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ORIGINAL ARTICLE

Observational Study

Right ventricle dysfunction does not predict mortality in patients with SARS-CoV-2-related acute respiratory distress syndrome on extracorporeal membrane oxygenation support

Chiara Lazzeri, Manuela Bonizzoli, Stefano Batacchi, Giovanni Cianchi, Andrea Franci, Filippo Socci, Marco Chiostri, Adriano Peris

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Abstract

BACKGROUND

The prognostic role of right ventricle dilatation and dysfunction (RVDD) has not been elucidated in patients with coronavirus disease (COVID)-related respiratory failure refractory to standard treatment needing extracorporeal membrane oxygenation (ECMO) support.

AIM

To assess whether pre veno-venous (VV) ECMO RVDD were related to in-intensive care unit (ICU) mortality.

METHODS

We enrolled 61 patients with COVID-related acute respiratory distress syndrome refractory to conventional treatment submitted to VV ECMO and consecutively admitted to our ICU (an ECMO referral center) from 31th March 2020 to 31th August 2021. An echocardiographic exam was performed immediately before VV ECMO implantation.

RESULTS

Males were prevalent (73.8%) and patients with a body mass index > 30 kg/m^2 were the majority (46/61, 75%). The overall in-ICU mortality rate was 54.1% (33/61). RVDD was detectable in more than half of the population (34/61, 55.7%) and associated with higher simplified organ functional assessment (SOFA) values (P = 0.029) and a longer mechanical ventilation duration prior to ECMO support (P = 0.046). Renal replacement therapy was more frequently needed in RVDD patients (P = 0.002). A higher in-ICU mortality (P = 0.024) was observed in RVDD patients. No echo variables were independent predictors of in-ICU death.

CONCLUSION

In patients with COVID-related respiratory failure on ECMO support, RVDD (dilatation and dysfunction) is a common finding and identifies a subset of patients characterized by a more severe disease (as indicated by higher SOFA values and need of renal replacement therapy) and by a higher in-ICU mortality. RVDD (also when considered separately) did not result independently associated with in-ICU mortality in these patients.

Key Words: Right ventricle; Echocardiography; Mortality; COVID; Acute respiratory distress syndrome; Right ventricle-pulmonary circulation coupling

Core Tip: In coronavirus disease-related respiratory failure on extracorporeal membrane oxygenation support right ventricle dilatation and dysfunction (defined as the coexistence of dilatation and dysfunction) is a common finding and identifies a subset of patients characterized by a more severe disease (as indicated by higher Sequential Organ Failure Assessment values and need of renal replacement therapy) and by a higher in-intensive care unit (ICU) mortality. However, at logistic regression analysis, right ventricle dilatation and dysfunction (even when considered separately) did not result independently associated with in-ICU mortality in these patients.

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INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) disease can evolve in some cases in severe respiratory failure, refractory to conventional therapies, which requires veno-venous extracorporeal membrane oxygenation (VV ECMO) support, possibly in experienced centers[1-3]. In coronavirus disease (COVID) respiratory disease, right ventricular (RV) dilatation is frequently encountered especially in severe disease[4,5], but, to date, the prognostic role of RV dilatation has not completed elucidated. In acute respiratory distress syndrome (ARDS) from different etiologies on ECMO support[3] RV dilatation and dysfunction (RVDD) were negatively associated with early outcome, while the prognostic role of RVDD has not been elucidated in patients with COVID-related respiratory failure refractory to standard treatment needing ECMO. We hypothesize that pre ECMO RVDD is related to in-intensive care unit (ICU) mortality, and we tested this hypothesis in 61 consecutive patients with COVID-related ARDS on ECMO support.

MATERIALS AND METHODS

In our prospective observational study, we enrolled 61 patients with COVID-related ARDS refractory to conventional treatment submitted to VV ECMO and consecutively admitted to our ICU (an ECMO referral center) from 31th March 2020 to 31th August 2021. No exclusion criteria. The study protocol was approved by our Ethical Committee ("Comitato Etico Area Vasta Centro" n.17024, approved on March 31th 2020) ("Florence COVID ICU Registry"). The written inform consent for each patient was waived for emerging infectious disease. The need for ECMO support was communicated to the patient's relatives by phone before implantation.

