Intensive Care Med
https://doi.org/10.1007/s00134-020-06272-3

LETTER

ECMO for COVID-19 patients in Europe and Israel

Roberto Lorusso[1,2], Alain Combes[3], Valeria Lo Coco[1], Maria Elena De Piero[1] and Jan Belohlavek[4*] on behalf of the EuroECMO COVID-19 WorkingGroup and Euro-ELSO Steering Committee

Dear Editor,

As of October 17th the novel coronavirus (SARS-CoV-2) caused a pandemic disease (coronavirus disease 2019, COVID-19) 40 million people worldwide, with almost one million deaths [1]. Although most patients have an uncomplicated clinical course, the more severe forms of COVID-19 require hospitalization and intensive care unit admission [2]. Conventional high-flow oxygen therapy, non-invasive and/or invasive mechanical ventilation, often in combination with pronepositioning, have all been reported to be effective in the majority of patients [2]. However, in severe cases, life-threatening, refractory hypoxemia may occur [2]. Secondary infections, myocardial disease involvement and a hypercoaguable state with/without pulmonary embolism may also contribute to the complexity of treating these critically ill patients [3–5]. In such cases rescue therapy may be required.

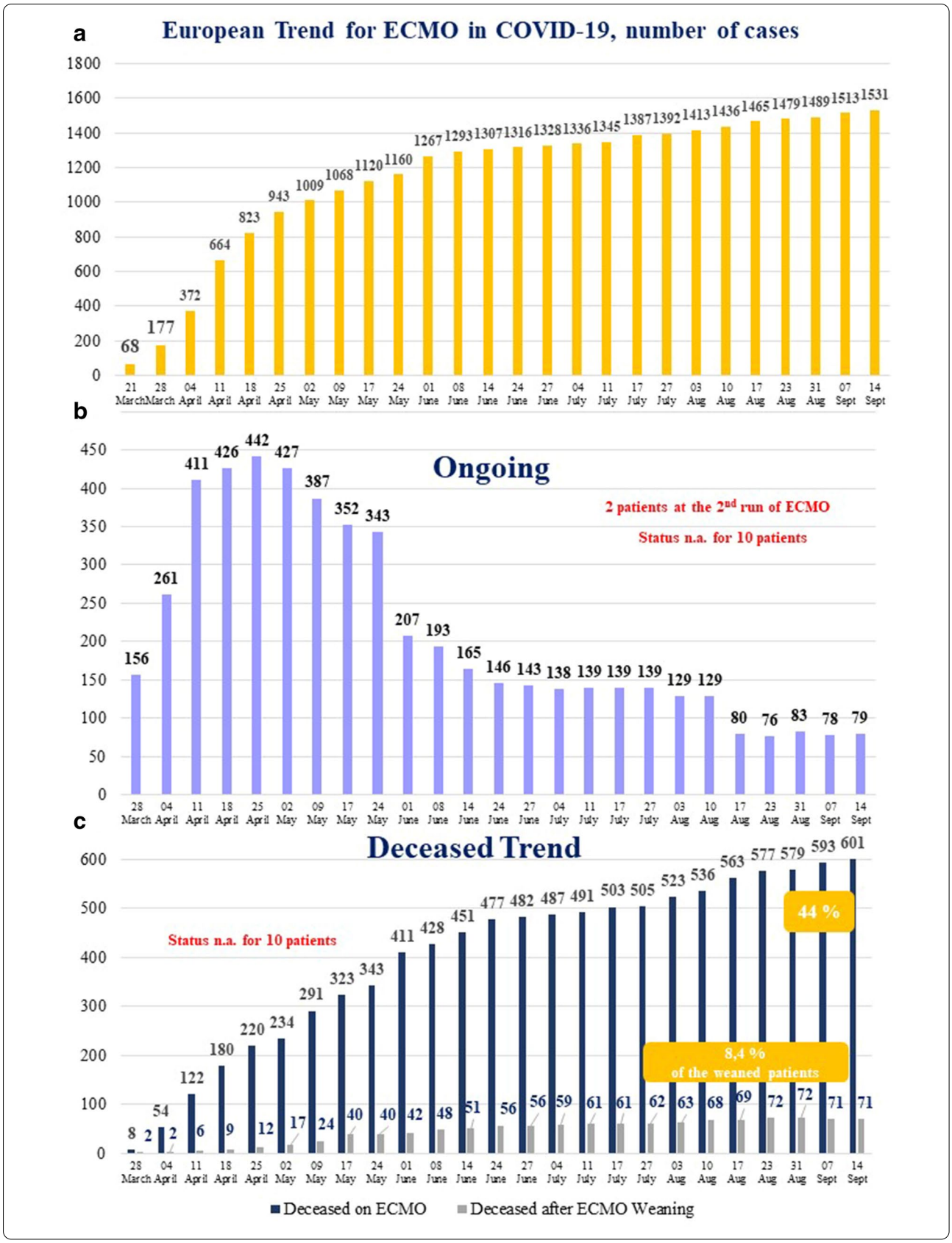
The World Health Organization (WHO) [6], the Extracorporeal Life Support Organization (www.elso.org) and others have advocated the use of extracorporeal membrane oxygenation (ECMO) for patients with severe cardiorespiratory failure. Few patients in China received ECMO support in the early phase of the pandemic and the mortality rate among these patients was high [7]. Initial experience with COVID-19 in Europe was similar as the high number of critically ill patients disrupted usual care pathways and stretched hospital resources [2]. There was probably some hesitation to provide a form of support which is considered highly resource consuming. However, despite the rapid growth in the number of critically ill COVID-19 patients in Europe, over time an unexpectedly high number of severely compromised patients were considered eligible for ECMO support. At this time the Steering Committee of the European chapter of the Extracorporeal Life Support Organization (Euro-ELSO) initiated prospective data collection among European and Israeli centres with the intention of providing near real-time information on ECMO use in COVID-19. The study was approved by the Maastricht University Ethical Committee (coordinating center) and is registered under ClinicalTrials.gov identifier: NCT04366921. Data are collected weekly and reported anonymously through the Euro-ELSO website https://www.euroelso.net/covid-19/covid-19-survey/. This voluntary study includes basic data on patients´ age and gender, the details of their ECMO treatment and real-time status (i.e., ongoing, successfully weaned, or died).

