**Supplemental Digital Content for Extracorporeal Membrane Oxygenation Characteristics and Outcomes in Children and Adolescents with COVID-19 or Multisystem Inflammatory Syndrome Admitted to U.S. Intensive Care Units**

**Table of Contents**

|  |  |
| --- | --- |
| **Overcoming COVID-19 Study Group Investigators** | Pages 2-4 |
| **CDC COVID-19 Response Team** | Page 4 |
| **Supplemental ECMO Overcoming COVID-19 Case Report Form** | Pages 5-6 |
| **Supplemental Table 1** – Additional Baseline Characteristics of 2,733 Patients <21 Years Admitted to the ICU for MIS-C or Acute COVID-19 Stratified by ECMO requirement | Page 7 |
| **Supplemental Table 2 –** Admission Laboratory Values Among Acute COVID-19 and MIS-C Patients With and Without ECMO Support | Page 8 |
| **Supplemental Figure 1 –** Supplemental Laboratory Values | Page 9 |

**Overcoming COVID-19 Study Group Investigators**

(listed in PubMed, and ordered by U.S. State)

The following study group members were all closely involved with the design, implementation, and oversight of the Overcoming COVID-19 study.

**Alabama:** Children’s of Alabama, Birmingham. Michele Kong, MD.

**Arizona:** University of Arizona, Tucson. Mary Glas Gaspers, MD; Katri V. Typpo, MD.

**Arkansas:** Arkansas Children’s Hospital, Little Rock. Ronald C. Sanders Jr., MD, MS; Katherine Irby, MD.

**California:** Children’s Hospital of Orange County, Orange County. Adam J. Schwarz, MD.

**California:** Miller Children’s & Women’s Hospital Long Beach, Long Beach. Christopher J. Babbitt, MD.

**California:** Children’s Hospital Los Angeles, Los Angeles. Pia S. Pannaraj, MD, MPH.

**California:** Rady Children’s Hospital, San Diego. Helen Harvey, MD, MS.

**California:** UCSF Benioff Children’s Hospital Oakland, Oakland. Natalie Z. Cvijanovich, MD.

**California:** UCSF Benioff Children’s Hospital, San Francisco. Matt S. Zinter, MD.

**Colorado:** Children’s Hospital Colorado, Aurora. Aline B. Maddux, MD, MSCS; Emily Port, BA, PMP; Sara Shankman, DNP, CPNC-AC; Rachel Mansour, BSN, RN, CPN.

**Connecticut:** Connecticut Children’s, Hartford. Christopher L. Carroll, MD, MS.

**Connecticut:** Yale New-Haven Children’s Hospital, New Haven. John S. Giuliano, Jr., MD.

**Florida**: Holtz Children’s Hospital, Miami. Gwenn E. McLaughlin, MD, MSPH.

**Florida**: Nicklaus Children’s Hospital, Miami. Paula S. Espinal, MD, MPH.

**Georgia:** Children's Healthcare of Atlanta at Egleston, Atlanta. Keiko M. Tarquinio, MD.

**Illinois:** Ann & Robert H. Lurie Children’s Hospital of Chicago, Chicago. Kelly N. Michelson, MD, MPH; Bria M. Coates, MD.

**Indiana:** Riley Hospital for Children, Indianapolis. Courtney M. Rowan, MD, MS.

**Iowa:** University of Iowa Stead Family Children’s Hospital, Iowa City. Kari Wellnitz, MD; Guru Bhoojhawon MBBS, MD.

**Kentucky:** University of Louisville and Norton Children’s Hospital, Louisville, Janice E. Sullivan, MD; Vicki L. Montgomery, MD; Kevin M. Havlin, MD.

**Louisiana:** Children's Hospital of New Orleans, New Orleans. Tamara T. Bradford, MD.

**Maryland:** Johns Hopkins Children’s Center, Baltimore. Melania M. Bembea, MD, MPH, PhD.

**Maryland:** University of Maryland Children’s Hospital, Baltimore. Ana Lia Graciano, MD.

**Maryland:** Sinai Hospital of Baltimore, Baltimore. Susan V. Lipton, MD, MPH.

**Massachusetts:** Boston Children’s Hospital, Boston. Adrienne G. Randolph, MD; Margaret M. Newhams, MPH; Sabrina R. Chen; Cameron C. Young, BS; Suden Kucukak, MD; Mary Beth F. Son, MD; Timothy McCadden; Madyson Fitzgerald, BS; Julia Worden; Benjamin Boutselis; Kasey Stewart; Ravi R. Thiagarajan, MBBS, MPH.

