# Multi-institutional Analysis of 100 Consecutive Patients with COVID-19 and Severe Pulmonary Compromise Treated with Extracorporeal Membrane Oxygenation: Outcomes and Trends Over Time

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The role of extracorporeal membrane oxygenation (ECMO) in the management of severely ill patients with coronavirus disease 2019 (COVID-19) continues to evolve. The purpose of this study is to review a multi-institutional clinical experience in 100 consecutive patients, at 20 hospitals, with confirmed COVID-19 supported with ECMO. This analysis includes our first 100 patients with complete data who had confirmed COVID-19 and were supported with ECMO. The first patient in the cohort was placed on ECMO on March 17, 2020. Differences by the mortality group were assessed using  $\chi^2$  tests for categorical variables and Kruskal-Wallis rank-sum tests and Welch's analysis of variance for continuous variables. The median time on ECMO was 12.0 days (IQR = 8-22 days). All 100 patients have since been separated from ECMO: 50 patients survived and 50 patients died. The rate of survival with veno-venous ECMO was 49 of 96 patients (51%), whereas that with veno-arterial ECMO was 1 of 4 patients (25%). Of 50 survivors, 49 have been discharged from the hospital and 1 remains hospitalized at the ECMO-providing hospital. Survivors were generally younger, with a lower median age (47 versus 56.5 years, p = 0.014). In the 50 surviving patients, adjunctive therapies while on ECMO included intravenous steroids (26), anti-interleukin-6 receptor blockers

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(26), convalescent plasma (22), remdesivir (21), hydroxychloroquine (20), and prostaglandin (15). Extracorporeal membrane oxygenation may facilitate salvage and survival of selected critically ill patients with COVID-19. Survivors tend to be younger. Substantial variation exists in the drug treatment of COVID-19, but ECMO offers a reasonable rescue strategy. ASAIO Journal 2021; 67;496–502

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As of October 4, 2020, 34,963,965 patients around the world have been diagnosed with coronavirus disease 2019 (COVID-19), with 1,034,185 associated deaths (2.96% mortality worldwide).<sup>1</sup> Meanwhile, in the USA, as of October 4, 2020, 7,385,837 patients have been diagnosed with confirmed COVID-19, with 209,408 associated deaths to date (2.84% mortality in the USA).<sup>1</sup> Most deaths in patients with COVID-19 are due to severe respiratory failure, with a small group succumbing to combined pulmonary and cardiac failure.<sup>2,3</sup>

We previously published an analysis of 32 COVID-19 patients with severe pulmonary compromise supported with extracorporeal membrane oxygenation (ECMO)<sup>4</sup> and concluded that "ECMO may play a useful role in salvaging selected critically ill patients with COVID-19. Additional patient experience and associated clinical and laboratory data must be obtained to further define the optimal role of ECMO in patients with COVID-19 and acute respiratory distress syndrome (ARDS). These initial data may provide useful information to help define the best strategies to care for these challenging patients, and may also provide a framework for much-needed future research about the use of ECMO to treat patients with COVID-19."<sup>4</sup>

Several recently published analyses describe cohorts of COVID-19 patients supported with ECMO.<sup>4-8</sup> Early data from Wuhan, China, reported an alarmingly high rate of mortality of 83% (5 out of 6) in COVID-19 patients supported with ECMO.<sup>5,6</sup> More recent data, however, reveal improved survival of COVID-19 ECMO patients.<sup>4,7,8</sup> Both recent individual institutional reports,<sup>7</sup> as well as recent reports from multi-institutional registries,<sup>8</sup> present detailed analyses with promising results and improvements in survival. Our current report from our multi-institutional database<sup>4</sup> corroborates these studies from individual institutions<sup>7</sup> and multi-institutional registries,<sup>8</sup> but additionally provides more granular, detailed information

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than a large-scale registry and more generalizable information than analysis from a single institution. It is a fact that the role of ECMO in the management of severely ill patients with COVID-19 continues to evolve. The purpose of this study is to review our multi-institutional clinical experience in 100 consecutive patients with confirmed COVID-19 and severe pulmonary compromise supported with ECMO and to document outcomes and trends in management over time.

## **Materials and Methods**

A prospective, multi-institutional cohort study was conducted on all patients with confirmed COVID-19 who were supported with ECMO at 20 hospitals. A multi-institutional database was created and utilized to assess these patients. This database is prospectively maintained on all patients and has been used for data collection and analysis. The database used is a component of the SpecialtyCare Operative Procedural REgistry, (SCOPE<sup>TM</sup>) [https://specialtycareus.com/]. (SpecialtyCare is a United States provider of Allied Health services, and the SCOPE<sup>™</sup> Registry contains data from over 1 million perfusion procedures in over 40 states at more than 300 hospitals. This manuscript describes the ECMO experience treating a subset of these patients with COVID-19.) Data captured included patient characteristics, pre-COVID-19 risk factors and comorbidities, confirmation of COVID-19 diagnosis, features of ECMO support, specific medications utilized in an attempt to treat COVID-19, and shortterm outcomes through hospital discharge.

This analysis includes our first 100 patients with complete data who had confirmed COVID-19 and were supported with ECMO, starting with our first COVID-19 patient who was placed on ECMO on March 17, 2020. These 100 patients include 96 patients supported with veno-venous ECMO and 4 patients supported with veno-arterial ECMO. The initial cohort included our first 104 patients who had confirmed COVID-19 and were supported with ECMO; four patients (one survivor and three nonsurvivors) were excluded from this analysis because of incomplete data. Inclusion in the analysis required complete data in the following fields: ECMO start date, ECMO end date, outcome (alive or dead), pre-COVID comorbidities (asthma, cancer, chronic renal failure, diabetes, heart disease, hypertension, or obesity), and adjunctive therapeutic interventions (antiviral medications, antimalarial medications, convalescent plasma, interleukin-6 blockers, prostaglandin, or steroids).

Criteria for placement on ECMO were determined by the individual patient care team(s) at each of the 20 hospitals submitting data; all patients were placed on ECMO with severe respiratory failure deemed to be refractory to conventional management. The decision to initiate ECMO, the mode of therapy (*i.e.*, veno-venous, veno-arterial, *etc.*), and the cannulation strategy were each determined by the individual ECMO Teams, in keeping with their respective individual institutional protocols and guidelines.