On ICU admission we measured: Troponin (pg/mL), N-terminal-pro brain natriuretic peptide (NT-BNP, pg/mL), C-reactive protein (mg/dL) creatinine (mg/dL), lactose dehydrogenase (UI/L), D-dimer (ng/mL), and interleukin 6 (pg/mL). According to our echocardiography protocol[3,5], an echocardiographic exam was performed immediately before ECMO implantation. Systolic pulmonary artery pressure (sPAP) is obtained using the simplified Bernouilli's equation. RVDD was defined in presence of RVEDA/LVEDA > 0.6 and tricuspid annular plane systolic excursion (TAPSE) < 15 mm (M-mode). Coupling of RV function to the pulmonary circulation was evaluated as the TAPSE to sPAP ratio. Each echo measure is performed three times, and the mean value was recorded[4,6].

All ultrasound cardiac procedures were performed using the necessary protective equipment for professionals. Dedicated machines (Ge HealthCare machine) were used in the COVID ICU and transducers are wrapped in single-use plastic covers. We considered VV ECMO in COVID when respiratory failure persisted despite optimum management including controlled ventilation with tidal volume 6 mL/kg, plateau pressure < 30 cm H_2O, use of neuromuscular blockers, high-positive end-expiratory pressure, and repeated prone positioning sessions[1-3,7,8]. All patients were encouraged to mobilize early[3]. Outcome was death in the ICU.

Statistical analysis

Data have been stored in a dedicated database and analyzed with SPSS for Windows 20.0 (SPSS Inc., Chicago, IL). *P* value less than 0.05 was considered statistically significant. Categorical variables are reported as frequencies and percentages; continuous variables are reported as mean ± standard deviation (SD) or median (range), as needed. Comparisons between the groups were performed using Chi square for categorical data, and student's *t* test and Kruskal-Wallis test for continuous data. Logistic regression backwards models have been developed to detect predictor(s) for ICU-death. Variables were selected based on univariate analysis and on clinical criteria. To avoid overfitting, each model included three variables. Receiver operating curve (ROC) was constructed to identify the cut-off for age and duration of pre-ECMO mechanical ventilation in relation to ICU-death.

RESULTS

Our population comprised 61 consecutive patients with COVID-related respiratory failure on ECMO support (Table 1). Patients transferred from peripheral hospitals accounted for the 62% of our population. Males were prevalent (73.8%) and patients with a body mass index > 30 kg/m^2 were the majority (46/61, 75%). Renal replacement therapy was needed in almost half of the entire population (48%). Renal replacement therapy was started on ICU admission in five patients (17%) and after ECMO start in the remaining 24 patients (83%). The overall in-ICU mortality rate was 54.1% (33/61). At echocardiography left ventricular ejection fraction (LVEF) was normal in all but three patients who had LVEF < 45% because of previously known heart disease.

RVDD vs no RVDD

Table 1 shows the comparison between patients with RVDD and those without. In the entire population, RVDD was detectable in more than half of the population (34/61, 55.7%). In the comparison between the two subgroups, patients with RVDD showed higher values of simplified organ functional assessment (SOFA) (P = 0.029) and a longer mechanical ventilation duration prior to ECMO support (P = 0.046). Renal replacement therapy was more frequently needed in RVDD patients (P = 0.002). A higher in-ICU mortality (P = 0.024) was shown in RVDD patients. Higher values of NT-pro BNP were observed in RVDD patients (P = 0.014). At echocardiography, RVDD patients exhibited higher values of sPAP (P = 0.015), E/e1 (P = 0.0003) and lower TAPSE/sPAP (P = 0.001). Higher doses of norepinephrine were needed in patients with RVDD (P = 0.011) when compared with those without. No differences were detectable in ventilatory parameters between the two subgroups.

Survivors vs no survivors

Table 2 shows the comparison between survivors and no survivors. No survivors were older (P = 0.003) and showed a higher SOFA (P = 0.010) and a longer mechanical ventilation duration before ECMO implantation (P = 0.006). Among biohumoral data, creatinine values were significantly higher in no survivors (P = 0.030), with no other significant difference between the two subgroups. Echocardiography, performed before ECMO implantation, did not show any significant difference between survivors and no survivors.

Multivariate logistic regression analysis

Different models were calculated (Table 3). The following parameters resulted independent predictors of in-ICU death: Age, SOFA, time from symptoms' onset, mechanical ventilation preECMO ≥ 10 d and creatinine. RV dilatation, RV dysfunction and RVDD (dilatation and dysfunction) were not independently associated with in-ICU mortality. At ROC analysis, the age cut-off was ≥ 57 years [area under the curve: 70.5% (95% confidence interval: 57.3- 83.7%), P = 0.006, sensitivity 72.7%, specificity 58.0%].

