Extracorporeal CO_2 Removal in Acute Exacerbation of COPD Not Responding to Non-Invasive Ventilation: a Single Center Experience

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Research

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Abstract

Background: Acute exacerbation of chronic obstructive pulmonary disease (ae-COPD) has a gold standard treatment: non-invasive ventilation (NIV). However, this treatment sometime fails, and an invasive mechanical ventilation (IMV) is required. The extracorporeal CO₂ removal (ECCO₂R) device can be an alternative to intubation. The aim of the study is to evaluate ECCO₂R efficiency and safety and enlighten ECCO₂R benefit/risk compared to IMV.

Methods: Consecutive ae-COPD patients for whom NIV failed were retrospectively analyzed during two periods: before and after the ECCO₂R device implementation in our ICU in 2015. We considered the before period as standard of care and patients were treated with IMV. The ECCO₂R device was a pump-driven veno-venous system (Xenios AG).

Results: The two groups (ECCO₂R n = 26 and Control group n = 25) were comparable at baseline except for the BMI which was significantly higher in the ECCO₂R group (30kg/m² versus 25kg/m²). The pH and PaCO₂ improved significantly in both groups. The mean time on ECCO₂R was 5,4 days whereas IMV lasted 27 days in the control group. Four patients needed IMV in the ECCO₂R group (of which 3 occurred after ECCO₂R weaning). There were 7 major bleeding events with ECCO₂R and 3 led to premature termination of ECCO₂R. In the control group, there were 8 ventilator associated pneumonia, 25 haemodynamic instability and 6 self extubations. The mean time in ICU and hospital stay in the ECCO₂R and control groups were 18 vs 30 days, 29 vs 49 days, respectively and the 90-day mortality rates were 15% vs 28%.

Conclusions: ECCO₂R brings significant improvement on pH and PaCO₂ in ae-COPD patients failing NIV therapy and permit to avoid intubation in 85% with low complication rates compared to IMV. These results have yet to be proven in a larger randomized study.

Trial registration: ClinicalTrials.gov, NCT04882410. Date of registration May 12th 2021, Retrospectively registered.

https://www.clinicaltrials.gov/ct2/show/NCT04882410

Background

Chronic Obstructive Pulmonary Disease (COPD) is a frequent pathology. It is expected to be the third cause of mortality in the world by 2030 (1). It is easily complicated by acute exacerbations (ae-COPD) which are associated with a significant increase in mortality (2).

Independently of the etiologic treatment of the exacerbation, non-invasive ventilation (NIV) has made it possible to significantly improve the prognosis of these exacerbations. Nevertheless, nearly 20% of NIV-treated patients require invasive mechanical ventilation (IMV) during their management (3, 4). This event is unquestionably a failure and is associated with significant mortality (5, 6), particularly due to ventilator-

associated pneumonia (7). Invasive ventilation also induces diaphragm weakness which is associated with weaning difficulties and poor clinical outcomes (8). Increased intrathoracic pressure associated with positive pressure ventilation raises pulmonary vascular resistance by crushing the alveolar vessels, worsening cor pulmonale which can pre-exist in COPD patients.

The extracorporeal CO_2 removal ($ECCO_2R$) device eliminates a portion of CO_2 through extracorporeal circulation but cannot oxygenate the blood because of the low flow system. Acute respiratory distress syndrome (ARDS) was the primary indication for $ECCO_2R$ therapy, with a primary goal of ultra-protective lung ventilation via managing CO_2 levels. Advances in technology and a better knowledge of the technique have enabled its use in other clinical syndromes such as ae-COPD and sometimes severe asthma (9). It can also be used as a bridge to pulmonary transplantation as it reduces the ventilator associated pneumonia risk and facilitates active physiotherapy. The use of $ECCO_2R$ in patients with ae-COPD may enhance the efficacy of CO_2 removal in combination with NIV, therefore lowering respiratory rate, dynamic hyperinflation, and intrinsic positive end-expiratory pressure (PEEP). By decreasing respiratory rates, it can reduce the work of breathing and lower CO_2 production of the respiratory muscles (10). The absence of sedation allows the patients to perform active physiotherapy preventing muscle deconditioning.

Two potential benefits for ae-COPD patients are currently being explored: avoid the use of IMV in case of NIV failure or facilitate IMV weaning (11–13).