Descriptive analysis of the entire cohort was performed using mean, standard deviation, median, and interquartile range (IQR), as appropriate. The primary outcome of interest was mortality during the index hospitalization. Potential differences in categorical variables by the mortality group were assessed using  $\chi^2$  tests, whereas potential differences in continuous variables by the mortality group were assessed using Kruskal–Wallis rank-sum tests and Welch's analysis of variance. Institutional Review Board approval and waiver of the need for consent were obtained. The human subjects research protocol for this study was reviewed and approved by an independent Institutional Review Board. Institutional ethics review board approval was obtained for the use of data from the SCOPE<sup>™</sup> Database (Protocol #012017, ADVARRA Center for IRB Intelligence, 6940 Columbia Gateway Drive, Suite 110, Columbia, Maryland, USA).

## Results

One hundred consecutive patients with COVID-19 were placed on ECMO at 20 different hospitals around the USA. All 100 patients have since been separated from ECMO: 50 patients survived and 50 patients died. Of the 50 survivors, 49 patients have been discharged from the hospital to date. Table 1 provides detailed data about all 100 patients with COVID-19 treated with ECMO. Of note, out of 100 patients, 57 were obese, 39 had hypertension, 37 had diabetes, 20 had asthma, 13 had heart disease, 5 had cancer, and 3 had chronic renal failure. The median time on ECMO was 12 days (IQR = 8–22 days).

Table 2 provides detailed data comparing the characteristics of 50 survivors with 50 nonsurvivors. Survivors were generally younger, with a lower median age (47 *versus* 56.5 years, p = 0.014). Although time on ECMO was shorter in survivors than nonsurvivors, this trend was not statistically significant: median time on ECMO in survivors was 10.5 days (IQR = 8–19), whereas median time on ECMO in nonsurvivors was 14 days (IQR = 8–26.25).

In the 50 surviving patients, adjunctive therapies received while on ECMO were: intravenous steroids (26/50), antiinterleukin-6 receptor monoclonal antibodies – Tocilizumab or Sarilumab – (26/50), convalescent plasma (22/50), antiviral medications – remdesivir – (21/50), hydroxychloroquine (20/50), and prostaglandin (15/50).

This analysis includes all COVID-19 patients placed on ECMO at the 20 hospitals participating in this study during the period of this analysis. None of these 100 patients were placed on ECMO during cardiopulmonary resuscitation (CPR). Extracorporeal CPR (ECPR) was not utilized for COVID-19 patients at these 20 hospitals. Of 50 survivors, 49 were supported only with venovenous ECMO (98%). Furthermore, only one out of four patients supported with veno-arterial ECMO survived. In the 50 patients who died, documented causes of death were: respiratory failure (26/50), multisystem organ failure including acute kidney injury (7/50), sepsis (5/50), disseminated intravascular coagulation (5/50), cerebral bleeding while on ECMO (4/50) cardiac arrest (2/50), and pneumothorax (1/50).

Figure 1 depicts the distribution of all 100 patients by category of outcomes. Figure 2 depicts the distribution of the age of the patients, comparing the survivors with the nonsurvivors. Figure 3 depicts the distribution of hours on ECMO, comparing the survivors with the nonsurvivors. Figure 4 depicts the monthly trends over time in the utilization of these adjunctive therapies in patients with COVID-19 while on ECMO during the 5 months of this analysis.

#### Discussion

Our multi-institutional analysis of 100 consecutive COVID-19 patients who were supported with ECMO and subsequently

Table 1. Overview of 100 Patients with COVID-19 Supported with ECMO

	Category	Overall
Number of Patients Days from COVID diagnosis to intubation (mean [SD])		100 4.85 (5.05)
Days from COVID diagnosis to intubation (median [IQR]) Days from intubation to cannulation (mean [SD])		3.50 (1.00, 8.00) 4.49 (4.33)
Days from intubation to cannulation (median [IQR]) Days on ECMO (mean [SD]) Days on ECMO (median [IQR])		4.00 (1.00, 6.00) 16.89 (14.89) 12.00 (8 00, 22 00)
Hours on ECMO (mean [SD]) Hours on ECMO (median [IQR])		(0.00, 22.00) 395.51 (357.36) 269.00 (170.75, 516.00)
Hours on ECMO (minimum, maximum) Age (mean [SD]) Age (median [IQR])		(170.73, 316.00) 31.00, 2175.00 50.10 (12.65) 51.00
Gender (count [%])	Female	(40.75, 60.25) 34 (34.0)
Asthma (count [%])	No	80 (80.0)
Cancer (count [%])	Yes No	20 (20.0) 95 (95.0)
Chronic renal failure (count [%])	No	5 (5.0) 96 (97.0)
Diabetes (count [%])	No	3 (3.0) 63 (63.0)
Heart disease (count [%])	ves No	37 (37.0) 87 (87.0)
Hypertension (count [%])	Yes No	13 (13.0) 61 (61.0)
Obesity (count [%])	Yes No	39 (39.0) 43 (43.0)
One or more comorbid conditions (count [%])	Yes No	57 (57.0) 20 (20.0)
Proned before ECMO (count [%])	No	30 (30.0) 30 (30.0)
CVVH or CRRT used (count [%])	No	70 (70.0) 71 (71.0)
ECMO Type (count [%])	Veno-arterial	29 (29.0) 4 (4.0)
Anticoagulation type (count [%])	Argatroban Bivalirudin	96 (96.0) 10 (10.0) 6 (6.0)
Antiviral medication (count [%])	Heparin No	84 (84.0) 66 (66.0)
Convalescent plasma (count [%])	Yes No	34 (34.0) 48 (52.2)
Hydroxychloroquine (count [%])	Yes No	44 (47.8) 63 (63.0)
Interleukin-6 blocker (count [%])	Yes No	37 (37.0) 53 (54.1)
Prostaglandin (count [%])	Yes No	45 (45.9) 66 (66.7)
Steroids (count [%])	Yes No Yes	33 (33.3) 46 (46.0) 54 (54.0)

CRRT, continuous renal replacement therapy; CVVH, continuous veno-venous hemofiltration; ECMO, extracorporeal membrane oxy-genation; IQR, interquartile range.

decannulated provides clear evidence that ECMO facilitates salvage and survival of selected critically ill patients with COVID-19. Survivors tend to be younger. Survival of patients supported only with veno-venous ECMO is 51% (49 out of 96) in our series. Substantial variation exists in the use of adjunctive drugs and therapies in the treatment of COVID-19, but ECMO offers a reasonable rescue strategy.