DISCUSSION

The main finding of the present investigation is that, in COVID-related respiratory failure on ECMO support, RVDD (defined as the coexistence of dilatation and dysfunction) is a common finding. The

Table 1 Comparison between patients with right ventricle dilatation and dysfunction and those without, *n* %

Variable	All patients	RVDD (No. 34)	No RVDD (No. 27)	*P* value
Clinical data				
Age (yr), mean ± SD	54.3 ± 10.3	53.8 ± 9.7	52.9 ± 11	0.735
Gender, M/F	45/16 (74/26)	28/6 (82/18)	17/10 (63/37)	0.087
BMI (kg/m^2), mean ± SD	32.9 ± 5.3	32.4 ± 5.6	32.7 ± 4.9	0.836
Charlson index, median (IQR)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	0.772
Transferred from peripheral hospitals	38 (62)	18 (52)	20 (74)	0.9
Time from symptoms' onset to ICU (d), median (IQR)	13 (10-13)	9 (8-12)	12 (10-14)	0.075
SOFA, median (IQR)	8.0 (7.0-10.0)	10 (8-10)	7 (6-10)	0.029
Mechanical ventilation length to ECMO support (d), median (IQR)	6.0 (8.0-11.0)	8.5 (6-12)	7 (4-10)	0.046
ECMO duration (d), median (IQR)	22 (13-42)	24.5 (9-44)	21 (15-35)	0.765
Renal replacement therapy	29 (48)	22 (65)	7 (26)	0.002
ICU death	33 (54.1)	21 (62)	12 (44)	0.024
Biohumoral data				
Creatinine (mg/dL), median (IQR)	1.00 (0.72-1.86)	0.83 (0.61-1.34)	1.65 (0.78-2.00)	0.025
D-dimer (ng/mL), median (IQR)	3594 (2252-7214)	3748 (1740-12085)	3550 (2368-5007)	0.425
CRP (mg/dL), median (IQR)	142 (88-144)	121 (87-174)	165 (98-212)	0.55
IL-6 (pg/mL), median (IQR)	34 (7.4-70.0)	45 (6.9-105.0)	34 (21-58.0)	0.772
Troponin (pg/mL), median (IQR)	21 (14.0-38.0)	33.0 (14.0-112.0)	21.0 (8.5-48.0)	0.253
NT-pro BNP (pg/mL), median (IQR)	874 (345-1654)	735 (252-1467)	1273 (585-1868)	0.058
LDH IU/L, median (IQR)	465 (375-538)	421 (363-510)	473 (424-542)	0.078
Echocardiographic data				
LVEF (%), mean ± SD	63.9 ± 7.6	64.3 ± 7.9	64.5 ± 7.5	0.113
RV/LV, mean ± SD	0.58 ± 0.17	0.69 ± 0.08	0.45 ± 0.14	0.0001
TAPSE (mm), mean ± SD	18.0 (10.0-21.0)	13.9 (10.0 ± 14.5)	17.4 (16.0-22.5)	0.015
sPAP (mmHg), mean ± SD	58.4 ± 9.4	64 ± 11	59.1 ± 7.7	0.015
e/e1	11 ± 3	12 ± 3	9 ± 3	0.0003
TAPSE/sPAP (mm/mmHg), mean ± SD	0.28 ± 0.13	0.19 ± 0.10	0.28 ± 0.11	0.001
Ventilatory parameters				
PEEP (cm H_2O), mean ± SD	12.2 ± 2.3	12.4 ± -2.4	12.1 ± 2.6	0.64
PO_2/FiO_2, mean ± SD	62 (50-88)	66 (54-88)	60 (50-88)	0.442
Norepinephrine, mean ± SD	0.34 ± 0.22	0.39 ± 0.26	0.24 ± 0.10	0.011

IQR: Interquartile range; RVDD: Right ventricle dilatation and dysfunction; BMI: Body mass index; ICU: Intensive care unit; LOS: Length of stay; CRP: C-reactive protein; IL-6: Interleukin 6, SOFA: Simplified organ functional assessment; ECMO: Extracorporeal membrane oxygenation; NT pro BNP: N terminal pro brain natriuretic peptide; RV: Right ventricle; LV: Left ventricle; EF: Ejection fraction; TAPSE: Tricuspid annular plane systolic excursion; sPAP: Systolic pulmonary arterial pressure; LDH: Lactate dehydrogenase; LVEF: Left ventricular ejection fraction; PEEP: Positive end-expiratory pressure.

presence of RVDD identifies a subset of patients characterized by a more severe disease (as indicated by higher SOFA values and need of renal replacement therapy) and by a higher in-ICU mortality. However, at logistic regression analysis, RVDD (even when considered separately) did not result independently associated with in-ICU mortality in these patients.

