Achieving Safe Liberation During Weaning From VV-ECMO in Patients With Severe ARDS
The Role of Tidal Volume and Inspiratory Effort

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BACKGROUND: Weaning from venovenous extracorporeal membrane oxygenation (VV-ECMO) has not been well studied. VV-ECMO can be discontinued when patients tolerate noninjurious mechanical ventilation (MV) during a sweep gas-off trial (SGOT). However, predictors of safe liberation are unknown.

RESEARCH QUESTION: Can safe liberation from VV-ECMO be predicted at the bedside?

STUDY DESIGN AND METHODS: Two observational studies of adults weaned from VV-ECMO for severe ARDS at Toronto General Hospital were conducted. MV settings, respiratory mechanics, and clinical variables were analyzed to predict safe liberation from VV-ECMO, defined a priori as avoidance of ECMO recannulation, increased MV support, need for rescue therapy, or hemodynamic instability developed within 48 h following decannulation.

RESULTS: During both studies, 83 patients were weaned from VV-ECMO, 21 (25%) of whom did not meet the criteria for safe liberation. In the retrospective study, higher tidal volume per predicted body weight (OR, 1.58; 95% CI, 1.05-2.40; P = .03) and heart rate (OR, 1.07; 95% CI, 1.022-1.15; P = .01) at the end of SGOT were significantly associated with increased odds of unsafe liberation when adjusted for age (OR, 1.02; 95% CI, 0.95-1.09; P = .63) and sequential organ failure assessment score (OR, 1.16; 95% CI, 0.86-1.56; P = .34). Change in ventilatory ratio had an imprecise association (OR, 2.7; 95% CI, 0.94-7.95; P = .06) with unsafe liberation when adjusted for age (OR, 1.03; 95% CI, 0.96-1.10; P = .42), sequential organ failure assessment score (OR, 1.11; 95% CI, 0.81-1.51; P = .52), and heart rate (OR, 1.07; 95% CI, 1.01-1.13; P = .02). In the prospective study, patients who had unsafe liberation from VV-ECMO also had significantly higher inspiratory efforts (esophageal pressure swings, 9 [7-13] vs 18 [7-25] cm H2O; P = .03) and worse outcomes (longer MV duration, ICU and hospital length of stay).

INTERPRETATION: Patients with higher tidal volume, heart rate, ventilatory ratio, and esophageal pressures swings during SGOT were less likely to achieve safe liberation from VV-ECMO.

KEY WORDS: ARDS; inspiratory effort; tidal volume per predicted body weight; venovenous extracorporeal membrane oxygenation; weaning

ABBREVIATIONS: AUC = area under the receiver-operating characteristic curve; ΔP = driving pressure; HR = heart rate; MP = mechanical power; MV = mechanical ventilation; PES = esophageal pressure; VR = ventilatory ratio; VTpbw = tidal volume per predicted body weight; VV-ECMO = venovenous extracorporeal membrane oxygenation

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Over the last two decades, the use of venovenous extracorporeal membrane oxygenation (VV-ECMO) in patients with severe ARDS has been growing substantially worldwide.\(^1\)\(^-\)\(^3\) Despite the lack of conclusive evidence supporting the use of VV-ECMO,\(^4\)\(^,\)\(^5\) a multicenter clinical trial suggested a positive signal in favor of the procedure, confirmed in post hoc\(^6\),\(^7\) and meta-analysis.\(^8\) However, the mortality of patients treated with VV-ECMO for ARDS is still high, suggesting that, in addition to patient selection, several aspects of the supportive care in these patients can be improved.

Management of the interplay between two artificial respiratory mechanical supports, mechanical ventilation (MV) and VV-ECMO, is complex. Although a number of investigations to define optimal strategies of MV during VV-ECMO have been reported,\(^9\)\(^-\)\(^11\) weaning from VV-ECMO has not received the same attention, and large clinical trials did not detail their weaning protocols.\(^4\)\(^,\)\(^6\) Hence, weaning from VV-ECMO is mainly based on expert opinion.\(^1\)\(^,\)\(^2\)\(^,\)\(^5\)\(^,\)\(^13\) Usually, VV-ECMO is weaned before MV,\(^14\) and patients may be assessed for readiness to be liberated with a sweep gas-off trial (SGOT), during which no oxygenation or CO\(_2\) clearance is provided by the circuit.

