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Implanting permanent left ventricular assist devices in patients on veno-arterial extracorporeal membrane oxygenation support: do we really need a cardiopulmonary bypass machine?†

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Abstract

OBJECTIVES: Selected patients who failed to be weaned off temporary veno-arterial extracorporeal membrane oxygenation (VA-ECMO) support may be considered for long-term left ventricular assist devices (LVADs). Activation of the systemic inflammatory response due to the cardiopulmonary bypass (CPB) machine and its associated deleterious effects on the coagulation system have been well documented. The aim of the study was to compare the outcome of patients receiving VAD on VA-ECMO with patients who were converted to CPB at the time of VAD implantation.

METHODS: Data of patients undergoing LVAD implantation between January 2010 and September 2015 were retrospectively reviewed. Inclusion criteria were patients with prior VA-ECMO. Perioperative characteristics and postoperative outcome of patients who received LVAD after VA-ECMO with (CPB group) or without CPB (no-CPB group) were compared.

RESULTS: A total of 110 permanent VADs were implanted during this time frame. Forty patients had VA-ECMO prior to VAD implantation and met the inclusion criteria. The CPB was used in 23 patients and 17 patients received VAD on VA-ECMO without using CPB. The preoperative characteristics of the patients were comparable except for lower body mass index, higher international normalized ratio (INR) and higher rate of preoperative intra-aortic balloon pump usage in the CPB group ($P = 0.035$, 0.008 and 0.003, respectively). The incidence of postoperative right VAD implantation and survival rate was comparable between both groups. However, the chest tube blood loss and amount of blood product usage was higher in the CPB group. The total blood loss in the first 24 h after surgery (2469 ± 2067 vs 1080 ± 941 ml, $P = 0.05$) and number of units of intraoperative fresh frozen plasma administered (4 ± 3 vs 1 ± 2, $P = 0.02$) remained higher in the CPB group even after adjustment for differences in preoperative INR value by propensity score matching.

CONCLUSIONS: This study demonstrates that the CPB machine can be safely omitted when a long-term VAD is implanted on VA-ECMO support. Blood loss in the first 24 h after surgery was less and a significantly lower number of blood products were necessary in these patients compared with patients in whom the CPB machine was used. However, similar survival rates between these two groups were observed.

Keywords: VAD • ECMO • ECLS • CPB • Cardiogenic shock

INTRODUCTION

The implantation of a left ventricular assist device (LVAD) has become the cornerstone in the treatment of patients with end-stage heart failure, either as a bridge to heart transplantation, temporary treatment until recovery or as a permanent treatment. Meanwhile, the veno-arterial extracorporeal membrane oxygenation (VA-ECMO) plays a major role in the treatment strategy of patients with cardiogenic shock [1, 2]. It provides cardiorespiratory support that can be used only as a short-term treatment. The primary aim of VA-ECMO implantation is to wean the patient off the ECMO support. However, selected patients who failed to be weaned from VA-ECMO may be considered for long-term LVADs.

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These high-risk patients are usually converted to the cardiopulmonary bypass (CPB) machine at the time of VAD implantation surgery.

On the one hand, CPB has advantages such as lower blood loss in the surgical field, but on the other hand, it may cause serious complications including activation of the systemic inflammatory response with the associated deleterious effects on the coagulation system that can lead to bleeding, thrombosis and embolism with subsequent multiorgan failure and increased blood product transfusion [3]. Since June 2012 we started omitting CPB machine usage for patients on VA-ECMO, who require long-term VAD support unless a simultaneous aortic valve procedure is necessary. A thorough literature search shows a few case series of LVAD implantation on VA-ECMO mainly using older-generation pumps [4, 5]. In this study, we aimed to compare the outcome of patients receiving VAD on VA-ECMO (no-CPB group) with patients who were converted to CPB at the time of VAD implantation (CPB group).

