

Extracorporeal membrane oxygenation using a modified cardiopulmonary bypass system

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TO THE EDITOR

Extracorporeal membrane oxygenation (ECMO), also known as an “artificial lung” or extracorporeal life support (ELS), provides continuous extracorporeal respiration and circulation for patients with severe cardiopulmonary failure. ECMO is suitable for cardiorespiratory arrest, acute severe heart failure, and acute severe respiratory failure arising from various causes. However, access to ECMO machines is limited, even in highly populated areas, and many hospitals do not have any ECMO access.^[1] According to the data of the Chinese Society of Extracorporeal Life Support committee, in 2018, ECMO was used to treat approximately 4000 patients in the ELS centers of 260 hospitals in China.^[2]

During the coronavirus disease 2019 (COVID-19) pandemic, ECMO is often used as a last resort “lifesaver” in the treatment of critically ill patients with COVID-19. It has been recommended by the World Health Organization, the Surviving Sepsis Campaign, and the Extracorporeal Life Support Organization (ELSO) for patients with acute hypoxic respiratory failure caused by COVID-19.^[3-8] During the pandemic, the demand for ECMO in local hospitals, and thus the market demand for ECMO equipment, increased sharply, but its market supply has remained limited. As a result, many patients have not been able to receive the best possible care. Here, we describe a case from

April 2021, in which a cardiopulmonary bypass system (CBS) was successfully used instead of a combination of ECMO and continuous renal replacement therapy (CRRT) to treat a patient who experienced refractory cardiogenic shock after coronary artery bypass grafting (CABG) at our hospital.

A 67-year-old male had undergone CABG due to three-vessel coronary artery disease and severe stenosis. Immediately after surgery, the patient exhibited hemodynamic instability. His blood pressure dropped to 68/30 mmHg and he had severely low cardiac output (CO) of 1.2 L/min, with an ejection fraction (EF) of 21%. With high doses of vasopressors and intra-aortic balloon pump (IABP), it was still difficult to maintain the blood pressure and ECMO was urgently needed to reverse cardiogenic shock. However, the only ECMO machine in our hospital was in use, and the urgency of the patient’s condition did not allow for the transfer of ECMO equipment from outside the hospital. After discussion among the ECMO team members, the decision was made to convert the CBS of the operating room into an ECMO alternative. The centrifugal pump head of the CBS was used to drive the blood flow, similar to the centrifugal pump on an ECMO, using a HILITE 7000 LT oxygenator (Medos, Stolberg, Germany) as the membrane oxygenator. Thus, an ECMO machine alternative was assembled in a short time (Figures 1 and 2).

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Figure 1: The modified cardiopulmonary bypass system from the front.



Figure 2: The modified cardiopulmonary bypass system from the back.

After the establishment of the modified CBS, the hemodynamics of the patient improved rapidly and the respiration and circulation stabilized. However, the patient had severe systemic edema. In order to treat the edema, we used the roller pump of the CBS to connect a hemoconcentrator downstream of the membrane oxygenator for dehydration treatment (slow continuous ultrafiltration [SCUF]). After dehydration, the blood was returned to the front of the membrane oxygenator (Figure 3). In order to control the extent of dehydration, we attached an infusion pump to the hemoconcentrator and controlled the speed of dehydration by regulating the pump speed. On the second day, the patient's serum creatinine increased to 232 $\mu\text{mol/L}$, indicating acute renal injury. CRRT was needed, but we did not have any more available CRRT equipment. Instead, we connected a hemofilter to the CBS roller pumps, downstream of the

membrane oxygenator and the hemoconcentrator (Figure 3). The pump speed and flow were controlled using the CBS control panel. The blood passed through the CRRT filter, and the filtered blood and replacement fluid were infused back in front of the membrane oxygenator. With the combined ECMO and CRRT provided by the modified CBS, the patient's circulation gradually stabilized and the machine was removed successfully on the sixth day after operation.