Besides potential positive effects, there are side effects. This technique requires the insertion of intravascular cannulas which expose the patient to side effects mainly represented by bleeding. A benefit-risk approach is therefore necessary before proposing this treatment more widely.

The objective of this study was to confirm the positive effect of this technique in a selected population of COPD for whom the NIV proves insufficient to normalize blood gases. Side effects were also collected.

Methods

Study design

It is an observational, single center (Centre Hospitalier de Saint-Denis, Saint-Denis, France), retrospective study. Successive ae-COPD patients for whom NIV failed were analyzed during two periods: before and after the $ECCO_2R$ device implementation.

Criteria used to define patients were: no improvement or worsening of respiratory acidosis after more than one hour of NIV treatment, and no improvement of respiratory distress signs or decreased level of consciousness. All selected patients had $pH < 7.35$ and $PaCO_2 > 45$ mmHg.

From January 2010 to February 2015, before implementation of the $ECCO_2R$ device in the ward, 25 patients fulfilled the inclusion criteria. Based on inclusion criteria, all patients in this group required invasive ventilatory support. From February 2015 to February 2020, 31 patients fulfilled the criteria and were treated with $ECCO_2R$. Five patients were excluded since they were not eligible for endotracheal intubation because of ethical withhold treatment decision. Hence, the $ECCO_2R$ group has 26 patients. Criteria for IMV despite $ECCO_2R$ treatment were agitation potentially leading to self-inflicted dislocation of the $ECCO_2R$ cannulas, deteriorating neurological status with loss of airway protective reflexes, development of unmanageable copious pulmonary secretions or progressive hypoxemia.

NIV management

The NIV was performed with Respironics V60 Ventilator (Philips Respironics®: United States) in a S/T mode as recommended in our unit protocol: the pressure support was increased by 2 cmH_2O steps depending on the patient's tolerance, until a maximum of 20 cmH_2O in order to reach a tidal volume of 8ml/kg of ideal body weight. The expiratory positive airway pressure (EPAP) was between 5 and 10 cmH_2O. The FiO_2 was adapted to reach an oxygen saturation between 90–92%. The interface was a full face mask (PerformaTrak, Philips Respironics®).

$ECCO_2R$ device

$ECCO_2R$ was performed with the Xenios console, iLA active iLA kit (Xenios AG, Heilbronn, Germany). The membrane used for every patient had a gas exchange area of 1.3 m^2. Anticoagulation was maintained with continuous intravenous unfractionated heparin with AntiXa monitoring. The target of anticoagulant therapy was 0.3 UI antiXa/mL. Most patients (92%) had femoral cannulation with Novaport twin 24 Fr (on the right side except for one patient). Two patients had jugular cannulation (18 and 22 Fr). Targeted blood flow through the circuit was 1L/min. Initiation of $ECCO_2R$ was decided by medical collective decision and cannulation performed by a medical doctor.

IMV and sedation management

Both the ventilation weaning strategy and the sedation withdrawal strategy were protocolized. The sedation was systematically adjusted by the nursing staff to ensure the comfort and safety of the patients according to a service protocol. Regarding weaning from mechanical ventilation, again according to pre-established criteria, pressure support was reduced until the patients were considered ready for extubation. These strategies are likely to homogenize the historical group of patients treated with IMV.

Data collection

The data collected (patient characteristics, arterial blood gas, report of the $ECCO_2R$ side effect, outcomes and duration) during the two periods (before and after the ECCO□R device implementation in the ward) were extracted from each patient's electronic health record. A first request including the inclusion criteria allowed the identification of each patient. The data were then exported from the different databases

containing texts, treatments, biological results and different dates to calculate the length of hospitalization, etc... to a single anonymized datasheet. It is from this material that the analyses were carried out.

Blood gases were collected at different time points: 6 hours before intervention ($ECCO_2R$ or endotracheal intubation), 2 hours before intervention, 6 hours after intervention, 24h after intervention and before decannulation or extubation. Major bleedings were defined by fatal bleeding or symptomatic bleeding in a critical area or fall in haemoglobin level of more than 2 g/dL or bleeding leading to transfusion of two or more units of packed red cells. Thrombocytopenia was defined by a blood platelet count under 100 G/L with more than a half of the baseline count.

