

Minimal Invasive Extra-corporeal Circulation on End Stage Coronary Artery Disease Patients Undergoing Myocardial Revascularization

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Abstract

Background: Patients with coronary artery disease (CAD) undergoing myocardial revascularization, with concomitant heart failure defined by left ventricular ejection fraction (LVEF) lower than 35%, constitute a population at risk of poor long-term prognosis and limited survival. The benefits of minimal invasive extracorporeal circulation (MiECC) on end stage coronary artery disease patients undergoing myocardial revascularization has not been described and evidenced by scientific studies.

Materials and Methods: In this single-centre control study of 60 end stage coronary artery disease patients undergoing isolated coronary artery bypass grafting. The patients was divided in two contemporary groups: in group (MiECC), n= 30 coronary artery bypass grafting (CABG) was used MiECC, whereas, in group conventional extracorporeal circulation (cECC), n=30 CABG was used cECC.

Results: Procedures of Group MiECC reported (mean values) of a DO_{2i} of 305 mL/min/m² in relation to O_2ER_i 21.5% vs a DO_{2i} of 288 mL/min/m² in relation to O_2ER_i 25.6% was found in group MiECC vs cECC (p=0.037). Lactate levels >3 mmol/L were reported in 7 group MiECC patients vs 20 group cECC patients (p=0.038), with blood glucose peak. Mean nadir Hb values during CPB were 9.7 g/dL in group MiECC vs 7.8 g/dL in group cECC (p = 0.044). CI during CPB was 2.4 L/min/m² in both groups. Total red blood cell administration was 8 units in group MiECC vs 21 units in group cECC (p=0.022). A glycemc peak was recorded in 7 patients of group MiECC vs 20 patients of group cECC (p=0.037).

Conclusion: The MiECC technique on end stage coronary artery disease was associated with a higher DO_{2i} compared to cECC. MiECC patients showed a significant reduction in red blood cells units administration, in peak intraoperative lactate levels, which correlated with better postoperative renal outcome and shorter length of stay.

Introduction

Patients with coronary artery disease (CAD) undergoing myocardial revascularization, with concomitant heart failure defined by left ventricular ejection fraction (LVEF) lower than 35%, constitute a population at risk of poor long-term prognosis and limited survival [21]. Acute kidney injury (AKI) in this population frequently occur after cardiopulmonary bypass and the perioperative techniques and strategies selection could be crucial for the prevention.

The management and monitoring of metabolic parameters during extra-corporeal circulation has gained widespread adoption over the years, particularly in relation to the target values of oxygen delivery (DO_2) > 262 mL/min/m², carbon dioxide production > 5.3, indexed oxygen extraction ratio (O_2ER_i) < 25% [1–3], with average blood pressure values during cardiopulmonary bypass (CPB) of 50–70 mmHg. This has made it possible to reduce the incidence of postoperative acute kidney injury and to improve the management of aerobic vs anaerobic metabolism during cardiac surgery procedures. At the same time,

minimally invasive extra-corporeal circulation (MiECC) technologies have been developed and introduced into clinical practice [4].

The aim of this study was to compare MiECC vs conventional extra-corporeal circulation (cECC) in end stage coronary artery disease patients undergoing myocardial revascularization, in terms of superiority in relation to metabolic parameters (maximum DO_2 , lower O_2ER_i), red blood cell (RBC) consumption, duration of mechanical ventilation and peak postoperative serum creatinine.

Material And Methods

Population and study design

Between February 2020 and May 2021, 60 patients aged > 75 to 83 years with a mean EuroSCORE II of 9.1–9.5% and left ventricular ejection fraction (LVEF) lower than 35% undergoing myocardial revascularization at our institution. A retrospective comparison was carried out in terms of maximum DO_2 and $O_2ER_i < 25%$ for standard cardiac index value 2.4 (l/min/m²). The patients was divided in two contemporary groups: in group “MiECC”, n = 30 coronary artery bypass grafting (CABG) was used MiECC, whereas, in group “cECC”, n = 30 CABG was used cECC (Table 1). Metabolic management through blood gas analysis integrated with the use of a metabolic parameter monitoring system during CPB was adopted in both groups.

Table 1
Preoperative characteristics.