Clinical guidelines for the management of patients with COVID-19 have been released by the World Health Organization <sup>9</sup> and the Centers for Disease Control and Prevention of the USA.<sup>10</sup> Additionally, the Extracorporeal Life Support Organization (ELSO)<sup>11</sup> and the American Society for Artificial Internal Organs<sup>12</sup> have published guidelines regarding the role of ECMO in treating patients with COVID-19. Nevertheless, the role of ECMO in the management of these challenging patients remains unclear.

Kon et al.<sup>7</sup> reported a retrospective analysis of all patients with COVID-19 admitted to New York University Langone Health Manhattan campus from March 10, 2020, to April 24, 2020 who were evaluated for ECMO support. Among 321 patients intubated for COVID-19, 77 patients (24%) were evaluated for ECMO support, and 27 patients (8.4%) were placed on veno-venous ECMO. Zero patients were supported with veno-arterial ECMO. At the time of publication of their study, survival was 96.3%, with only one death to date in more than 350 days of total ECMO support. Thirteen patients (48.1%) remained on ECMO support, and 13 patients (48.1%) were successfully decannulated. Of the 13 decannulated patients, seven patients (25.9%) were discharged from the hospital and six patients (22.2%) remained in the hospital, with four on room air. The authors concluded that "The early outcomes presented here suggest that the judicious use of ECMO support in severe COVID-19 may be clinically beneficial".7

In contrast, the use of veno-arterial ECMO in patients with COVID-19 has been associated with poor survival. Indeed, in patients with COVID-19, if the extent of end organ damage necessitates veno-arterial ECMO, then the prognosis is poor in comparison to patients with isolated respiratory dysfunction requiring only veno-venous ECMO. Furthermore, if the disease is so severe that the patient has a cardiac arrest refractory to CPR without ECMO, the patient is unlikely to survive and the use of veno-arterial ECMO is likely to be futile.

Barbaro et al.8 reported a cohort study of 1035 patients aged 16 years or older with confirmed COVID-19 who had ECMO support initiated between Jan 16, 2020, and May 1, 2020, at 213 hospitals in 36 countries, using data from the ELSO Registry. At the time of publication, of these 1035 patients, 67 (6%) remained hospitalized, 311 (30%) were discharged home or to an acute rehabilitation center, 101 (10%) were discharged to a long-term acute care center or unspecified location, 176 (17%) were discharged to another hospital, and 380 (37%) died. The estimated cumulative incidence of in-hospital mortality 90 days after the initiation of ECMO was 37.4% (95% Cl, 34.4-40.4). Mortality was 39% (380 of 968) in patients with a final disposition of death or hospital discharge. In the subset of patients receiving veno-venous ECMO and characterized as having ARDS, estimated in-hospital mortality 90 days after the initiation of ECMO was 38.0% (95% Cl, 34.6-41.5). The ECMO for circulatory support was independently associated with higher in-hospital mortality (hazard ratio 1.89, 95% Cl, 1.20-2.97).

## The Value of This Analysis

Our study adds to the body of knowledge and the literature by providing more granular multi-institutional data about

