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Modifying a Venovenous Extracorporeal Membrane Oxygenation Circuit to Reduce Recirculation

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Lung rest is the primary goal of venovenous extracorporeal membrane oxygenation for severe acute respiratory failure. To achieve this there has to be adequate extracorporeal flow. This can be achieved by a two-cannula technique in most cases. In some cases, extra flow is either not achievable or causes excessive recirculation. We report 8 patients in whom we achieved adequate blood and oxygen delivery using a three-cannula technique. Five patients survived (62.5%).

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Percutaneous venovenous extracorporeal membrane oxygenation (ECMO) is a promising therapy for severe acute respiratory failure (ARF) unresponsive to conventional treatment in adults [1–4]. It is a high-flow technique, with one drainage cannula and one return cannula. Gas exchange with large surface area membrane oxygenators allows lung rest [3]. The standard two-cannula technique can usually achieve lung rest in most patients [5]. However, sometimes this is not possible because of inadequate venous drainage, limiting the amount of extracorporeal support. Unfortunately, as blood flow is increased, recirculation also increases, such that a higher flow does not always achieve better oxygenation.

In 8 patients with this problem, the ECMO cannulation was reconfigured with two drainage cannulas and one return cannula. This allowed higher flows, reduced recirculation and ventilation, and achieved lung rest.

Technique

Standard Two-Cannula Venovenous Technique

Blood is drained from the right atrium through a cannula (28 F, 35 cm venous cannula, DLP, Grand Rapids, MI) in the right internal jugular vein (RIJV) and is returned via a cannula (21 F femoral arterial cannula, DLP) in the left femoral vein (LFV). Our ECMO circuit has been described previously [2]. Once maximum ECMO flow is achieved, ventilation is gradually reduced to allow lung rest. Rest ventilator settings are: pressure control, inspiratory pressure 20 to 25 cm H_2O, end-expiratory pressure 10 cm H_2O, rate 10/min, and 30% oxygen [2]. Thereafter, flow and sweep gas are adjusted to keep arterial saturation more than 85% with normocapnia. If rest settings cannot be achieved, the drainage cannula is checked radiologically and repositioned if necessary. Blood is transfused if required. If rest settings still cannot be achieved within 2 to 3 days, standard perfusion is converted to modified perfusion.

Modified Perfusion Technique

One hundred centimeters of 3/8-inch polyvinyl chloride tubing is connected to the bridge by the Y connector. An additional long cannula (28 F, 70 cm femoral venous cannula, DLP) is inserted percutaneously into the right femoral vein (RFV). The cannula tip is placed in the inferior vena cava (IVC), just below the right atrium (40 cm). The patient is hand ventilated with 100% oxygen, the bridge is declamped, and both return and drainage lines are clamped, separating the patient from ECMO. The return tubing is cut 30 cm from the return cannula, and the distal end is connected to the new cannula. Both return and drainage lines are declamped and the bridge is clamped; ECMO is restarted. The proximal cut end of the tubing is connected to the new tubing, so that drainage is from both the RIJV and LFV (Fig 1). Cannula placement is confirmed radiologically. The patient is put back on mechanical ventilation, which is gradually weaned to rest settings.

Comment

Between May 1997 and February 1998, we treated 27 adults (mean age, 41.3 ± 11.1 years; mean weight, 78.2 ± 24.2 kg) with severe ARF (mean PaO_2/FIO_2 ratio, 64.7 ± 31 mm Hg) (mean ECMO duration, 246.1 ± 220.6 hours). All patients received venovenous ECMO; 18 survived (66.7%).