Statistical analysis

The software R Studio (Version 1.2.1335 © 2009–2019 RStudio, Inc.) was used for analyses. Variables are reported as mean ± standard deviation (SD) for quantitative data and number (percentage) for categorical data. Population distribution was tested with the Shapiro-Wilk normality test. Quantitative variables were compared with t test or paired t test with a 95% confidence interval and with Welch Two Sample t-test when the two populations had unequal variances. One of the variables was not following a normal distribution therefore, we used Wilcoxon rank sum test with continuity correction. Qualitative variables were compared with Pearson's Chi-squared test with or without Yates' continuity correction depending on the theoretical distribution of variables. The analyses were conducted at a two-sided alpha level of 5%.

Ethics

The study was approved by the Institutional Review Board (IRB/T0004). In accordance with the French legislation, the IRB required a specific information with the possibility for the patient to object to his/her participation in the study.

The database was declared to the “Commission Informatique et Libertées”. All data treatments were conducted on anonymized datasheet.

Results

Patient characteristics

Patients were mostly men (72%) with a mean ± SD age of 69 ± 11 years. The two groups ($ECCO_2R$ n = 26 and IMV group n = 25) were comparable at baseline except for the BMI which was significantly higher in the $ECCO_2R$ group (30 kg/m² versus 25 kg/m²) (Table 1). In the $ECCO_2R$ group, 9 patients (35%) had a BMI superior to 35 kg/m² and 4 patients superior to 40 kg/m². Comorbidities were similar in both groups (hypertension, diabetes, heart failure, etc). In the $ECCO_2R$ group, 11(42%) and 7(27%) patients had respectively long-term oxygen therapy (LTOT) and non-invasive ventilation (NIV) prior to hospitalization. No significant difference was observed compared with the IMV group. Four patients (15%) had an

exacerbation related to influenza in the $ECCO_2R$ group whereas none of them in the IMV group. There were obvious heart failure signs for 9 patients (35%) in the $ECCO_2R$ group and 6 patients (24%) in the IMV group without significant difference.

Table 1
Baseline patients characteristics

Patients characteristics	$ECCO_2R$ group (n = 26)	Control group (n = 25)	p value
Demographic data			
Gender (male)	20 (77)	17 (68)	0.48
Age (years)	67 ± 12	72 ± 11	0.08
BMI (kg/m²)	30 ± 9	25 ± 7	**0.035**
SAPS II	49 ± 14	50 ± 15	0.81
Glasgow	13 ± 3	12,4 ± 3,6	0.62
Comorbidities			
Hypertension	13 (50)	16 (64)	0.31
Diabetes	8 (31)	10 (40)	0.49
Renal failure	4 (15)	1 (4)	0.37
Heart failure	6 (23)	7 (28)	0.69
Coronaropathy	6 (23)	6 (24)	0.94
Atrial fibrillation	3 (12)	6 (24)	0.42
Stroke	2 (8)	2 (8)	1
Sleep apnea	5 (19)	2 (8)	0.45
Asthma	1 (4)	2 (8)	0.97
Cancer < 5 years	2 (8)	6 (24)	0.22
Systemic corticosteroid	1 (4)	3 (12)	0.57
LTOT	11 (42)	10 (40)	0.87
NIV	7 (27)	4 (16)	0.34
Causes of exacerbation			
Influenza A	4 (15)	0	0.13
Pneumonia	8 (31)	5 (20)	0.38
Bronchitis	7 (27)	4 (16)	0.34

Values presented as mean ± standard deviation or number (%)

$ECCO_2R$ extracorporeal carbon dioxide removal, *BMI* body mass index, *SAPS II* simplified acute physiology score II, *LTOT* Long-term oxygen therapy, *NIV* noninvasive ventilation, *N/A* not applicable

Patients characteristics	$ECCO_2R$ group (n = 26)	Control group (n = 25)	p value
Heart failure	9 (35)	6 (24)	0.41
Nothing found	4 (15)	10 (40)	0.09
Arterial blood gases 6h before			
pH	7,24 ± 0,05	7,23 ± 0,13	0.91
$PaCO_2$ (mmHg)	86 ± 21	82 ± 24	0.64
PaO_2 (mmHg)	69 ± 28	78 ± 31	0.43
Bicarbonates (mmol/L)	36 ± 9	37 ± 9	0.75
Values presented as mean ± standard deviation or number (%)			
$ECCO_2R$ extracorporeal carbon dioxide removal, *BMI* body mass index, *SAPS II* simplified acute physiology score II, *LTOT* Long-term oxygen therapy, *NIV* noninvasive ventilation, *N/A* not applicable			

Arterial blood gases (pH, $PaCO_2$, PaO_2 and HCO_{3-}) carried out 6 hours before intervention were not different between the two groups. In the $ECCO_2R$ group, 19 patients (73%) had a $PaCO_2$ superior to 75 mmHg and 15 patients (58%) had a pH < 7.25 before intervention.