Since March 15th, 2020, 177 centres from Europe and Israel have joined the study, routinely reporting on the ECMO support they provide to COVID-19 patients. The mean annual number of cases treated with ECMO in the participating centres before the pandemic (2019) was 55. The number of COVID-19 patients has increased rapidly each week reaching 1531 treated patients as of September 14th. The greatest number of cases has been reported from France ($n=385$), UK ($n=193$), Germany ($n=176$), Spain ($n=166$), and Italy ($n=136$) (See Supplementary Fig. 1).

*Correspondence: jan.belohlavek@vfn.cz
[4] 2nd Department of Internal Medicine, Cardiovascular Medicine General Teaching Hospital and 1st Faculty of Medicine, Charles University in Prague, U Nemocnice 2, Praha 2, Prague 128 00, Czech Republic
Full author information is available at the end of the article

Members of the EuroECMO COVID-19 Working Group and of the Euro-ELSO Steering Committee are listed in the Acknowledgements Section.

Springer


a
European Trend for ECMO in COVID-19, number of cases
1800
1600
1400
1200
1000
800
600
400
200
0
68
177
372
664
823
943
1009
1068
1120
1160
1267
1293
1307
1316
1328
1336
1345
1387
1392
1413
1436
1465
1479
1489
1513
1531
21 March
28 March
04 April
11 April
18 April
25 April
02 May
09 May
17 May
24 May
01 June
08 June
14 June
24 June
27 June
04 July
11 July
17 July
27 July
03 Aug
10 Aug
17 Aug
23 Aug
31 Aug
07 Sept
14 Sept
b
Ongoing
2 patients at the 2nd run of ECMO
Status n.a. for 10 patients
450
400
350
300
250
200
150
100
50
0
156
261
411
426
442
427
387
352
343
207
193
165
146
143
138
139
139
139
129
129
80
76
83
78
79
28 March
04 April
11 April
18 April
25 April
02 May
09 May
17 May
24 May
01 June
08 June
14 June
24 June
27 June
04 July
11 July
17 July
27 July
03 Aug
10 Aug
17 Aug
23 Aug
31 Aug
07 Sept
14 Sept
c
Deceased Trend
Status n.a. for 10 patients
44 %
8,4 %
of the weaned patients
600
500
400
300
200
100
0
8
2
54
2
122
6
180
9
220
12
234
17
291
24
323
40
343
40
411
42
428
48
451
51
477
56
482
56
487
59
491
61
503
61
505
62
523
63
536
68
563
69
577
72
579
72
593
71
601
71
28 March
04 April
11 April
18 April
25 April
02 May
09 May
17 May
24 May
01 June
08 June
14 June
24 June
27 June
04 July
11 July
17 July
27 July
03 Aug
10 Aug
17 Aug
23 Aug
31 Aug
07 Sept
14 Sept
Deceased on ECMO
Deceased after ECMO Weaning

(See figure on previous page.)
Fig. 1 European trends of extracorporeal membrane oxygenation in COVID-19 as of September 14th, 2020. **a** Absolute number of ECMO cases as observed in 177 European/Israeli centres. **b** Number and percentage of ongoing cases, 2 patients at the 2nd run of ECMO included. **c** Number of patients deceased on ECMO and after ECMO weaning. Currently, 44% died overall, 8,4% died after weaning, e.g. 4,7% of all

The mean age of treated patients was 52.6 years (range 16–80), 79% were male. The ECMO configuration used was VV in 91% of cases, VA in 5% and other in 4%. The mean PaO_2 before ECMO implantation was 65 mmHg. The mean duration of ECMO support thus far has been 18 days and the mean ICU length of stay of these patients was 33 days. As of the 14th September, overall 841 patients have been weaned from ECMO support, 601 died during ECMO support, 71 died after withdrawal of ECMO, 79 are still receiving ECMO support and for 10 patients status n.a. (Fig. 1).

Our preliminary data suggest that patients placed on ECMO with severe refractory respiratory or cardiac failure secondary to COVID-19 have a reasonable (55%) chance of survival. Further extensive data analysis is expected to provide invaluable information on the demographics, severity of illness, indications and different ECMO management strategies in these patients.

Electronic supplementary material
The online version of this article (https://doi.org/10.1007/s00134-020-06272-3) contains supplementary material, which is available to authorized users.