However, timing and duration of the SGOT and how to precisely best determine its success or failure are unknown. Unsafe liberation from VV-ECMO could potentially expose patients to ventilator-induced or patient self-inflicted lung injury,\(^15\)\(^-\)\(^17\) as well as prolonged sedation\(^18\)\(^-\)\(^20\); these factors in turn can prolong MV, leading to poor clinical outcomes.\(^21\)

The goal of the current study, therefore, was to identify clinical and MV parameters measured during SGOT that could predict safe liberation from VV-ECMO.

### Study Design and Methods

We conducted two observational studies in the medical-surgical ICU at Toronto General Hospital. The first was a retrospective study (January 2012-September 2016), and the second was a prospective physiological study (July 2018-June 2019) that included esophageal pressure (P\(_{\text{ES}}\)) measurements that had become routine practice. Both studies were approved by the hospital Research Ethics Board (#16-6095 and #17-6251). Follow-up for both studies was performed until the patient was discharged from our institution. Strengthening the Reporting of Observational Studies in Epidemiology guidelines\(^22\) were used for reporting the cohort studies.

#### Patients

Both studies included consecutive adults (aged ≥ 18 years) diagnosed with ARDS, supported and then liberated from VV-ECMO. Weaning from VV-ECMO was not standardized but performed according to a concurred strategy within our center (e-Appendix 1). Patients were excluded if they required a hybrid mode of extracorporeal life support (veno-venous-arterial ECMO), if VV-ECMO was used as a bridge to lung transplantation or in obstructive lung disease, and in the prospective study if they had a contraindication to esophageal catheter insertion.

#### Data Collection

Patient demographic characteristics, baseline physiological parameters, and comorbid states were recorded for both studies. For the retrospective study, clinical and MV parameters were recorded during the first hour of the SGOT and just prior to liberation from VV-ECMO (during the last hour of the SGOT). If
any variable was deemed to have significantly changed between these two time points, the hourly data were collected for the duration of SGOT, if available. For the prospective study, physiological respiratory mechanics variables based on $P_{ES}$ in addition to clinical and MV parameters were recorded at one time point during SGOT, within 4 h prior to liberation from VV-ECMO. Data on duration of MV, ICU and hospital length of stay, and mortality were also collected. Further details are provided in e-Appendix 1.

Outcome Measures

The primary outcome of the study was unsafe liberation from VV-ECMO, defined a priori as development of one or more of the following criteria within 48 h of decannulation: (1) VV-ECMO recannulation; (2) escalation of MV (change from a partially assisted mode to controlled MV, or dynamic driving pressure ($\Delta P$) $\geq 16$ cm H$_2$O$^{23,24}$ and delta change from previous setting of $\geq 5$ cm H$_2$O); (3) use of rescue therapies (ie, new need for paralysis and deep sedation$^{25}$ or inhaled pulmonary vasodilators$^{26}$ or high-frequency oscillatory ventilation$^{27}$); or (4) new worsening hemodynamics requiring addition of any vasoactive agents with no evidence of sepsis or hypovolemia.$^{28,29}$ Secondary outcomes were duration of MV, ICU and hospital length of stay, and in-hospital mortality.

Statistical Analysis

Descriptive statistics are reported with median and interquartile range or proportion, as appropriate. Characteristics of patients categorized according to safe vs unsafe liberation from VV-ECMO were compared by using the Wilcoxon rank sum test, or Fisher exact tests, as appropriate. For the retrospective study, multivariable logistic regression was performed to evaluate the association between clinical and MV variables during SGOT and the unsafe liberation from VV-ECMO (four variables at a time). To indicate the trajectory of available clinical or MV variables over the first 24 h, spaghetti plots were used. For the prospective study, respiratory mechanics variables in addition to the significant variables identified in the retrospective study were examined. Receiver-operating characteristic curves were generated to show the performance of significant variables in predicting unsafe liberation from ECMO. Correlations were evaluated by using the Pearson correlation coefficient. All statistical analyses were performed by using R version 3.6.0 (https://www.r-project.org/), and descriptive statistics were performed by using the tableone package. Further details are provided in e-Appendix 1.

Results

Retrospective Study

Baseline Characteristics: Fifty-five patients were weaned from VV-ECMO (e-Fig 1); they were predominantly male (75%) with a median age of 45 [34-52] years (Table 1). Fourteen (26%) patients met the criteria of unsafe liberation (12 patients required escalation of MV, seven patients needed rescue therapies, and seven patients required new vasoactive agents) (e-Table 1). The predominant cause of ARDS was pulmonary in origin (89%). The clinical characteristics of patients unsafely liberated from VV-ECMO were comparable with those who were safely liberated, except for the duration of SGOT, which was longer in patients unsafely liberated (20 [12-25] vs 24 [22-27] h; $P = .04$).

