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Case Report Open Access

Use of Extracorporeal CO_2 Removal to Avoid Invasive Mechanical Ventilation in Hypercapnic Coma and Failure of Noninvasive Ventilation

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Abstract

Invasive mechanical ventilation is known to be detrimental to patients with respiratory failure due to acute exacerbation of chronic obstructive pulmonary disease (AECOPD). If hypercapnic respiratory failure and acidosis cannot be controlled by noninvasive mechanical ventilation, extracorporeal carbon dioxide removal ($ECCO_2R$) serves as an alternative option. Currently applied systems like extracorporeal membrane oxygenation (ECMO) or pumpless extracorporeal lung assist (PECLA) are associated with potentially significant bleeding complications and require a very high nursing standard. We report a case of AECOPD with hypercapnic coma and failure of noninvasive ventilation for which we used a novel low-flow $ECCO_2R$ device, called the Hemolung Respiratory Assist System. This device requires only a single 15.5 French double-lumen venous catheter and operates at blood flows of 350 mL/min to 550 mL/min. Use of this device enabled the patient to avoid general anesthesia and invasive mechanical ventilation without adverse events. In addition, weaning from noninvasive mechanical ventilation, early mobilization, communication and nutrition were facilitated. CO_2 removal with low extracorporeal blood flow avoided intubation in the treatment of hypercapnic coma with failure of non-invasive ventilation.

Keywords: COPD; Acute exacerbation; Hypercapnic coma; Extracorporeal carbon dioxide removal; $ECCO_2R$; Hemolung

Case Presentation

Chronic obstructive pulmonary disease (COPD) is projected to become the third most common cause of death in the world by 2020 [1]. Its prevalence is still increasing [2], mainly caused by demographic changes [3]. As its prevalence increases, it can be expected that the number of patients with acute exacerbations of COPD (AECOPD) requiring intensive care and mechanical ventilation will increase accordingly. Noninvasive mechanical ventilation (NIV) has been established as the primary mode of respiratory support for AECOPD patients with hypercapnia and respiratory acidosis [4]. However, carbon dioxide levels often cannot be sufficiently reduced. Consequently, respiratory acidosis and rapid shallow breathing can persist due to a high respiratory workload. In the event of NIV failure, intubation and controlled mechanical ventilation become inevitable [5-12]. Despite its necessity, invasive mechanical ventilation in patients with COPD is associated with a poor prognosis [13-15].

In recent years, extracorporeal carbon dioxide removal ($ECCO_2R$) has proven to be an effective alternative to invasive mechanical ventilation for AECOPD patients who are failing support with NIV [16-19]. Methods of $ECCO_2R$ include pumpless extracorporeal lung assist (pECLA), veno-arterial and veno-venous extracorporeal membrane oxygenation (av- and vv- ECMO), and more recently, low-flow $ECCO_2R$ systems. These treatments are mainly used in ECMO centers due to the potential for severe adverse events which include bleeding and hemorrhagic complications associated with the need for anticoagulation therapy, as well as air embolism and blood clotting.

The Hemolung Respiratory Assist System (ALung Technologies, Pittsburgh, PA, United States) is a new $ECCO_2R$ device with low extracorporeal blood flows that was recently introduced and successfully applied in a pilot study of patients experiencing AECOPD [20]. Unlike earlier conventional $ECCO_2R$ systems, the Hemolung RAS requires only one venous 15.5 French (F) double lumen catheter that can be inserted either in the femoral vein or the right jugular vein. Decarboxylation takes place through an innovative membrane cartridge integrated with a centrifugal pump that operates at blood flow rates of 350 mL/min to 550 mL/min.

We report the case of a patient with AECOPD in a persistent hypercapnic coma where $ECCO_2R$ with the Hemolung was able to avoid invasive mechanical ventilation, and to enable successful treatment of the coma and the acute exacerbation.

Case Description

A 72-year-old Caucasian woman with a long history of severe COPD (GOLD 4, nocturnal home ventilation therapy since 2012) and with a Do-Not-Intubate (DNI) order was brought to our emergency room in July 2013 in a hypercapnic coma (Glasgow Coma Score, GCS, of 3), most likely caused by acute exacerbation of chronic obstructive pulmonary disease. On admittance pH was 6.97 and arterial CO_2 blood gas tension ($PaCO_2$) exceeded the upper detection limit (>150 mmHg). The patient received immediate maximal anti-obstructive treatment with corticosteroids, fast-acting bronchospasmolytics and noninvasive mechanical ventilation. She was hemodynamically stable with a high respiration rate of 28 breaths per minute and an impaired oxygen saturation of 88% on oxygen with an inspired fraction (FiO_2) of 30%. After 30 minutes of treatment the arterial blood gas tension showed a pH=7.13, $PaCO_2$=139.3 mmHg and PaO_2=59 mmHg. At this point the patient was still nearly unconscious and was transferred to our intensive care unit for further treatment.