The initiation of the therapy, IMV or $ECCO_2R$, seems started earlier in the IMV group compared to $ECCO_2R$ group: respectively 20 ± 35 hours and 42 ± 69 hours from the initiation of NIV, but no statistically significant differences were identified.

Thirteen (50%) cannulations were done during night shift (between 7 pm and 8 am).

NIV has been continued for 18 patients (69%) of the $ECCO_2R$ group. Nine patients (35%) had high flow nasal oxygen therapy (HFNOT) during the $ECCO_2R$ treatment because of mild hypoxemia. Table 2 provides details of the clinical course and outcomes.

Table 2
Clinical course and outcomes

Clinical course	$ECCO_2R$ group (n = 26)	Control group (n = 25)	p value
Duration between NIV and $ECCO_2R$ or IMV (h)	42 ± 69	20 ± 35	0.15
Days on $ECCO_2R$	5,4 ± 4	N/A	
Days on IMV	N/A	27 ± 43	
Curarization	N/A	7 (28)	
Prone position or NO	N/A	0	
IMV rate	4 (15)	N/A	
Tracheotomy	2 (8)	5 (20)	0.38
NIV during $ECCO_2R$	18 (69)	N/A	
HFNOT during $ECCO_2R$	7 (27)	N/A	
Haemodynamic instability	3 (12)	16 (64)	**0.0001**
RRT	3 (12)	3 (12)	1
HIT	0	1 (4)	0.98
Pulmonary Embolism	2 (8)	1 (4)	1
Weaning from successful $ECCO_2R$ or IMV	17 (65)	16 (64)	0.91
Length of stay			
Days in ICU	18 ± 14	30 ± 43	0.18
Days in hospital	29 ± 22	49 ± 53	0.54
Mortality			
During ICU	2 (8)	7 (28)	0.12
28-day mortality	3 (12)	4 (16)	0.63
90-day mortality	4 (15)	7 (28)	0.26
Values presented as mean ± standard deviation or number (%)			

NIV non-invasive ventilation, *IMV* invasive mechanical ventilation, *HFNOT* high flow nasal oxygen therapy, *$ECCO_2R$* extracorporeal CO_2 removal, *RRT* renal replacement therapy, *HIT* heparin-induced thrombocytopenia, *ICU* intensive care unit, *NO* nitrogen monoxide, *N/A* not applicable

Arterial blood gases results

The pH and $PaCO_2$ improved quickly in both groups without significant difference between them (Fig. 1).

pH was significantly lower 6 hours before $ECCO_2R$ (7.24 ± 0.05) than at decannulation (7.41 ± 0.06) ($p < 0.001$). Likewise, the $PaCO_2$ value 6 hours before $ECCO_2R$ was significantly higher (86 ± 21 mmHg) than at decannulation (53 ± 10 mmHg) ($p < 0.001$). In the IMV group, the mean arterial blood pH 6 hours before intubation was 7.23 ± 0.13 and rose to 7.39 ± 0.06 before extubation ($p < 0.001$). The mean $PaCO_2$ value 6 hours before IMV was 82 ± 24 mmHg and decreased to 52 ± 13 mmHg before extubation ($p < 0.001$). Figure 1 and Table 2 describe pH and $PaCO_2$ changes over time.

Four patients (15%) of the $ECCO_2R$ group had recurrent hypercapnia requiring the initiation of IMV. For one patient, this situation occurred during the $ECCO_2R$ procedure. For the other three, it occurred after $ECCO_2R$ weaning (Table 3).