Author details
[1] Cardio-Thoracic Surgery Department, Heart and Vascular Centre, Maastricht University Medical Centre, Maastricht, The Netherlands. [2] Cardiovascular Research Institute Maastricht, Maastricht, The Netherlands. [3] Medical Intensive Care Unit, Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital, Paris, France. [4] 2nd Department of Internal Medicine, Cardiovascular Medicine General Teaching Hospital and 1st Faculty of Medicine, Charles University in Prague, U Nemocnice 2, Praha 2, Prague 128 00, Czech Republic.

Acknowledgements
We thank below Euro-ELSO Steering Committee Members for the approval and a critical review of the study: M. Velia Antonini (Intensive Care Unit, University Hospital of Parma, Parma, Italy); Nicholas A. Barrett, M.D., (Guy's and St Thomas' NHS Foundation Trust, London, UK); Mirko Belliato M.D., PhD., (Department of Intensive Medicine, IRCCS Policlinico San Matteo Foundation, Pavia, Italy); Mark Davidson, M.D., (Pediatric ICU and ECMO, Royal Hospital for Children, Glasgow, Scotland); Matteo Di Nardo, M.D. (Pediatric Intensive Care Unit, Children's Hospital Bambino Gesù, IRCCS, Rome, Italy); Simon Finney, M.D., Ph.D. (Dept. of Cardio-Thoracic Anesthesia and Intensive Care, Barts Healths NHS Trust, London, UK); Jo-Anne Fowles, MSc (Critical Care & ECMO, Royal Papworth Hospital NHS Foundation Trust, Cambridge, UK); Maximilian Halbe, EC.C.P. (Dept. Cardio-Vascular surgery, University Hospital, Zurich, Switzerland); Felix Hennig, M.D., Ph.D. (Dept. Cardiothoracic-Vascular Surgery, German Heart Institute, Berlin, Germany); Tim Jones, M.D. (Dept. of Cardiac Surgery, Birmingham Children Hospital, Birmingham, UK); Thomas Mueller, M.D., Ph.D. (University Medical Center Regensburg, Regensburg, Germany); Luis Pinto (Centro Hospitalar Sao Joao, Porto, Portugal); Jonathan Smith, M.D. (Dept. of Cardiac Surgery, Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle, UK); Jordi Riera, M.D., Ph.D. (Intensive Care Unit, Vall d'Hebron University Hospital, Vall d´Hebron Research Institute, Barcelona, Spain); Peter Roeleveld, M.D. (Pediatric Intensive care, Leiden University Medical Centre, Leiden, The Netherlands); Justyna Swol, M.D. (Pneumology Department, Paracelsus Medical University, Nuremberg, Germany); Leen Vercaemst, R.N., EC.C.P. (Cardiac Surgery Unit, Gasthuisberg Hospital, Catholic University, Leuven, Belgium). We also thank for the contribution of the EuroECMO COVID-19 Working Group members listed below for providing data: Thijs Delnoij, M.D., Ronny Schnabel, M.D., Ph.D., Iwan van der Horst, M.D., Ph.D. (Intensive Care Unit Dept., Maastricht University Medical Centre, Maastricht, The Netherlands); Dinis Reis Miranda, M.D. (Intensive Care Dept., ERASMUS University Hospital, Rotterdam, The Netherlands); Marcel van der Linden, M.D., Merijn Kant (Dept. Cardiothoracic Surgery and Intensive care Unit, Breda Hospital, Breda, The Netherlands); J.J. van der Heijden, M.D., Ph.D. (Dept. Intensive Care, University Medical Centre Utrecht, Utrecht, The Netherlands); Erik Scholten, M.D., Ph.D. (Dept. Intensive Care, St. Anthonius Ziekenhuis, Nieuwegeijn, The Netherlands); Nicole van Belle-van Haren, M.D. (Dept. of Cardiac Surgery, St. Anthonius Ziekenhuis, Nieuwegeijn, The Netherlands); Wim Lagrand, M.D., Ph.D. (Dept. Intensive Care, University Medical Centre Amsterdam, Amsterdam, The Netherlands); Sytse de Jong, EC.C.P. (Dept. Cardiothoracic Surgery, Radboud University Medical Centre, Nijmgen, The Netherlands); Dario Candura, M.D., Ph.D. (Cardiac Surgery Dept., Leiden University Medical Centre, The Netherlands); Jacinta Maas, M.D., M.J. van Gijlswijk van den Berg, R.N. (Intensive Care, Leiden University Medical Center, Leiden, The Netherlands); Maarten Strauven EC.C.P. (Dept. Cardiosurgery, Ziekenhuis Oost Limburg, Genk, The Netherlands); Maximilian Malfertheiner, M.D., Esther Dreier, M.S., Thomas Mueller, M.D., Ph.D. (University Medical Center Regensburg, Regensburg, Germany); Udo Boeken, M.D., Ph.D., Payam Akhyari, M.D., Artur Lichtenberg, M.D. (Dept. of Cardiac Surgery, Heinrich Heine University, Dusseldorf, Germany); Diyar Saeed, M.D., Ph.D., Holger Thiele, M.D., Ph.D. (Leipzig Heart Centre, Leipzig, Germany); Matthias Baumgaertel, M.D. (Department of Pulmonology, Intensive Care Medicine, Paracelsus Medical University, Nuremberg, Germany); Jan D. Schmitto, M.D., Ph.D., Silvia Mariani, M.D. (Dept. Cardiac-Thoracic-Vascular Surgery, Hannover Medical School, Hannover, Germany); Matthias Thielmann, M.D., Ph.D. (West-German Heart and Vascular Center, University of Duisburg, Essen, Germany), Thorsten Brenner, M.D. (Dept. of Anesthesiology and Intensive Care, University Hospital, Essen, Germany); Cristoph Benk, Ph.D., Martin Czerny, M.D., M.B.A. (University Heart Center Freiburg Bad Krozingen, Bad Krozingen, Germany-Faculty of Medicine, University Freiburg, Germany); Johannes Kalbhenn, M.D. (Dept. of Anesthesiology and Intensive Care, Medical Centre-University of Freiburg, Germany); Sven Maier, M.Sc., David Schibilsky M.D., Dawid L Staudacher M.D. (University Heart Centre Freiburg Bad Krozingen, Germany, Faculty of Medicine, University Freiburg, Germany); Philipp Henn, M.D. (Dept. of Anesthesiology and Intensive Care, University Hospital, Tubingen, Germany), Aron-Frederik Popov, M.D., Ph.D. (Dept. of Cardio-Thoracic Surgery, University Hospital, Tubingen, Germany); Torje Iuliu, M.D., Ralf Muellenbach, M.D., Christian Reyher MD, Caroline Rolfes M.D. (Dept. Intensive Care, ECMO Center, Kassel, Germany); Kai Zacharowski, M.D. Ph.D., Gösta Lotz M.D., Michael Sonntagbauer M.D. (Dept. of Anesthesiology, ECLS Centre Frankfurt University Hospital, Germany); Alexander Kersten, M.D. (Department of Pneumology and Critical Care, University Hospital RWTH Aachen, Germany); Christian Karagiannidis, M.D., Simone Schafer M.D. (Intensive Care Unit, ARDS E-ECMO Centre, Koln-Merheim, Germany); Julia Fichte, M.D., Hans-Bernd Hopf, M.D., (Asklepios Klinik Langen, Dept. of Anesthesia, perioperative Medicine and interdisciplinary Intensive Care Medicine, ECLS-ECMO center Langen, Cardiac arrest center Langen, Langen, Germany); Robertas Samalavicius, M.D., Ph.D. (Vilnius University Hospital Santariškių Klinikos, Vilnius, Lithuania); Luca Lorini, M.D., Davide Ghitti, EC.C.P., Lorenzo Grazioli, M.D. (Dept. of Intensive Care, Papa Giovanni XXIII Hospital, Bergamo, Italy); Antonio Loforte, M.D., Massimo Baiocchi, M.D., Erika Dal Checco, M.D., Davide Pacini, M.D. (Dept. Cardio-Thorac-Vascular Surgery and Intensive Care Unit, S. Orsola University Hospital, Bologna, Italy); Paolo Meani, M.D. (Cardiology Unit, Niguarda Hospital, Milan, Italy); Antioco Cappai, M.D., Claudio Francesco Russo, M.D., Maurizio Bottiroli, M.D. (Cardiac Surgery Unit, Niguarda Hospital, Milan, Italy); Michele Mondino, M.D. (Cardio-Thoracic Surgery Intensive Care Unit, Niguarda Hospital, Milan, Italy); Marco Ranucci,