	Group MiECC (n = 30)	Group cECC (n = 30)
Age (years), mean	78.7	79.3
Male sex, <i>n</i> (%)	22 (73)	21 (70)
Body surface area (m ²), mean	1.79	1.78
Left ventricular ejection fraction (%), mean	28	29
NYHA class, median	3	3
EuroSCORE II	9.1	9.5
Pre-CPB Hct (%), mean ± SD	32.4 ± 1.2	32.6 ± 1.9
Pre-CPB Hb (g/dL), mean ± SD	11.7 ± 1.1	11.8 ± 1.2
Chronic obstructive pulmonary disease, <i>n</i>	6	5
Creatinine (mg/dL), mean ± SD	1.14 ± 0.2	1.13 ± 0.5
Obstructive coronary artery disease,	30	30
Peripheral arterial disease	2	3
cECC, conventional extra-corporeal circulation; MiECC minimally invasive extra-corporeal circulation; CPB, cardiopulmonary bypass; Hb, hemoglobin; Hct, hematocrit; NYHA, New York Heart Association; SD, standard deviation.		

The study protocol was approved by the local ethics committee and all patients provided written informed consent to data treatment.

Data collection

Patients were selected according to the following criteria:

- Patients with coronary artery disease (CAD) undergoing myocardial revascularization, with concomitant heart failure and left ventricular ejection fraction (LVEF) lower than 35% and complete CPB and cardioplegic arrest had to be foreseen with an expected CPB duration > 90 min.
- Patients were excluded if they presented abnormal plasma lactate levels (> 2 mmol/L) before entering CPB, liver failure, obesity, uncompensated diabetes, autoimmune disease, active infection, any immunosuppressive therapy, or coagulation disorder. Patients undergoing combined surgery (e.g. aortic valve replacement (AVR) + CABG, about 300 patients during the study period) or surgery with circulatory arrest or having preoperative hematocrit (Hct) < 27% were also excluded.

The cardiac surgery procedures that were analyzed for this study were CABG (n = 100). Preoperative data included patient demographics, baseline serum creatinine, left ventricular ejection fraction, comorbidities (chronic obstructive pulmonary disease, previous cerebrovascular accident), baseline hemoglobin (Hb), EuroSCORE II and New York Heart Association functional class [1].

Perioperative data included type of operation, CPB duration, nadir body temperature during CPB, nadir hematocrit (Hct) and Hb value (measured at the start of CPB and every 20 min thereafter), nadir DO_{2i} , nadir DO_{2i} / O_{2ER_i} ratio during CPB, nadir cardiac index (CI), nadir CI/mixed venous oxygen saturation (SvO_2), peak serum lactate and glucose during CPB and perioperative red blood cells administrations.

Postoperative data included peak serum creatinine, mechanical ventilation time and days spent in the intensive care unit (ICU).

The primary endpoints were: maximum DO_{2i} in relation to O_{2ER_i} during CPB compared between groups in terms of intraoperative lactate and glycemia trends. Secondary endpoints were: and total red blood cells consumption, peak postoperative serum creatinine level [5–7], mechanical ventilation time and length of ICU stay.

Anesthetics and surgical procedures

Patients were monitored with five-lead electrocardiography, a left radial artery catheter, capnography, pulse oximetry, and rectal/urine bladder temperature sensors. Transesophageal echocardiography was performed in all patients. Anticoagulant therapy consisted of heparin sodium before CPB at 300 IU/kg to give an activated clotting time of > 480 s (ACT PLUS Medtronic, Minneapolis, MN, USA); for antagonization of heparin, 0.5–0.75 mg protamine was applied for every 100 heparin units. Anesthesia was induced with intravenous sufentanil (0.5–1 μ g/kg) and midazolam (0.08–0.2 mg/kg), and tracheal intubation was facilitated with intravenous rocuronium (0.6–1 mg/kg). Anesthesia was maintained with propofol (2–5 mg/kg) and sufentanil (0.5–2.0 μ g/kg), and the depth of anesthesia was monitored using bispectral index values (BIS XP, Aspect Medical System, Newton, MA, USA). The dosage of propofol was titrated to maintain bispectral index values between 40 and 60. AVR and CABG procedures were performed in median sternotomy with central cannulation, and surgical procedures were performed as routine by two surgeons. Concentrated red blood cells were transfused whenever Hb concentrations fell below 6 g/dL during surgery or below 8 g/dL during ICU stay. The goal of the hemoconcentration was to eliminate the excess of crystalloid administration.