Clinical and MV Variables During the First and Last Hour of SGOT: Partial-assist ventilation was the predominant mode of ventilation throughout the SGOT trial (40 patients [73%]). During the first hour of SGOT, there was no difference in clinical or MV parameters between patients who had safe vs unsafe liberation from VV-ECMO. However, during the last hour of SGOT, tidal volume per predicted body weight ($V_{Tpbw}$) (7.1 [6.0-8.4] vs 9.1 [6.1-10.3] mL/kg; $P = 0.05$), heart rate (HR) (95 [90-100] vs 108 [100-118] beats/min; $P < .01$) and ventilatory ratio (VR) (2.0 [1.4-2.7] vs 2.6 [2.2-2.9]; $P = .03$) were all significantly higher in patients who were unsafely liberated from VV-ECMO (e-Table 2, Fig 1).

Predictors of Unsafe Liberation From VV-ECMO: $V_{Tpbw}$ (OR, 1.42; 95% CI, 1.03-1.97; $P = .03$), HR (OR, 1.07; 95% CI, 1.02-1.12; $P < .01$), and VR (OR, 2.40; 95% CI, 1.05-5.50; $P = .03$) recorded during the last hour of SGOT were identified in the univariate logistic regression to be significantly associated with unsafe liberation from VV-ECMO (e-Table 3). We included these variables in two separate models given the significant correlation between $V_{Tpbw}$ and VR (e-Fig 2). When adjusted for age and sequential organ failure assessment score during SGOT, both $V_{Tpbw}$ (OR, 1.58; 95% CI, 1.05-2.40; $P = .03$) and HR (OR, 1.08; 95% CI, 1.02-1.15; $P = .01$) during the last hour of SGOT remained independently associated with unsafe liberation from VV-ECMO, whereas VR was imprecisely associated with unsafe liberation (OR, 2.7; 95% CI, 0.94-7.95; $P = .06$) (Table 2).

Change Over Time During SGOT: Assessment of the spaghetti plots of $V_{Tpbw}$ and HR revealed a clear separation of the means in patients unsafely liberated from VV-ECMO compared with those safely liberated. Significant separation between the two groups occurred at the fourth hour of the SGOT, as shown by the significant mean difference of $V_{Tpbw}$ and HR (e-Figs 3, 4; e-Table 4; Fig 1).

Secondary Outcomes: In patients with available data (e-Table 5), there was no difference in duration of MV or ICU or hospital length of stay; there was a difference in mortality (0 vs 1; $P = .02$). However, 25 of 55 patients (45%) were repatriated to a different institution after...
### TABLE 1  
Baseline Clinical Characteristics of Patients With Severe ARDS Supported With and Liberated From VV-ECMO, For Whom Liberation Was Deemed Safe or Unsafe

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Retrospective Cohort (n = 55)</th>
<th>Prospective Cohort (n = 28)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Patients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>45 [34-52]</td>
<td>42 [33-52]</td>
<td>47 [40-51]</td>
</tr>
<tr>
<td>Male sex</td>
<td>41 (74.5)</td>
<td>30 (73.2)</td>
<td>11 (78.6)</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score</td>
<td>0 [0-1]</td>
<td>0 [0-0]</td>
<td>0 [0-1]</td>
</tr>
<tr>
<td>APACHE II</td>
<td>29 [28-33]</td>
<td>29 [28-33]</td>
<td>29 [27-33]</td>
</tr>
<tr>
<td><strong>Cause of ARDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary</td>
<td>49 (89)</td>
<td>37 (90)</td>
<td>12 (86)</td>
</tr>
<tr>
<td>Extrapulmonary ±</td>
<td>6 (11)</td>
<td>4 (10)</td>
<td>2 (14)</td>
</tr>
<tr>
<td>MV prior to VV-ECMO, h</td>
<td>72 [36-168]</td>
<td>96 [48-168]</td>
<td>48 [36-162]</td>
</tr>
<tr>
<td>Sweep-gas flow before SGOT</td>
<td>1 [0.5-1]</td>
<td>1 [1-1]</td>
<td>1 [0.5-1]</td>
</tr>
</tbody>
</table>

Results are expressed as median [interquartile range] or No. (%). APACHE II = Acute Physiology and Chronic Health Evaluation II; MV = mechanical ventilation; SGOT = sweep gas-off trial; SOFA = Sequential Organ Failure Assessment; VV-ECMO = venovenous extracorporeal membrane oxygenation.

aTrauma, pancreatitis, intraabdominal sepsis, subarachnoid hemorrhage.
bP < .05.
48 h from ECMO liberation, and thus data on secondary outcomes are not available for the entire retrospective cohort.

