

Review

# Minimal Invasive Extracorporeal Circulation (MiECC) in Cardiac Surgery: A Narrative Review

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**Abstract:** The heart remained a mystery for many years and was considered surgically untouchable. With the use of extracorporeal circulation, there has been a revolution in this area. Due to its mechanical components and interactions with blood, cardiopulmonary bypass (CPB) can cause significant changes in the body. Factors such as contact between artificial materials and blood, continuous flow, hemodilution, hypothermia and anticoagulation affect all organs during CPB, and may result in various complications. The minimally invasive extracorporeal circulation (MiECC) system was developed to minimize the contact of blood with air and foreign surfaces during conventional CPB. In addition, the biocompatibility of the components that make up the MiECC circuits increased, which reduced the inflammatory response. The absence of a venous reservoir and shorter lines allow the prime volume to be used to decrease, which also reduces the damage to the blood elements, and consequently, the need for blood transfusion. The MiECC system also has its downsides, the most important one being the difficulty in removing the air that can enter through the venous line, the impairment of the pump function, and embolization. During the use of these systems, perfusion safety and communication with the whole team must be at the highest level. In line with this information, the use of these systems can become standard in cardiac surgery with new technological additions.

**Keywords:** Extracorporeal Circulation, Cardiopulmonary Bypass, Minimally Invasive, Pump, Heart Surgery

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## 1. Introduction

### 1.1. Historical Development of Cardiopulmonary Bypass

The heart remained a mystery for many years and was considered surgically untouchable. Although studies on extracorporeal circulation date back to the 19th century, clinical applications in this area were realized only in the middle of the 20th century [1].

Physiologists' interest in blood circulation in the 19th century led to the study of isolated organs. The first design of artificial circulation was determined by Le Gallois in 1813. Brown-Séquard obtained oxygenated blood by mixing air and blood between 1848 and 1858. Ludwig and Schmidt developed a device that could infuse blood and provide better perfusion of isolated organs in 1868. Von Schroeder developed a primitive bubble (oxygenator) in 1882 consisting of a reservoir containing venous blood. In 1885, Von Frey and Gruber demonstrated that the perfusion solution could be oxygenated with an artificial heart-lung system without interrupting blood flow [2].

One of the notable events in cardiac surgery is the clinical use of heparin, which enabled the utilization of the extracorporeal circulatory system. Heparin was discovered by Mc. Lean in 1916, when he was a medical student at the time, and its commercial production began in the 1920s. In the 1930s, the first clinical studies began. In the same years, Olson and Chargoff discovered that the effect of heparin could be neutralized with protamine [1]. Another important discovery enabling cardiac surgery was that of the ABO blood group system by Landsteiner in 1900. This enabled safe transfusion and eliminated many problems related to blood incompatibility [2].

The first isolated organ perfusion was reported by Loebell in 1849. Gibbon Jr. started making a machine for extracorporeal circulation in Boston in 1934. The first description of this system was published in 1937. Gibbon developed the first model of the heart lung machine in 1949 and the second model in 1951. After several unsuccessful attempts in 1952, the first successful surgical intervention on the heart (closing an atrial septal defect) was performed on 6 May 1953 using the cardiopulmonary bypass (CPB) system [3].

### **1.2. Extracorporeal Oxygenators and Pumps**

Various models have been classified for adequate oxygenation, which has brought about numerous problems, including hemolysis, foaming, and synthesis and release of vasoactive substances. Several oxygenators have been developed over time, i.e., film oxygenators, roller oxygenators, screen oxygenators, disc oxygenators, bubble oxygenators and modern membrane oxygenators used today. Cardiopulmonary bypass pumps are classified in two categories according to their mechanisms: Roller pumps and kinetic (centrifugal) pumps. The first roller pump was developed in 1855 by Porter and Bradley. In 1934, DeBakey made some changes that allowed its use for blood transfusions, and its commercial use began in 1955. The first centrifugal pump was developed by Denis Papin in the late 17th century. Rotary wing design was developed in England in 1851 by John Appold. The working principle of centrifugal pumps is based on fluid engineering [2].