Table 3
$ECCO_2R$-associated adverse events

Adverse events (n)	$ECCO_2R$ group
Major bleeding	7
Scarpa (Cannula insertion site)	3
During cannula removal	1
Retroperitoneal haematoma (psoas)	1
Haemothorax	1
Pectoral bleeding	2
Cerebral bleeding	0
Digestive bleeding	0
More than 2 globular transfusion	7
Time to onset from cannulation (days)	4 ± 3,7
Leading to premature termination of $ECCO_2R$	3
Minor bleeding	6
Scarpa (cannula insertion site)	3
During cannula removal	3
Epistaxis	1
Haematuria	2
Device-related complications	15
Circuit thrombosis	3
Unexplained stop	1
Slow decease in $PaCO_2$	2
Haemolysis	3
Thrombocytopenia < 100G/L	6
Premature termination of $ECCO_2R$ causes	9
Major bleeding	3

Values presented as mean ± standard deviation or number of events

$ECCO_2R$ extracorporeal CO_2 removal, *OTI o*rotracheal intubation

Adverse events (n)	$ECCO_2R$ group
Circuit thrombosis	3
Unexplained stop	1
Haemolysis	1
Death	1
Intubation rate	4
Due to $ECCO_2R$ complication	1
Due to hypoxemia	0
After $ECCO_2R$ weaning	3
Days between $ECCO_2R$ -OTI	3,2 ± 4
Values presented as mean ± standard deviation or number of events	
$ECCO_2R$ extracorporeal CO_2 removal, *OTI o*rotracheal intubation	

Complications related to $ECCO_2R$

Seven major bleeding events in 6 patients (23%) occurred in the $ECCO_2R$ group.

For 11% of patients (3 patients), the $ECCO_2R$ was interrupted due to bleeding : one patient underwent a haemorrhagic choc and respiratory distress due to an haemothorax during the jugular cannula insertion (18 French) complicated by a cardiac arrest requiring emergency intubation (this patient was still alive at day 90) ; another patient had recurrent bleeding on the cannula insertion femoral site with rectus abdominis muscle haematoma; the last one had an haematoma of the right pectoral muscle (jugular insertion 22 French cannula). Major bleeding occurred on the scarpa cannula insertion site for 3 patients. One patient experienced an ilio-psoas hematoma the day of $ECCO_2R$ weaning, he was treated with anticoagulants for pulmonary embolism. There were six minor bleeding episodes (minor scarpa bleeding, epistaxis, haematuria), which involved 5 patients (20%). There were no cerebral or digestive bleeding events.

Three patients (11%) had haemolysis due to $ECCO_2R$. Six patients had thrombocytopenia < 100 G/L. There were three circuit thromboses and they all led to premature termination of $ECCO_2R$. They occurred at 4,8 days (mean) of $ECCO_2R$. One of them required intubation the day after, due to the hypercapnia recurrence.

No patients developed pneumonia in the $ECCO_2R$ group.

Complications related to IMV

Eight patients (32%) experienced ventilator associated pneumonia (VAP). Most of them were late pneumonia. The average time of onset of these pneumonias after intubation was 18 ± 16 days. Twenty-five haemodynamic instability events occurred in 19 patients (76%). Catecholamines were needed for more than 24 hours in most of the cases (Table 4). Self-extubations occurred in 6 patients. They all needed reintubation except one.

Table 4
IMV-associated adverse events

Adverse events (n)	Control group
Ventilator associated pneumonia (VAP)	8
Time since intubation (days)	18 ± 16
Early pneumonia (< 7days post intubation)	2
Haemodynamic instability	25
- Post intubation	16
Catecholamine > 24h	12
- Due to VAP septic shock	4
Catecholamine > 24h	3
Pneumothorax due to high intrinsic PEEP	1
Self extubation	6
Reintubation	5
Death related with IMV complication	3
Values presented as mean ± standard deviation or number of events	
VAP ventilator associated pneumonia, *ICU* intensive care unit, *IMV* invasive mechanical ventilation	

Three patients (12%) died due to IMV related complications: one patient had a pneumomediastinum after reintubation (self extubation) consequently to a high intrinsic PEEP; another patient was discovered disconnected from the respiratory device; the last one passed away due to a haemorrhagic shock and respiratory distress after a massive bleeding of his tracheotomy.

Outcomes and durations

The interventions, $ECCO_2R$ and IMV, lasted respectively 5.4 ± 4 and 27 ± 43 days (p = 0.019). Seven patients (28%) required neuromuscular blocking agent after intubation because of high intrinsic PEEP.

