Extracorporeal Life Support Organization (ELSO)

Identification and management of recirculation in venovenous ECMO

Authors:
Darryl Abrams, MD (New York, US)
Daniel Brodie, MD (New York, US)

Editors:
Nicolas Brechot, MD, PhD – Adult Cardiac Content Editor (Paris, France)
Eddy Fan, MD, PhD – Adult Respiratory Content Editor (Toronto, Canada)
Vin Pellegrino, MBBS, FRACP, FCICM - Adult Section Editor (Melbourne, Australia)
Dan Brodie, MD – Managing Editor (New York, US)

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Extracorporeal Life Support Organization (ELSO) Clinical Guideline

Key words and abbreviations

CVL central venous line
ECMO extracorporeal membrane oxygenation
IVC inferior vena cava
SVC superior vena cava
SaO₂ saturation of arterial blood
Sₚₒ₂ saturation of blood entering the membrane oxygenator
Sₚₒ₂ saturation of blood leaving the membrane oxygenator
SvO₂ saturation of venous blood returning to the vena cavae
Overview

Recirculation is a phenomenon, exclusive to venovenous ECMO, in which reinfused oxygenated blood is withdrawn through the drainage cannula without passing through the systemic circulation. Because recirculated blood does not contribute to systemic oxygen delivery, its presence decreases the efficiency with which ECMO provides oxygenation. Whether the amount of recirculation has clinical significance, and whether it requires intervention, depends on the degree to which the patient is dependent on ECMO for oxygenation.

Of note, recirculation should be distinguished from differential venous oxygenation that may occur in venoarterial circuits when there is residual native cardiac output and impaired native gas exchange. Poorly oxygenated blood will supply the upper body whereas the lower body will be perfused by well-oxygenated blood. The well-saturated blood returning to the IVC may be taken up by the drainage cannula, a phenomenon that may be interpreted as a form of recirculation. However, because the blood has already passed through the systemic circulation prior to reuptake by the circuit, this does not constitute recirculation in the classical sense.

Factors affecting recirculation

Cannula configuration and positioning

In two-site venovenous ECMO with femoral and internal jugular cannulation, the reinfusion jet is directed toward the drainage port. When the drainage and reinfusion cannulae are in closer proximity, one can expect a higher amount of recirculation. Changes in patient positioning may likewise affect the amount of recirculation, though this relationship is less predictable.

Pump speed, cannula size, and extracorporeal blood flow

Increases in pump speed and ECMO blood flow rate correlate with increases in recirculation, with varying relationships depending on cannula type, size, and position, and method used to measure recirculation. The use of larger cannulae may mitigate the amount of recirculation by allowing for higher blood flow rates with less negative venous pressure in the drainage limb.

Changes in intra-thoracic, intra-cardiac, and intra-abdominal pressures

Increases in intra-thoracic and intra-cardiac pressure (i.e. pneumothorax, pericardial tamponade) will impede venous return to the heart, which may preferentially direct reinfused extracorporeal blood flow toward the drainage cannula, increasing recirculation. Extreme elevations in these pressures may lead to cessation of extracorporeal blood flow altogether. Effects on increased intra-abdominal pressure are less well defined.
Direction of ECMO blood flow

In two-site venovenous ECMO with femoral and internal jugular cannulation, the direction of drainage and reinfusion impacts the amount of recirculation. Femoral drainage and atrial reinfusion via the internal jugular vein (femoro-atrial flow) results in less recirculation than femoro-atrial flow, making femoral drainage and atrial reinfusion the preferred direction of blood flow for this configuration.\(^\text{10}\)

Identifying and quantifying the amount of recirculation

Percent recirculation is quantified by the following equation:

\[
\text{Recirculation (\%)} = \frac{(S_{\text{preO}_2} - \text{SvO}_2)}{(S_{\text{postO}_2} - \text{SvO}_2)} \times 100;
\]

However, SvO\(_2\) is difficult to measure because of the presence of reinfused oxygenated blood. Several methods have been used to quantify the amount of recirculation (Table 1). None of these methods has been definitively shown to accurately measure the percent recirculation, though trends in each of these values, in conjunction with assessments in SaO\(_2\), may be useful in identifying changes in the amount of recirculation and, therefore, efficiency of the ECMO circuit over time.