PATIENTS AND METHODS

Patient population

The study protocol was approved by the local University Health Research Ethics Board. Patients undergoing the implantation of permanent VAD between January 2010 and September 2015 were retrospectively reviewed. Inclusion criteria were patients with prior VA-ECMO support. Prior to June 2012, we used to convert all patients to the CPB machine at the time of VAD implantation. Afterwards, we did only few VAD implantations without the CPB machine. Nowadays, we perform all VAD implantation procedures without the CPB machine if the patient is on VA-ECMO prior to VAD implantation. In this study, the outcome of patients who received LVAD after VA-ECMO with the CPB machine (CPB group) was compared with that of patients who were converted to VAD without using the CPB machine (no-CPB group).

Pre-, intra- and postoperative data were considered. All preimplant (prior to VAD) patients' characteristics including renal and liver function tests, blood build, blood gas analysis parameters and catecholamine requirements were evaluated. Postoperative bleeding and administration of blood products as well as end-organ damage and survival were considered as outcome measures.

Surgical procedures and anticoagulation protocol

At the time of surgery, intravenous heparin was administered with target activated clotting time of >400 s in all patients regardless if CPB was used or not. Cell Saver was used in both the CPB and the no-CPB group. All patients except 2 patients with central (VA-ECMO) had peripheral VA-ECMO in place at the time of LVAD implantation. The VA-ECMO cannulas were connected to the CBP machine at the time of surgery for patients who were operated on using the CPB machine (CPB group). Pump implantation was performed in traditional way using a sternotomy approach. For patients in the no-CPB group either sternotomy or a minimally invasive approach (J-sterotomy and anterolateral thoracotomy) approach was used. The cardiac apex was exposed using a deep stitch, which we conventionally used in off-pump bypass surgery procedures. The metal ring was fixed at the cannulation site with continuous non-resorbable sutures. Afterwards, either rapid pacing (170 beat/min) or intravenous adenosine (25 mg) was used and the apical access in the middle of the metal ring was created, the apex cannula was inserted, fixed and de-aired. The outflow graft was anastomosed to the ascending aorta after the application of a side clamp. Under monitoring with transoesophageal echocardiography, the left ventricle and the VAD were de-aired and then the VAD pump was started and the VA-ECMO was slowly weaned. After effective haemostasis, the chest wall was closed. The peripheral VA-ECMO cannulas were then removed. In patients who developed right ventricular (RV) failure, a right VAD (RVAD) was implanted. Indications of RVAD implantation were determined clinically including high central venous pressure >20 mmHg, low pump index, low blood pressure and reduced RV ejection fraction.

Our anticoagulation protocol in patients with VAD includes intravenous heparin starting 24 h following the surgery. The goal activated partial thromboplastin time between the first 24 and 48 h is 40–50 s, between the third and seventh day is 50–60 s and from the seventh day onwards without significant bleeding is 60–80 s. Additionally, 100 mg of acetylsalicylic acid (ASA) was given starting from the first postoperative day. Anticoagulation was withheld in patients with active bleeding. The long-term anticoagulation consists of phenprocoumon and low-dose platelet aggregation inhibitor (ASA 100 mg/day). The first phenprocoumon dose was given after removal of the chest tubes and pacemaker cable. The target international normalized ratio (INR) was 2.0–3.0.

Statistical analysis

All statistical analyses were performed with SPSS for Windows (Version 22, 2013; IBM Corporation, Armonk, NY, USA). Demographic and clinical patient characteristics of both groups were compared with Student's *t*-tests for continuous variables and χ^2 tests for categorical variables. Group differences in intraoperative and postoperative variables were evaluated with the same methodology. Fisher's exact test was used for comparisons of categorical variables with a minimum expected cell count of 5 or less in 20% of cases. Survival was estimated using the Kaplan–Meier method. The log-rank test was used to compare survival differences between the groups. Propensity scores were computed by binary logistic regression with CPB usage as an outcome variable and INR value as a covariate. A 1:1 nearest neighbour matching algorithm with a calliper of 0.2 of the standard deviation of the logit of the propensity score was chosen to achieve highest possible representativeness and precision. As 35% of the CBP group and 12% of the no-CBP group did not meet the matching criteria, they were discarded from the adjusted analysis yielding 30 patients (15 patients in CPB group versus15 patients in no-CPB group). Clinical outcome and differences between matched CPB and no-CPB groups were compared with Student's *t*-tests for continuous variables and χ^2 tests for categorical variables. A *P*-value of ≤ 0.05 was considered statistically significant.