# ECMO AND COVID-19

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Table 2. Comparison of the 50	Survivors to	the 50 No	onsurvivors
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Number of Patients     50     50       Days from COVID diagnosis to intubation (mean [SD])     5.35 (5.90)     4.35 (4.10)     0.85 (5.00)       Days from COVID diagnosis to intubation (mean [SD])     4.33 (4.61)     4.66 (4.98)     0.05 (7.00)       Days from mutubation to camulation (mean [SD])     4.33 (4.61)     4.66 (4.98)     0.05 (7.00)       Days from mutubation to camulation (mean [SD])     4.33 (4.61)     4.66 (4.98)     0.05 (7.00)       Days on ECMO (median [ICPI)     14.00 (8.02, 26.22)     10.50 (8.00, 19.00)     0.537       Hours on ECMO (median [ICPI)     14.00 (8.02, 26.22)     10.50 (8.00, 19.00)     0.549       Hours on ECMO (median [ICPI)     31.60 (17.00, 63.20)     236.50 (190.00, 44.00)     0.549       Age (mean [SD])     33.00 (12.28)     37.55 (8.98) (9.0, 0.0, 44.00)     0.549       Age (mean [ICPI)     S3.08 (12.98)     47.12 (1.69)     0.018       Age (mean [SD])     No     38 (76.0)     24 (4.0)     0.527       Age (mean [CPI)     No     47 (94.0)     48 (96.0)     1       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Cancer (count [%]		Category	Nonsurvivors	Survivors	p-value
Days from COVID diagnosis to intubation (mean [SD])     5.35 (5.90)     4.35 (4.06)     0.43       Days from COVID diagnosis to intubation (mean [SD])     3.00 (1.00, 10.00, 10.00)     4.00 (1.00, 7.00)     0.854       Days from intubation to cannulation (mean [SD])     4.33 (4.61)     4.66 (4.08)     0.765       Days on ECMO (median [IQR])     18.58 (17.43)     15.20 (11.76)     0.253       Days on ECMO (median [IQR])     14.00 (8.00, 26.25)     10.50 (8.00, 19.00)     0.537       Hours on ECMO (median [IQR])     316.00 (17.000, 622.00)     355 (51 (9.00, 0.44.00)     0.549       Hours on ECMO (median [IQR])     31.00, 2175.00     61.00, 1344.00     0.549       Age (mean [IDR])     53.06 (12.89)     47.12 (11.69)     0.018       Age (mean [ICR])     Keined in [IQR])     53.06 (12.80, 0.47.00)     42.00     24.00       Age (mean [ICR])     Keined in [IQR])     No     37.00 (12.89)     47.12 (11.69)     0.018       Gender (count [%)     Female     15 (30.0)     19 (36.0)     0.527       Asthma (count [%)     No     37 (6.0)     2 (4.0)     1     1     1     0.00     1     0.00 <td>Number of Patients</td> <td></td> <td>50</td> <td>50</td> <td></td>	Number of Patients		50	50	
Days from COVID diagnosis to intubation (median [IQR])     3.00 (1.00, 1.00)     4.00 (1.00, 7.00)     0.684       Days from intubation to cannulation (median [IQR])     4.33 (4.61)     4.66 (4.06)     0.766       Days on ECMO (mean [SD])     18.58 (17.43)     15.20 (11.76)     0.258       Days on ECMO (mean [SD])     18.58 (17.43)     15.20 (11.76)     0.268       Hours on ECMO (mean [SD])     316.00 (170.00, 62.50)     236.50 (190.00, 444.00)     0.549       Hours on ECMO (meining IQR])     56.50 (45.25, 62.00)     236.50 (190.00, 444.00)     0.549       Age (mean [SD])     55.50 (61.25, 62.00)     236.50 (190.00, 444.00)     0.549       Age (mean [CR])     S5.50 (62.25, 62.00)     47.12 (11.68)     0.013       General (Count [%])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Diabetes (count [%])     No     47 (94.0)     49 (96.0)     1       Diabetes (count [%])     No     47 (94.0)     49 (96.0)     1	Days from COVID diagnosis to intubation (mean [SD])		5.35 (5.90)	4.35 (4.06)	0.44
Days from intubation to cannulation (mean [SD])     4.33 (4.61)     4.66 (4.08)     0.76       Days from intubation to cannulation (median [IGR])     4.00 (1.00, 7.00)     4.00 (1.75, 6.00)     0.873       Days on ECMO (median [IGR])     18.58 (17.43)     15.20 (11.76)     0.258       Days on ECMO (median [IGR])     435.44 (418.63)     355.58 (281.97)     0.268       Hours on ECMO (median [IGR])     31.00, 2175.00     61.00, 1344.00     0.59       Hours on ECMO (median [IGR])     53.08 (12.98)     47.12 (11.69)     0.118       Age (median [IGR])     56.50 (45.25, 62.00)     47.00 (40.00, 57.00)     0.014       Age (median [IGR])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     No     37 (70.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (16.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.0)     36 (60.0)     1       Vers     23 (46.0)     14 (20.0)     22 (44.0)     1       Diabetes	Days from COVID diagnosis to intubation (median [IQR])		3.00 (1.00, 10.00)	4.00 (1.00, 7.00)	0.854
Days form intubation to cannulation (median [IĜR])     4.00 (1.00, 7.00)     4.00 (1.75, 6.00)     0.258       Days on ECMO (median [IGR])     18.58 (17.43)     15.20 (1.7.6)     0.258       Days on ECMO (median [IGR])     435.44 (418.63)     355.58 (281.97)     0.266       Hours on ECMO (median [IGR])     316.00 (17.00, 62.82)     355.58 (281.97)     0.266       Hours on ECMO (minimum, maximum)     31.00 .2175.00     61.00, 1344.00     64.00       Age (mean [ISD])     55.00 (42.58, 62.00)     47.02 (44.0)     0.57       Age (mean [IGP])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%)     No     47 (94.0)     48 (96.0)     1       Cancer (count [%)     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%)     No     47 (95.0)     24 (40.0)     1       Vers     24 (64.0)     36 (72.0)     0.986       Heart disease (count [%)     No     47 (95.9)     49 (98.0)     0.986       Heart disease (count [%)     No	Days from intubation to cannulation (mean [SD])		4.33 (4.61)	4.66 (4.08)	0.766
Days on ECMO (median [IGN])     18.58 [17.43)     15.20 (11.76)     0.258       Days on ECMO (median [IGR])     14.00 (8.00, 26.25)     10.50 (8.00, 19.00)     0.537       Hours on ECMO (median [IGR])     316.00 (170.00, 623.00)     236.50 (19.00)     0.44.00)       Age (mean [SD])     316.00 (175.00)     61.00, 1344.00)     0.549       Age (mean [SD])     53.08 (12.98)     47.12 (11.69)     0.549       Age (mean [GD])     55.00 (45.25, 62.00)     47.10 (40.00, 57.00)     0.018       Age (mean [GD])     56.50 (45.25, 62.00)     47.10 (40.00, 57.00)     0.018       Age (mean [GD])     No<38 (76.0)	Days from intubation to cannulation (median [IQR])		4.00 (1.00, 7.00)	4.00 (1.75, 6.00)	0.873
