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KISA RAPOR
SHORT REPORT

Removal of extracorporeal carbon dioxide in chronic obstructive pulmonary disease patients

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SUMMARY

Removal of extracorporeal carbon dioxide in chronic obstructive pulmonary disease patients

The use of invasive mechanical ventilation (IMV) procedures in chronic obstructive pulmonary disease (COPD) patients suffering from episodes of acute exacerbation are associated with high rates of mortality. In this case study, we describe the use of a new device for extracorporeal carbon dioxide removal (ECCO2R) that can provide partial respiratory support for patients where noninvasive ventilation (NIV) proved insufficient. The case described in this manuscript represents the first clinical feasibility study for the Hemolung device, and was also the first use and application of the device at our department.

Key words: *Extracorporeal carbon dioxide removal, mechanical ventilation, chronic obstructive pulmonary disease*

ÖZET

Kronik obstrüktif akciğer hastalığı olan hastalarda ekstrakorporeal karbondioksit uygulaması

KOAH hastalarının akut alevlenmelerinde, invaziv mekanik ventilasyon kullanımında mortalite oranı yüksektir. Biz bu olguda noninvaziv mekanik ventilasyonun yetersiz kaldığı durumda extracorporeal carbon dioxide removal (ECCO2R) sistemi ile invaziv mekanik ventilasyonu birlikte kulanarak solunumsal destek sağladık. Bu sistem kliniğimizde ilk kez uyguladığımız bir sistem olduğu için olgumuzu literatür eşliğinde sunmayı planladık.

Anahtar kelimeler: *Ekstrakarporeal karbondioksit uygulaması, mekanik ventilasyon, kronik obstrüktif akciğer hastalığı*

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INTRODUCTION

In nearly all present-day societies, COPD is one of the main causes of human morbidity and mortality. COPD is currently the fourth leading cause of death around the world, and is expected to become the third leading cause of death by the year 2020 (1). In severe COPD patients, exacerbations are frequently associated with acute hypercapnic respiratory failure, which require ventilatory support and hospitalization (2). Despite advances in NIV procedures – which are now considered as the standard treatment for respiratory failure associated with acute COPD exacerbations – these methods prove insufficient in nearly 15-26% of patients with acute exacerbations, who consequently require a transition from NIV to IMV (3,4).

In this case report, we present and describe the application of a new ECCO2R device for partial respiratory support in patients where NIV support was not sufficient. Through a single 15.5 F veno-venous cannula inserted percutaneously into the left femoral vein, the Hemolung Respiratory Assist System (RAS (A Lung Technologies, Pittsburgh, Pa) provided ECCO2R through a blood flow rate of approximately 500 mL/min (5,6).

CASE REPORT

A 76-year-old man was admitted to our clinic for a severe COPD exacerbation. The patient has a long and ongoing smoking history of 35 pack-years, as well as a diagnosis of "Global Initiative for Chronic Obstructive Lung Disease" (GOLD) grade IV COPD, with the patient's forced expiratory volume in 1 second being 21% of its predicted value. The initial examinations we performed on the patient revealed that he was unable to form complete sentences due to breathlessness; the patient also had a continuous wheeze during expiration. The patient's serum C-reactive protein levels had also risen considerably to 132 mg/L, while a radiography of the chest revealed hyper-inflated areas within the lung.

Before being transferred to our clinical, the patient had already received at the referring hospital a conservative treatment including intravenous corticosteroids and antibiotics, oxygen supplementation, nebulized bronchodilators, and NIV for two hours. Following his transfer, the patient exhibited severe dyspnea, with a $PaCO_2$ of 110 mmHg, and a pH of 7.21. Following two hours of NIV, the patient's $PaCO_2$ rose to 91 mmH, while his pH fell to 7.19. However, the patient's condition continued to worsen, with gradually progressing tachypnea, increased effort required for breathing, and signs of significant exhaustion while on NIV. For this reason, the patient was transferred to our hospital's level 3 intensive care unit, where he received optimized lung protective ventilation. However, the patient's gas exchange continued to worsen, with significant hypercapnia and hypoxemia that increasingly required invasive ventilation. The patient was then evaluated and screened for the Hemolung trial, with the patient's informed consent being obtained regarding his inclusion into the study. The patient hemodynamically stable, and did not have any comorbidities. We inserted a 15.5 F femoral catheter into the left femoral vein without causing any complications, and by ensuring little or no blood loss. Heparin infusions were administered at 3-19 U/min to ensure anticoagulation, such that the activated clotting time (ACT) was maintained between 150 and 200 seconds. Throughout the treatment, a blood flow level between 420 and 500 mL/min was maintained through the extracorporeal circuit.

Almost immediately following the initiation of ECCO2R treatment with the Hemolung device, the breathing rate of the patient dropped to less than 10 breaths per minute. Arterial $PaCO_2$ dropped from 91 to 75 mmHg soon after the treatment was commenced, and remained between 55 and 50 mmHg for the remaining period of the treatment. Over the following three days of therapy, the patient's clinical status showed steady improvement.

Discontinuing MV was not possible at the beginning of the Hemolung therapy. The patient showed improvement in the ensuing three days; for this reason, he was simultaneously taken off of ECCO2R and weaned from mechanical ventilation. The catheter was removed from the patient, who was, at the time of removal, exhibiting normal coagulation values, as well as no additional bleeding. NIV treatment was intermittently used to support the patient. Patient was discharged five days after admission on home oxygen therapy and nocturnal NIV support. Data for the case are summarized in Table 1.