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In accordance with the DNI and in light of the high predictive mortality for patients with severe COPD who fail noninvasive ventilation and require intubation and invasive mechanical ventilation [13], we decided to initiate treatment with the Hemolung $ECCO_2R$ system. A 15.5 F double-lumen catheter was inserted into the patient's left femoral vein and $ECCO_2R$ was started with blood flow rates of 370 mL/min. The device was well tolerated and did not impair the hemodynamic stability of the patient. Systemic anticoagulation was initiated with unfractionated heparin.

Within the first hour of the Hemolung treatment, $PaCO_2$ levels declined from 109 mmHg to 89 mmHg (Figure 1). The level of consciousness improved constantly and after 25 minutes the patient was awake. As a result, subjective well-being increased. After a period of two hours, the $PaCO_2$ level was approximately 80 mmHg with a normalized pH. After four hours, $PaCO_2$ persisted at 65 mmHg with normalized pH until the end of the treatment. The Hemolung was weaned after seven days. After the fourth hour of treatment, Hemolung treatment was also compatible in facilitating oral nutrition, communication and early mobilization.

Over a period of seven days, weaning from NIV during the day was completed. $PaCO_2$ levels ranged from 41 mmHg to 61 mmHg with oxygen supplementation of 2 L/min to 4 L/min via nasal cannula (Figure 2). According to the patient's history of severe COPD, nocturnal ventilation via face mask was still necessary and well tolerated.

Severe adverse events did not occur during the treatment. However, hemoglobin levels gradually declined within the seven days of the Hemolung treatment. As a result, the patient received a total of two units of concentrated erythrocytes on the seventh day of treatment to increase hemoglobin to the established level of 10 mg/dL. Mild hemolysis with a decrease in hemoglobin is common in all extracorporeal elimination devices.

After a total of 11 days, the patient left our intensive care unit in a stable physical and mental state and moved to a normal ward. Her pulmonary function was still severely impaired due to her underlying severe COPD (FEV_1=20%, pH=7.45, PaO_2=76 mmHg, $PaCO_2$=56 mmHg with 2 L/min oxygen supplementation). She was able to walk around the hospital garden with her rollator when admitted to rehabilitation after 19 more days.

Discussion

This case demonstrates both the feasibility and efficacy of using the novel Hemolung low-flow $ECCO_2R$ system in the treatment of hypercapnic coma and failure of noninvasive mechanical ventilation in a patient with severe AECOPD. The need for intubation and in this case imminent death due to a DNI order was avoided. In addition weaning from NIV, early mobilization, communication and nutrition were facilitated. The device was well tolerated and serious adverse events did not occur. This is the first published case of an AECOPD patient with hypercapnic coma that was successfully treated with the Hemolung $ECCO_2R$ system.

Our results are encouraging with regard to the need for new modalities in the treatment of hypercapnic respiratory failure in AECOPD, since these patients are known to have a high mortality rate, especially when invasive mechanical ventilation is required. The Hemolung device evades common complications of more invasive extracorporeal therapies by the use of one venous catheter and low blood flow rates. Hence, it may be suitable for a broader range of applications in critical care medicine.

