Retrieval of severe acute respiratory failure patients on extracorporeal membrane oxygenation: Any impact on their outcomes?

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ABSTRACT

Objective: Mobile extracorporeal membrane oxygenation (ECMO) retrieval teams (MERTs) assure ECMO implantation and under-ECMO retrieval of patients with most severe acute respiratory failure (ARF) to experienced ECMO centers. Although described as feasible, mobile ECMO has only been poorly evaluated in comparison with on-site implantation. This study was undertaken to compare the indications, characteristics, and outcomes of MERT-implanted patients with venovenous (VV)-ECMO versus those implanted on site in our intensive care unit (ICU).

Methods: Retrospective, single-center study.

Results: Among 157 VV-ECMO implantations from 2008 to 2012, the MERT hooked up 118 (75%) patients with refractory ARF, as reflected by their median partial pressure of O₂ in arterial blood/fraction of inspired oxygen of 58 (interquartile range, 50–73). ARF was accompanied by severe multiorgan failure, with a median Simplified Acute Physiology Score-II of 71 (61–81), median Sequential Organ Failure Assessment score of 14 (10–16), and with 82% of the patients receiving inotropes. All patients were transported by ground ambulance: median distance was 15 (6–25) km, and median transport time was 35 (25–35) minutes, during which no major ECMO system–related event occurred. For the MERT- and on-site–implanted groups, ICU mortality was comparable (46.6% vs 53.8%, respectively, $P = .5$), as were ECMO-related complication rates (53.4% of MERT vs 53.8% of on-site–implanted groups, $P = 1.0$). According to multivariable analysis, MERT ECMO implantation was not associated with ICU mortality (odds ratio, 1.1; 95% confidence interval, 0.4–2.7; $P = .85$).

Conclusions: ICU mortality and ECMO-related complications of patients with MERT-implanted VV-ECMO who were transferred to our ECMO referral center were comparable with those implanted on site by the same team, thereby supporting this strategy to manage patients with severe ARF. (J Thorac Cardiovasc Surg 2018;155:1621–9)

Example of patient retrieval under VV-ECMO.

Central Message

Implantation of venovenous extracorporeal membrane oxygenation by a mobile extracorporeal membrane oxygenation retrieval team does not impact the prognosis of patients with acute respiratory failure compared with on-site implantation.

Perspective

The way to organize venovenous extracorporeal membrane oxygenation (VV-ECMO) activity remains debated. In this rigorous retrospective study, implantation of VV-ECMO by a mobile ECMO retrieval team and transfer under ECMO to a referral center did not impact the outcome of patients with refractory acute respiratory failure in comparison with on-site implantation. This supports using this strategy to manage patients with most severe acute respiratory distress syndrome.

See Editorial Commentary page 1630.

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Venovenous extracorporeal membrane oxygenation (VV-ECMO) has been used increasingly over the past few years as a rescue therapy for acute respiratory failure

Scanning this QR code will take you to supplemental tables, figures, and video for this article.

Abbreviations and Acronyms

ARF	= acute respiratory failure
CI	= confidence interval
ECMO	= extracorporeal membrane oxygenation
ICU	= intensive care unit
MERT	= mobile extracorporeal membrane oxygenation retrieval team
P _a O ₂ /F _i O ₂	= partial pressure of O ₂ in arterial blood/fraction of inspired oxygen
VA-ECMO	= venoarterial extracorporeal membrane oxygenation
VV-ECMO	= venovenous extracorporeal membrane oxygenation

(ARF) refractory to conventional treatment.^{1,2} Its usefulness as early therapy during severe ARF is currently under investigation.³⁻⁵ However, the organization and the diffusion of extracorporeal membrane oxygenation (ECMO) programs remain a matter of debate.

Mobile extracorporeal membrane oxygenation retrieval teams (MERTs) have been created as part of regional or national ECMO networks to provide access to the technique for patients hospitalized in primary care hospitals and for whom transport without ECMO to the network ECMO center would be hazardous. Because previous studies only reported on the feasibility of this strategy,⁶⁻¹⁴ the objective of this study was to compare the outcomes of patients with severe respiratory failure retrieved on ECMO with those of patients who received ECMO in our tertiary care ECMO center.

MATERIALS AND METHODS**Setting**

All patients implanted with VV-ECMO from 2008 to 2012 were retrospectively screened for inclusion from the prospective ECMO database of our 26-bed intensive care unit (ICU); none were excluded. In accordance with the ethical standards of our hospital's institutional review board, the Committee for the Protection of Human Subjects, informed consent for demographic, physiologic, and hospital-outcome data analyses was not obtained because this observational study did not modify existing diagnostic or therapeutic strategies. The ICU database is registered with the national data protection authority (CNIL 1950673).