Prone positioning was not used as patients did not show signs of acute respiratory distress syndrome. The rate of tracheotomy in the IMV group was 20% (5 patients) and 8% (2 patients) in the $ECCO_2R$ group. We observed a length of ICU stay of 18 ± 14 days in the $ECCO_2R$ group compared to 30 ± 43 days in the IMV group. The length of hospital stay was 29 ± 22 days in the $ECCO_2R$ group compared to 49 ± 53 days in the IMV group. No significant differences were identified for these parameters, neither for the 28-day or 90-day mortality. The 90-day mortality was 15% and 28% respectively in the $ECCO_2R$ and IMV group,

Discussion

This study has numerous important limitations. It is a retrospective, monocentric and observational study. In addition, the before/after character as well as the extended period during which patients were studied may make the results questionable. However, treatments outside $ECCO_2R$ were protocolized. International recommendations regarding NIV, invasive ventilation and sedation were followed. Thus, an extrapolation beyond the single center is conceivable. In addition, the data analyzed are mostly objective numerical data that are not affected by the retrospective design. Last but not least our ambition was only to document the feasibility of $ECCO_2R$.

$ECCO_2R$ brings significant improvement on pH and $PaCO_2$ in ae-COPD patients (Fig. 1). This improvement was comparable to that produced by IMV. IMV was avoided for 85% of patients treated with $ECCO_2R$ (15% of $ECCO_2R$ patients had to be intubated). Most often, $ECCO_2R$ failures were due to recurrent hypercapnia occurring after weaning from $ECCO_2R$ suggesting too early decannulation.

A particular attention should be taken in hypoxemic patients for whom $ECCO_2R$ failure seem to be more frequent in other studies (14, 15). As explanation, the excessive CO_2 removal leads, during spontaneous ventilation, to a decrease of the tidal volume with increased risk of atelectasis and a decrease of alveolar PO_2(16). There was no intubation because of hypoxemia under $ECCO_2R$ in our study.

Just over 20% of $ECCO_2R$ patients in our study had significant bleeding complications. They occurred on average 4 days (0–10 days) after the start of $ECCO_2R$ cannulation. None of cerebral haemorrhage has been noticed. The fact that the two patients with jugular cannulation had serious haemorrhagic and pulmonary complications should probably lead to reflection on the sites of cannulation in these patients mostly with significant pulmonary hypertension and emphysema. We suggest femoral cannulation in such situations.

There were 3 circuit thromboses and they all led to premature termination of $ECCO_2R$. Some studies sometimes report a rate of nearly 25% (17). This complication, together with bleeding issue, underscores the importance of the anticoagulant strategy.

Conclusion

This study reveals the possibility to treat NIV failure patients with $ECCO_2R$. It shows that intubation can be avoided, especially in case of lack of significant hypoxemia. However, it is important to consider side effects of the $ECCO_2R$ treatment, especially its haemorrhagic complications. It requires constant monitoring and team training. It is therefore important to better understand in which subset of patients and at which point in the course of their disease this technique could be useful. Finally, this article also raises the question of the optimal moment of weaning from $ECCO_2R$. It is not excluded that technical progress will facilitate the management of this emerging technique in the near future.

Abbreviations

COPD: Chronic Obstructive Pulmonary Disease;

ae-COPD: Acute exacerbation of Chronic Obstructive Pulmonary Disease;

NIV: Non-invasive ventilation;

IMV: Invasive mechanical ventilation;

$ECCO_2R$: Extracorporeal carbon-dioxide removal;

ARDS: Acute respiratory distress syndrome;

ICU: Intensive care unit;

PEEP: Positive end-expiratory pressure;

$PaCO_2$: Partial alveolar carbon-dioxide pressure;

EPAP: expiratory positive airway pressure;

FiO_2: Fraction of inspired oxygen;

SD: standard deviation;

IRB: Institutional Review Board;

LTOT: Long-term oxygen therapy;

PaO_2: Partial alveolar oxygen pressure;

BMI: Body mass index;

HFNOT: high flow nasal oxygen therapy;

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional review board (number T0004).

The clinical trial protocol was registered with www.clinicaltrials.gov (ClinicalTrials.gov identifier: NCT04882410).

Consent for publication

An information letter was sent to all the patients, explaining that they can refuse to be included in this study.

Availability of data and materials

Please contact author for data requests.

Conflicts of Interest

Rita Serbouti, from Fresenius Medical Care France, Medical affairs, helped train staff in Extracorporeal CO_2 Removal Device and participated in the proofreading of this paper. No financial support from the industry were received.

