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Extra Corporeal co2 Removal in Critical Care : A Review

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Abstract

Hypoxia and hypercapnia are the consequences of respiratory failure. Correcting hypercapnia with a low risk of ventilator induced lung injury has drawn the attention of the researchers to extracorporeal technologies that facilitate extracorporeal CO2 removal (ECCO2 R). In this review article, we briefly discussed the definition, the physiology of ECCO2R and its role as an adjunct to mechanical ventilation in acute respiratory distress syndrome. In patients with chronic obstructive pulmonary disease, when noninvasive ventilation fails, ECCO2R could be an alternative to mechanical ventilation. Patients awaiting lung transplantation, who are more prone to life threatening hypercapnia, benefit from ECCO2R.

Keywords :

Introduction

Respiratory failure refers to a condition in which the respiratory system is unable to maintain adequate gas exchange to satisfy metabolic demands. An important syndrome leading to respiratory failure in critically ill patients is the acute respiratory distress syndrome (ARDS), which leads to poor lung function with hypoxemia, hypercapnia, and low respiratory system compliance. In these conditions, mechanical ventilation provides adequate oxygenation and facilitate CO2 removal. Nonetheless, ventilation occurs at the expense of a secondary injury to the lung (ventilator-induced lung injury or VILI) due to inhomogeneous lung over distension. In this situation, inflammatory mediators are released and cause multiple organ failure. Ultra protective ventilation strategy employs lower tidal volumes, a lower respiratory rate, lower driving pressures, and lower plateau pressures while maintaining an adequate mean airway pressure to avoid a reduction in functional residual capacity. However, the strategy puts its user at the risk of hypercapnia and its consequences include systemic and cerebral vasodilatation, cardiovascular depression, arrhythmia, and pulmonary vasoconstriction with an increase in pulmonary arterial pressure. Acute pulmonary hypertension increases right ventricular (RV) afterload and causes acute cor pulmonale which is associated with high mortality rates [12]. The need to correct hypercapnia without exposing the lung to mechanical trauma has drawn the attention of the researchers to extracorporeal CO2 removal (ECCO2 R).

Definition and physiology of ECCO2R:

ECCO2 R is a technique of partial respiratory support that removes CO2 from the blood through a low blood flow (0.4–1 L/min) extracorporeal circuit, without any significant effect on blood oxygenation. Consider that extracorporeal membrane oxygenation (ECMO) uses blood flows of 3–7 L/min to provide total respiratory support with significant oxygenation and CO2 removal. In many expert centers the devices used to provide ECMO and ECCO2R support are the same. Although the original purpose for ECCO2R was to provide additional CO2 clearance in patients with severe ARDS to reduce tidal volumes and inspiratory pressures, it can also be employed for the patients suffering from Chronic Obstructive Pulmonary Disease (COPD) and work as a bridge to transplant or facilitate thoracic surgery.

Blood oxygenation is dependent on blood flow, whereas CO2 exchange is dependent on ventilation, gas flow, blood CO2 content, hemoglobin [13] and the efficacy of the gas exchange membrane.

An ECCO2R circuit consists of a drainage cannula placed in a large central vein (or artery), a membrane lung, and a return cannula into the venous system. In the case of arterio venous (AV) systems, the patient's blood pressure provides the driving pressure across the membrane, while veno venous systems require a pump to be placed within the circuit. (Figure 1, 2) [26]

Access to the circulation is obtained either through separate arterial and venous cannula (AV systems or pump less systems) or by using double-lumen cannula (VV systems).

Figure : 1

Figure : 2

The AV system needs two single-lumen wire reinforced cannula, one in the femoral artery to access blood and one in the femoral vein to return the blood to the venous side. Dis advantages of this cannula are arterial injury and limb ischemia which is thought to relate to operator experience, patient factors such as peripheral vascular disease, and the size of arterial cannula. The venous cannula is usually larger than the arterial cannula to reduce resistance to blood flow. They can be placed in any large central vein although the jugular and femoral approaches are most commonly used [14]. Some cannulae have heparin coatings to decrease the risk of thrombosis.

Evidence shows that by using ECCO2R, PaCO2 can be reduced and arterial pH due to respiratory acidosis improved [15]. AV ECCO2R has also been shown to reduce minute ventilation in an uncontrolled cohort of 159 patients over 10 years [16]. Similarly VV ECCO 2 R can effectively decrease PaCO2, tidal volume and airway pressures in patients with ARDS [17,18].