Mobile ECMO Retrieval Team Organization

Organization of our center's mobile venoarterial extracorporeal membrane oxygenation (VA-ECMO) program was described previously.¹⁵ Our MERT is available 24 hours/day, 7 days/week. MERT-dedicated material is maintained ready for use by perfusionists, who use a checklist to verify that all necessary equipment is on-board before departure. Once contacted, indication for ECMO implantation is evaluated in a medical-surgical staff meeting, including at least 1 surgeon and 1 intensivist. Once the indication is retained, a MERT team, comprising a cardiovascular surgeon and a perfusionist, is sent to the patient's bedside, by car or helicopter

depending on the distance. The patient is re-evaluated at bedside with the local intensivist managing the patient. Once VV-ECMO has been implanted, the patient is transferred to our ICU by an emergency physician-staffed public ambulance (Service d'Aide Médicale d'Urgence) and the perfusionist (Video 1).

ECMO Management

Management of ECMO-implanted patients in our ICU has been described previously.¹⁶ VV-ECMO is percutaneously inserted with 23- to 29-F/18- to 23-F cannulation. Percutaneous femoral-jugular ultrasonography-guided cannulation with a large drainage cannula is highly recommended. Pump speed is adjusted to obtain blood oxygen saturation >90%.¹⁷ The adequate position of cannulas is verified by ultrasonography and chest radiograph. Intravenous unfractionated heparin is given to maintain the activated partial thromboplastin time at 1.5 to 2 times normal. Plasma-free hemoglobin and fibrinogenemia are monitored daily. Patients are assessed daily for possible ECMO-weaning using previously described clinical and biological criteria.³

VIDEO 1. Organization of mobile ECMO retrieval team in La Pitié-Salpêtrière Hospital, Paris. Video available at: [http://www.jtcvsonline.org/article/S0022-5223\(17\)32431-5/fulltext](http://www.jtcvsonline.org/article/S0022-5223(17)32431-5/fulltext).

Data Collection

All information at ECMO implantation and during follow-up was extracted from our prospective ECMO database and patients' electronic medical records and records from the referring hospital. Transfer data were extracted from Service d'Aide Médicale d'Urgence transfer charts. An inotrope score was used to quantify inotropes at ECMO implantation, defined as dobutamine dose ($\mu\text{g/kg/min}$) + (epinephrine dose [$\mu\text{g/kg/min}$] + norepinephrine dose [$\mu\text{g/kg/min}$]) $\times 100$.¹⁸ Circuit thrombosis was defined as a thrombosis affecting ECMO blood flow. Hemolysis was defined as plasma-free hemoglobin >500 mg/L and massive hemolysis as plasma free hemoglobin >1000 mg/L associated with clinical signs of hemolysis.

Statistical Analyses

Continuous variables were expressed as median (interquartile range) and compared with the Mann–Whitney U test or standard t test as appropriate. Categorical variables were expressed as number (%) and compared with the Fisher exact test. Log-rank tests compared Kaplan–Meier estimates of event-free survival. Patients' demographic, clinical, and biological characteristics were tested in univariable analyses for association with in-ICU death. Factors achieving $P < .20$ in our univariable analysis were entered into a multivariable regression model. Continuous variables were dichotomized using their median value. Thereafter, multiple backward-stepwise logistic-regression analyses eliminated variables with an exit threshold set at $P > .10$. All potential explanatory variables included in the multivariable analyses were subjected to collinearity analysis with a correlation matrix. Variables associated with one another were not included in the multivariable model.

As a sensitivity analysis, ICU mortality between patients implanted on site and by MERT was tested again in multivariable analysis in groups with comparable risk of mortality. On-site and MERT groups were weighted on a propensity score for potential confounding factors independently associated with ICU mortality (age >46 years, immunodeficiency, mechanical ventilation-ECMO time >5 days, viral infection, bacterial infection, and pH < 7.24 at ECMO initiation). Standardized mean differences were confirmed <0.1 for all factors between weighted on-site and MERT groups (Figure E1).¹⁹

Statistical significance was set at $P < .05$. Analyses were computed with Prism 4.0c (GraphPad Software, La Jolla, Calif), Statview 5.0 (SAS Institute, Inc, Cary, NC), and SPSS 22 (SPSS Inc, Chicago, Ill) software packages.

RESULTS

Demographics

Among 157 patients receiving VV-ECMO support in our ICU, between 2008 and 2012, 118 (75%) were implanted by the MERT team (Figure 1). The annual number of VV-ECMO implantations has increased gradually over the years (Figure E2).

