Case Report

Pumpless Extracorporeal Lung Assist

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ABSTRACT

Extracorporeal lung assist (ECLA) is an established form of treatment for acute pulmonary insufficiency. Classically, it takes the form of veno-venous bypass. The femoral vein and the subclavian vein are favored cannulation sites. Blood is pumped with either a roller or a centrifugal pump. Sometimes heparin-coated cannulae, membrane oxygenators (MO), and tubing are used, which may significantly reduce the risk of bleeding. A device pumping 1.0 to 4.0 liters per minute nevertheless signifies a persistent mechanical stress for the cellular blood components and causes some degree of hemolysis.

A 42 year old patient with acute pancreatitis and marginal clotting parameters developed profound pulmonary insufficiency. All modes of mechanical ventilation were exhausted and proved to be inadequate. Under good hemodynamic conditions, an arterio-venous pumpless ECLA was instituted for a duration of 10 days, when the patient could be successfully weaned. The membrane oxygenator was connected via cannulae in the femoral artery and femoral vein.

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INTRODUCTION

Acute pulmonary insufficiency is a known and dreaded complication of pancreatitis (1). It can develop into a full Adult Respiratory Distress Syndrome (ARDS) picture, which carries a high mortality. Also common in adult pancreatitis is moderate to severe clotting abnormalities (2). The institution of a classic extracorporeal membrane oxygenation (ECMO) system with either a centrifugal or roller pump in this setting can result in disastrous bleeding complications.

This case report presents a patient who developed acute refractory pulmonary insufficiency secondary to acute pancreatitis, which was not responsive to conventional mechanical ventilation. Additionally, he suffered a progressive deterioration in clotting parameters. The patient had, however, an excellent hemodynamic status, which prompted the installation of a pumpless, arteriovenous, extracorporeal lung assist (ECLA).

Figure 1: Arterial paO$_2$, paCO$_2$, and oxygen fraction (FiO$_2$) of the ventilator as a function of time

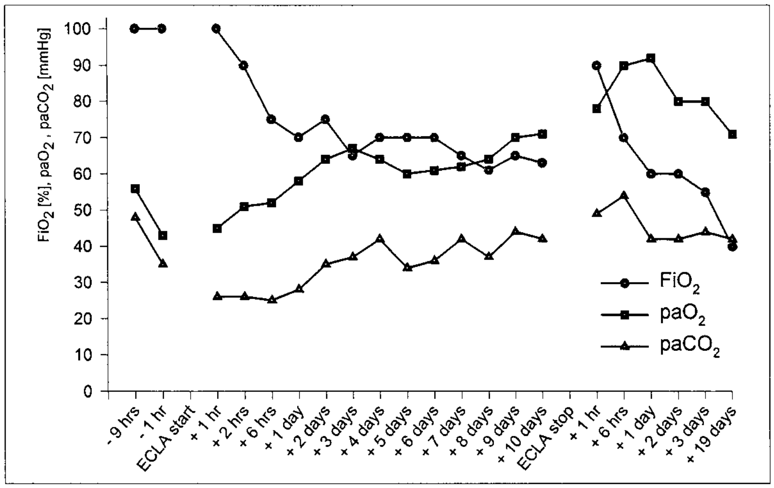
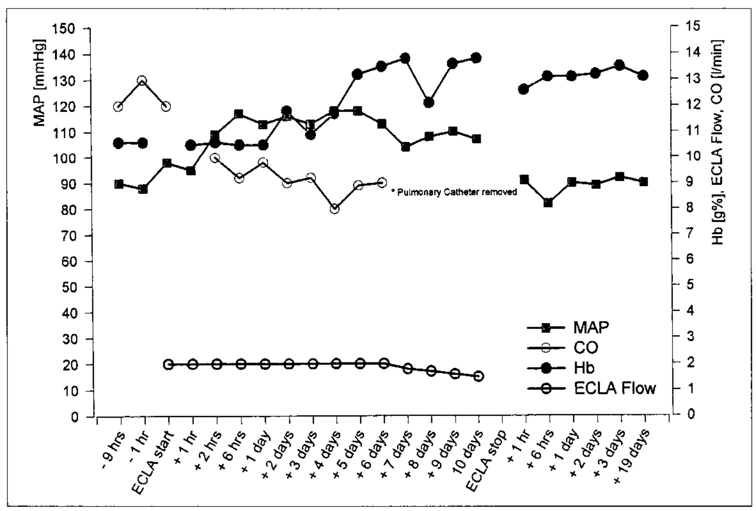


Figure 2: Mean arterial pressure, cardiac output, hemoglobin, and flow through the MO, over the course



CASE REPORT

A 42 year old male patient was admitted to the hospital with acute abdominal distress. Initial clinical signs and laboratory results pointed to an acute pancreatitis (lipase 1860 U/L). Presumed causative factors were known alcohol abuse and profound hyperlipidemia (cholesterol 1100 mg/dl, triglyceride > 1000 mg/dl) present on admission. Biliary pancreatitis was excluded. The day following admission, the patient developed worsening respiratory function, requiring intubation and mechanical ventilation.