The role of extracorporeal CO2 removal as an adjunct to mechanical ventilation in ARDS:

Dominant features of ARDS include injury to the alveolar-capillary membrane, which results in severe hypoxemia, decrease in pulmonary compliance, and increase in pulmonary vascular resistance [1,2]. Despite new hopeful therapeutic interventions such as protective ventilation, prone positioning, use of neuromuscular blockers and conservative fluid balance, ARDS remains a devastating disease [3,4]. Mortality rates are still remains near 40%, because of hemodynamic complications of this syndrome [5]. Positive-pressure mechanical ventilation is the important part of symptomatic treatment for ARDS [3], but may further increase pulmonary hypertension and right ventricular (RV) afterload, leading to acute cor pulmonale and RV failure [6]. Mechanical ventilation induces additional lung injuries due to overdistention, repeated stretch to the alveoli, atelectotrauma, and increased inflammatory mediator levels [7]. Ventilation strategy involving limitation of mean tidal volume to 6 ml/kg, as compared with a more traditional tidal volume of 12 ml/kg [3], shows a reduction in mortality. However, utilization of lower tidal volumes leads to permissive hypercapnia. Indeed, the need to substantially reduce tidal volume and improve the outcome in ARDS patients remains questionable [8]. As the discussion about optimization of mechanical ventilation in ARDS patients continues, extracorporeal CO2 removal (ECCO2R) come up. Modern technology used for optimization, could effectively remove metabolically produced CO2 while permitting significant reductions in minute ventilation in preclinical [9,10] and clinical settings [11]. Specifically, combination therapy using reduction in tidal volumes to around 4 ml/kg along with ECCO2R has been shown to effectively manage permissive hypercapnia in ARDS [11]. In moderate to severe ARDS, ECCO2R should be considered as a therapeutic adjunct which is combined with further decrease in tidal volume. Recent major technological improvements in devices make them simpler, safer, less invasive and more efficient, requiring lower blood flow rates and smaller access cannulas with reduced anticoagulation requirements.

$ECCO_2R$ as an alternative to mechanical ventilation when noninvasive ventilation fails in COPD:

In severe COPD exacerbations, hypercapnia is the result of high airway resistance, ventilation/perfusion mismatch, dynamic hyperinflation,and increased work of breathing with increased CO2 production.

ECCO2R is being considered as an adjunctive therapy to noninvasive respiratory support (NIV) to promote the withdrawal of NIV, avoid intubation, or facilitate early extubation. The feasibility of using VV ECCO2R for acute hypercapnic respiratory failure due to COPD exacerbations has been demonstrated in several recent cases and cohort studies [19-22].

In a retrospectively propensity matched cohort study it was found that AV ECCO2R could consistently decrease PaCO2

, improve respiratory acidosis, and reduce respiratory rate in 21 patients suffering from acute hypercapnic respiratory failure (mainly COPD) who were failing NIV [23]. In this study 90% of the patients treated with AV ECCO2R did not require intubation and invasive mechanical ventilator support, and showed a tendency towards a reduced length of hospital stay, but not mortality.

There has been a recent retrospective cohort study using historical controls reported from Italy where 25 patients at high risk of NIV failure who received ECCO2R via a dual-lumen cannula in the femoral vein. They experienced lower intubation rates (HR 0.27) and a lower mortality [24]. But 36% of patients experienced device malfunctions and 12% of patients had bleeding complications, including one vessel perforation.

ECCO2R can be a bridge to transplant

The Patients awaiting lung transplantation, who are prone to life-threatening hypercapnia, may benefit from ECCO2R as bridge to transplantation. The mortality of patients with an acute deterioration requiring mechanical ventilation is substantially increased when compared with those patients who do not require mechanical ventilation. The possible advantages of ECCO2R are the avoidance of intubation and mechanical ventilation.

In a study of 20 patients, the most common underlying diagnoses were reported to be bronchiolitis obliterans syndrome, cystic fibrosis, and idiopathic pulmonary fibrosis, Hypercapnia and acidosis were corrected in all patients within the first 12 h of ECCO2R therapy: nineteen patients (95%) were successfully transplanted. Hospital and 1-year survival were 75 and 72%, respectively [25].

ECCO2R and complementary continuous renal replacement therapy (CRRT)

In patients with acute kidney injury (AKI), volume overload and activation of inflammatory factors with excretion of cytokines, induce apoptosis of pulmonary cells endothelium, leads to respiratory distress. On the other hand, in acute lung injury, hypoxia, hypercapnia and respiratory acidosis could lead to AKI. Increasing the level of positive end-expiratory pressure (PEEP) cause decreasing cardiac output and renal blood flow which follows by renal cell apoptosis. Considering, atrial natriuretic peptide production suppress, so oliguria and volume overload occurs. In respiratory distress, pro inflammatory cytokines could cause renal injury too. As a result continuous renal replacement therapy (CRRT) is needed. Addition of gas exchanger to this renal circuit could combine ECCO2R and CRRT, leads to protection against respiratory distress effect and acidosis. Patients usually require several central venous catheters; there for using a single pathway for ECCO2R and CRRT might be beneficial. (28, 29)

Conclusion:

Technological advances in ECCO2R, can create an opportunity for an extended role of partial extracorporeal CO 2 removal. For patients with moderate-severe ARDS and patients with hypercapnic respiratory failure, it can serve as a supportive modality. The potential complications of ECCO2R need to be assessed when considering patients for extracorporeal support.

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