Demographic and clinical data of MERT- and on-site-implanted patients are given in Table 1. Patients had severe ARF, reflected by low partial pressure of O_2 in arterial blood/fraction of inspired oxygen ($\text{P}_{\text{aO}_2}/\text{FiO}_2$) ratios, comparable for the 2 groups. Most of them had severe multiorgan failure at the time of ECMO implantation, reflected by high Simplified Acute Physiology Score II and Sequential Organ Failure Assessment scores, and with 77% of them receiving inotropes. Patients were on protective mechanical ventilation. However, the on-site group had a greater

FIGURE 1. Flowchart of the study. VV-ECMO, Venovenous extracorporeal membrane oxygenation; ECMO, extracorporeal membrane oxygenation; VA-ECMO, venoarterial extracorporeal membrane oxygenation.

percentage of postcardiac surgery patients, whereas patients undergoing MERT were more severely ill.

ECMO was implanted early after mechanical ventilation onset for both groups, with less prone positioning and nitric oxide administered to the on-site group. The ECMO-cannulation technique was the same for both groups, consisting mostly of percutaneous femoral–jugular cannulation. All implantations were performed at the patient's bedside. The rates of major ECMO implantation–related complications did not differ between groups (3/118 [2.5%] for the MERT group vs 2/39 [5.1%] for the on-site group; $P = .26$). For the MERT group, major events were 1 hypoxic resuscitated cardiac arrest during ECMO implantation and 2 pneumothoraxes, one of which caused transient cardiac arrest. For the on-site group, ECMO implantation was complicated by 1 pneumothorax and 1 major hemorrhage at the cannulation site, leading to the patient's death.

Transfer Data

For the MERT group, time between the call and ECMO initiation was 192 minutes (154–225); all patients were transported by ground ambulance (median distance of 15 km [6–25] and median transport time of 35 minutes [25–35]), during which no major ECMO system–related event occurred. Nine (7.6%) patients experienced significant hemodynamic deterioration during transport, responsible for 1 (0.8%) patient's death. Others necessitated emergency switching to VA-ECMO on arrival. Patients who deteriorated during transport did not exhibit longer time or distance transfer than those who remained stable (Table E1). However, they had more severe multiorgan failure and myocardial dysfunction at the time of ECMO implantation, as indicated by lower left ventricular ejection fraction and aortic time–velocity integral compared with other patients. Deteriorated hemodynamics due to right ventricular dysfunction did not require switching from VV- to VA-ECMO. Percentages

TABLE 1. Demographic and clinical data at ECMO implantation

Parameter	MERT ECMO, n = 118	On-site ECMO, n = 39	P value
Demographics			
Age, y	44 (32-55)	50 (38-58)	.09
Year of implantation	2011 (2010-2012)	2011 (2009-2011)	.03
Male	68 (57.6)	29 (74.4)	.08
Body mass index, kg/m ²	26 (23-31)	25 (23-29)	.2
Charlson score	1 (0-2)	1 (1-3)	.2
McCabe and Jackson score	1 (0-2)	1 (1-2)	.1
Immunocompromised	33 (27.9)	15 (38.5)	.2
Solid transplant	8 (6.8)	5 (12.8)	.3
Chronic lung disease	15 (12.7)	7 (17.9)	.4
Reason for ECMO*			
Viral pneumonia	26 (22.0)	6 (15.4)	.5
A(H1N1) pneumonia	21 (17.8)	4 (10.3)	.3
Bacterial pneumonia	52 (44.1)	19 (48.7)	.7
Aspiration pneumonia	12 (10.2)	6 (15.4)	.4
Asthma	2 (1.7)	0 (0)	1.0
Trauma/burns	8 (6.8)	0 (0)	.2
Other	25 (21.2)	9 (23.1)	.8
Postoperative	18 (15.3)	10 (25.6)	.15
Cardiac surgery	0 (0)	7 (17.9)	<.0001
At ECMO implantation			
SAPS-II score	71 (61-81)	63 (55-77)	.03
SOFA score	14 (10-16)	12 (9-14)	.02
MV-ECMO interval, d	4.5 (1.0-9.0)	5.0 (2.0-13.0)	.2
Adjunctive therapy			
Prone positioning	86 (72.9)	15 (38.5)	.0002
Nitric oxide	109 (92.4)	27 (69.2)	.0007
Neuromuscular blockers	116 (98.3)	38 (97.4)	1.0
Steroids	17 (14.4)	8 (20.5)	.4
High-frequency oscillation	1 (0.8)	0 (0)	1.0
Pre-ECMO ventilatory settings			
Tidal volume, mL/kg PBW	6.0 (5.2-6.9)	5.9 (5.2-6.6)	.8
Tidal volume <7 mL/kg PBW, %	91 (77.1)	30 (76.9)	1.0
PEEP, cm H ₂ O	10 (8-13)	10 (7-12)	.07
Plateau pressure, cm H ₂ O	32 (22-35)	32 (30-35)	.5
Driving pressure, cm H ₂ O	21 (18-24)	23 (19-26)	.2
Crs, mL/cm H ₂ O	19.0 (13.3-23.3)	18.1 (13.1-22.1)	.56
Blood gases			
pH	7.23 (7.16-7.31)	7.24 (7.16-7.34)	.7
P _a O ₂ /FiO ₂	58.0 (50.0-73.2)	55.0 (49.0-75.0)	.8
P _a CO ₂ , mm Hg	61.5 (49.0-75.0)	60.0 (46.0-73.0)	.7
Bicarbonate, mmol/L	26.0 (22.0-29.0)	26.5 (20.9-32.0)	.6
S _a O ₂ , %	86.0 (80.7-92.0)	85.0 (80.0-89.0)	.3
Inotrope score, µg/kg/min	38 (8-87)	19.4 (0.0-72.9)	.13
Pre-ECMO cardiac arrest	10 (8.5)	4 (10.3)	.7
LVEF, %	60 (50-60)	60 (54-65)	.05
Aortic VTI, cm	17 (15-18)	18 (16-19)	.03
Right ventricular dysfunction	28 (23.7)	4 (10.3)	.1
Serum lactate, mmol/L	2.2 (1.2-4.2)	2.0 (1.4-3.1)	.4
Renal-replacement therapy	20 (16.9)	8 (20.5)	.6
Cannulation type			
Percutaneous	116 (98.3)	38 (97.4)	.8
Femoral–jugular	103 (87.3)	36 (92.3)	.6
Femoral–femoral	15 (12.7)	3 (7.7)	.6