Cardiopulmonary bypass setting

Group (MiECC)

Closed circuit was performed with MiECC type III with Stöckert S5 heart-lung machine (LivaNova, London, UK) [4], whose design presents the characteristics of a volume management circuit (MiECTiS classification). A shunted venous soft-shell reservoir (Closed, Eurosets, Medolla, Italy) was used, the

aortic root and pulmonary artery suction was managed in series venous return. Components (Biopassive Coating Phisio, LivaNova, London, UK) (Fig. 1): venous-arterial line diameter (3/8), venous bubble-trap (Sherlock, Eurosets), a centrifugal pump (Biomedicus BPX80, Medtronic, Eden Prairie, MN, USA), and a polypropylene fiber oxygenator (Alone, Eurosets). A bubble detection system was used to remove the air from the bubble trap and the circuit (Stockert, LivaNova). Circuit filling volume 500 mL crystalloid solution. 300 IU/kg of sodium heparin were administered, the activated clotting time prior to CPB was 501 s, the cannulas were connected to the air-free circuit, and the bypass with a closed system was set up, the reference value of management of venous drainage was the central venous pressure, maintained around 5 mmHg using urapidil as a vasodilator for higher values, or upon request of drainage by the surgeon, for lower values the Trendelenburg position was used [3, 4, 8, 9]. All patients were treated with mild hypothermic CPB (34°C to 36°C). For the administration of myocardial protection, a closed circuit for cardioplegia with heat exchanger, with an infusion syringe pump in series and Saint Thomas solution with procaine were used and repeated every 30 min. The Landing monitoring system (Eurosets, Medolla, Italy) was used for DO₂ management during CPB. In both groups, blood gas analyses were performed using alpha-stat management with a blood gas analyzer (GEM Premier 3000 IQM, Instrumentation Laboratory, Werfen Group IVD company, Munchen, Germany) set to measure at 37°C [10]. On the basis of arterial blood data, we assessed the lowest Hct (percentage) on CPB; every 20 min, an arterial blood gas analysis, including blood glucose (mg/dL) and lactate (mmol/L) determination, was obtained. An Hb value < 6 g/dL during CPB was considered the trigger point for red blood cell transfusion. All patients received tranexamic acid according to routine protocol. Mean arterial pressure during CPB procedures was managed for values between 55–70 mmHg.

Group (cECC)

Open circuits with roller pumps (Admiral, Remo-well Eurosets, Medolla, Italy; Inspire 6 F, LivaNova, London, UK) were used for CPB. Pericardial blood was collected separately and could be processed or reinjected, if needed. The hard shell and softshell reservoir, oxygenating module and circuits were treated with phosphorylcholine (Agile Eurosets, Medolla, Italy; Phisio, LivaNova, London, UK). All patients were treated with mild hypothermic CPB (34°C to 36°C); a volume of 1250 mL crystalloid Ringer acetate solution was used for priming. The surgical procedures selected for this study do not justify the use of moderate hypothermia by falling below 34°C. For this reason, in the event of an initial increase in anaerobic metabolism, the first compensation approach was not to lower the temperature but possibly liquids or red blood cells were integrated.

The hardware consisted of a Stöckert S5 heart-lung machine and a Stöckert Heater Cooler System 3T (LivaNova, London, UK) and the same cannulae were employed in both groups. For the administration of myocardial protection, a closed circuit for cardioplegia with heat exchanger, with an infusion syringe pump in series and Saint Thomas solution with procaine were used and repeated every 30 min. The Landing monitoring system (Eurosets, Medolla, Italy) was used for DO₂ management during CPB. In both groups, blood gas analyses were performed using alpha-stat management with a blood gas analyzer

(GEM Premier 3000 IQM, Instrumentation Laboratory, Werfen Group IVD company, Munchen, Germany) set to measure at 37°C [10]. On the basis of arterial blood data, we assessed the lowest Hct (percentage) on CPB; every 20 min, an arterial blood gas analysis, including blood glucose (mg/dL) and lactate (mmol/L) determination, was obtained. An Hb value < 6 g/dL during CPB was considered the trigger point for red blood cell transfusion. All patients received tranexamic acid according to routine protocol. Mean arterial pressure during CPB procedures was managed for values between 55–70 mmHg. The management of mean arterial pressure the same in both groups.

Results

Demographic, preoperative and operative details of the patient population are shown in Tables 1 and 2. There are no difference between groups in terms on preoperative characteristics; the patients are isolated CABG procedures with LVEF low than 35% and assessed risk (Euroscore II 9.1–9.5% respectively).