DISCUSSION

In cases where respiratory acidosis or severe dynamic hyperinflation persist even when conventional and optimal management are employed, the clinician

Table 1. Ventilatory and oxygenation parameters for patients before and after ECCO2R

	Pre	Post
Oxygenation parameters		
Inspired oxygen fraction	0.3	0.55
PEEP, cmH_2O	3	7
Arterial PaO_2, mmHg	35	61
Ventilatory parameters		
Plateau inspiratory pressure, cmH_2O	36	26
PEEP, cmH_2O	3	7
Tidal volume, mL	180	120
Tidal volume, mL/kg	4.0	2.5
Respiratory rate, per min	24	14
Minute volume, litres	4.6	3.1
Arterial $PaCO_2$, mmHg	91	75
pH	7.19	7.38
Arterial blood gases upon initiation of NIV [$PaCO_2$ (mmHg)/pH]	110/7.21	
Before initiation of Hemolung RAS (baseline)	91/7.19	
1 hour after initiation	75/7.31	
6 hours after initiation	65/7.35	
24 hours after initiation	54/7.38	
Time on Hemolung RAS (days)*	3	

should consider initiation ECCO2R for refractory hypercapnia. In this patient, we were able to correct respiratory acidosis by applying ECCO2R, thereby succeeding in decreasing the respiratory tidal volume and the respiratory rate, which had the effect of reversing the dynamic hyperinflation.

The ECCO2R method demonstrated significant removal of CO_2 in both mathematical and animal models, as well as in a small-scale phase I clinical trials (7,8). These models and studies showed the removal of CO_2 and blood-flow rates at approximately 112 mL/min and > 500 mL/min, respectively (9). Mathematical simulations show that, with a sweep gas-to-blood flow ratio > 5, and by using an extracorporeal shunt fraction that is 10% to 15% of cardiac output, it is possible to achieve total CO_2 removal (7). Quantification of CO_2 removal is possible by using capnometry or mass spectrometry, which involves employing the product of the sweep-gas flow rate and the fraction of expired CO_2 (7). The patient illustrated the difficulties associated with a case exhibiting hypercapnia that required ECCO2R. Mani et al. previously described the use of the Hemolung RAS for providing temporary partial, low-flow ECCO2R ventilatory support during an acute COPD exacerbation, where standard support involving NIV proved insufficient (10).

The main risks associated with low-flow extracorporeal support that utilizes the Hemolung RAS device include possible complications stemming from the central venous cannulation and the employed anticoagulation treatment (thrombosis, bleeding, coagulopathy). However, these risks are comparatively less problematic than those related to extracorporeal membrane oxygenation (ECMO) therapy, since the ECCO2R method is associated with a lower priming volume, a lower blood flow, the elimination of the need for arterial cannulation, a lower membrane surface area, the use of a single dual-lumen catheter, and other technological advances relating to this method. The ECMO method, on the other hand, necessitates the use of complex technology and procedures that can be hazardous for the patients. In the case we described, there were no serious complications caused from the Hemolung treatment. However, it is still important to bear in mind and avoid overlooking the potential risks of extracorporeal therapy, and careful monitoring is required to minimize them. The potential risks of the method must also be considered against its potential benefits; similarly the clinician should take into consideration the risks associated with the standard treatment and the underlying disease (11).

The Hemolung RAS can be used at the bedside fairly easily, and its operation and maintenance does not require additional resources in terms of respiratory treatment and nursing. ECCO2R has a less complicated circuit compared to ECMO devices, and does not require a pump. Consequently, we were able to use the Hemolung RAS without a full ECMO team being required, and with the system being primed and inserted by a single clinician.

This present case demonstrated that the Hemolung RAS can safely and effectively remove CO_2 through a venous configuration with single cannula, while requiring very little anticoagulation treatment. COPD patients experiencing severe exacerbations benefit from treatments that provide maximum expiratory time, and which thereby reduce airway and intrathoracic pressures, the occurrence of barotrauma, and the occurrence of hyperinflation/air trapping. Although permissive hypercapnia is usually well tol-

erated, it often requires the patients to be heavily sedated. Using ECCO2R and reducing both hyperinflation and hypercapnia may lead to a considerable decrease in respiratory drive, while also reducing sedation requirements and enabling a higher tolerance of invasive ventilation. It is possible that, if administered at a sufficiently early stage, ECCO2R can serve as an alternative to ventilation support procedures during acute exacerbations of COPD accompanied by respiratory failure/complications. In contrast to NIPPV, no synchronization is necessary for ensuring the smooth and effective functioning of ECCO2R. Finally, an approach that would seem both interesting and useful for many respiratory physicians is the possibility of utilizing short-term ECCO2R in severely hypercarbic patients suffering from acute lung disease-related reversible exacerbations – where non-invasive ventilation is insufficient for providing adequate treatment, while invasive mechanical ventilation is not suitable in terms of potential complications. Whether such methods have a noticeable effect on the quality of life in the long term is not known. There is consequently a clear need to conduct further randomized trials in order to assess the clinical efficacy of ECCO2R.

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