(Continued)

TABLE 1. Continued

Parameter	MERT ECMO, n = 118	On-site ECMO, n = 39	P value
Admission cannula size, Fr	24 (24-25)	24 (24-25)	.3
Return cannula size, Fr	18 (17-19)	18 (17-19)	.6

Values are expressed as median (IQR) or n (%). *MERT*, Mobile extracorporeal membrane oxygenation retrieval team; *ECMO*, extracorporeal membrane oxygenation; *SAPS-II*, Simplified Acute Physiology Score-II; *SOFA*, Sequential Organ Failure Assessment; *MV-ECMO*, mechanical ventilation extracorporeal membrane oxygenation; *PBW*, predicted body weight; *PEEP*, positive end-expiratory pressure; *Crs*, respiratory system compliance; P_aO_2/FiO_2 , partial pressure of O_2 in arterial blood/fraction of inspired oxygen; P_aCO_2 , partial pressure of carbon dioxide in arterial blood; S_aO_2 , oxygen saturation; *LVEF*, left ventricular ejection fraction; *VTI*, velocity–time integral. *Several factors may be combined.

of patients switched from VV- to VA-ECMO because of hemodynamic worsening were comparable for the MERT and on-site groups (8/118 [6.8%] vs 2/39 [5.1%], respectively; $P = .7$).

Outcomes

After ECMO initiation, both groups received ultraprotective ventilation, with tidal volumes and driving pressures being dramatically reduced (Table 2). ECMO-related complications rates were comparable between MERT and on-site implanted patients (Table 2). Notably, cannulation-site infections and hemorrhages were not more frequent in the MERT group. The need for subsequent surgical intervention on the ECMO system was also

comparable between groups. Importantly, 47% of patients with femoral–femoral cannulation required subsequent femoral–jugular cannulation because of inadequate oxygenation, whereas only 7.8% of the patients with initial femoral–jugular cannulation necessitated subsequent recannulation ($P = .0005$ vs those with femoral–femoral lines). The ECMO circuit had to be replaced in approximately one third of the patients, with ~20% of them being emergency replacements in each group.

ICU mortality was comparable for MERT- and on site–implanted groups (55/118 [46.6%] vs 21/39 [53.8%], respectively; $P = .5$), as was 30-day mortality (Figure E3). Factors associated with ICU mortality are reported in Table 3. According to multivariable analyses, MERT