Days on ECMO (median [ICR])     14.00 (8:00, 28:25)     10.50 (8:00, 19:00)     0.355       Hours on ECMO (median [ICR])     316.00 (17:00, 06:30, 00)     236.50 (19:00, 00, 444, 00)     0.266       Hours on ECMO (median [ICR])     316.00 (17:00, 06:30, 00)     236.50 (19:00, 19:44, 00)     0.266       Age (median IICR))     50.08 (12:98)     47.12 (11.69)     0.014       Age (median IICR))     56.00 (45:25, 62:00)     31(6:00)     57.00     0.114       Gender (count [%])     No     38 (76.0)     31(6:0)     47.00 (4:00, 57.00)     0.527       Asthma (count [%])     No     38 (76.0)     31(6:0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (96:0)     1       Chronic renal failure (count [%])     No     47 (96:0)     14 (2:0)     0.986       Diabetes (count [%])     No     47 (96:0)     14 (2:0)     12 (2:0)     0.098       Heart disease (count [%])     No     27 (54.0)     34 (6:0)     14 (28.0)     1       Obesity (count [%])     No     8 (16:0)     14 (2:0)     20 (40:0)     1	Davs on ECMO (mean [SD])		18.58 (17.43)	15.20 (11.76)	0.258
Hours on ECMO (meain [SD])*     435.44 (141 8.3)*     355.58 (281 97)**     0.286       Hours on ECMO (minimum, maximum)     316.00, 177.00, 623.00     236.50 (190.00, 244.00)     0.549       Age (mean [SD])*     56.00 (45.25, 62.00)     47.10 (11.69)     0.018       Age (mean [SD])*     56.00 (45.25, 62.00)     47.10 (40.00, 57.00)     0.014       Age (mean [SD])*     Yes     12 (24.0)     31 (62.0)     19 (38.0)     0.527       Asthma (count [%])     No     38 (75.0)     42 (84.0)     0.453       Cancer (count [%])     No     38 (75.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (54.0)     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (54.0)     38 (72.0)     0.986       Diabetes (count [%])     No     47 (94.0)     0.472.0)     0.974       Heard disease (count [%])     No     31 (62.0)     30 (60.0)     1       Heard disease (count [%])     No     31 (62.0)     30 (60.0)     1       Obesity (count [%])     No     31 (62.0)     30 (60.0)     1	Days on ECMO (median [IQR])		14.00 (8.00, 26.25)	10.50 (8.00, 19.00)	0.537
Hours on ECMO (meailar) [GKR])     316.00 (17) 000 (23.00)     236.50 (190.00 (244.00)     0.549       Age (mean [SD])     53.08 (12.98)     47.12 (11.60)     0.0118       Age (meal an [GR])     56.00 (45.28,00)     47.00 (40.00, 57.00)     0.014       Gender (count [%])     Female     15 (30.0)     19 (38.0)     0.227       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     34 (76.0)     42 (84.0)     0.59       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     27 (54.0)     36 (72.0)     0.098       Heart disease (count [%])     No     31 (62.0)     3 (6.0)     1       Hypertension (count [%])     No     31 (62.0)     3 (6.0)     1       One or more comorbid conditions (count [%])     No     31 (62.0)     3 (6.0)     1       One or more comorbid conditions (count [%])     No     31 (62.0)     3 (6.0)     1	Hours on ECMO (mean [SD])		435.44 (418.63)	355.58 (281.97)	0.266
Hours on ECMO (minimum, maximum)     53 100, 2175,600     61.00, 134,400     61.00       Age (mean [QR])     50.308 (12.98)     47.12 (11.69)     0.018       Age (mealin [QR])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     Male     35 (70.0)     31 (60, 21.75, 60)     47.00 (40.00, 57.00)     0.014       Gender (count [%])     No     38 (76.0)     42 (84.0)     0.453       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Diabetes (count [%])     No     47 (95.5)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.4)     3 (6.0)     1       Heart disease (count [%])     No     40 (80.0)     47 (94.0)     0.074       Hypertension (count [%])     No     21 (42.0)     28 (66.0)     1       Obesity (count [%])     No     21 (42.0)     28 (66.0)     1       Ore or more comorbid conditions (count [%])     No     21 (42.0)     28 (66.0)     1	Hours on ECMO (median [IOB])		316.00 (170.00, 623.00)	236 50 (190 00 444 00)	0.549
Age (mean [SD])     53.08 (12.98)     47.12 (11.69)     0.018       Age (median [IQR])     56.00 (45.25, 62.00)     47.00 (40.00, 57.00)     0.011       Age (median [IQR])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     No     38 (76.0)     31 (62.0)     0.42 (84.0)     0.453       Cancer (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     27 (54.0)     36 (72.0)     0.098       Heart disease (count [%])     No     27 (54.0)     36 (60.0)     1       Hypertension (count [%])     No     21 (42.0)     3 (60.0)     1       Obesity (count [%])     No     21 (42.0)     36 (0.0)     1       One or more comorbid conditions (count [%])     Yes     29 (58.0)     28 (56.0)     1       One or more comorbid conditions (count [%])     No     3 (16.0)     1 (2.0)     0.610	Hours on ECMO (minimum maximum)		31 00 2175 00	61 00 1344 00	0.010
Add end in [GR])     56.50 (if 2.25 (if 2.0)     47.00 (if 0.00 (if 7.00)     0.014       Gender (count [%])     Female     15 (30.0)     19 (38.0)     0.527       Astma (count [%])     No     38 (if 76.0)     42 (84.0)     0.453       Cancer (count [%])     No     38 (if 76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (16.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.9)     49 (98.0)     0.986       Heart disease (count [%])     No     27 (54.0)     36 (if 72.0)     0.098       Heart disease (count [%])     No     40 (80.0)     47 (94.0)     0.074       Hypertension (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     21 (42.0)     28 (40.0)     31 (62.0)     1       One or more comorbid conditions (count [%])     No     8 (16.0)     12 (24.0)     0.453       Proned before ECMO (count [%])     No     8 (16.0) <td>Age (mean [SD])</td> <td></td> <td>53 08 (12 98)</td> <td>47 12 (11 69)</td> <td>0.018</td>	Age (mean [SD])		53 08 (12 98)	47 12 (11 69)	0.018