<table>
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<tr>
<th>Method of estimating % recirculation</th>
<th>Description</th>
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| CVL\(^4,11,12\)                      | Formula: \(\frac{(S_{\text{preO}_2} - \text{SvO}_2)}{(S_{\text{postO}_2} - \text{SvO}_2)} \times 100\)  
SvO\(_2\) estimated by measuring venous saturation of blood from SVC or IVC via central venous catheter |
| SvO\(_2\)^\(4,5,11\)                 | Formula: \(\frac{(S_{\text{preO}_2} - \text{SvO}_2)}{(S_{\text{postO}_2} - \text{SvO}_2)} \times 100\)  
SvO\(_2\) = S\(_{\text{preO}_2}\) when sweep gas turned off and ventilator used to achieve an equivalent SaO\(_2\) |
| Ultrasound dilution\(^12\)           | Saline injected into reinfusion limb; ultrasound sensor detects differences in dilution between drainage and reinfusion limb |
| Thermodilution\(^6\)                 | Cold saline injected into reinfusion limb; thermistor-tipped catheter detects changes in temperature in drainage limb |
| Trending S\(_{\text{preO}_2}\)^\(13,14\) | Observation of changes in S\(_{\text{preO}_2}\) and SaO\(_2\) over time; increasing S\(_{\text{preO}_2}\) and decreasing SaO\(_2\) suggest clinically relevant recirculation |

Table 1. Methods of estimating the amount of recirculation
Interventions to reduce recirculation

Increasing distance between cannulae

Increasing the distance between drainage and reinfusion ports in a two-site venovenous ECMO configuration, by withdrawing one or both cannulae, is the most direct way to reduce the amount of recirculation. However, there is no standard distance that should be maintained between ports. Chest radiography and ultrasonography may be used to assess cannula positioning. It is recommended that the femoral drainage cannula be positioned with the side ports in the hepatic IVC, as this portion of the IVC is least likely to collapse and impede venous drainage when under negative pressure. Maintaining this position may limit how far the drainage cannula can be withdrawn. Any manipulation of cannulae requires that close attention be paid to the $S_{\text{preO}_2}$, blood flow, and negative venous pressure.

Alterations in ECMO circuit configuration

- Use of a bicaival, dual-lumen cannula

  Bicaival dual-lumen cannulae permit venovenous ECMO via a single venous access site. When properly positioned, which usually requires both echocardiographic and fluoroscopic guidance, drainage ports are located in the SVC and IVC and the reinfusion jet is directed toward the tricuspid valve. Recirculation with this configuration may be as low as 2%, although malposition of the cannula may significantly increase the rate of recirculation. Any adjustment of the cannula after its initial insertion should be done under echocardiographic guidance to ensure appropriate orientation of the reinfusion jet.

- Addition of a drainage cannula

  Given the relationship between pump speed, negative venous pressure and recirculation, an additional drainage cannula may permit comparable blood flow rates to be achieved at lower pump speeds and at less negative pressure, thereby lowering the amount of recirculation.

- Manipulation of the reinfusion cannula

  Attempts have been made to alter the reinfusion cannula in a two-site configuration in order to direct the reinfusion jet toward the tricuspid valve, with or without simultaneous repositioning of the drainage cannula. Given the limited data, such approaches are not generally recommended.
References


Figures

![Figure 1. Impact of recirculation on effective blood flow. At higher circuit flows, recirculation increases and effective circuit blood flow decreases. Reproduced from Abrams D, Bacchetta M, Brodie D. Recirculation in venovenous extracorporeal membrane oxygenation. ASAIO J. 2014;In press.](image-url)