M.D., Dario Fina, M.D., Andrea Ballotta, M.D. (Dept. Intensive Care, S. Donato Hospital, Milan, Italy); Anna Mara Scandroglio, M.D., Alberto Zangrillo, M.D., Marina Pieri, M.D, Pasquale Nardelli, M.D., Evgeny Fominskiy, M.D., Giovanni Landoni, M.D. (Dept. of Anesthesia and Intensive Care, IRCCS, San Raffaele Scientific Institute, Milan, Italy); Vito Fanelli, M.D., Luca Brazzi, M.D., Ph.D., Giorgia Montrucchio, M.D., Gabriele Sales, M.D., Umberto Simonetti, M.D., Rosario Urbino, M.D. (Department of Anaesthesia and Critical Care - AOU Città della Salute e della Scienza di Torino – University of Turin, Italy); Sergio Livigni, M.D. (Dept. Intensive Care, S. Giovanni Bosco Hospital, Turin, Italy); Mirko Belliato, M.D. (UOC Anestesia e Rianimazione 1, Foundation IRCCS Policlinico San Matteo, Pavia, Italy); Antonella Degani, EC.C.P. (Cardio-Thoracic Unit, IRCCS Policlinico San Matteo, Pavia, Italy);
Giuseppe Raffa, M.D., Ph.D., Michele Pilato, M.D. (Dept. of Cardiac Surgery, IRCCS-ISMETT Hospital, Palermo, Italy); Gennaro Martucci, M.D., Antonio Arcadipane, M.D. (Dept. of Anesthesia and Intensive Care, IRCCS-ISMETT Hospital, Palermo, Italy); Giovanni Chiarini, M.D., Nicola Latronico, M.D., Sergio Cattaneo, M.D., Carmine Puglia, M.D. (Dept. Intensive Care, Spedali Civili Hospital, Brescia, Italy); Gianfranco Reina, M.D. (Dept. Intensive Care dell'Angelo Hospital Venice/Mestre, Mestre, Italy); Sandro Sponga, M.D., Ph.D., Ugolino Livi, M.D. (Cardiac Surgery Department , University Hospital of Udine, Udine, Italy); Giuseppe Foti, M.D., Marco Giani, M.D., Roberto Rona, M.D., Leonello Avalli, M.D., Michela Bombino, M.D., Maria Cristina Costa, EC.C.P. (Dept. of Emergency and Intensive Care, S. Gerardo Hospital, Monza, Italy); Roberto Carozza, EC.C.P., Abele Donati, M.D. (University ICU, Ospedali Riuniti, Lancisi Cardiovascular Center, AOU Riuniti Hospital, Ancona, Italy); Marco Picichè, M.D., Ph.D., Alessandro Favaro, M.D., Loris Salvador, M.D. (Dept. Cardiac Surgery, S. Bortolo Hospital, Vicenza, Italy); Vinicio Danzi, M.D., Anita Zanin, M.D. (Dept. of Anesthesia and Intensive Care, S. Bortolo Hospital, Vicenza, Italy); Ignazio Condello, EC.C.P., Flavio Fiore, M.D., Ph.D., Marco Moscarelli, M.D., Ph.D., Giuseppe Nasso, M.D., Ph.D., Giuseppe Speziale, M.D., Ph.D. (Cardiac Surgery Dept., Gruppo Villa Maria Hospitals, Bari, Italy); Luca Sandrelli, M.D. (Cardiac Surgery Unit, S. Giorgio Clinic, Alessandria, Italy); Andrea Montalto, M.D., Francesco Musumeci, M.D. (Cardiac Surgery Unit, S. Camillo Hospital, Rome, Italy); Alessandro Circelli, M.D., Emiliano Gamberini, M.D., Emanuele Russo, M.D., Marco Benni, M.D., Vanni Agnoletti, M.D. (Dept. of Intensive Care, Bufalini Hospital, Cesena, Italy); Ruggero Rociola, EC.C.P., Aldo D. Milano, M.D. (Dept. Cardiac Surgery, Policlinico Hospital, Bari, Italy), Salvatore Grasso, M.D., Antonio Civita, M.D., Francesco Murgolo, M.D. (Anestesiology Dept. Policlinico Hospital, Bari, Italy); Emanuele Pilato, M.D., Giuseppe Comentale, M.D. (Dept. Cardiac Surgery, Federico II University Hospital, Naples, Italy); Andrea Montisci, M.D. (Department of Cardiac Anesthesia and Intensive Care, Sant'Ambrogio Cardiothoracic Center, Milan, Italy); Francesco Alessandri M.D., Antonella Tosi M.D., Francesco Pugliese M.D. (Dept. of Anaesthesiology and Intensive Care, "Sapienza" University of Rome, Policlinico Umberto I, Rome, Italy); Simone Carelli M.D., Domenico Luca Grieco M.D., Massimo Antonelli M.D. (Dept of Anesthesiology, Intensive Care and Emergency Medicine, Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Rome, Italy); Enrico Ramoni M.D. (Dept. Intensive and Sub-Intensive