TABLE 2. Outcomes of ECMO-implanted patients

Parameter	MERT ECMO, n = 118	On-site ECMO, n = 39	P value
Post-ECMO ventilatory settings			
Tidal volume, mL/kg PBW	3.1 (1.9-4.1)	3.4 (1.7-4.4)	.9
Tidal volume <6 mL/kg PBW, %	114 (97)	39 (100)	.5
PEEP, cm H ₂ O	12 (10-12)	12 (10-14)	.4
Plateau pressure, cm H ₂ O	24 (24-25)	24 (22-24)	.06
Driving pressure, cm H ₂ O	14 (12-14)	12 (12-14)	.4
ECMO duration, d	9 (4-24)	10 (6-21)	.5
Post-ECMO MV duration, d	19 (7-38)	20 (9-37)	.6
Renal-replacement therapy	63 (53.4)	20 (51.3)	.8
ECMO-related complication	63 (53.4)	21 (53.8)	1.0
Bleeding at cannulation site	12 (10.2)	4 (10.2)	1.0
Cannulation-site infection	20 (16.9)	7 (17.9)	1.0
Bacteremia	29 (24.6)	10 (25.6)	1.0
Number of episodes	38	14	
Hemolysis	38 (32.2)	9 (23.1)	.3
Circuit replacement	42 (35.6)	12 (30.1)	.7
Number of episodes	83	17	
Emergency replacement*	21 (17.8)	9 (23.1)	.5
Circuit thrombosis	10 (8.5)	6 (15.4)	.2
Massive hemolysis	8 (6.8)	5 (12.8)	.3
Massive DIC + bleeding	4 (3.4)	2 (5.1)	.6
Oxygenator dysfunction	1 (0.8)	0 (0)	1.0
Accidental decannulation	1 (0.8)	0 (0)	1.0
Subsequent surgical intervention	20 (16.9)	6 (15.4)	1.0
Number of episodes	32	8	
ICU mortality	55 (46.6)	21 (53.8)	.5

Values are expressed as median (IQR) or n (%). *MERT*, Mobile extracorporeal membrane oxygenation retrieval team; *ECMO*, extracorporeal membrane oxygenation; *PEEP*, positive end-expiratory pressure; *MV-ECMO*, mechanical ventilation extracorporeal membrane oxygenation; *DIC*, disseminated intravascular coagulation; *ICU*, Intensive care unit. *Several factors may be combined.

ECMO implantation was not associated with ICU mortality (odds ratio, 1.1; 95% confidence interval [CI], 0.4-2.7; $P = .85$). Factors independently associated with ICU death retained by those analyses were age, immunocompromised status, bacterial infection as opposed to viral infection, noninfectious underlying ARF, pre-ECMO time on mechanical ventilation, and blood pH at ECMO implantation (Figure 2). Lastly, ICU mortality also was not different between groups (OR, 1.04; 95% CI, 0.49-2.18; $P = .92$) in a multivariable analysis weighting patient data on a propensity score of factors independently associated with ICU mortality.

DISCUSSION

In this study, ICU mortality and ECMO-related complications were comparable for patients retrieved on VV-ECMO implanted by our MERT team and those implanted on site. To date, although the feasibility of transferring a patient on ECMO has been described for several cohorts,⁶⁻¹⁴ most of them were restricted to small samples, included patients over large periods of time, and comprised both VA- and VV-ECMO hook-ups. For the largest cohorts, mortality associated with MERT implantation ranged from 0% to 4% and minor events during transportation from 0 to 43%.^{8,9,12-14} The latter were mostly missing material, loss of electrical power, circuit issues, and pump-console failure. Hospital discharge rates ranged from 44% to 85%. However, MERT results were not compared with a control group in those studies, meaning that patient selection might have been an important confounding factor. The outcomes of MERT-implanted patients herein were comparable with those reported previously.⁶⁻¹⁴ Importantly, they remained comparable between MERT and on-site patients implanted by the same ECMO team, even after we accounted for possible confounding factors in multivariable analyses.

That comparability may have important implications for the organization of VV-ECMO activity, which remains intensely debated.^{4,20} Transferring VV-ECMO patients to ECMO referral centers is supported by several issues. First, ECMO-associated morbidity and mortality has been demonstrated to be independently linked with case-volume number.^{2,21,22} According to the large retrospective study on the Extracorporeal Life Support Organization registry, being treated in a center with an annual case-volume exceeding 30 was associated with almost halved mortality compared with being treated in a low case-volume center (OR, 0.61; 95% CI, 0.46-0.8).² Second, patients undergoing VV-ECMO require a high level of specialized interventions,^{23,24} as was the case for approximately one half of our patients. Third, the most severe patients with ARF may require switching from VV- to VA-ECMO because of hemodynamic compromise.