**Prospective Study**

**Baseline Characteristics:** Of the 40 patients prospectively followed up, 28 were weaned from VV-ECMO (e-Fig 1); one-half were male (54%), with a median age of 46 [33-54] years. Seven (25%) patients met the criteria of unsafe liberation from VV-ECMO (two patients recannulated with VV-ECMO, six patients required escalation of MV, four patients received rescue therapies, and three patients required new vasoactive agents) (e-Table 1). The clinical characteristics of patients with unsafe liberation from VV-ECMO were comparable with those of patients safely liberated, except for hours of MV prior to VV-ECMO (36 [12-84] vs 120 [96-168] h; P < .01) and duration of ECMO (9 [5-13] vs 30 [14-48] days; P = .01), which were significantly longer in patients who met the criteria of unsafe liberation (Table 1).

**Clinical and MV Variables During SGOT:** Partial-assisted ventilation was the principal MV modality during SGOT (27 patients [96%]). V\textsubscript{Tpbw} (7.1 [6.7-7.9] vs 8.2 [8.1-9.0] mL/kg; P = .02), HR (90 [85-100] vs 115 [105-118] beats/min; P < .01), and VR (1.7 [1.3-2.2] vs 2.6 [2.6-3.1]; P < .01) were all significantly higher in patients unsafely liberated (e-Fig 5, e-Table 6). These patients also received higher MV intensity (static ΔP, 13 [10-18] vs 17 [17-25] [P = .02]; static mechanical power [MP] 12.5 [7.4-14.5] vs 23.4 [20.0-31.3] J/min [P < .01]) (e-Fig 6, e-Table 6). In the univariate logistic regression analysis, V\textsubscript{Tpbw} (OR, 2.10; 95% CI, 1.00-4.42; P = .05), HR (OR, 1.09; 95% CI, 1.01-1.17; P = .02), VR (OR, 5.07; 95% CI, 1.21-21.3; P = .02), static ΔP (OR, 1.17; 95% CI, 1.01-1.37; P = .04), and static MP (OR, 1.24; 95% CI, 1.04-1.57; P = .01) were associated with increased odds of unsafe liberation (e-Table 7).

**Inspiratory Effort and Respiratory Mechanics During SGOT:** Inspiratory drive and effort, as measured by airway occlusion pressure (airway occlusion pressure in the first 100 milliseconds, 3.1 [2.5-4.0] vs 4.7 [4.1-5.3] cm H\textsubscript{2}O; P = .03), P\textsubscript{ES} swing (9 [7.13] vs 18 [7-25] cm H\textsubscript{2}O; P = .03) (e-Fig 5C, e-Table 6) and driving transpulmonary pressure (10 [8-14] vs 15 [14-22]; P = .03) were significantly higher in unsafely liberated patients (e-Fig 6). In univariate logistic regression analysis, P\textsubscript{ES} swing (OR, 1.28; 95% CI, 1.04-1.57; P = .02), and driving transpulmonary pressure (OR, 1.17; 95% CI, 1.00-1.65; P = .05) were also associated with increased odds of unsafe liberation (e-Table 7).

**Prediction of Unsafe Liberation From VV-ECMO:** We examined the variables that discriminated between safe and unsafe liberation with receiver-operating characteristic curves and identified optimal cutoffs for V\textsubscript{Tpbw} (7.8 mL/kg, sensitivity 100%, specificity 71%, area under the receiver-operating characteristic curve [AUC] 0.81), HR (110 beats/min, sensitivity 71%, specificity 85%, AUC 0.82), VR (2.3, sensitivity 100%, specificity...
81%, AUC 0.89), and PES swing (16 cm H2O, 71% sensitivity, 100% specificity, AUC 0.78) (Fig 2).

Correlation Between Inspiratory Effort and MV and Clinical and Respiratory Mechanics Variables: PES swings were significantly correlated with V_Tpbw ($R = 0.50; P < .01$), HR ($R = 0.58; P < .02$), VR ($R = 0.53; P < .01$), static ΔP ($R = 0.53; P < .01$), and static MP ($R = 0.45; P < .02$) but not with compliance of the respiratory system ($R = -0.17; P = .38$), sedation-agitation score ($R = 0.34; P = .08$), or PaO2/FIO2 ($R = 0.05; P = .80$) (e-Fig 7).