Care Unit, Istituto Clinico Casal-palocco, Rome-3 Covid Hospital, Rome, Italy); Matteo Di Nardo, M.D. (Pediatric Critical CareUnit, Bambino Gesu' Children Hospital, Rome, Italy); Francesco Maisano, M.D. (Dept. Cardio-Vascular surgery, University Hospital, Zurich, Switzerland); Dominique Bettex, M.D. (Dept. of Cardio-Thoracic Anesthesia, University Hospital, Zurich, Switzerland); Alberto Weber, M.D., Jurg Grunen-felder, M.D. (Dept. Cardia-Vascular Surgery, Herzzentrum, Zurich, Switzerland); Gianluca Agus (Cardiocentro Ticino, Lugano, Switzerland); Jolanda Consiglio, EC.C.P., Jenni Hansjoerg, EC.C.P. (Dept. Cardiothoracic surgery, University Hospital, Bern, Switzerland); Matthias Haenggi, M.D. (Department of Intensive Care Medicine, University Hospital Bern, University of Bern, Bern, Switzerland); Thomas Doeble, EC.C.P., Urs Zenklusen, EC.C.P. (Division of Cardiac Surgery, University Hospital Basel, Basel, Switzerland); Xavier Bechtold, EC.C.P. (CHUV, Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland); Bernard Stockman, M.D. (Dept. of Cardiac Surgery, OLV Hospital Aalst, Belgium); Daniel De Backer, M.D., Simone Giglioli, M.D. (Dept. of Intensive Care, CHIREC Hospitals, Université Libre de Bruxelles, Brussels, Belgium); Bart Meyns, M.D., Ph.D., Leen Vercaemst, R.N., EC.C.P. Greet Herman Ph.D., Philippe Meersseman, M.D., Christophe Vandenbriele, Ph.D., Dieter Dauwe, Ph.D., Dirk Vlasselaers, Ph.D. (Cardiac Surgery Unit, Medical Intensive Care, Cardiac Intensive Care, Gasthuisberg Hospital, Catholic University, Leuven, Belgium); Matthias Raes, M.D. (Dept. Intensive Care, University Hospital Brussels, Belgium); Gerdy Debeuckelaere, EC.C.P., Inez Rodrigus, M.D., Ph.D. (University Hospital Antwerp, Antwerp, Belgium); Patrick Biston, M.D., Michael Piagnerelli, M.D., Ph.D. (Dept. Intensive Care, CHU Marie Curie, Charleroi, Belgium); Harlinde Peperstraete, M.D. (Dept. Intensive Care, University Hospital, Ghent, Belgium); Korneel Vandewiele, EC.C.P (Department of PerfusionUniversity Hospital, Ghent, Belgium); Olivier Germay, EC.C.P. (Perfusion Dept., Anesthesia Dept., CHU St Pierre de Bruxelles, Université Libre de Bruxelles, Belgium); Dimitri Van-deweghe, EC.C.P., Ine Witters, M.D., Sven Havrin, EC.C.P., Marc Bourgeois, M.D. (Dept. of Critical Care and Anesthesia, Az Sint Jan brugge - Oostende av, Bruges, Belgium); Fabio Silvio Taccone, M.D., Ph.D., Leda Nobile, M.D., Olivier Lheureux, M.D., Alexandre Brasseur, M.D., Jacques Creteur, M.D. (Dept. of Intensive Care, Erasme Hospital, Universite' Libre de Bruxelles, Brussels, Belgium) Marc-Gilbert Lagny, EC.C.P., Ph.D., Jean-Olivier Defraigne, M.D., Ph.D., Benoît Misset, M.D., Ph.D. (CHU Sart Tilman, Liege, Belgium); Romain Courcelle, M.D. (Dept. Intensive Care, Pole Hospitalier Jolimont, La Luviere Hospital, Belgium); Philippe Jr. Timmermans, M.D., Jeroen Lehaen CCP, EC.C.P. (Dept. Cardiac Intensive Care, Jessa Hospital, Hasselt, Belgium); Piet Lormans, M.D., Bruno Verhamme, M.D., Frederik Bonte EC.C.P (AZ Delta Hospital, Roeselare, Belgium); Miguel Ángel Castro, M.D. (Cardiac Surgery Dept.); Elisabet Gallart, R.N., Ph.D., María Martínez-Martínez, M.D., Eduard Argudo, M.D., Marina García-de-Acilu, M.D. (Intensive care Unit, Vall d´Hebron Hospital, Vall d´Hebron Research Institute, Barcelona, Spain); Raul de Pablo Sanchez, M.D., Ph.D. Aaron Blandino Ortiz, M.D. (Dept. Intensive Care, Ramón y Cajal University Hospital. Alcalá de Henares University, Madrid, Spain); Mari-Paz Fuset Cabanes, M.D. (Intensive Care Unit, University Hospital of Bellvitge, Barcelona, Spain); Karina Osorio Higa, M.D., Albert Miralles Cassina, M.D., Daniel Ortiz