Table 2
Operative data.

	Group MiECC (n = 30)	Group cECC (n = 30)	p-value
CPB time (min), mean ± SD	115 ± 9.2	110 ± 6.17	0.93
Aortic cross-clamp time (min), mean ± SD	71 ± 4	69 ± 6	0.83
Nadir temperature (°C) during CPB, mean ± SD	34.9 ± 1.1	34.7 ± 2.1	0.75
Nadir Hb value (mg/dL) during CPB, mean ± SD	9.7 ± 1.5	7.8 ± 1.2	0.044
Nadir Hct (%) during CPB, mean ± SD	29.8 ± 0.3	25.1 ± 2.1	0.043
Nadir Hb value (mg/dL) after CPB, mean ± SD	9.4 ± 0.1	7.2 ± 0.8	0.044
Nadir Hct (%) after CPB, mean ± SD	29.2 ± 0.1	24.3 ± 0.9	0.045
Nadir DO _{2i} (mL/min/m ²) during CPB, mean ± SD	305 ± 9	288 ± 6	0.037
O ₂ ER _i (%) during CPB, mean ± SD	20 ± 1	25 ± 3	0.0029
Nadir CI (L/min/m ²) during CPB, mean ± SD	2.4 ± 0.2	2.4 ± 0.1	0.94
Nadir SvO ₂ (%)	81 ± 2	75 ± 5	0.038
Crystalloid solution (mL)	328 ± 41	727 ± 57	0.039
Red blood cells (Units)	8	21	0.021
Red blood cells during (Units) in CPB	3	10	0.023
Red blood cells (Units) Intensive Care Unit	5	11	0.024
cECC, conventional extra-corporeal circulation; MiECC minimally invasive extra-corporeal circulation; CI, cardiac index; CPB, cardiopulmonary bypass; DO _{2i} , indexed oxygen delivery; Hb, hemoglobin; Hct, hematocrit; O ₂ ER _i , indexed oxygen extraction ratio; SD, standard deviation; SvO ₂ , mixed venous oxygen saturation.			

Procedures of Group MiECC reported (mean values) of a DO_{2i} of 305 mL/min/m² in relation to O₂ER_i 21.5% vs a DO_{2i} of 288 mL/min/m² in relation to O₂ER_i 25.6% was found in group MiECC vs cECC (p = 0.037). Lactate levels > 3 mmol/L were reported in 7 group MiECC patients vs 20 group cECC patients (p = 0.038), with blood glucose peak (Table 3) (. Mean nadir Hb values during CPB were 9.7 g/dL in group MiECC vs 7.8 g/dL in group cECC (p = 0.044). CI during CPB was 2.4 L/min/m² in both groups. As for liquid administration, including the anesthesiologic infusions, 727 mL and 328 mL of crystalloid solution were given to group MiECC and cECC patients, respectively (p = 0.039) (Table 2). Total red blood cell administration was 8 units in group MiECC vs 21 units in group cECC (p = 0.022). A glycemc peak was

recorded in 7 patients of group MiECC vs 20 patients of group cECC ($p = 0.037$). Patients with hyperlactatemia during CPB had a significant increase in serum creatinine value [6], a higher rate of prolonged mechanical ventilation and a longer ICU stay (Table 4). No patient underwent ultrafiltration during cardiopulmonary bypass.

Table 3

Analysis for peak blood lactate and DO_{2i} in relation to O_2ER_i on cardiopulmonary bypass for group MiECC and group cECC.

	No hyperlactatemia or hyperglycemia	hyperlactatemia and hyperglycemia
Group (MiECC)		
No. patients	23	7
Peak blood lactate (mmol/L) on CPB	1.08 ± 0.19	1.93 ± 0.25
Mean DO_{2i} (mL/min/m ²) on CPB	304 ± 21	275 ± 19
Mean O_2ER_i (%) on CPB	20 ± 3	38 ± 4
Blood glucose (mg/dL) on CPB	129 ± 9	205 ± 11
Group (cECC)		
No. patients	10	20
Peak blood lactate (mmol/L) on CPB	1.28 ± 0.45	3.91 ± 1.21
Highest DO_{2i} (mL/min/m ²) on CPB	289 ± 11	265 ± 19
Highest O_2ER_i (%) on CPB	25 ± 3	33 ± 4
Blood glucose (mg/dL) on CPB	149 ± 3	230 ± 11
cECC, conventional extra-corporeal circulation; DO_{2i} , indexed oxygen delivery; HG, hyperglycemia; HL, hyperlactatemia; MiECC minimally invasive extra-corporeal circulation; O_2ER_i , indexed oxygen extraction ratio.		