**Massachusetts:** MassGeneral Hospital for Children, Boston. Ryan W. Carroll, MD, MPH; Phoebe H. Yager, MD; Neil D. Fernandes, MBBS.

**Massachusetts**: Baystate Children’s Hospital, Springfield. Kimberly L. Marohn, MD.

**Michigan:** University of Michigan CS Mott Children’s Hospital, Ann Arbor. Heidi R. Flori, MD, FAAP.

**Michigan:** Children’s Hospital of Michigan, Detroit. Sabrina M. Heidemann, MD.

**Minnesota:** University of Minnesota Masonic Children’s Hospital, Minneapolis, Janet R. Hume, MD, PhD.

**Minnesota:** Mayo Clinic, Rochester. Emily R. Levy, MD.

**Mississippi:** Children’s Hospital of Mississippi, Jackson. Charlotte V. Hobbs, MD; Lacy Malloch, BS; Lora Martin, MSN; Chidinma Chikere, MPH, BSN; Cameron Sanders, BS; Kayla Patterson, MSc; Preeti Vemula, Pharm.D., MPH; Sara McGraw, DNP

**Missouri:** Children’s Mercy Hospital, Kansas City. Jennifer E. Schuster, MD.

**Missouri:** Washington University in St. Louis. Philip C. Spinella MD; Amanda R. Kolmar MD.

**Nebraska:** Children’s Hospital & Medical Center, Omaha. Melissa L. Cullimore, MD, PhD; Russell J. McCulloh, MD.

**New Jersey:** Hackensack University Medical Center, Hackensack. Katharine N. Clouser, MD.

**New Jersey:** Cooperman Barnabas Medical Center, Livingston. Shira J. Gertz, MD.

**New Jersey:** Bristol-Myers Squibb Children's Hospital, New Brunswick. Lawrence C. Kleinman, MD, MPH, FAAP; Simon Li, MD, MPH; Steven M. Horwitz, MD.

**New Jersey:** Newark Beth Israel Medical Center, Newark. Rowan F. Walsh, MD

**New York:** Golisano Children’s Hospital, Rochester. Joseph Kuebler, MD.

**New York:** Maria Fareri Children's Hospital, Valhalla.Aalok R. Singh, MD.

**New York:** Hassenfeld Children’s Hospital at NYU Langone, New York.Adam J. Ratner, MD, MPH; Heda Dapul, MD; Vijaya L. Soma, MD.

**New York:** Stony Brook University Hospital, Stony Brook. Katherine V. Biagas MD.

**New York:** SUNY Downstate Medical Center University Hospital, Brooklyn.Sule Doymaz, MD.

**New York**: Kings County Hospital, New York. Michael A. Keenaghan, MD.

**North Carolina:** University of North Carolina at Chapel Hill, Chapel Hill. Stephanie P. Schwartz, MD; Tracie C. Walker, MD.

**Ohio:** University Hospitals Rainbow Babies and Children's Hospital, Cleveland. Steven L. Shein, MD, FCCM; Amanda N. Lansell, MD; Peter Paul C. Lim, MD.

**Ohio:** Nationwide Children’s Hospital, Columbus. Mark W. Hall MD, FCCM.

**Ohio:** Akron Children’s Hospital, Akron. Ryan A. Nofziger, MD, MBA.

**Ohio:** Cincinnati Children’s Hospital, Cincinnati. Mary Allen Staat, MD, MPH.

**Pennsylvania:** Children’s Hospital of Philadelphia, Philadelphia. Julie C. Fitzgerald, MD, PhD, MSCE; Ryan H. Burnett, BS; Jenny L. Bush, RNC, BSN.

**Pennsylvania:** Penn State Children’s Hospital, Hershey. Neal J. Thomas, MD, MSc.

**Pennsylvania:** UPMC Children’s Hospital of Pittsburgh. Ericka L. Fink, MD, MS; Joseph A. Carcillo, MD.

**Pennsylvania:** St. Christopher’s Hospital for Children, Philadelphia. Andrew Butler MD.

**South Carolina:** MUSC Children’s Health, Charleston. Elizabeth H. Mack, MD, MS; Nelson Reed MD.

**Tennessee:** Monroe Carell Jr. Children’s Hospital at Vanderbilt, Nashville. Natasha B. Halasa, MD, MPH; Laura Stewart, PhD; Meena Golchha, MD.