Berbel, M.D. (Dept. of Cardiac Surgery, University Hospital of Bellvitge, Barcelona, Spain); Jose Carlos Sánchez-Salado, M.D. (Coronary Intensive Care Unit, Cardiology Dept., University Hospital of Bellvitge, Barcelona, Spain); Blasco-Lucas Arnau, M.D., Ph.D. (Department of Cardiac Surgery, University Hospital of Bellvitge, L'Hospitalet de Llobregat, Barcelona, Spain); Pablo Ruiz de Gopegui, M.D. (Critical Care Dept., Miguel Servet University Hospital, Zaragoza, Spain); Pilar Ricart, M.D., Ph.D. (Critical Care Dept. Hospital Universitari Germans Trias i Pujol, Barcelona, Spain); Elena Sandoval, M.D. (Cardiovascular Surgery Dept., ICCV, Hospital Clínic, Barcelona, Spain); Javier Veganzones, M.D. (Anesthesiology Dept., Hospital Universitario La Paz, Madrid, Spain); Pablo Millán (Crítical Care Dept., Hospital Universitario La Paz, Madrid, Spain); Enrique Pérez de la Sota, M.D. FECTS (Cardiac Surgery Department, Hospital 12 de Octubre, Madrid, Spain); Patricia Santa Teresa M.D., Ph.D. (Intensive Care Unit, Hospital Universitario Gregorio Maranon, Madrid, Spain); Sara Alcantara M.D. (Intensive Care Unit, Jessica Garcia Anesthesiology Dept., Hospital Universitario Puerta de Hierro Majadahonda, Madrid, Spain); Jorge Duerto Alvarez, M.D., Ph.D. (Intensive Care Unit, Clinico San Carlos University Hospital, Madrid, Spain); Ánxela Vidal González, M.D. (Universitary Hospital Fundación Jiménez Díaz and Universitary Hospital Rey Juan Carlos, Madrid, Spain); Marta Lopez, M.D. (Intensive Care Unit, Hospital de Valdecilla, Santander, Spain); Antonio Gordillo, M.D. (Intensive Care Unit, Hospital Puerta del Mar, Cadiz, Spain); Josè Naranjo-Izurieta, M.D. (Intensive Care Unit, Hospital Reina Sofia, Cordoba, Spain); Ricardo Gimeno Costa, M.D. (Critical Care Dept., Hospital Universitari i Politècnic La Fe, Valencia, Spain); Carlos L. Albacete Moreno, M.D., Ph.D. (Critical Care Dept., Adult ECMO Program, Virgen de la Arrixaca University Clinic Hospital, Murcia, Spain); José Ángel de Ayala, M.D., Pablo Blanco-Schweizer, M.D. (Critical Care Department, ARF & ECMO Program, Hospital Universitario Río Hortega, Valladolid, Spain); Nicolás Hidalgo Andrés, M.D. (Critical Care Dept., Hospital Clínico Universitario, Valladolid, Spain); Victoria Boado, M.D. (Critical Care Dept., Hospital Universitario Cruces Barakaldo, Bilbao, Spain); José María Núñez Martínez, M.D. (Critical Care Dept., Hospital de Vinalopó Elche-Crevillente, Alicante, Spain); Vanesa Gómez Casal, M.D. (Critical Care Dept., Hospital Álvaro Cunqueiro, Vigo, Spain); Esperanza Fernández García, M.D. (Critical Care Dept., Hospital Universitario Virgen Macarena, Sevilla, Spain); Luis Martin-Villen, M.D. (Unidad de Gestión Clínica de Medicina Intensiva, Hospital Universitario Virgen del Rocío, Sevilla, Spain); Joaquín Colomina Climent, M.D. (Critical Care Dept., Hospital Universitari Son Espases, Palma de Mallorca, Spain); Luis F. Pinto, M.D. (Cardiac Surgery Unit, Sao Joao University Hospital, Porto, Portugal); Pascal Leprince, M.D., Ph.D. (Cardiac Surgery Dept., Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital); Guillaume Lebreton, M.D., Ph.D. (Cardio-Thoracic Surgery Intensive Care Unit Dept., Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital), Charles Juvin, M.D., Matthieu Schmidt, M.D., Ph.D., Marc Pineton, M.D., Ph.D. (Medical Intensive Care Unit, Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière Hospital, Paris, France); Thierry Folliguet, M.D., Ph.D., Gabriel Saiydoun,M.D. (Dept. Cardiothoracic and Vascular Surgery, Henri Mondor Hospital, Paris, France); Philippe Gaudard, M.D., Ph.D., Pascal Colson, M.D., Ph.D. (Univ