We describe the successful use of a modified CBS to provide prolonged ECMO and CRRT. As most hospital operating rooms are equipped with CBS, this could be used to widely increase access to ECMO treatment. Particularly during a shortage of ECMO machines, CRRT, and other equipment due to a pandemic situation, CBS can replace the heart, lung, and kidney functions of patients and provide the opportunity to save lives.

In addition to increasing access, our strategy integrates the functions of ECMO, CRRT, and SCUF, reducing the complexity of pipeline connections and the chance of nosocomial infection. ECMO draws blood from a large vein and passes it through an oxygenator, where a membrane allows for exchange of oxygen and carbon dioxide.^[9] The oxygenated blood is returned to an artery, effectively circulating the blood without relying on cardiac function, replacing both the heart and lungs. CBS not only uses similar pumps to provide the same function during surgery, but also includes additional pumps that can be used to connect other treatments in series with the oxygenator. Combining these functions potentially limits the risk of infection and complications while allowing for the combination of treatments required for critically ill patients to recover.

CBS may successfully be used to provide ECMO and other life support to patients in the absence of available standard technology. This technique expands the access to life-saving treatment and provides new ideas for the development of integrated life support equipment in the future. Further studies are needed to compare the safety and efficacy of existing ECMO and other individual treatments to modified CBS providing those treatments in series.

Consent to Participate

The authors certify that they have obtained all appropriate consent forms from the guardians of the patient.

Conflict of Interest

The authors declare that they do not have any competing interests.

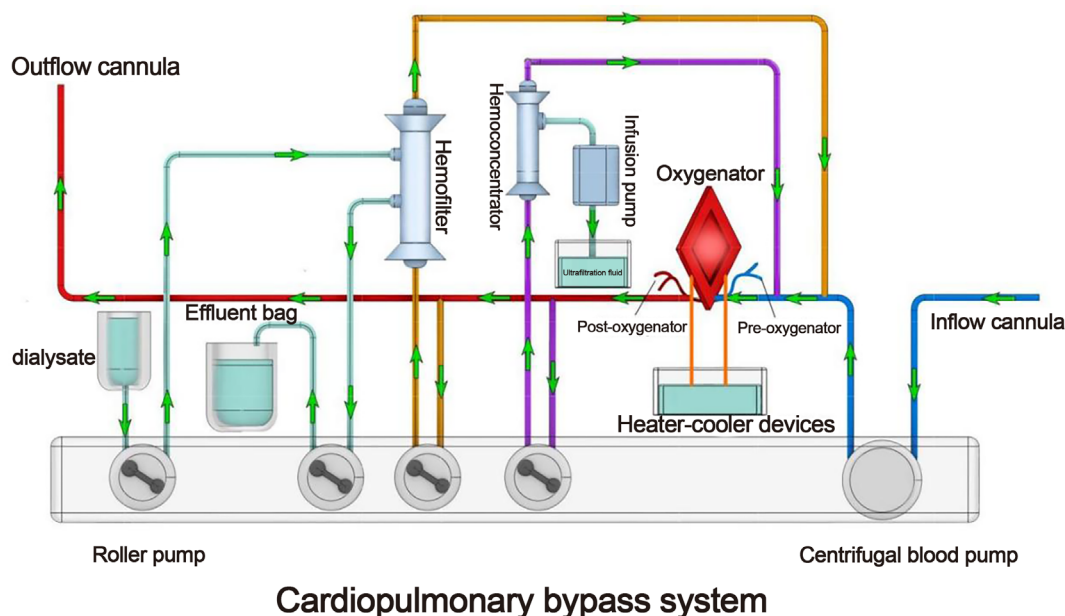


Figure 3: Schematic for the modified cardiopulmonary bypass system with ECMO, CRRT, and SCUF functions. CRRT: continuous renal replacement therapy; ECMO: extracorporeal membrane oxygenation; SCUF: slow continuous ultrafiltration.

Authors' Contributions

Wang C contributed to the conception, Song X and Wang H contributed to the design, Song X and Wang H contributed to the drafting of the article, Wang C and Kashani KB contributed to the critical revision of the article for important intellectual content, and Wang C gave the final approval for the article. The authors read and approved the final manuscript.

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