Transporting patients with severe ARF with or without ECMO support has never been compared to date. In the Conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR) trial, patients randomized to the ECMO group were transported without ECMO²⁵; 5 (5.5%) of them died before arriving at the ECMO center in a cohort with a mean Acute Physiology and Chronic Health Evaluation-II score of 20 ± 6 and a mean P_aO_2/FiO_2 ratio of 76 ± 29 . Our cohort was more severely ill, with a mean P_aO_2/FiO_2 ratio of 64 ± 30 and a mean Acute Physiology and Chronic Health Evaluation-II score of 27 ± 7 , making transport of those patients without an ECMO more hazardous. Despite this greater severity, only 2 (1.7%) of our patients died before arriving in ICU. Our findings that morbidity and mortality were not affected by ECMO implantation outside our ICU and patient retrieval on ECMO further support transporting most critically ill patients under ECMO to referral centers.

Optimal MERT staffing remains unknown and ranges from 3 to 6 persons in the literature.^{8,9,11-13,26,27} According to our organization, only 1 surgeon and 1 perfusionist from our team are mobilized for MERT ECMO implantation, thereby minimizing the impact on our in-ICU activity. Importantly, almost one half of the patients with femoral-femoral VV-ECMO hook-up had to be switched to femoral-jugular cannulation because of insufficient oxygenation. This proportion was consistent with those reported in other ECMO cohorts using a femoral-femoral set-up.²³ That observation favors the initial implementation of femoral-jugular cannulation.

Another striking issue is the high rate of emergency switching from VV- to VA-ECMO in our cohort. Compared with patients maintained on VV-ECMO, those switched from VV- to VA-ECMO suffered from major left ventricular dysfunction, as reflected by their severe cardiovascular failure (decreased left ventricular ejection fraction and aortic velocity-time integral, and severe lactic acidosis despite high catecholamine doses). That finding indicates that all patients should undergo a careful cardiac evaluation before VV-ECMO implantation and be initially cannulated with VA-ECMO or veno-arteriovenous-ECMO when signs of refractory cardiogenic shock are associated with ARF.¹⁶ When hemodynamic compromise results from right ventricular dysfunction, switching from VV- to VA-ECMO is usually not necessary.

VV-ECMO was used as rescue therapy for our cohort. Factors independently associated with ICU mortality were consistent with those reported previously.^{13,28,29} Pertinently, the pre-ECMO duration of mechanical ventilation strongly impacted mortality.

TABLE 3. Comparisons between ICU survivors and nonsurvivors

Parameter	Survivors, n = 81	Nonsurvivors, n = 76	P value
MERT implantation	63 (77.8)	55 (72.4)	.5
Demographic data			
Age, y	40 (31-53)	50 (37-58)	.006
Year of implantation	2011 (2010-2012)	2011 (2010-2012)	.8
Male	49 (60.1)	48 (63.2)	.7
Body mass index, kg/m ²	28 (24-31)	25 (23-28)	.03
Charlson score	1 (0-1)	1 (1-2)	.04
McCabe and Jackson score	1 (0-1)	2 (1-3)	<.0001
Immunocompromised	13 (16.0)	35 (46.1)	<.0001
Chronic lung disease	12 (14.8)	10 (13.2)	.8
Reason for ECMO*			
Viral pneumonia	22 (27.2)	10 (13.2)	.04
A(H1N1) pneumonia	21 (25.9)	4 (5.3)	.0004
Bacterial pneumonia	32 (39.5)	54 (71.1)	.0001
Aspiration pneumonia	11 (13.6)	7 (9.2)	.4
Asthma	1 (1.2)	1 (1.3)	1.0
Trauma/burns	6 (7.4)	2 (2.6)	.3
Other	13 (16.0)	21 (27.6)	.08
Postoperative	11 (13.6)	17 (22.4)	.2
Cardiac surgery	1 (1.2)	6 (7.9)	.06
At ECMO implantation			
SAPS-II score	65 (57-76)	73 (62-87)	.004
SOFA score	12 (9-16)	13 (11-16)	.1
MV-ECMO interval, d	3 (1-7)	8 (3-13)	<.0001
Adjunctive therapy			
Prone positioning	53 (65.4)	48 (63.2)	.9
Nitric oxide	75 (92.6)	61 (80.3)	.03
Neuromuscular blockers	80 (98.7)	74 (97.3)	.6
Steroids	9 (11.1)	16 (21.1)	.12
High-frequency oscillation	0 (0)	1 (1.3)	.5
Ventilatory settings			
Tidal volume, mL/kg IBW	6.0 (5.3-6.8)	5.9 (5.2-6.9)	.7
PEEP, cm H ₂ O	10 (10-14)	10 (7-12)	.0009
Plateau pressure, cm H ₂ O	32 (29-35)	32 (30-35)	.5
Driving pressure, cm H ₂ O	20 (17-24)	22 (18-26)	.1
Blood gases			
pH	7.28 (7.19-7.36)	7.19 (7.13-7.28)	.0003
P _a O ₂ /FiO ₂	55 (47-71)	61 (51-75)	.15
P _a CO ₂ , mm Hg	55 (47-68)	67 (54-78)	.001
Bicarbonate, mmol/L	26 (21-29)	26 (22-31)	.6
S _a O ₂ , %	85 (81-90)	85 (80-92)	.6
Inotrope score, µg/kg/min	33 (6-75)	33 (4-98)	.6
Pre-ECMO cardiac arrest	2 (2.5)	12 (15.8)	.004
LVEF, %	60 (47-60)	60 (50-60)	.11
Aortic VTI, cm	17 (15-19)	17 (15-19)	.7
Right ventricular dysfunction	18 (22.2)	14 (18.4)	.7
Serum lactate, mmol/L	2.3 (1.5-3.9)	2.0 (1.2-4.0)	.3
Renal-replacement therapy	12 (14.8)	16 (21.0)	.4
Cannulation type			
Femoral–jugular	75 (92.6)	63 (82.9)	.08
Percutaneous insertion	80 (98.8)	75 (98.7)	1.0
Admission cannula size, Fr	24 (24-25)	24 (24-25)	.8
Return cannula size, Fr	18 (18-18)	18 (17-20)	.2