**Tennessee:** Le Bonheur Children’s Hospital, Memphis. Dai Kimura, MD.

**Texas:** Texas Children’s Hospital, Houston. Laura L. Loftis, MD; Marian Samperio MD.

**Texas:** University of Texas Health Science Center, Houston. Alvaro Coronado Munoz, MD; Jacob Qurashi, RN.

**Texas:** University of Texas Southwestern, Children’s Medical Center Dallas, Dallas. Cindy Bowens, MD, MSCS; Mia Maamari, MD.

**Utah:** Primary Children’s Hospital, Salt Lake City. Hillary Crandall, MD, PhD.

**Virginia:** Children's Hospital of The King's Daughters, Norfolk. Cassyanne L. Aguiar, MD.

**Washington:** Seattle Children’s Hospital, Seattle. Lincoln S. Smith, MD; John K. McGuire, MD.

**Wisconsin:** University of Wisconsin-Madison, Madison. Pelin Cengiz, MD.

**CDC COVID-19 Response Team on Overcoming COVID-19:**

Angela P. Campbell, MD, MPH; Laura D. Zambrano, MPH, PhD; Manish M. Patel, MD, MPH

**Supplemental ECMO Overcoming COVID-19 Case Report Form**

Patient ID: COVR-XXX-XXX

Type of ECMO Support (if both, check both):

Veno-venous  Yes  No

Veno-arterial  Yes  No

If the patient received both VV and VA ECMO, what was the initial mode?

Veno-venous  Veno-arterial

Date and time of ECMO initiation: \_\_\_\_ / \_\_\_\_ / \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Date and time of ECMO discontinuation: \_\_\_\_ / \_\_\_\_ / \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

*Discontinuation defined as time of ECMO cannula removal AND cessation of ECMO support for a time period greater than 12 hours.*

Date and time of second ECMO initiation (if applicable): \_\_\_\_ / \_\_\_\_ / \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Date and time of second ECMO discontinuation (if applicable): \_\_\_\_ / \_\_\_\_ / \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Reason for ECMO Support According to Site PI (mark all that apply):

*if available to adjudicate, copy de-identified note from EMR at time of ECMO initiation*

Primarily Cardiac (low cardiac function)

Primarily Respiratory (hypoxia with lung disease)

Other, describe: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Was ECMO done as part of ECPR Rescue?

Yes  No  Unclear

*ECPR is the application of rapid-deployment veno-arterial ECMO, usually by peripheral cannulation, to provide circulatory support in patients in whom conventional CPR is unsuccessful in achieving sustained return of spontaneous circulation (sustained ROSC). Sustained ROSC is deemed to have occurred when chest compressions are not required for 20 consecutive minutes and signs of circulation*

*persist.*

Which vasoactive agent(s) was the patient receiving in the 4 hours prior to ECMO initiation? Check all that apply and indicate the highest dose given in those 4 hours.

Dopamine, highest dose: \_\_\_\_\_\_\_ μg/kg/min

Dobutamine, highest dose: \_\_\_\_\_\_\_ μg/kg/min

Epinephrine, highest dose: \_\_\_\_\_\_\_ μg/kg/min

Norepinephrine, highest dose: \_\_\_\_\_\_\_ μg/kg/min

Milrinone, highest dose: \_\_\_\_\_\_\_ μg/kg/min

Vasopressin, highest dose: \_\_\_\_\_\_\_U/kg/min

Pre-ECMO Oxygenation Index within 6 hours of ECMO initiation (mark -6 if unavailable):

PaO2: \_\_\_\_\_\_ mmHg

FiO2 (at time of PaO2): \_\_\_\_\_\_\_\_

Mean airway pressure: \_\_\_\_\_\_\_\_\_ cmH2O

pH: \_\_\_\_\_\_\_

PaCO2: \_\_\_\_\_\_\_\_mmHg

Date and time of measurement: \_\_\_\_ / \_\_\_\_/ \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Pre-ECMO Lactate Closest to ECMO initiation:

Lactate level: \_\_\_\_\_\_\_ mmol/L

Date and time of lactate: \_\_\_\_ / \_\_\_\_/ \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Not measured