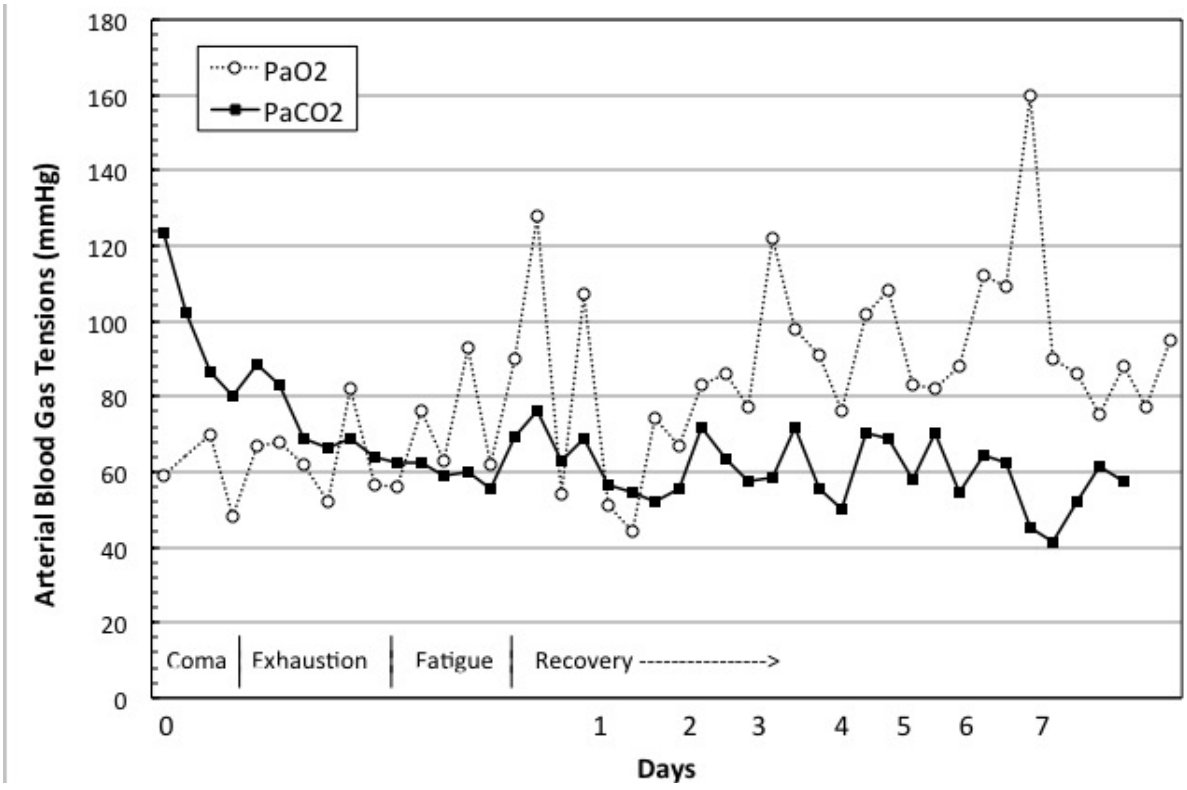

Figure 1: PaO_2 and $PaCO_2$ changes during $ECCO_2R$ treatment.

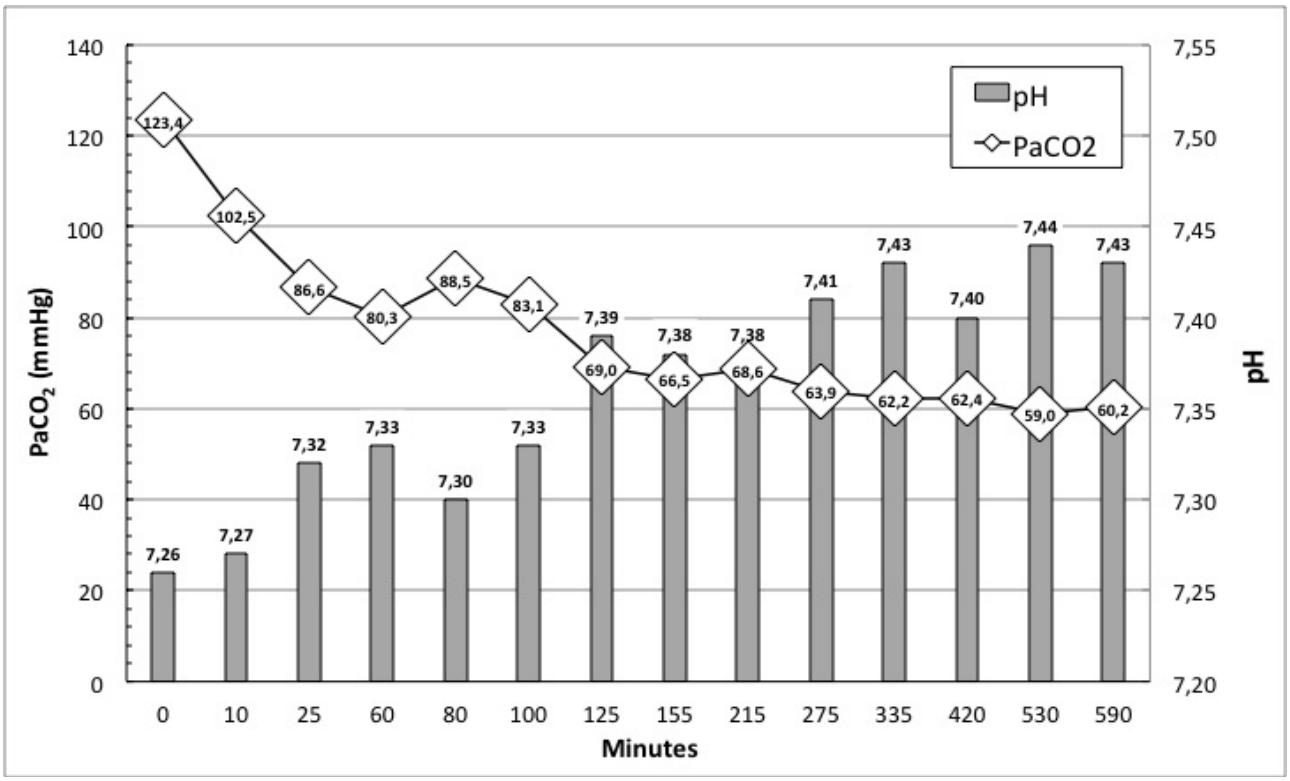

Figure 2: pH and $PaCO_2$ changes during $ECCO_2R$ treatment.

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