Sonographic and CT investigation showed a thickened edematous pancreas with peri-pancreatic exudate as well as a small amount of ascites around the liver and spleen. Conventional X-ray and CT investigation of the lungs showed bilateral diffuse infiltrations. Bronchoscopy was macroscopically normal. Culture of bronchoscopically obtained secretions yielded staphylococcus aureus initially, and later enterococcus, citrobacter freudii and candida albicans, which were antibiotically treated according to sensitivity. The patient's pulmonary function, however, progressively deteriorated over the next three days, despite intensive medical treatment. Maximum ventilatory support proved to be inadequate, despite pressure controlled inverse-ratio ventilation, FIO$_2$ of 1.0, PEEP of 13 cm H_2O, and peak pressures > 40 mmHg at these settings. Pulmonary shunt fraction was 39%. Hemodynamically, the patient was hyperdynamic with a cardiac output (CO) of 9.7 L/min (cardiac index 4.1 L/min/m^2) and a peripheral vascular resistance (PVR) of 533 dynes·cm^{-5}. The decision was made to place the patient on pumpless ECLA, taking into consideration the excellent cardiac function and the deteriorating clotting parameters with an additional profound decrease in platelet count.

With initiation of ECLA, ventilatory settings could be progressively reduced with simulaneous improvement in patient oxygenation (Figures 1-3). Interestingly enough, conventional X-ran and CT investigation of the lung did not significantly change during the duration of the ECLA run. Clinical parameters, however, continued to improve, and the ECLA could be discontinued on day 10. Ventilatory support was continued via tracheostomy until day 37. On day 41, the patient was transferred in good clinical condition to rehabilitation.

Figure 3: Laboratory values

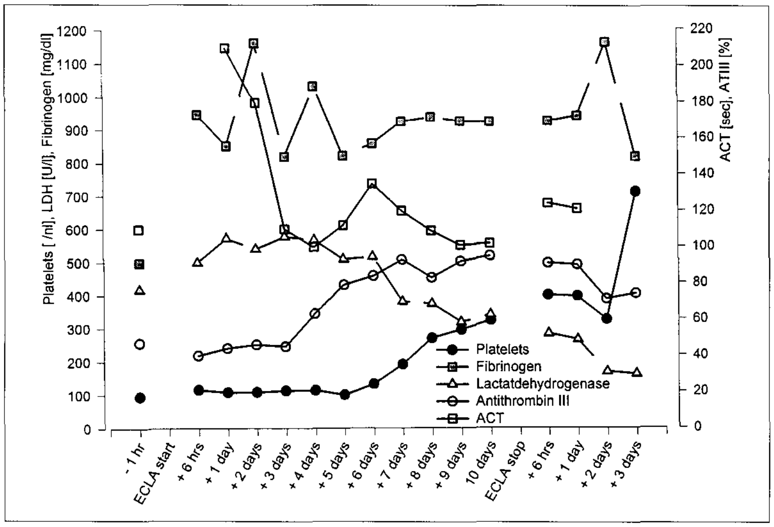
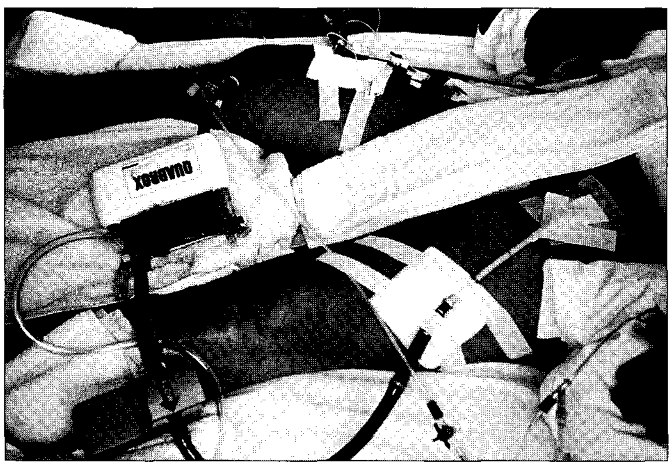