Lage (notatin [total])     Female     15 (30.0)     19 (38.0)     0.527       Asthma (count [%])     No     38 (76.0)     31 (62.0)     Asthma (count [%])     0.527       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     27 (54.0)     36 (72.0)     0.098       Heart disease (count [%])     Yes     23 (46.0)     14 (22.0)     0.098       Hypertension (count [%])     Yes     10 (20.0)     3 (60.0)     1       Hypertension (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     21 (42.0)     22 (44.0)     1       Ores     Yes     19 (38.0)     32 (46.0)     32 (46.0)     1       One or more comorbid conditions (count [%])     No     8 (16.0)     12 (24.0)	Age (median [IOB])		56 50 (45 25 62 00)	47.00 (40.00.57.00)	0.014
Carter (count [%])     Tentales     15 (200)     15 (200)     0.527       Asthma (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (16.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.9)     49 (98.0)     0.986       Heart disease (count [%])     No     27 (4.1)     1 (2.0)     0.986       Heart disease (count [%])     No     27 (4.0)     36 (6.0)     1       Hypertension (count [%])     No     40 (80.0)     47 (94.0)     0.074       Hypertension (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     8 (16.0)     37 (74.0)     0.659       Froned before ECMO (count [%])     No     15 (30.0)     1     12 (24.0)     0.453       CVVH or CRRT used (count [%])     No     34 (68.0) <td< td=""><td>Gender (count [%])</td><td>Female</td><td>15 (30.0)</td><td>19 (38 0)</td><td>0.527</td></td<>	Gender (count [%])	Female	15 (30.0)	19 (38 0)	0.527
Ashma (count [%])     No     38 (76.0)     42 (84.0)     0.433       Cancer (count [%])     No     38 (76.0)     42 (84.0)     0.453       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.886       Diabetes (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     47 (95.9)     49 (98.0)     0.098       Heart disease (count [%])     No     47 (95.9)     49 (98.0)     0.074       Hypertension (count [%])     No     47 (95.9)     49 (98.0)     0.074       Hypertension (count [%])     No     31 (62.0)     31 (62.0)     1       Obesity (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     81 (6.0)     12 (24.0)     0.453       Proned before ECMO (count [%])     No     15 (30.0)     1     1       CVVH or CRRT used (count [%])     No     35 (70.0)     35 (70.0)     13 (26.0)     1		Malo	35 (70.0)	31 (62 0)	0.527
Astimic (count [%])     No     36 (76.0)     42 (94.0)     8 (16.0)       Cancer (count [%])     No     47 (94.0)     48 (96.0)     1       Chronic renal failure (count [%])     No     47 (95.9)     49 (98.0)     0.986       Diabetes (count [%])     No     27 (54.0)     36 (72.0)     0.098       Heart disease (count [%])     No     27 (54.0)     36 (72.0)     0.098       Heart disease (count [%])     No     42 (82.0)     14 (28.0)     14 (28.0)       Hypertension (count [%])     No     31 (62.0)     30 (60.0)     1       Obesity (count [%])     No     21 (42.0)     22 (44.0)     1       One or more comorbid conditions (count [%])     No     15 (30.0)     1     2 (24.0)     0.453       Proned before ECMO (count [%])     No     15 (30.0)     1     2 (26.0)     0.650       ECMO type (count [%])     No     35 (70.0)     35 (70.0)     35 (70.0)     35 (70.0)     36 (60.0)       CVVH or CRRT used (count [%])     No     3 (6.0)     1 (2.0)     0.610     1 (2.0)     0.610 <td>Asthma (count [0/])</td> <td>No</td> <td>38 (76.0)</td> <td>42 (84 0)</td> <td>0 453</td>	Asthma (count [0/])	No	38 (76.0)	42 (84 0)	0 453
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Astrina (Count [70])	NO	10 (04 0)	42 (04.0)	0.455
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Concer (count $[0/1]$ )	res	12 (24.0)	8 (10.0) 48 (06.0)	-1
$\begin{array}{c cccc} & Yes & 3 (6.0) & 2 (4.0) \\ Yes & 3 (6.0) & 47 (95.9) & 49 (98.0) & 0.986 \\ Yes & 2 (4.1) & 1 (2.0) \\ Yes & 2 (4.1) & 1 (2.0) \\ Yes & 2 (4.1) & 1 (2.0) \\ Yes & 2 (4.0) & 36 (72.0) & 0.098 \\ Yes & 2 (4.0) & 14 (28.0) \\ Yes & 10 (20.0) & 37 (60.0) & 1 \\ Ypertension (count [%]) & No & 40 (80.0) & 47 (94.0) & 0.074 \\ Yes & 10 (38.0) & 20 (40.0) & 1 \\ Yes & 19 (38.0) & 20 (40.0) & 1 \\ Obesity (count [%]) & No & 31 (62.0) & 30 (60.0) & 1 \\ Yes & 19 (38.0) & 20 (42.0) & 22 (44.0) & 1 \\ One or more comorbid conditions (count [%]) & No & 8 (16.0) & 12 (24.0) & 0.453 \\ Yes & 29 (58.0) & 28 (56.0) & 0.659 \\ Yes & 35 (70.0) & 35 (70.0) & 15 (30.0) & 1 \\ CVVH or CRRT used (count [%]) & No & 34 (68.0) & 37 (74.0) & 0.659 \\ Yes & 16 (32.0) & 13 (22.0) & 0.610 \\ Yes & 16 (32.0) & 13 (22.0) & 0.610 \\ Yes & 16 (32.0) & 13 (22.0) & 0.610 \\ Yes & 16 (32.0) & 13 (26.0) & 0.610 \\ Yeno-Venous & 47 (94.0) & 49 (98.0) & 0.610 \\ Weno-Venous & 47 (94.0) & 49 (98.0) & 0.610 \\ Weno-Venous & 47 (94.0) & 42 (84.0) & 0.610 \\ Yeno-Venous & 47 (94.0) & 42 (84.0) & 0.139 \\ Anticoagulation type (count [%]) & No & 37 (74.0) & 29 (58.0) & 0.139 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 21 (42.0) & 0.610 \\ Yes & 13 (26.0) & 22 (45.8) & 0.139 \\ Yes & 13 (26.0) & 22 (45.8) & 0.139 \\ Yes & 13 (26.0) & 22 (45.0) & 0.610 \\ Yes & 13 (26.0) & 22 (45.0) & 0.610 \\ Yes & 13 (26.0) & 22 (45.0) & 0.610 \\ Yes & 13 (26.0) & 22 (45.0) & 0.619 \\ Yes & 17 (34.0) & 20 (40.0) & 0.619 \\ Yes & 19 (39.6) & 26 (52.0) & 0.619 \\ Yes & 18 (36.7) & 15 (30.0) & 0.619 \\ Yes & 18 (36.7) & 15 (30.0) & 0.619 \\ Yes & 28 (56.0) & 22 (42.0) & 24 (48.0) & 0.303 \\ Yes & 28 (46.0) & 24 (48.0) & 0.641 \\ Yes & 28 (46.0) & 24 (48.0) & 0.641 \\ Yes & 28 (46.0) & 24 (48.0) & 0.641 \\ Yes & 28 (46.0) & 24 (48.0) & 0.641 \\ Yes & 28 (46.0) & 24 $		INO	47 (94.0)	46 (96.0)	1
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		Yes	3 (6.0)	2 (4.0)	0.000
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Chronic renal failure (count [%])	NO	47 (95.9)	49 (98.0)	0.986