Growing evidence suggests that, in COVID respiratory failure, varEchoious echocardiographic patterns may be observed across disease severity progression, ranging from isolated systolic pulmonary hypertension to RVDD. Studies are quite often heterogeneous, especially in respect to selected echo parameters and definition of RV dysfunction and dilatation. In a small series of mechanically ventilated

Table 2 Comparison between survivors and no survivors, *n* %

Variable	All patients	Survivors (No. 28)	No survivors (No. 33)	*P* value
Clinical data				
Age (yr), mean ± SD	54.3 ± 10.3	50.1 ± 11.6	58.0 ± 7.3	0.003
Gender, M/F	45/16 (73.8/26.2)	18/10 (40.0/62.5)	6/27 (60.0/37.5)	0.121
BMI (kg/m^2), mean ± SD	32.9 ± 5.3	31.8 ± 4.0	33.8 ± 6.1	0.138
Charlson index, median (IQR)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	0.772
Time from symptoms' onset to ICU (d), median (IQR)	13 (10-13)	10 (8-13)	13 (10-15)	0.066
SOFA, median (IQR)	8.0 (7.0-10.0)	7.5 (5.5-9.0)	10.0 (8.0-10.0)	0.01
Mechanical ventilation length to ECMO support (d), median (IQR)	6.0 (8.0-11.0)	6.5 (4.5-9.5)	10.0 (7.0-12.0)	0.006
ECMO duration (d), median (IQR)	22 (13-42)	35 (19-48)	18 (10-30)	0.015
ICU death	33 (54.1)	-	-	-
Biohumoral data				
Creatinine (mg/dL), median (IQR)	1.00 (0.70-1.88)	0.82 (0.60-1.35)	1.60 (0.77-2.00)	0.03
D-dimer (ng/mL), median (IQR)	3694 (2153-7326)	3948 (1740-13095)	3600 (2378-5007)	0.418
CRP (mg/dL), median (IQR)	140 (86-143)	120 (85-172)	164 (97-215)	0.553
IL-6 (pg/mL), median (IQR)	35.5 (7.9-71.0)	46.5 (6.8-107.0)	35.5 (20.5-59.0)	0.851
Troponin (pg/mL), median (IQR)	20.5 (15.0-39.0)	34.0 (15.0-115.0)	22.0 (9.0-50.0)	0.281
NT-pro BNP (pg/mL), median (IQR)	875 (355-1754)	734 (254-1542)	1272 (586-1870)	0.064
LDH IU/L, median (IQR)	466 (378-540)	423 (367-513)	475 (426-543)	0.089
Echocardiographic data				
LVEF (%)	63.9 ± 7.6	65.6 ± 8.1	62.5 ± 6.9	0.113
RV/LV	0.58 ± 0.17	0.58 ± 0.19	0.58 ± 0.16	0.945
TAPSE (mm)	18.0 (10.0-21.0)	19.0 (10.0 ± 22.5)	18.0 (10.0-21.0)	0.375
RVDD	34 (55.7)	13	21	0.275
sPAP (mmHg)	58.4 ± 9.4	60.2 ± 7.6	61.3 ± 10.7	0.638
E/e1	11 ± 3	10.7 ± 2.9	11.6 ± 3.7	0.34
TAPSE/sPAP (mm/mmHg)	0.28 ± 0.13	0.29 ± 0.13	0.27 ± 0.13	0.692
Ventilatory parameters				
PEEP (cm H_2O)	12.2 ± 2.3	12.3 ± 2.3	12.2 ± 2.4	0.91
PO_2/FiO_2	62 (50-88)	66 (54-88)	60 (50-88)	0.442
Norepinephrine (μg/kg/min), mean ± SD	0.34 ± 0.22	0.30 ± 0.20	0.35 ± 0.24	0.388

IQR: Interquartile range; RVDD: Right ventricle dilatation and dysfunction; BMI: Body mass index; ICU: Intensive care unit; LOS: Length of stay; CRP: C-reactive protein; IL-6: Interleukin 6; SOFA: Simplified organ functional assessment; ECMO: Extracorporeal membrane oxygenation; NT pro BNP: N terminal pro brain natriuretic peptide; RV: Right ventricle; LV: Left ventricle; EF: Ejection fraction; TAPSE: Tricuspid annular plane systolic excursion; sPAP: Systolic pulmonary arterial pressure; LDH: Lactate dehydrogenase; LVEF: Left ventricular ejection fraction; PEEP: Positive end-expiratory pressure.