Values are expressed as median (IQR) or n (%). *MERT*, Mobile extracorporeal membrane oxygenation retrieval team; *ECMO*, extracorporeal membrane oxygenation; *SAPS-II*, Simplified Acute Physiology Score-II; *SOFA*, Sequential Organ Failure Assessment; *MV-ECMO*, mechanical ventilation extracorporeal membrane oxygenation; *IBW*, ideal body weight; *PEEP*, positive end-expiratory pressure; *P_aO₂/FiO₂*, partial pressure of O₂ in arterial blood/fraction of inspired oxygen; *P_aCO₂*, partial pressure of carbon dioxide in arterial blood; *S_aO₂*, oxygen saturation; *LVEF*, left ventricular ejection fraction; *VTI*, velocity–time integral. *Several factors may be combined.

FIGURE 2. Multivariable analysis of factors associated with intensive care unit mortality. *CI*, Confidence interval; *MV-ECMO*, mechanical ventilation extracorporeal membrane oxygenation; *ARF*, acute respiratory failure; *ECMO*, extracorporeal membrane oxygenation.

The interpretation of our results is limited mostly by the retrospective design of the study. In particular, adjunctive therapies for patients with acute respiratory distress syndrome were not well-balanced between the 2 groups. On-site–implanted patients were less frequently prone-positioned before receiving ECMO, probably attributable to recruitment biases, because this group contained a greater percentage of cardiac surgery patients. Difference in prone-positioning did not longer reach statistical significance when postcardiotomy patients were excluded from the analysis, although mortality remained comparable between groups (data not shown). Nonetheless, we were able to constitute a large panel of our patients' parameters and conduct several multivariable analyses to minimize those biases. Transfer times and distances were short in this cohort, limiting the applicability of our results to larger areas with longer transport times. Lastly, it should be noted that our results might not be applicable to centers using primarily dual lumen cannulation, because we never used this more-complex approach for our MERT patients.

CONCLUSIONS

ICU mortality and ECMO-related complications of our study patients implanted with VV-ECMO by the MERT and transferred to our ECMO referral center were comparable with those implanted on site by the same team. These results further support the use of this strategy to manage refractory ARF patients.

Conflict of Interest Statement

Dr Combes is the primary investigator of the Extracorporeal Membrane Oxygenation for Severe Acute Respiratory Distress Syndrome (EOLIA) trial, NCT01470703, a randomized trial of venovenous–extracorporeal membrane oxygenation supported in part by Maquet. Dr Combes has received honoraria for lectures from Maquet. Dr Bréchet and Dr Schmidt received honoraria for lectures from Maquet. All other authors have nothing to disclose with regard to commercial support.

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Key Words: acute respiratory distress syndrome, acute respiratory failure, extracorporeal membrane oxygenation, mobile, retrieval

FIGURE E1. SMDs between on-site and mobile extracorporeal membrane oxygenation retrieval team groups for factors independently associated with mortality, in unmatched patients and patients propensity-score weighted. *MV-ECMO*, Mechanical ventilation extracorporeal membrane oxygenation; *SMD*, standardized mean difference.

FIGURE E3. Probability of survival in on-site and MERT-implanted patients. *ECMO*, Extracorporeal membrane oxygenation; *MERT*, mobile extracorporeal membrane oxygenation retrieval team.

FIGURE E2. Annual number of venovenous extracorporeal membrane oxygenation. *ECMO*, Extracorporeal membrane oxygenation.