Competing interests

RS is part of Fresenius Medical Care France, Medical affairs

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None

Authors' contributions

MA: patient management, data acquisition, data analysis, writing and proofreading of the article

JA: writing, proofreading

SA, DU, LF, VI, NM, TI, ML and LL: patient management and proofreading

RS: team training, proofreading

DS: coordination, study design, patient management, writing and proofreading

All authors have read and approved the final manuscript.

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Figures

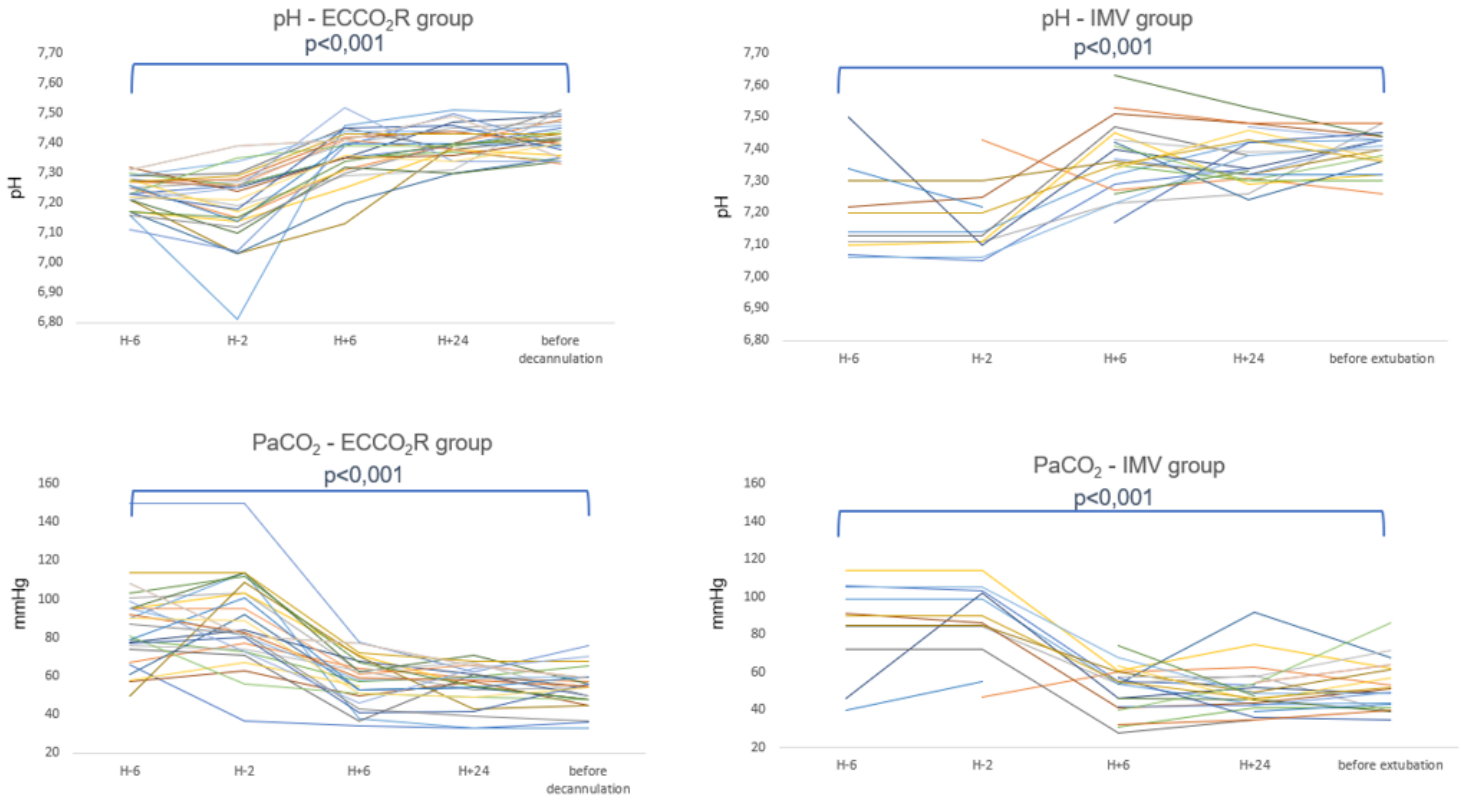

Figure 1

Evolution of pH and carbon dioxide arterial partial pressure (PaC02) from 6 hours before cannulation or intubation until the moment before weaning

Supplementary Files

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