COVID patients, acute pulmonary hypertension (observed in the 39%) was associated with higher 30-d mortality[9]. Likewise, in a retrospective investigation including 214 patients, RV dysfunction, pulmonary hypertension, and moderate to severe tricuspid regurgitation were associated with increased odds for 30-d mortality[10]. In 98 consecutive COVID-related respiratory failure, three different subgroups were identified at serial echocardiograms according to the presence/occurrence and timing of RVDD (defined as the association of RVDD), that is admission RVDD, new onset RVDD, no RV changes. Admission and newly developed RVDD subgroups identified severe COVID respiratory disease which in a high percentage of cases needed ECMO support[11]. In the present investigation, the

Table 3 Multivariate logistic regression analysis (intensive care unit death outcome)

Model	OR	95%CI	*P* value
Model 1			
Age (yr)	1.09	1.02-1.16	0.015
SOFA	1.26	0.99-1.62	0.062
Admission RV/LV	0.64	0.02-21.42	0.805
Model 2			
SOFA	1.24	0.98-1.56	0.062
RV DYS	0.98	0.31-3.84	0.985
Creatinine (mg/dL)	1.78	0.82-3.11	0.14
Model 3			
Age (yr)	1.1	1.03-1.18	0.005
BMI (kg/m^2)	1.09	0.97-1.22	0.138
TAPSE (mm)	0.97	0.89-1.06	0.544
Model 4			
SOFA	1.29	1.03-1.61	0.026
BMI (kg/m^2)	1.06	0.95-1.19	0.278
TAPSE/SPAP (mm/mmHg)	2.53	0.03-20.92	0.68
Model 5			
BMI (kg/m^2)	1.1	0.98-1.24	0.107
Charlson index	0.59	0.29-1.18	0.133
Time from symptom's onset (d)	1.26	1.02-1.56	0.032
Model 6			
NT pro BNP (pg/mL)	0.99	0.97-1.02	0.517
Mechanical ventilation to ECMO ≥ 10 (d)	4.64	1.42-15.12	0.011
Creatinine (mg/dL)	2.56	1.16-5.67	0.02

BMI: Body mass index; SOFA: Symplified organ functional assessment; RV: Right ventricle; TAPSE: Tricuspid annular plane systolic excursion; sPAP: Systolic pulmonary arterial pressure; ECMO: Extracorporeal membrane oxygenation; NT-pro BNP: N terminal pro brain natriuretic peptide; OR: Odd ratio; CI: Confidence index.

study population comprises the most severe state of COVID-related respiratory failure, refractory to standard treatment and requiring ECMO support in whom RVDD (dilatation and dysfunction) is quite common being detectable in more than a half of the entire population. Few data are available on echocardiographic data in patients with COVID-related respiratory failure on ECMO support.

In the series by Bleakley *et al*[11] quite a large proportion of enrolled patients (38/90, 42%) were on ECMO support, but they were not analysed separately. Kopanczyk *et al*[12] performed echocardiography in 11 consecutive patients on ECMO and observed that RV dysfunction (as indicated by abnormal free wall longitudinal strain and fractional area change) was present in the majority (9/11 patients). RV dysfunction was defined as RV dilatation (visual assessment) and abnormal septal motion in the study by Ortiz *et al*[13] who documented that no echo variable was predictor of outcomes (survival to discharge and survival to decannulation) in 64 COVID patients on ECMO (echocardiography performed post cannulation). In a small series of COVID patients on ECMO, we observed, by means of serial echocardiographic exams, that RVDD (defined as the coexistence of dilatation and dysfunction) may be reversible, especially in survivors[13]. We confirm and extend previous findings in a larger series, focusing on the prognostic role (if any) of RVDD for in-ICU death. According to our data, patients with RVDD showed a more severe disease (as indicated by SOFA) and a higher incidence of renal impairment (as inferred by the higher use of renal replacement therapy). Higher values of systolic pulmonary arterial pressure and of NT-pro BNP, observed in RVDD patients, suggest increased RV pressure which might contribute to renal impairment. The lack of differences in creatinine serum values between patients with RVDD and those without can be due to renal replacement therapy itself which does affect creatinine levels. Despite the higher in-ICU mortality observed in patients with RVDD,