Pre-ECMO Troponin Closest to ECMO initiation:

Troponin level: \_\_\_\_\_\_\_ ng/mL

Date and time of troponin: \_\_\_\_ / \_\_\_\_/ \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Not measured

Worst Troponin while on ECMO:

Troponin level: \_\_\_\_\_\_\_\_ ng/mL

Date and time of troponin: \_\_\_\_ / \_\_\_\_/ \_\_\_\_\_\_ \_\_\_\_:\_\_\_\_

Not measured

ECMO Discontinuation Reason:

*if available to adjudicate, copy de-identified note from EMR at time of ECMO discontinuation*

Recovery

Poor prognosis/redirection of goals of care

Transition to other cardiac supports (VAD or Impella)

Lung transplant

Death on ECMO

Other, describe: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Comments regarding this patient’s ECMO course:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Supplemental Table 1** – Additional Baseline Characteristics of 2,733 Patients <21 Years Admitted to the ICU for MIS-C or Acute COVID-19 Stratified by ECMO requirement

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Clinical Characteristics** | **MIS-C not Receiving ECMO (n=1,493)** | **MIS-C Receiving ECMO (n=37)** | **P-value** | **Acute COVID-19 not Receiving ECMO (n=1,132)** | **Acute COVID-19 Receiving ECMO (n=71)** | **P-value** |
| **SARS-CoV-2 testing, no. (%)** |  |  |  |  |  |  |
| SARS-CoV-2 RT-PCR Performed | 1463 (98) | 36 (97) | 0.54 | 1132 (100) | 71 (100) | 1.00 |
| SARS-CoV-2 RT-PCR Positive | 585/1463 (40) | 18/36 (50) | 0.30 | 1132/1132 (100) | 71/71 (100) | 1.00 |
| SARS-CoV-2 Antibody Test Performed | 1368 (92) | 35 (95) | 0.76 | 240 (21) | 19 (27) | 0.30 |
| SARS-CoV-2 Antibody Test Positive | 1320/1368 (97) | 32/35 (91) | 0.13 | 122/240 (51) | 14/19 (74) | 0.06 |
| **Year of admission, no. (%)** |  |  |  |  |  |  |
| Hospitalized in 2020 | 618 (41) | 20 (54) | 0.17 | 501 (44) | 12 (17) | <0.001 |
| Hospitalized in 2021 | 875 (59) | 17 (46) | 631 (56) | 59 (83) |
| **Underlying conditions, no. (%)**a |  |  |  |  |  |  |
| Previously healthyb | 1008 (68) | 22 (60) | 0.39 | 283 (25) | 13 (18) | 0.26 |
| Respiratory | 200 (13) | 4 (11) | 0.81 | 402 (36) | 22 (31) | 0.52 |
| Cardiac | 37 (3) | 0 (0) | 1.00 | 140 (12) | 10 (14) | 0.81 |
| Neurologic | 49 (2) | 3 (8) | 0.13 | 254 (22) | 12 (17) | 0.35 |
| Oncologic or immune compromised | 28 (2) | 4 (11) | 0.006 | 95 (8) | 3 (4) | 0.27 |
| Hematologic | 28 (2) | 0 (0) | 1.00 | 81 (7) | 7 (10) | 0.54 |
| Renal | 16 (1) | 0 (0) | 1.00 | 84 (7) | 3 (4) | 0.48 |
| Gastrointestinal | 43 (3) | 3 (8) | 0.10 | 228 (20) | 9 (13) | 0.17 |
| Endocrine | 43 (3) | 3 (8) | 0.10 | 182 (16) | 11 (16) | 1.00 |
| Genetic/Metabolic (excluding obesity) | 18 (1) | 0 (0) | 1.00 | 111 (10) | 5 (7) | 0.58 |
| BMI-based obesityc | 481/1425 (34) | 13/36 (36) | 0.91 | 453/923 (49) | 37/59 (63) | 0.06 |

Abbreviations: SARS-CoV-2=Severe Acute Respiratory Syndrome CoV-2; COVID-19 = coronavirus disease 2019; MIS-C= Multisystem Inflammatory Syndrome in Children; ICU = intensive care unit; IQR = interquartile range; ECMO = extracorporeal membrane oxygenation; RT-PCR = reverse transcriptase polymerase chain reaction; No. = number.