Secondary Outcomes: Duration of MV (14 vs 46 days; $P < .01$), ICU length of stay (20 vs 46 days; $P < .01$), hospital length of stay (36 vs 52 days; $P = .04$), and mortality (0 vs 2; $P < .01$) were all significantly higher in patients unsafely liberated (e-Table 5). Because four of 28 patients (14%) were repatriated to a different institution after 48 h from ECMO liberation, data on secondary outcomes are not available for the entire prospective cohort.

Discussion
To our knowledge, this study is the first to outline the weaning process of VV-ECMO. It found that a significant proportion of patients with severe ARDS liberated from VV-ECMO required an unplanned escalation of MV settings and hemodynamic support within 48 h of decannulation. Our results show that V_Tpbw and HR recorded at the end of the SGOT were independently associated with higher odds of unsafe liberation from VV-ECMO in the retrospective study. Furthermore, with a median SGOT of 22 h, we showed that change in V_Tpbw and HR over time occurs only in patients with unsafe liberation as early as 4 h from the beginning of SGOT and thus potentially leads to a remarkable shortening of SGOT and facilitation of a clinician’s early decision-making. Although the prospective study confirmed the association of V_Tpbw and HR with unsafe ECMO liberation, it also revealed that higher inspiratory effort, as reflected in PES swings, was associated with unsafe liberation, serving as the plausible physiological explanation of the findings of the retrospective study. Moreover, higher inspiratory effort during SGOT was significantly correlated with higher intensity of MV (ie, V_Tpbw, static ΔP, static MP). Finally, the duration of MV and ICU and hospital length of stay were all significantly worse for patients deemed unsafely liberated from VV-ECMO in the prospective study.

The results from the retrospective study show that median V_Tpbw increased significantly during SGOT in patients deemed unsafely liberated, whereas it remained unchanged in those deemed safely liberated from VV-ECMO. Furthermore, in the prospective study, the AUC suggests the presence of a V_Tpbw threshold of about 8 mL/kg predicting the occurrence of unsafe liberation. The increased tidal volume during SGOT in patients unsafely liberated from ECMO may be explained by increased inspiratory effort, which might not be detected by change in respiratory rate or sedation and agitation scores but could be reflected by increased HR, as seen in the retrospective study. This hypothesis was in fact confirmed in the prospective study showing that PES swings were higher in patients with unsafe ECMO liberation. In addition, in the prospective study, we also reported the significant

<table>
<thead>
<tr>
<th>Clinical Variables</th>
<th>OR (95% CI)</th>
<th>P Value</th>
</tr>
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<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Age</td>
<td>1.02 (0.95-1.09)</td>
<td>.63</td>
</tr>
<tr>
<td>2. SOFA score during SGOT</td>
<td>1.16 (0.86-1.56)</td>
<td>.34</td>
</tr>
<tr>
<td>3. Heart rate a</td>
<td>1.08 (1.02-1.15)</td>
<td>.01</td>
</tr>
<tr>
<td>Tidal volume, per 1 mL/kg predicted body weight a</td>
<td>1.58 (1.05-2.40)</td>
<td>.03</td>
</tr>
<tr>
<td>Model 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Age</td>
<td>1.03 (0.96-1.10)</td>
<td>.42</td>
</tr>
<tr>
<td>2. SOFA score during SGOT</td>
<td>1.11 (0.81-1.51)</td>
<td>.52</td>
</tr>
<tr>
<td>3. Heart rate a</td>
<td>1.07 (1.01-1.13)</td>
<td>.02</td>
</tr>
<tr>
<td>Ventilatory ratio, per 1-unit change a</td>
<td>2.71 (0.93-7.92)</td>
<td>.07</td>
</tr>
</tbody>
</table>

SGOT = sweep gas-off trial; SOFA = sequential organ failure assessment; VV-ECMO = venovenous extracorporeal membrane oxygenation.
aDuring last hour of SGOT.
correlation between $P_{ES}$ swings and HR and MV variables, including $V_{Tpbw}$, VR, static $\Delta P$, and static MP but not the sedation-agitation score, $Pao_2/Fio_2$ ratio, or respiratory system compliance. Indeed, a seminal study on predictors of weaning failure from MV showed that higher $P_{ES}$ swings (7.9 vs 14.5 cm H$_2$O) were associated with weaning failure. Moreover, in a case report of a patient with ARDS on VV-ECMO, premature initiation of spontaneous breathing resulted in a significant increase in respiratory drive with generation of high $P_{ES}$ swings (from 2 to –35 cm H$_2$O). In addition, it has been shown that VV-ECMO can at least partially modulate the inspiratory effort proportionally to the amount of extracorporeal CO$_2$ removal. Similarly, it has been speculated that during a stepwise decrease in sweep-gas flow, maintaining $P_{ES}$ swings $< 15$ cm H$_2$O or airway occlusion pressure in the first 100 milliseconds $< 10$ cm H$_2$O, can lead to safe ECMO decannulation.