Table 4
Hyperlactatemia during cardiopulmonary bypass and postoperative outcome.

	Group (n = 30) MiECC		Group (n = 30) cECC	
	No HL (n = 23)	HL (n = 7)	No HL (n = 10)	HL (n = 20)
Peak serum creatinine (mg/dL)	1.1 ± 0.1	1.4 ± 0.5	1.19 ± 1.1	1.7 ± 1.5
MV time (h)	19.6 ± 45	55 ± 31	22.6 ± 55	52 ± 49
ICU stay (days)	1.2 ± 2.1	5.2 ± 4.9	1.5 ± 2.1	6.1 ± 2.9

cECC, conventional extra-corporeal circulation; MiECC minimally invasive extra-corporeal circulation; HL, hyperlactatemia; ICU, intensive care unit; MV, mechanical ventilation.

Discussion

This retrospective study aimed at comparing two different CPB techniques (i.e. MiECC type III vs cECC) on end stage coronary artery disease patients undergoing myocardial revascularization in terms of DO_{2i} values in relation to O_{2ER_i} with the same target CI, and of incidence of peak lactate and correlation with postoperative outcome. In particular, the type of ECC technique can influence either intraoperative DO_{2i} values for the same consumption of blood products or hemodilution. In other words, mean DO_{2i} was higher in MiECC group compared to the cECC with a higher Hg and Hct although with less transfusions since the flow rate of the two circuits would have been the same. The reduced hemodilution with MiECC can also explain the better obtained results in this group in terms of lower indexed oxygen ratio. The link between hyperlactatemia and hyperglycemia through the above mechanism was confirmed by Revelly et al. in 2005 [11] in an elegant study dealing with cardiogenic or septic shock. The role of adrenergic agonists in this setting is well defined: in cardiogenic shock, they are both endogenous or administered for cardiovascular therapy; in our model, they are endogenous in the majority of patients. None received epinephrine during CPB, and few received norepinephrine; however, unlike epinephrine, norepinephrine usually does not increase glucose production or induce an increase in plasma lactate concentration [12–14]. The two mechanisms leading to hyperlactatemia in various clinical conditions are therefore (i) anaerobic metabolism due to a poor DO_2 , and (ii) excess lactate production due to glucose failing to enter the oxidative pathway and being degraded to lactate by the glycolytic pathway [12, 14, 15]. These mechanisms, if independently considered, lead to different acid-base balance conditions, the former being accompanied by metabolic acidosis and the latter not necessarily so. However, in the clinical conditions of this observational study, the acid-base balance is constantly maintained at a normal pH value by bicarbonate corrections applied by the perfusionist whenever the base excess starts decreasing. Therefore, we are unable to identify differences in hyperlactatemia related to different values of peak blood lactate. However, the evidence that only four patients demonstrated hyperlactatemia without

hyperglycemia and that only patients with an hyperlactatemia-HG hyperglycemia syndrome had a significantly lower value of DO_2 seems to confirm that, in our specific clinical environment, hyperlactatemia and hyperglycemia are linked by the causative factor of a poor DO_2 , leading on one side to lactate production through the anaerobic pathway and on the other hand to a vicious cycle of lactate production due to the poor ability to use glucose through the aerobic pathway [2, 5, 10, 16]. Reduced oxygen content in cases of acute anemia is usually compensated by reduced blood viscosity with increased blood flow in the microcirculation and by a compensatory increase in cardiac output [17]. This last mechanism may be impaired during CPB, where pump flow is usually adjusted on the basis of the patient's body surface area and temperature, not the Hb value. On the basis of our data, the main rationale for explaining hyperlactatemia during CPB is a DO_2 inadequate to guarantee the needed oxygen consumption of the patient.