Montpellier, PhyMedExp, INSERM, CNRS, Dept. Anaesthesiology and Intensive Care, CHU Montpellier, Montpellier, France); Jean-Francois Obadia, M.D., Ph.D., Matteo Pozzi, M.D., Ph.D. (Dept. Cardio-vascular surgery, Hospices Civils de Lyon and Claude Bernard University, Lyon, France), Jean Luc Fellahi, M.D., Ph.D. (Dept. of Anesthesia and ICU, "Louis Pradel" Cardiologic Hospital, Lyon, France), Hodane Yonis, M.D., Jean Christophe Richard, M.D., Ph.D. (Dept. of Medical ICU, "Croix Rousse" Hospital, Lyon, France); Alessandro Parasido, EC.C.P., Jean-Philippe Verhoye, M.D., Ph.D., Erwan Flecher, M.D., Ph.D., Lucrezia Ajrhourh, EC.C.P. (Cardiac Surgery Dept., CHU University Hospital, Rennes, France); Nicolas Nesseler, M.D., Alexandre Mansour M.D. (Anesthesiology Dept., CHU University Hospital, Rennes, France); Pierre-Grégoire Guinot M.D., Ph. D. (Center of Anesthesia and Surgical Revives, Unitécardiovasculaire, Centre Hospitalier Universitarie de Dijon, Université de Bourgogne Franche-Comtè, Dijon, France); Jonathan Zarka, M.D. (Dept. Intensive Care de Marne-la Vallee Hospital Center-Jossigny, France); Patricia Besserve, M.D. (Department of Intensive Care Unit, CHU, Amiens, France); Maged Makhoul, M.D., Gil Bolotin, M.D., Ph.D. (Dept. of Cardio-thoracic Surgery, Rambam Health Care Campus, Haifa, Israel); Yigal Kassif, M.D. (Cardiac Surgery Unit, ECMO Service, Sheba, Tel Ha Shomer, Israel) Dimitros Soufleris, M.D. (Cardiac Surgery Dept., Athens Medical Center, Athens, Greece); Peter Schellongowski, M.D. (Dept. Intensive Care, Medical University Hospital, Vienna, Austria); Nikolaos Bonaros, M.D., Ph.D., Christoph Krapf, M.D., Kathrin Ebert, M.D., Peter Mair, M.D. (Dept. of Cardiac Surgery, Medical University Hospital of Innsbruck, Austria); Florian Kothleutner, (Dept. Cardiac Surgery, University Hospital, St. Polten-Lilienfeld, Austria); Mariusz Kowalewsky, M.D., Piotr Suwalski, M.D. (Dept. Cardiothoracic Surgery, Central Clinical Hospital Warsaw, Poland); Steffen Christensen, M.D., Ph.D. (Aarhus University Hospital, Denmark); Finn Møller Pedersen, M.D. (Cardiothoracic Intensive Care Unit, University Hospital, Copenhagen, Denmark); Martin Balík, M.D., Ph.D., Jan Bláha, M.D., Ph.D., Michal Lipš, M.D., Michal Otáhal, M.D. (Dept. of Anesthesia, Resuscitation and Intensive Care Medicine, Complex Cardiovascular Centre, General University Hospital, Charles University, Prague, The Czech Republic); Luigi Camporota, M.D., Kathleen Daly, M.D., Nicola Agnew, M.D. (Intensive Care Unit, Guy's and St. Thomas's Hospital and NHS Foundation Trust, London, UK); Julian Barker, M.D., Laura Head, M.D., Miguel Garcia, M.D. (Cardiothoracic Critical Care Unit, Wythenshawe Hospital, Manchester, UK); Stephane Ledot, MD., Verna Aquino, Rebecca Lewis, M.D., Jennifer Worthy, M.D., Hamza Noor, M.D. (Intensive Care Unit, Royal Brompton & Harefield, London, UK); Ian Scott, M.D. (Dept. of Anesthesia and Intensive Care, Aberdeen Royal Infirmary, Aberdeen, UK); Serena O'Brien MSc. Ian Conrick-Martin, M.D., Edmund Carton, M.D. (Dept. of Critical Care Medicine, Mater Misericordiae University Hospital, Dublin, Ireland); Stuart Gillon, M.D. (Dept. of Anaesthesia, Royal Infirmary Hospital, Edinburgh, Scotland); Ian Scott M.D., Lucy Flemming, R.N. (Aberdeen Royal Infirmary, Foresterhill Health Campus, Aberdeen, Scotland); Lars Mikael Broman, M.D., Ph.D. (ECMO Centre Karolinska, Karolinska University Hospital, Stockholm, Sweden); Edgars Grins, M.D. (Cardiothoracic ICY, Lund University Hospital, Lund, Sweden); Michail Ketskalo, M.D.,Sergey Tsarenko, M.D. (Dept. of Anaesthesia and ICU, ECMO Center of Moscow City Hospital, Moscow, Russian Federation); Konstantin Popugaev M.D. (Regional Vascula Center, Sklifosoysky, N.V. Research Institute of Emergency Medicine, Moscow, Russian Federation); Sergei Minin, M.D. (Botkin Infection Hospital & Almazov Centre, S. Petersburg, Russian Federation); Igor Kornilov, M.D., Ph.D. (Intensive Care Unit, Novosibirsk National Medical Center, Novosibirsk, Russian Federation); Alexander Skopets, M.D. (Krasnodar Regional Hospital, Krasnodar, Russian Federation); Roman Kornelyuk, M.D., Ph.D. (Kemerovo Hospital, Kemerovo, Russian Federation); Alexandr Turchaninov, M.D., Ph.D. (Federal Center for Cardiovascular Surgery, Chelyabinsk, Russian Federation); Vojka Gorjup M.D., Ph.D. (Dept. of Intensive Internal Medicine of the University Medical Centre, Ljubljana, Slovenia); Daniil Shelukhin, M.D., Ph.D. (Dept. of Anaesthesiology and Intensive Care, The Nikiforov Russian Center of Emergency and Radiation Medicine, Saint Petersburg, Russian Federation); Youssef El Dsouki, EC.C.P. (Kosuyolu High Speciality Education and Research Hospital, Istanbul, Turkey); Basar Cander, M.D. (Dept. of Emergency Medicine, Kanuni Sultan Suleyman Training and Research Hospital, Istanbul, Turkey); Murat Sargin M.D. (Dept. of Cardiovascular Surgery, Dr. Siyami Ersek Cardiovascular Surgery Research and Training Hospital, Istanbul, Turkey); Mehmet Ali Kaygin M.D. (Dept. of Cardiovascular Surgery, Health Sciences University Erzurum Regional Training and Research Hospital, Erzurum, Turkey); Shestakova Liana, M.D. (Dept. Cardiothoracic Surgery, Republic Center Cardiology, Minsk, Belarus); Severin Puss, M.D. (Dept. Anesthesia and Intensive Care, North Regional Hospital & Tartu University Clinic, Tallin, Estonia); Gro Soerensen, M.D. (Dept. of Cardiothoracic Surgery, Oslo University Hospital, Rikshospitalet, Oslo, Norway); Rosén Magnus, M.D. (Dept. Cardiovascular Surgery, University Hospital Linkoping, Sweden); Mikael Kanetoft EC.C.P. (Dept. Cardiovascular Surgery, University Hospital, Orebro, Sweden); Pia Watson R.N., B.Sc., Bengt Redfors, M.D., PhD. (Cardiothoracic Intensive Care Unit, Sahlgrenska University Hospital, Gothenburg, Sweden; Niklas Krenner, Mag., MSc (Dept. of Perfusion and VAD-Coordination, Kepler University Hospital, Linz, Austria)).