Diabetes (count [%])No27 (64.0)36 (72.0)0.093Yes23 (46.0)14 (28.0)Heart disease (count [%])No40 (80.0)47 (94.0)0.074Hypertension (count [%])No31 (62.0)30 (60.0)1Obesity (count [%])No21 (42.0)22 (44.0)1One or more comorbid conditions (count [%])No8 (16.0)12 (24.0)0.453Yes29 (58.0)28 (56.0)26 (50.0)1One or more comorbid conditions (count [%])No8 (76.0)1CVVH or CRRT used (count [%])No15 (30.0)15 (30.0)1CVVH or CRRT used (count [%])No34 (68.0)37 (74.0)0.659Yes16 (32.0)13 (26.0)1200.610Anticoagulation type (count [%])Yes16 (32.0)1 (2.0)0.610Veno-Arterial3 (6.0)3 (6.0)110.0Antiviral medication (count [%])Argatroban5 (10.0)11No37 (74.0)29 (58.0)0.13910.0Yes12 (26.0)22 (42.0)22 (42.0)0.453Convalescent plasma (count [%])No33 (66.0)30 (60.0)0.679Yes12 (50.0)22 (45.0)22 (45.0)24 (48.0)0.303Yes13 (26.0)22 (50.0)22 (45.8)0.139Convalescent plasma (count [%])No33 (66.0)30 (60.0)0.679Yes12 (50.0)22 (40.0)24 (48.0) </td <td></td> <td>Yes</td> <td>2 (4.1)</td> <td>1 (2.0)</td> <td></td>		Yes	2 (4.1)	1 (2.0)	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Diabetes (count [%])	No	27 (54.0)	36 (72.0)	0.098
Heart disease (count [%])   No   40 (80.0)   47 (94.0)   0.074     Hypertension (count [%])   No   31 (62.0)   30 (60.0)   1     Hypertension (count [%])   No   31 (62.0)   30 (60.0)   1     Obesity (count [%])   No   21 (42.0)   22 (44.0)   1     One or more comorbid conditions (count [%])   No   8 (16.0)   12 (24.0)   0.453     Proned before ECMO (count [%])   No   8 (16.0)   15 (30.0)   1   1     CVH or CRRT used (count [%])   No   34 (68.0)   37 (74.0)   0.659     ECMO type (count [%])   No   34 (68.0)   37 (74.0)   0.610     Yes   16 (32.0)   13 (26.0)   1   10.0   1     ECMO type (count [%])   Veno-Arterial   3 (6.0)   1 (2.0)   0.610     Maticoagulation type (count [%])   Argatroban   5 (10.0)   1   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0   1   10.0		Yes	23 (46.0)	14 (28.0)	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Heart disease (count [%])	No	40 (80.0)	47 (94.0)	0.074
Hypertension (count [%])     No     31 (62.0)     30 (60.0)     1       Yes     19 (38.0)     20 (40.0)     22 (44.0)     1       Obesity (count [%])     No     21 (42.0)     22 (44.0)     1       Yes     29 (58.0)     28 (56.0)     26 (56.0)     0.453       One or more comorbid conditions (count [%])     No     8 (16.0)     12 (24.0)     0.453       Proned before ECMO (count [%])     No     15 (30.0)     1     5 (30.0)     1       CVVH or CRRT used (count [%])     No     34 (68.0)     37 (74.0)     0.659       Yes     16 (32.0)     13 (26.0)     12 (20)     0.619       CVVH or CRRT used (count [%])     Veno-Arterial     3 (6.0)     1 (2.0)     0.610       Anticoagulation type (count [%])     Veno-Venous     47 (94.0)     49 (98.0)     1       Anticoagulation (count [%])     No     37 (74.0)     29 (58.0)     0.13       Convalescent plasma (count [%])     No     22 (50.0)     22 (45.8)     0.13       Convalescent plasma (count [%])     No     22 (50.0)     26 (54.2)		Yes	10 (20.0)	3 (6.0)	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Hypertension (count [%])	No	31 (62.0)	30 (60.0)	1
Obesity (count [%])     No     21 (42.0)     22 (44.0)     1       Yes     29 (58.0)     28 (56.0)     28 (56.0)     28 (56.0)       One or more comorbid conditions (count [%])     No     8 (16.0)     12 (24.0)     0.453       Proned before ECMO (count [%])     No     15 (30.0)     15 (30.0)     15 (30.0)     1       CVVH or CRRT used (count [%])     No     34 (68.0)     37 (74.0)     0.659       Yes     16 (32.0)     13 (26.0)     12 (24.0)     0.659       ECMO type (count [%])     Veno-Arterial     3 (6.0)     12 (20.0)     0.610       Anticoagulation type (count [%])     Veno-Venous     47 (94.0)     49 (98.0)     1       Anticoagulation type (count [%])     Veno-Venous     47 (94.0)     49 (98.0)     1       Antiviral medication (count [%])     Veno-Venous     47 (94.0)     49 (98.0)     1       Convalescent plasma (count [%])     No     37 (74.0)     29 (58.0)     0.139       Yes     13 (26.0)     22 (50.0)     22 (42.0)     24 (42.0)       Updroxychloroquine (count [%])     No <t< td=""><td></td><td>Yes</td><td>19 (38.0)</td><td>20 (40.0)</td><td></td></t<>		Yes	19 (38.0)	20 (40.0)	
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$\begin{array}{c cccc} \text{CVVH or CRRT used (count [\%])} & \text{No} & 34 (68.0) & 37 (74.0) & 0.659 \\ & \text{Yes} & 16 (32.0) & 13 (26.0) \\ & \text{Veno-Arterial} & 3 (6.0) & 1 (2.0) & 0.610 \\ & \text{Veno-Venous} & 47 (94.0) & 49 (98.0) \\ & \text{Articoagulation type (count [\%])} & \text{Argatroban} & 5 (10.0) & 5 (10.0) & 1 \\ & \text{Bivalirudin} & 3 (6.0) & 3 (6.0) \\ & \text{Heparin} & 42 (84.0) & 42 (84.0) \\ & \text{Artiviral medication (count [\%])} & \text{No} & 37 (74.0) & 29 (58.0) & 0.139 \\ & \text{Yes} & 13 (26.0) & 21 (42.0) \\ & \text{Convalescent plasma (count [\%])} & \text{No} & 22 (50.0) & 26 (54.2) & 0.849 \\ & \text{Yes} & 22 (50.0) & 22 (45.8) \\ & \text{Hydroxychloroquine (count [\%])} & \text{No} & 33 (66.0) & 30 (60.0) & 0.679 \\ & \text{Yes} & 17 (34.0) & 20 (40.0) \\ & \text{Interleukin-6 blocker (count [\%])} & \text{No} & 29 (60.4) & 24 (48.0) & 0.303 \\ & \text{Yes} & 19 (39.6) & 26 (52.0) \\ & \text{Prostaglandin (count [\%])} & \text{No} & 31 (63.3) & 35 (70.0) & 0.619 \\ & \text{Yes} & 18 (36.7) & 15 (30.0) \\ & \text{Steroids (count [\%])} & \text{No} & 22 (44.0) & 24 (48.0) & 0.841 \\ & \text{Yes} & 28 (56.0) & 26 (52.0) \\ \end{array}$		Yes	35 (70.0)	35 (70.0)	
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$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Convoloppent plasma (count [0/])	No	13 (20.0)	21 (42.0)	0.940
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Steroids (count [%])     No     22 (44.0)     24 (48.0)     0.841       Yes     28 (56.0)     26 (52.0)     26 (52.0)		Yes	18 (36.7)	15 (30.0)	
Yes 28 (56.0) 26 (52.0)	Steroids (count [%])	No	22 (44.0)	24 (48.0)	0.841
		Yes	28 (56.0)	26 (52.0)	