In the present study, we investigated the role of potentially modifiable factors related to CPB surgery in determining postoperative hyperlactatemia (e.g. due to inadequate perfusion) and HG hyperglycemia [18]. Our results demonstrate, that a $DO_{2i} < 270$ mL/min/m² with $O_2ER_i > 35\%$ and low CI (< 2.4 L/min/m²) with $SvO_2 < 65\%$ during CPB are associated with hyperlactatemia and hyperglycemia and $DO_{2i} > 290$ mL/min/m² with $O_2ER_i < 25\%$ and CI > 2.4 L/min/m² with $SvO_2 > 75\%$ during CPB are associated with a low incidence of hyperlactatemia (HL) and hyperglycemia. Various preoperative factors or comorbidities may create the right environment for HL during CPB. Age, female gender, congestive heart failure, low left ventricular ejection fraction, hypertension, atherosclerosis, diabetes, preoperative Hb value, redo or complex surgery, and emergency procedures were found to be risk factors for hyperlactatemia by Demers and coworkers [19], who reported an hyperlactatemia incidence of 18%. Some of these factors were confirmed in our study, and other new factors were identified; however, our study population had a significantly shorter CPB duration and a lower degree of hemodilution during CPB. Given that both these factors seem to favor the onset of hyperlactatemia, the lower hyperlactatemia rate in our population is reasonably explained. The role of CPB duration in the determination of hyperlactatemia during CPB has been highlighted by other authors [1, 19, 20]. Moreover, the additional volume of crystalloid in the cECC group resulted in significant hemodilution as indicated by the mean hemoglobin values were more than 2 g/dL greater for the MiECC group during bypass. This factor alone could have had a large impact on the other dependent variables including lactate levels and oxygen delivery.

Study Limitations

Several study limitations should be acknowledged. First, we do not know the microcirculation response for the higher Hb values in the MiECC group compared to cECC. Second, the absence of inflammatory markers (cytokines) that could affect postoperative outcome; also on the indexed oxygen delivery. Third, eight pre- and intraoperative factors were found to be significantly associated with peak blood lactate level during CPB at univariate analysis: age, isolated coronary operation, lowest pump flow/blood pressure, requirement of vasopressor or inotropic medications, lowest temperature, Hct, and DO_{2i} were negatively correlated with peak blood lactate value during CPB, whereas CPB duration and peak blood

glucose were positively correlated with peak blood lactate value during CPB. Despite this limitation, the samples were made homogeneous for the characteristics (Table 1). The Landing monitoring system was used for DO₂ management during CPB; however, we don't record duration of time < 280ml/min/m².

Finally, the choice to use one or the other was based on the availability of the perfusionists with and without skills needed to manage the MiECC technique is another limitation of the study.

Conclusion

The end stage coronary artery disease patients undergoing myocardial revascularization with the MiECC technique had a higher DO_{2i} in relation to O₂ER_i 20–25% compared to patients operated on with the cECC technique. MiECC patients showed a significant reduction in blood red cells units administration in the incidence of peak intraoperative lactate, which correlated with reduced postoperative serum creatinine values and shorter mechanical ventilation and ICU stay, as compared to cECC patients.

List Of Abbreviations

CAD, Patients with coronary artery disease; MiECC, Minimal invasive extracorporeal circulation; cECC, Conventional extracorporeal circulation; DO_{2i}, Indexed Oxygen delivery; O₂ER_i, Indexed oxygen extraction ratio; CPB, Cardiopulmonary bypass; CI, Cardiac index; ACT, Activated clotting time; Hct, Hematocrit; Hb, Hemoglobin; HI, hyperlactatemia; LVEF, left ventricular ejection fraction; CABG, Coronary artery bypass grafting; AVR, Aortic valve replacement.

Declarations

Ethics approval and consent to participate: The study was evaluated and approved by the institutional board for clinical trials, Anthea Hospital GVM Care&Research (internal protocol; decision 2020 Feb) and Informed consent was obtained from all subjects involved in the study.

Consent for publication: All authors have read and agreed to the published version of the manuscript.

Availability of data and materials: The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: None.

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Authors' contributions: I.C. participated in manuscript writing, revision and conception. G.S. writing the manuscript. F.B. and G.V. gives support in conception. N.D. and M.M. participated in conception and manuscript vision. V.V. and V.T. gives support in statistical analysis. M.G. and F.R. participated in support

and supervision. G.S. participated in support and conception. G.N. participated in support, re-writing and revision. All authors read and approved the final manuscript.

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Figures



Figure 1

Minimal Invasive Extracorporeal Circulation (MiECC) during myocardial revascularization on end stage coronary artery disease patient.