The results of our study provide supportive clinical data for these hypotheses based on physiological principles. Evaluating the balance between benefit and harm of spontaneous breathing in ARDS remains challenging, and VV-ECMO might be an effective strategy to allow spontaneous breathing while limiting patient self-inflicted lung injury. In this context, our study importantly identifies parameters that can guide the clinical decision for safe liberation from VV-ECMO.

The results of the current study show that successful weaning from VV-ECMO during the recovery phase of ARDS is related more to ventilation than to oxygenation. Although the $Pao_2/Fio_2$ ratio did not significantly change during SGOT, VR (a surrogate of pulmonary dead space

Figure 2 – Receiver-operating characteristic and AUC for $V_{Tpbw}$, HR, Vent.ratio, and inspiratory effort as measured by esophageal pressure swing, at one point within 4 h of the sweep gas-off trial for 28 consecutive patients (prospective study) with severe ARDS supported with and liberated from venovenous extracorporeal membrane oxygenation, for whom liberation was deemed unsafe. AUC = area under the curve; HR = heart rate; Vent.ratio = ventilatory ratio; $V_{Tpbw}$ = tidal volume per predicted body weight.
fraction) significantly rose during SGOT only in patients who had unsafe liberation from ECMO and remained unchanged in patients safely liberated in the retrospective study. Similar findings were seen in the prospective study; VR measured 4 h prior to decannulation was significantly lower in patients safely liberated from VV-ECMO compared with those deemed unsafely liberated. In patients with ARDS, VR ≥ 2 was independently associated with increased risk of worse outcomes, including mortality; similarly, our study shows that VR may be a useful predictor of unsafe liberation from VV-ECMO.

The current study objective was not to identify a readiness weaning test throughout the course of VV-ECMO support but rather to evaluate parameters predicting safe vs unsafe liberation from ECMO during SGOT, mirroring spontaneous breathing trial predictors of safe liberation from MV. We therefore propose the following strategy for ECMO liberation. Once clinicians have deemed a patient fit to be weaned from VV-ECMO, whether based on physiological or radiologic improvement, SGOT should be initiated. During this time, oxygen saturation should be monitored and sweep-gas flow turned back on if oxygen saturation drops < 90%. If the oxygen saturation is maintained ≥ 90%, then VTpbw, HR, VR, and inspiratory effort (PES swing or other equivalent variables) should be closely monitored. If the patient does not develop a VTpbw > 8 mL/kg, HR > 110 beats/min, VR > 2.3, and PES swing > 16 cm H$_2$O over 4 h, then the patient has a high probability of being safely decannulated from VV-ECMO. If any of these failure criteria are met within 4 h from the beginning of the SGOT trial, then the sweep-gas flow should be turned back on and another trial attempted at a later time, while patient conditions are improved (eg, following diuresis, resolution of the underlying illness) (Fig 3).

Our study has several important limitations. First, this was a single-center study, with a small sample size and significant number of patients being repatriated prior to establishing patient-important outcomes, which reports on the practices of a high-volume ECMO center. The external validity of the results therefore needs to be confirmed, as weaning practices might differ in other centers. Second, duration of SGOT, MV, and respiratory mechanics variables were collected with no standardization of the MV provided or the possibility of testing interventions, as this was strictly an observational study. Finally, the variables were collected at one time point only, especially in the prospective study, and we could not examine change over time of these variables.

Interpretation

In our ECMO center, a significant proportion of patients with severe ARDS liberated from VV-ECMO required an unplanned escalation of respiratory and hemodynamic support within 48 h of decannulation. VTpbw, HR, VR, and PES swing can predict safe liberation from VV-ECMO and differentially shorten the weaning process during SGOT. More studies are needed to confirm the clinical impact of these findings and to optimize the management of weaning from artificial respiratory support during the course of VV-ECMO.
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Additional information: The e-Appendix, e-Figures, and e-Tables can be found in the Supplemental Materials section of the online article.

References