### **1.3. Complications of Cardiopulmonary Bypass**

Due to its mechanical components and interactions with blood, CPB can cause significant changes in the body. Factors such as contact between artificial materials and blood, continuous flow, hemodilution, hypothermia and anticoagulation affect all organs during CPB, and may result in various complications. The main complications of CPB include bleeding, low cardiac output, arrhythmias, respiratory failure, renal failure, neurological or neuropsychiatric changes, fluid and electrolyte imbalances, hemolysis, systemic inflammatory response syndrome, and inflammation [4, 5].

## **2. Minimally Invasive Extracorporeal Circulatory System**

The minimally invasive extracorporeal circulation (MiECC) system was developed to minimize the contact of blood with air and foreign surfaces during conventional CPB. It is also aimed to reduce the inflammatory response by further increasing the biocompatibility of the components that make up the MiECC circuits [6]. The minimally invasive extracorporeal circulation system consists of a centrifugal pump, membrane oxygenator, heparin-coated shortened circuits and a vacuum line that can be added as needed [7].

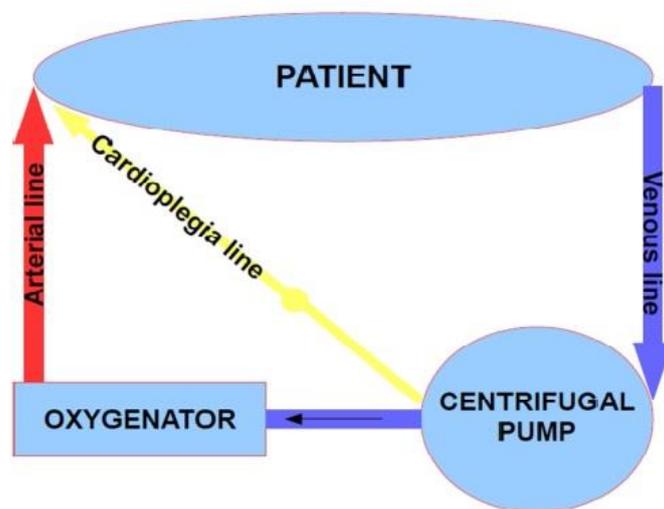
The venous reservoir and standard vacuum line present in the conventional CPB system are not included in this circuit. Due to the lack of a reservoir, the blood from the venous system is not collected anywhere. In the classical MiECC system, there is no contact with air and there is a completely closed circuit. As a result, damage to the blood elements is prevented. The absence of a venous reservoir and shorter lines allow the prime volume to be used to decrease. In these fully closed, heparin-coated and biocompatibility enhanced circuits, the heparin dose is half the dose administered in conventional CPB (150 IU / kg). Both the smaller prime volume and the lower dose of heparin allow a decrease in hemodilution, perioperative blood loss and need for blood transfusion during CPB in

patients who receive MiECC [4, 8]. It has also been shown to have positive effects on platelet functions [9]. The first publication regarding its use in coronary bypassgraft surgery was published in 2004. In this study, 30-day mortality was similar to that reported in the conventional method, and the need for blood transfusion was decreased [10].

**2.1. MiECC Circuit Types [11]**

**2.1.1. MiECC type I**

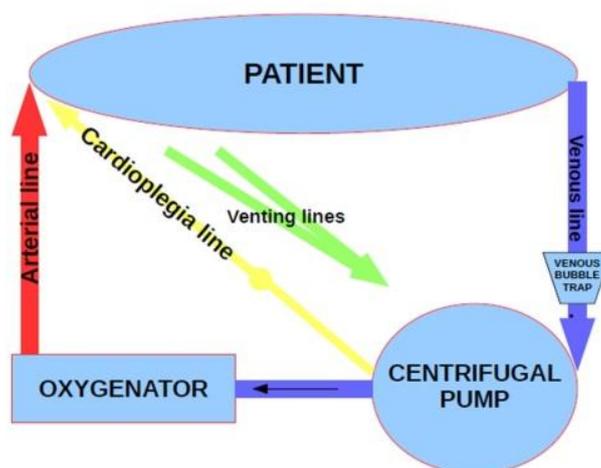
It consists of a closed circuit containing the oxygenator and pump. The circuit does not have an open venous reservoir. All components of the MiECC circuits are coated with heparin and the length of the tubing lines is significantly reduced. Its fundamental areas of use include extracorporeal life support (ECLS) and coronary artery bypass graft (CABG) surgery. It consists of a closed tube line, centrifugal pump, and a membrane oxygenator (Figure 1)



**Figure 1.** Type I minimal invasive extracorporeal circulation system

**2.1.2. MiECC type II**

Unlike type I, the MiECC type II circuit includes a venous bubble sensor and venous ventilation device. Additionally, the pulmonary artery vent system can be integrated into the MiECC type II circuit (Figure 2).



