Extracorporeal carbon dioxide removal (ECCO$_2$R) in respiratory deficiency and current investigations on its improvement: a review

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Received: 4 December 2015 / Accepted: 5 May 2016 © The Japanese Society for Artificial Organs 2016

Abstract The implementation of extracorporeal carbon dioxide removal (ECCO$_2$R) as one of the extracorporeal life support system is getting more attention today. Thus, the objectives of this paper are to study the clinical practice of commercial ECCO$_2$R system, current trend of its development and also the perspective on future improvement that can be done to the existing ECCO$_2$R system. The strength of this article lies in its review scope, which focuses on the commercial ECCO$_2$R therapy in the market based on membrane lung and current investigation to improve the efficiency of the ECCO$_2$R system, in terms of surface modification by carbonic anhydrase (CA) immobilization technique and respiratory electrodialysis (R-ED). Our methodology approach involves the identification of relevant published literature from PubMed and Web of Sciences search engine using the terms Extracorporeal Carbon Dioxide Removal (ECCO$_2$R), Extracorporeal life support, by combining terms between ECCO$_2$R and CA and also ECCO$_2$R with R-ED. This identification only limits articles in English language. Overall, several commercial ECCO$_2$R systems are known and proven safe to be used in patients in terms of efficiency, safety and risk of complication. In addition, CA-modified hollow fiber for membrane lung and R-ED are proven to have good potential to be applied in conventional ECCO$_2$R design.

The detailed technique and current progress on CA immobilization and R-ED development were also reviewed in this article.

Keywords Extracorporeal carbon dioxide removal (ECCO$_2$R) · Extracorporeal life support · Carbonic anhydrase immobilization · Respiratory electrodialysis

Introduction

Respiratory failure is characterized by inadequate gas exchange process in the human body due to dysfunctionality of one or more vital organs that is important in the respiratory system. There are several diseases that can lead to respiratory failure, such as acute respiratory distress syndrome (ARDS), chronic obstructive pulmonary disease (COPD), asthma and many more. To cope up with these fatal diseases, different treatments have been employed to reduce the mortality rate of patients with respiratory failure, including non-invasive ventilation (NIV) [1–4], endotracheal intubation [5, 6], mechanical ventilation [5, 7, 8] and also extracorporeal life support (ECLS). ECLS is a technique that involves the process of blood removal from patients and circulates it through a membrane lung via a pump [9]. Even though ECLS is the most sophisticated method in dealing with respiratory failure, it is usually implemented as a salvage therapy, where it is used only when the other respiratory procedures such as NIV, endotracheal intubation and mechanical ventilation failed [10–12]. The earliest ECLS therapy that has been introduced is extracorporeal membrane oxygenation (ECMO). The first successful attempt in clinical use of ECMO to an adult was recorded in 1971 by Dr. Donald Hill [13], where a 24-year-old polytrauma patient with ruptured aorta survived after