TABLE E1. Characteristics of MERT-implanted patients who developed significant hemodynamic complication during transfer (death or the need to switch for VA-ECMO)

Parameter	Hemodynamic complication, n = 9	No hemodynamic complication, n = 109	P value
Demographics			
Age, y	45 (32-55)	44 (32-55)	.9
Year of implantation	2012 (2011-2012)	2011 (2010-2012)	.16
Male	5 (55.6)	63 (57.8)	1.0
Body mass index, kg/m ²	23 (20-27)	26 (24-31)	.1
Charlson score	2 (1-3)	1 (0-2)	.2
McCabe and Jackson score	2 (0-3)	1 (0-2)	.1
Immunocompromised	3 (33.3)	30 (27.5)	.7
Chronic lung disease	1 (11.1)	14 (12.8)	1.0
Reason for ECMO*			
Viral pneumonia	2 (22.2)	24 (22.0)	1.0
A(H1N1) pneumonia	1 (11.1)	20 (18.3)	1.0
Bacterial pneumonia	5 (55.6)	47 (43.1)	.5
Aspiration pneumonia	1 (11.1)	11 (10.1)	1.0
Asthma	0 (0)	2 (1.8)	1.0
Trauma/burns	0 (0)	8 (7.3)	1.0
Other	1 (11.1)	24 (22.0)	.7
Postoperative	2 (22.2)	16 (14.7)	.6
Cardiac surgery	0 (0)	0 (0)	
At ECMO implantation			
SAPS-II score	94 (85-102)	69 (60-78)	<.0001
SOFA score	17 (16-18)	13 (10-16)	.003
MV-ECMO interval, d	1 (0-5)	5 (1-10)	.02
Adjunctive therapy			
Prone positioning	8 (88.9)	78 (71.6)	.4
Nitric oxide	9 (100)	100 (91.7)	1.0
Neuromuscular blockers	9 (100)	107 (98.2)	1.0
Steroids	0 (0)	17 (15.5)	.3
High-frequency oscillation	0 (0)	1 (0.9)	1.0
Ventilatory settings			
Tidal volume, mL/kg IBW	6.8 (5.9-8.6)	5.9 (5.1-6.8)	.03
PEEP, cm H ₂ O	10.0 (6.5-13.0)	10.0 (8.5-13.0)	.6
Plateau pressure, cm H ₂ O	30 (28-33)	32 (29-35)	.1
Driving pressure, cm H ₂ O	19.5 (17.2-21.7)	21.0 (18.0-25.0)	.4
Blood gases			
pH	7.16 (7.12-7.22)	7.25 (7.16-7.32)	.03
P _a O ₂ /FiO ₂	63 (50-79)	58 (50-73)	.6
P _a CO ₂ , mm Hg	67 (57-69)	58 (49-75)	.7
Bicarbonate, mmol/L	22 (21-26)	26 (22-30)	.08
S _a O ₂ , %	83 (75-92)	86 (81-92)	.5
Inotrope score, µg/kg/min	100 (17-141)	36 (7-82)	.16
Pre-ECMO cardiac arrest	2 (22.2)	8 (7.4)	.17
LVEF, %	45 (35-62)	60 (50-60)	.15
Aortic velocity–time integral, cm	13 (8-16)	17 (15-19)	.003
Right ventricular dysfunction	2 (22.2)	26 (23.8)	1.0
Serum lactate, mmol/L	3.5 (2.5-7.5)	2.2 (1.2-4.0)	.03
Renal replacement therapy	1 (11.1)	19 (17.4)	1.0
Transfer data			
Distance, km	5.9 (5.2-34.5)	15.0 (6.0-25.0)	.7
Time, min	55 (23-81)	34 (25-53)	.2
Switch from VV to VA-ECMO	8 (88.9)	0 (0)	<.001
ICU mortality	7 (77.8)	48 (44.0)	.08

Values are expressed as median (IQR) or n (%). *ECMO*, Extracorporeal membrane oxygenation retrieval team; *SAPS-II*, Simplified Acute Physiology Score-II; *SOFA*, Sequential Organ Failure Assessment; *MV-ECMO*, mechanical ventilation extracorporeal membrane oxygenation; *IBW*, ideal body weight; *PEEP*, positive end-expiratory pressure; *P_aO₂/FiO₂*, partial pressure of O₂ in arterial blood/fraction of inspired oxygen; *P_aCO₂*, partial pressure of carbon dioxide in arterial blood; *S_aO₂*, oxygen saturation; *LVEF*, left ventricular ejection fraction; *VV-ECMO*, venovenous extracorporeal membrane oxygenation; *VA-ECMO*, venoarterial extracorporeal membrane oxygenation; *ICU*, intensive care unit. *Several factors may be combined.