Compliance with ethical standards

Conflicts of interest

R.L. declares to be a consultant for Medtronic, LivaNova and Member of the Medical Advisory Board for Eurosets. J.B. declares to be a consultant for Abiomed and Getinge. The other authors declare that they have no conflict of interest.

Publisher's Note

Accepted: 30 September 2020
Published online: 09 January 2021

References

1. European Centre for Disease Prevention and Control. https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
2. Huang C, Wang Y, Li X et al (2020) Clinical features of patients infected with 2019 novel coronavirus in Wuhan. China Lancet 325:467–506
3. Li Y, Li H, Li M et al (2020) The prevalence, risk factors and outcome of cardiac dysfunction in hospitalized patients with COVID-19. Intensive Care Med. https://doi.org/10.1007/s00134-020-06205-0
4. Shi S, Qin M, Shen B et al (2020) Association of cardiac injury with mortality in hospitalized patients with COVID-19 in Wuhan China. JAMA Cardiol. https://doi.org/10.1001/jamacardio.2020.0950
5. Helms J, Tacquard C, Severac F et al (2020 Jun) CRICS TRIGGERSEP Group (clinical research in intensive care and sepsis trial group for global evaluation and research in sepsis) high risk of thrombosis in patients with severe SARS-CoV-2 infection: a multicenter prospective cohort study. Intensive Care Med 46(6):1089–1098
6. World Health Organization. (2020). Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected: interim guidance, 13 March 2020. World Health Organization. https://apps.who.int/iris/handle/10665/331446.
7. Li X, Guo Z, Li B, Zhang X, Tian R, Wu W, Zhang Z, Lu Y, Chen N, Clifford SP, Huang J (2020) Extracorporeal membrane oxygenation for coronavirus disease, 2019 in Shanghai, China. Asaio J. https://doi.org/10.1097/MAT.0000000000001172