**Figure 2.** Type II minimal invasive extracorporeal circulation system

### 2.1.3. MiECC type III

In open heart surgery, there are times when blood and air interact more intensively. The modular setup of MiECC circuits needs to be adapted to such situations for aortic and mitral valve surgery. The main difference of MiECC type III from the first two systems is its ability to control volume changes more efficiently. A soft shell reservoir is integrated into the MiECC type III to correct excessive volume changes. In addition, pulmonary artery vent, aortic root vent and left ventricle vent systems can be integrated into the circuit of MiECC type III (Figure 3). These modifications help ensure a bloodless surgical field. One of the main principles during the use of MiECC type III is that blood within the soft shell reservoir can be re-transfused.

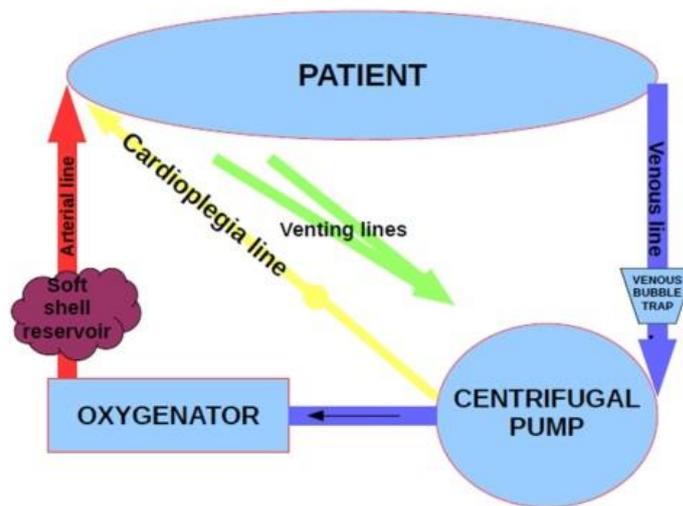


Figure 3. Type III minimal invasive extracorporeal circulation system

### 2.1.4. MiECC type IV

In this type, a rigid additional venous reservoir is added to the venous drainage system of Type III (Figure 4). Thus, the extracorporeal circuit system is made open. This system allows better blood management.

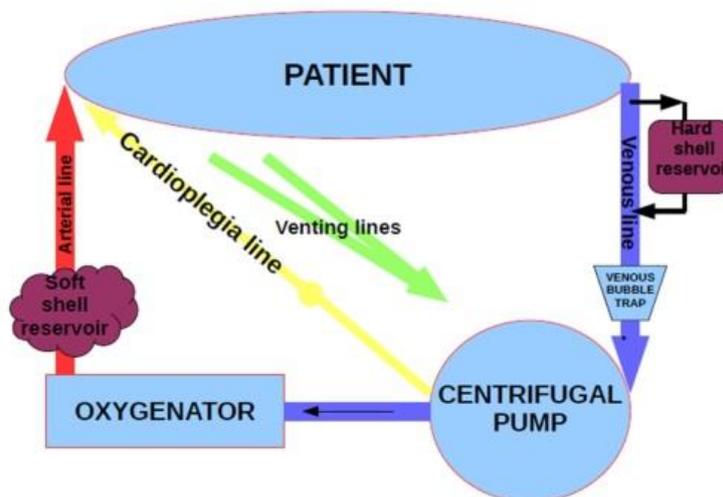


Figure 4. Type IV minimal invasive extracorporeal circulation system

## 2.2. Advantages and Disadvantages of MiECC

Despite the risks, this system provides a safe procedure in cardiac surgery because it reduces systemic inflammatory response and morbidity. Since contact with the artificial surface is decreased, endothelial damage, granulocyte sequestration and activation are much lower. In addition, it is a small circuit, resulting in less hemodilution and less blood loss compared to conventional CPB, and consequently the need for blood and blood products is reduced. Thus, when MiECC is used, organs are better protected, and lower mortality rates are obtained. It is also more advantageous in terms of myocardial protection [4, 12]. In a study, aimed to compare patients who underwent CABG with MiECC (N = 1053) and CECC (N = 373) by perioperatively evaluating the myocardial markers (cardiac troponin I [CTnI]) and inflammatory markers. They found that CTnI and inflammatory markers (interleukin-6, SC5b-9) were significantly lower in the MiECC group. Also, patients who underwent CABG with MiECC had faster recovery times. They emphasized that the MiECC system is a safe perfusion technique for CABG [13].