RVDD (even when considered separately) are not independent predictor of early death in our population. This might be due to several factors. Firstly, the high incidence of RVDD in these patients, in agreement with previous investigations[3,12,13]. Secondly, at serial echocardiographic assessments, RVDD may be reversible in COVID-related respiratory failure on ECMO support, though a percentage of critically ill COVID patients has been reported to develop RVDD during ICU course[13].

Finally, factors other than RV echo variables can independently predict in-ICU death in COVID-related refractory respiratory failure on ECMO support, such as age and duration of mechanical ventilation. The high frequency of RVDD may be responsible for the lack of association between echocardiographic data and mortality in our patients. Our results are in keeping with those reported by investigations enrolling only critically ill COVID patients who, similarly, were not able to detect a relation between mortality and RV dilatation[13].

In our series, multivariate logistic regression analysis identified the following predictors of in-ICU analysis: Age, severity of disease (as inferred by SOFA and creatinine values) and COVID-disease duration (indicated by time from symptoms' onset) and mechanical ventilation pre-ECMO. A longer time from symptoms' onset to ICU suggests more severe forms of disease, characterized by more pronounced pulmonary derangements, often unresponsive to therapy. Age is a well-known strong predictor in COVID respiratory failure, in line with recent evidence[1] and, though we enrolled patients aged < 65 years according to guidelines, the ROC-determined cut-off was 57 years in our series. Regarding the duration of pre-ECMO mechanical ventilation to date there is no clear indication on the optimal duration of mechanical ventilation before ECMO implantation in COVID disease. Extracorporeal Life Support Organization guidelines report that a period of more than 10 d of mechanical ventilation should be considered a contraindication for ECMO support, while a period of 7 d is reported as a cut-off by other studies[1,2].

Limitations of the study

This is a single centre investigation, including a limited number of patients. On the other hand, ours is a high-volume ECMO centre. Indeed 61 COVID patients on ECMO support were managed at our center in a 15-mo period, treated by the same intensive care team.

CONCLUSION

In patients with COVID-related respiratory failure on ECMO support RVDD (dilatation and dysfunction) is a common finding and identifies a subset of patients characterized by a more severe disease (as indicated by higher SOFA values and need of renal replacement therapy) by a higher in-ICU mortality. RVDD (also when considered separately) did not result independently associated with in-ICU mortality in these patients.

ARTICLE HIGHLIGHTS

Research background

Echocardiography is recognized as a clinical tool in coronavirus disease (COVID)-related respiratory failure needing veno-venous extracorporeal membrane oxygenation (VV ECMO).

Research motivation

The assessment of the prognostic role of right ventricle dilatation and dysfunction (RVDD) in COVID-related respiratory failure refractory to standard treatment requesting ECMO.

Research objectives

In COVID-related respiratory failure on ECMO RVDD is a common finding and identifies a subset of patients characterized by a more severe disease (as indicated by higher sequential organ failure assessment values and need of renal replacement therapy) by a higher in-intensive care unit (ICU) mortality. RVDD (also when considered separately) did not result independently associated with in-ICU mortality in these patients.

Research methods

Observational single center study.

Research results

An echocardiographic examination was performed before ECMO implantation.

Research conclusions

In patients with COVID-related respiratory failure on ECMO support, RVDD is a common finding and identifies a subset of patients characterized by a more severe disease and by a higher in-ICU mortality. RVDD (also when considered separately) did not result independently associated with in-ICU mortality in these patients.

Research perspectives

Risk stratification in COVID-related refractory respiratory failure.

FOOTNOTES

Author contributions: Lazzeri C was the guarantor and designed the study; Batacchi S, Cianchi G, Franci A and Socci F participated in the acquisition, analysis, and interpretation of data; Bonizzoli M, Chiostri M and Peris A drafted the initial manuscript; and all authors revised the article critically for important intellectual content.

Institutional review board statement: The study protocol was approved by our Ethical Committee ("Comitato Etico Area Vasta Centro" n.17024, approved on March 31th 2020) ("Florence COVID ICU Registry").

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