CRRT, continuous renal replacement therapy; CVVH, continuous veno-venous hemofiltration; ECMO, extracorporeal membrane oxygenation; IQR, interquartile range.

our cohort of 100 COVID-19 patients supported with ECMO at 20 hospitals. As described in the third paragraph of the *Introduction*, several previously published analyses have studied the outcomes of ECMO in patients with COVID-19, and these outcomes have been quite heterogenous.<sup>4–8</sup> Our analysis of the SpecialtyCare SCOPE<sup>TM</sup> Registry adds another dataset of multi-institutional data to the growing body of literature about the use of ECMO in patients with COVID-19 and demonstrates that support with ECMO facilitates salvage and survival of selected critically ill patients with COVID-19.

In our analysis, survival of patients supported with only venovenous ECMO was 51% (49 out of 96). Survival in patients requiring veno-arterial ECMO was poor (1 out of 4 = 25%). Our finding of higher survival with veno-venous ECMO in comparison to veno-arterial ECMO in patients with COVID-19 is consistent with the published literature. It is likely that if the extent of end-organ damage necessitates veno-arterial ECMO in patients with COVID-19, then the prognosis is poor in comparison to patients with isolated respiratory dysfunction requiring only veno-venous ECMO. Our study also reveals that, not surprisingly, survivors were younger than non-survivors (median age = 47 in survivors *versus* 56.5 years in nonsurvivors, *P* = 0.014). This finding corroborates with the study from Barbaro *et al.*<sup>8</sup> where patients >40 years of age had an increasing risk of mortality compared to those 16–39 years of age.

Finally, our study also documents the previously unpublished finding that substantial variation exists in the use of adjunctive therapies in the treatment of COVID-19. The use



Figure 1. Patient status flowchart: the distribution of all 100 patients by category of outcome.



Distribution of Age by Outcome for 100 Cases

Figure 2. Distribution of age – survivors versus nonsurvivors: the distribution of the age of the patients, comparing the survivors with the nonsurvivors.

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Distribution of Hours on ECMO by Outcome for 100 Cases

Figure 3. Distribution of hours on ECMO – survivors versus nonsurvivors: the distribution of hours on ECMO, comparing the survivors with the nonsurvivors.





Date of Cannulation

**Figure 4.** Percent of COVID-19 ECMO patients receiving six adjunctive therapies stratified by month of cannulation. This figure depicts the monthly trends over time in the utilization of six adjunctive therapies in patients with COVID-19 while on ECMO during the 5 months of this analysis: 1.Green line = anti-interleukin-6-receptor monoclonal antibodies (Tocilizumab or Sarilumab). 2. Brown line = antiviral medications (remdesivir). 3. Purple line = convalescent plasma. 4. Blue line = hydroxychloroquine. 5. Yellow line = prostaglandin (Flonan). 6. Gray line = intravenous steroids.

of these various adjunctive medications and treatments has changed over time as more information has been learned regarding the role and potential success of these medications.

In patients with COVID-19 supported with ECMO, outcomes are likely largely governed by the viral burden, the extent of inflammatory cascade, and the response of the patients to the different drugs utilized to address this viremia and inflammation. ECMO is acting as a supportive technology, but may not, as such, in and of itself, be the primary driver of mortality or recovery.

### Future Directions

Much remains to be learned about the role of ECMO in these patients. From our analysis, no specific demographic,

clinical, or laboratory data, to date, is predictive of outcome with ECMO in patients with COVID-19, with the exception of younger age. Similarly, the role of multiple medications in the treatment of COVID-19 remains unclear.

Important additional potential future research projects that will provide valuable information include the following analyses:

- 1. An analysis of the variation in processes of care and outcomes across hospitals.
- 2. An analysis of the relationship between programmatic ECMO volume and outcome.
- 3. An analysis of survival trends over time, from March 2020 to later.
- 4. A multivariable analysis of risk factors for survival.
- 5. A multivariable analysis of the influence of various medications and adjunctive therapies on survival.

# Limitations

This analysis is based on the available data in our database. Additional follow-up is required on all surviving patients. Further patient accrual will enhance continued analysis of outcomes. We plan to continue gathering data to provide additional insight as to guideposts for patient selection and predictors of outcomes. It is our hope that by sharing our experience, other centers and patients may benefit.

# Conclusions

Our experience and analysis of 100 consecutive patients at 20 hospitals reveal that ECMO facilitates salvage and survival of selected critically ill patients with COVID-19. Survivors tend to be younger. Survival of patients supported with only veno-venous ECMO is 51% in our cohort. Substantial variation exists in the drug treatment of COVID-19, but ECMO offers a reasonable rescue strategy. Additional gathering and analysis of data will inform appropriate selection of patients and provide guidance as to best use of ECMO in terms of timing, implementation, duration of support, and best criteria for discontinuation. Expansion of studies such as the current analysis presented here will provide a means to further define the role of ECMO in the management of severely compromised patients with COVID-19 and will serve to refine the optimal

use of ECMO in these patients, with the goal of continuing to enhance survival.

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