO centres are examples of ways to expand capacity for providing ECMO support. Given the emerging data on the importance of ECMO in ARDS, careful attention to workforce issues is timely and important.

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None.

Conflicts of Interest

None.

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