aPatients may have more than 1 underlying condition.  
b”Previously healthy” was defined as an absence of reported underlying conditions (including obesity) and on no prescription medications.  
cThe determination of BMI-based obesity was based on CDC national reference standard for age and sex among patients who were at least 2 years of age

**Supplemental Table 2** –Admission Laboratory Values Among Acute COVID-19 and MIS-C Patients With and Without ECMO Support

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Clinical Characteristics** | **MIS-C, not receiving ECMO (n=1,493)** | | **MIS-C, receiving ECMO (n=37)** | | **P-value** | **Acute COVID-19, not receiving ECMO (n=1,132)** | | **Acute COVID-19, receiving ECMO (n=71)** | | **P-value** |
| **Admission laboratory markers (units)** | N | Median (IQR) | N | Median (IQR) |  | N | Median (IQR) | N | Median (IQR) |  |
| Absolute neutrophil count (103/µL) | 1,286 | 7.61 (4.88, 11.3) | 31 | 12.85 (8.53, 20.49) | **0.043** | 822 | 4.93 (2.88, 8.14) | 53 | 6.15 (4.11, 11.42) | **0.004** |
| White blood cell count (103/µL) | 1,470 | 10.04 (7.10, 14.10) | 36 | 15.53 (12.10, 23.24) | **<0.001** | 1,025 | 7.71 (4.70, 11.50) | 67 | 8.30 (6.30, 14.74) | **0.006** |
| Neutrophil to lymphocyte ratio | 1,283 | 8.93 (4.98, 15.00) | 31 | 12.34 (5.00, 23.56) | 0.06 | 820 | 3.90 (1.96, 7.88) | 53 | 5.93 (2.92, 12.86) | **0.004** |
| Lactate (mmol/L) | 727 | 1.7 (1.3, 2.6) | 24 | 4.6 (3.2, 11.1) | **<0.001** | 376 | 1.6 (1.0, 2.8) | 44 | 1.5 (1.1, 3.0) | 0.83 |
| Creatinine (mg/dL) | 1,379 | 0.64 (0.46, 0.99) | 32 | 1.32 (0.74, 2.93) | **<0.001** | 909 | 0.57 (0.37, 0.78) | 59 | 0.72 (0.49, 0.93) | **0.005** |
| Alanine transaminase (U/L) | 1,300 | 38 (23, 65) | 30 | 53 (23, 81) | 0.26 | 756 | 31 (19, 57) | 55 | 44 (23, 69) | 0.06 |
| Procalcitonin (ng/mL) | 646 | 5.73 (2.14, 18.00) | 15 | 8.91 (2.90, 30.87) | 0.42 | 306 | 0.24 (0.11, 1.03) | 22 | 0.92 (0.26, 12.43) | **0.004** |
| Ferritin (ng/mL) | 1,071 | 527 (290, 990) | 23 | 1170 (280, 1965) | 0.14 | 318 | 274 (112, 598) | 16 | 913 (219, 1938) | **0.014** |
| C-reactive protein (mg/dL) | 1,230 | 18.1 (10.7, 25.0) | 24 | 22.0 (15.6, 33.8) | **0.044** | 539 | 4.0 (1.4, 8.9) | 36 | 7.1 (3.8, 12.7) | **0.008** |
| Hemoglobin (g/dL) | 1,365 | 11.3 (10.2, 12.4) | 34 | 12.4 (10.8, 13.7) | **0.014** | 910 | 12.6 (11.1, 14.0) | 61 | 12.4 (10.5, 13.9) | 0.26 |
| Platelet count (103/µL) | 1,353 | 155 (108, 213) | 33 | 198 (134, 259) | **0.013** | 889 | 221 (165, 311) | 59 | 202 (138, 283) | 0.10 |
| Absolute lymphocyte count (103/µL) | 1,318 | 0.87 (0.51, 1.48) | 32 | 1.33 (0.66, 1.91) | **0.043** | 844 | 1.19 (0.70, 2.19) | 53 | 1.15 (0.60, 1.85) | 0.31 |

**Supplemental Figure 1 –** Supplemental Admission Laboratory Values.

  
\*Denotes significant difference between ECMO and non-ECMO patients (p<0.05)

Abbreviations: ECMO: extracorporeal membrane oxygenation; MIS-C: multisystem inflammatory syndrome in children; COVID-19: coronavirus disease 2019