Figure 4: Pumpless ECLA in situ



MATERIALS AND METHODS

The ECLA circuit we used consisted of the following materials: Quadrox bioline low pressure MO[a], 2 x 30 cm 3/8" PVC heparin-coated tubing, Flow Probe Bioactive 3/8"[b] and femoral cannulae set[b] (Arterial 96535-017, Venous 96605-021). Following the administration of 50 IU/kg heparin, the cannulae were inserted into the femoral artery and femoral vein using the Seldinger technique. The two pieces of PVC tubing with the integrated flow sensor were attached to the oxygenator, which was primed with an isotonic saline solution (total priming volume 300 ml). The system was attached to the cannulae via two straight 3/8" connectors with luer lock connectors to facilitate intermittent sampling of arterial and venous blood gases. First, the arterial cannula was connected, and potential microbubbles were eliminated over the vent port of the oxygenator. Then the venous cannula was attached and flow was initiated. Gas flow was set at 8-10 L/min with an FIO_2 of 1.0. The ACT was kept just slightly above the normal range at 120 to 130 sec by continuous low dose heparin administration. As the system was positioned between the patient's thighs (Figure 4), heat loss was negligible, and a heater/cooler was not necessary.

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DISCUSSION

ECLA usually consists of varying lengths of PVC tubing, a pump and one or two membrane oxygenators (MO). Sometimes a reservoir is included (3, 4). The type of MO usually employed is the microporous capillary membrane oxygenator. To improve hemo- and biocompatibility, the components are heparin-coated (5). Duration of function of these membrane oxygenators is relatively limited with an average of 1 to 6 days. An explanation for this is the destruction of the hydrophobic surface of the microporous capillary during long term use. When the surface becomes hydrophilic, plasma can enter the microporous capillaries, and the effluent may exit at the gas outlet. This leakage interferes with gas exchange and also poses a risk of infection.

In contrast, silicone membrane oxygenators possess a good long-time functional capacity of 1 to 2 weeks on average. One disadvantage, however, is their low efficiency in terms of gas transfer, which has to be compensated for by a large surface area of approximately 4.5-9.0 m^2, and so two oxygenators are usually used. Poor flow dynamics are another disadvantage with a pressure drop across the oxygenator of the blood side of greater than 170 mmHg at a blood flow of 5 L/min. Microporous capillary membrane oxygenators, on the other hand, display a pressure drop of about 40 to 100 mmHg at a comparable blood flow, depending on the type. The limiting factor in the long-term use of centrifugal pumps is primarily thrombotic plaque formation. From approximately the third day on, thrombus formation can be detected in the pump head despite coating and systemic (low dose) heparinization. The manufacturer recommends a changeout after 4 to 6 days. One of the problems in using roller pumps is degeneration of the pump segment (6, 7). Furthermore, ECLA produces a hemolysis necessitating the transfusion of 1 to 2 units of packed cells per day.

With certain hemodynamic and respiratory conditions, the use of a pumpless ECLA can be considered. Prospective candidates require good hemodynamic function with a sufficiently high cardiac output, some residual respiratory function, and femoral vessels of sufficient caliber, which ideally are assessed beforehand by doppler sonography. The sum pressure determinants for actual flow in the extracorporeal system can be expressed by the following formula:

$$\text{Driving force} = \text{MAP} - \text{pd art. cannula} - \text{pd MO} - \text{pd ven. cannula} - \text{CVP}$$

where MAP = mean arterial pressure, CVP = central venous pressure, and pd = pressure drop = resistance to flow.

Use of a 17 Fr arterial cannula results in a flow of about 2 L/min, provided the MAP is between 90 and 100 mmHg. A higher MAP does not produce a higher flow in our experience, whereas a MAP below 90 mmHg results in noticeably decreased flow. The Quadrox Bioline oxygenator has a pressure drop of about 10 mmHg under clinical conditions at a blood flow rate of 2.0 L/min. The amount of oxygen which can be delivered to the patient via this arterio-venous extracorporeal shunt lies in the range of 90 to 100 ml/O_2/min. The relatively slow blood flow through the oxygenator results in a very effective CO_2 elimination (8). Also advantageous is the pulsatile flow. The resulting turbulence in the oxygenator reduces thrombus formation which in turn prolongs the duration of function. On termination of the ECLA after 10 days, the pO_2 measured post oxygenator was still > 500 mmHg and there was no sign of effluent from the oxygenator vent port. Macroscopic examination showed minimal thrombotic plaque formation around the outer edges of the oxygenator.

In conclusion we feel that pumpless ECLA is an acceptable form of treatment for a select group of patients suffering therapy resistant profound pulmonary insufficiency. The drastic reduction in the extracorporeal circuitry minimizes blood trauma and potential technical problems. Oxygen supply and CO_2 elimination at a blood flow rate of approximately 2 L/min is effective enough to allow reduction in ventilatory settings to tolerable levels to aid lung recovery.

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