The advantages of MiECC include a less activated hemostatic system, lower degrees of thrombin production and thrombocyte activation, requirement of a lower hemodilution level, decreased biochemical changes, reduced blood loss and the need for allogeneic blood transfusion, lower thromboembolic complications, and postoperative atrial fibrillation rate. It is also safer for lung and kidney function [7]. Anastasiadis *et al.* conducted the analysis of randomized controlled trials to evaluate the results of conventional extracorporeal circulation (CECC) and MiECC in terms of mortality and major adverse cardiovascular events in patients undergoing cardiac surgery. In this meta-analysis, they included a total of 2,770 patients in 24 studies with at least 40 patients each. The use of MiECC significantly decreased the rate of postoperative mortality (0.5% vs. 1.7%,  $P = 0.02$ ), myocardial infarction (1.0% vs 3.8%,  $P = 0.03$ ) and neurological events (1.0% vs 0.5%,  $P = 0.02$ ), along with systemic inflammatory response, decrease of hematocrit due to hemodilution, blood transfusion need, peak troponin levels, inotropic support need, peak creatinine level, postoperative atrial fibrillation, mechanical ventilation duration and duration of intensive care. [14].

Soykan *et al.* aimed to examine the results of the MiECC system in terms of reducing the inflammatory response in their prospective observational study. They hypothesized that this system could reduce excessive pathological scarring after surgery. To examine this hypothesis, they compared patients who received MiECC with those who received CECC with dexamethasone in terms of pathological hypertrophic scar development in the postoperative period. They demonstrated that the MiECC system did not reduce hypertrophic scar formation compared to CECC with dexamethasone, but MiECC use was more beneficial than CECC due to circulatory and immunological advantages, and treatment with dexamethasone could be skipped [15].

Cardiac surgery is a major operation, and the aim is to provide maximum benefit with minimal damage. Many cardiac surgical interventions can be performed with very low mortality and morbidity with cardiopulmonary bypass systems. However, it is not possible to completely avoid complications related to CPB. Especially in high-risk patients, complication rates can be reduced with MiECC systems. Nowadays, it is important to reduce the costs of the treatments in addition to providing good health care. In a current study conducted in this field, MiECC and CECC were compared in terms of cost, in which a total of 354 patients, 118 in the MiECC group and 236 in the CECC group, were included. Clinical evaluations have shown that a cost reduction of £ 679.50 per patient can be achieved in the MiECC group [16].

The fact that the system has a structure that can collapse is an important disadvantage. One of the most important problems encountered in closed systems is the difficulty of removing the air that can enter through the venous line, the impairment of the pump

function due to air entry into the venous system, and subsequent embolization. Air embolization is the leading cause of neurological disorders in cardiac operations [4]. During the use of these systems, perfusion safety and communication with the whole team must be at the highest level.

### 3. Conclusion

Minimally invasive extracorporeal circulation system minimizes the contact of blood with air and foreign surfaces. In addition, the biocompatibility of the components that make up the MiECC circuits increased, which reduced the inflammatory response. The absence of a venous reservoir and shorter lines allow the prime volume to be used to decrease, which also reduces the damage to the blood elements, and consequently, the need for blood transfusion. Full enclosure, heparin coating, and increased biocompatibility provide less heparin use. It is also more advantageous in terms of myocardial protection. It provides a safe procedure because it reduces morbidity and mortality in cardiac surgery. The MiECC system also has its downsides, the most important one being the difficulty in removing the air that can enter through the venous line, the impairment of the pump function, and embolization. During the use of these systems, perfusion safety and communication with the whole team must be at the highest level. In line with this information, the use of these systems can become standard in cardiac surgery with new technological additions.

#### Ethics approval and consent to participate

Not applicable. This is a review article

#### Consent for publication

Not applicable.

#### Availability of data and material

Data sharing not applicable to this narrative review

#### Competing interests

We have no competing interest

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