Of these 27 patients, 8 were converted to modified perfusion (29.6%). The characteristics of these patients were: male, 6 (75%); age, 41.4 ± 9.2 years; body weight, 90.9 ± 23.4 kg; pre-ECMO PaO_2/FIO_2 ratio, 62.7 ± 33.9; and total perfusion, 293.6 ± 220.2 hours. The indication for additional cannula placement was the inability to

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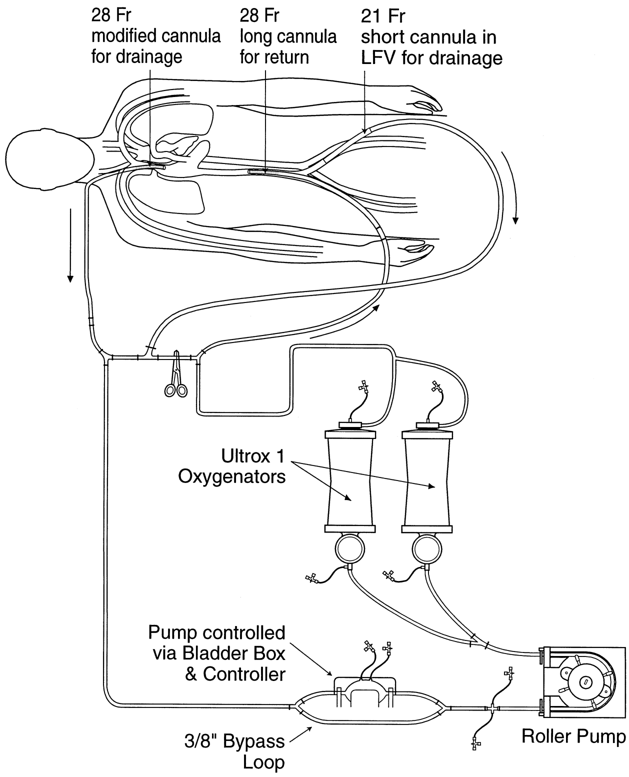

Fig 1. Modified venovenous perfusion. Blood is drained from two cannulas placed in the right internal jugular vein and left femoral vein (LFV) *(which was previously used as the return cannula). Arterialized blood is returned to the high inferior vena cava through the new longer cannula placed through the right femoral vein.*

achieve resting ventilator settings. Rest settings were achieved in the patients receiving the two-cannula technique at 5.2 ± 5.2 hours of ECMO; at this time, flow was 3.89 ± 0.78 L/min and PaO_2 was 53.7 ± 6.2 mm Hg. In 1 patient rest settings were achieved at 9 hours of ECMO, but he subsequently deteriorated, requiring a third cannula at 145 hours. This patient is included in the analysis of survival and demographics but is excluded from the subsequent data as an outlier.

In the remaining 7 patients the third cannula was inserted at 21 ± 13.9 h of ECMO. Before insertion patients were receiving 87.2% ± 13% oxygen, peak airway pressure 29.4 ± 3.7 cm H_2O, and end-expiratory pressure 11.0 ± 3.6 cm H_2O; ECMO flow was 4.62 ± 0.53 L/min giving a PaO_2 of 45.8 ± 11 mm Hg. One hour after the third cannula insertion ECMO flow had increased to 5.12 ± 0.82 L/min. Rest settings were achieved 6.9 ± 6.9 h after addition of the third cannula and 33.1 ± 20.1 h after initiation of ECMO. ECMO flow on rest settings was 4.99 ± 0.87 L/min giving a PaO_2 of 55 ± 4.4 mm Hg. Lung rest was achieved in all patients; 5 survived (62.5%).

Because the second drainage cannula is in the desaturated iliac region and is separated from the return cannula high in the IVC, recirculation is reduced, greatly improving oxygenation. Withdrawal of the jugular venous drainage cannula so that its orifice is at the superior vena cava/right atrium junction also reduces recirculation. It is possible that using a long arterial cannula instead of the multihole venous cannula as the return line could further reduce recirculation; unfortunately, such a device is not available. As a result of the additional cannula, venous drainage was improved, thereby facilitating diuresis or hemofiltration. Venoarterial ECMO was avoided. One patient suffered a hematoma due to puncture of the right femoral artery. No major complication related to modified perfusion was observed, specifically there was no leg edema. The cause of death in both groups was irreversible pulmonary fibrosis and multiple organ dysfunction.

This technique allows higher blood flows and reduces recirculation during venovenous ECMO, thereby allowing sufficient reduction in ventilator settings to achieve lung rest.

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