RESULTS

A total of 110 permanent VADs were implanted during this time frame. Forty patients with a mean age of 52 ± 12 years had VA-ECMO prior to VAD implantation and met the inclusion criteria. All patients had cardiogenic shock at the time of VA-ECMO implantation and many patients underwent ECMO implantation under cardiopulmonary reanimation. The primary diagnosis was

dilated cardiomyopathy in 12 patients (30%) and ischaemic myopathy in 28 patients (70%). Only five patients (13%) underwent VA-ECMO implantation in the operation theatre after failure to wean from the CPB machine. The mean VA-ECMO support duration prior to permanent VAD implantation was 6 ± 5 days. At the time of permanent VAD implantation, CPB was used in 23 patients with a mean age of 51 ± 12 years. Meanwhile, 17 patients with a mean age of 54 ± 11 years received VAD on VA-ECMO without using CPB ($P = 0.37$). Table 1 gives the preoperative characteristics of the patients. The average VA-ECMO support duration prior to LVAD implantation was 5 ± 4 vs 7 ± 6 days for patients in the CPB versus no-CPB group ($P = 0.45$). None of these patients (CPB group or no-CPB group) required any simultaneous intracardiac procedures at the time of VAD implantation. The patients' characteristics in both groups were comparable except for a lower body mass index of 23 ± 5 in the CPB group versus 27 ± 7 in the no-CPB group ($P = 0.035$). Furthermore, 43% of the CPB group had intra-aortic balloon pump support prior to LVAD surgery versus none in the no-CPB group ($P = 0.002$). Considering blood chemistry and the rest of the blood work as well as catecholamine requirements prior to LVAD surgery, both groups were comparable except for a higher INR value of 1.3 ± 0.2 in the CPB group compared with1.1 ± 0.1 in the no-CPB group ($P = 0.003$) (Table 2). Heartware ventricular assist device (HVAD) was used as the LVAD

Table 1: Pre-VAD implantation patients' characteristics

Patients' characteristics	CPB ($n = 23$) Mean ± SD, *N* (%)	No CPB ($n = 17$) Mean ± SD, *N* (%)	*P*-value[a]
Age (year)	51 ± 12	54 ± 11	0.37
Male gender	17 (74)	14 (82)	0.70
BMI[a]	23 ± 5	27 ± 7	0.03
Diagnosis (ICM)	16 (70)	10 (59)	0.52
Atrial fibrillation	5 (22)	7 (44)	0.17
Diabetes mellitus	10 (43)	4 (25)	0.31
Peripheral vascular disease	1 (4)	1 (6)	1.00
Redo surgery	8 (35)	3 (18)	0.29
VA-ECMO support duration (days)	5 ± 4	7 ± 6	0.45
Haemodialysis prior to surgery	8 (35)	5 (29)	1.00
Preoperative IABP	8 (43)	0 (0)	0.002

BMI: body mass index; ICM: ischaemic cardiomyopathy; VA-ECMO: veno-arterial extracorporeal membrane oxygenation; IABP: intra-aortic balloon pump; VAD: ventricular assist device; CPB: cardiopulmonary bypass; SD: standard deviation.
[a]Student's *t*-test, χ^2 test or Fisher's test as appropriate.

Table 2: Pre-VAD implantation blood gas analysis, renal, liver and inflammatory parameters as well as catecholamine requirements

Parameter	CPB ($n = 23$) Mean ± SD, *N* (%)	No CPB ($n = 17$) Mean ± SD, *N* (%)	*P*-value[a]
Creatinine (mg/dl)	1.5 ± 1.0	1.0 ± 0.3	0.05
Blood urea nitrogen (mg/dl)	61 ± 34	48 ± 24	0.18
AST (U/l)	259 ± 346	320 ± 631	0.72
ALT (U/l)	240 ± 370	213 ± 552	0.87
Serum bilirubin (mg/dl)	5.2 ± 6.8	2.9 ± 3.3	0.18
aPTT (s)	51 ± 12	44 ± 12	0.06
INR	1.3 ± 0.2	1.1 ± 0.1	0.003
MELD score	20 ± 9	15 ± 9	0.06
Platelet count (10^3/μl)	96 ± 51	95 ± 36	0.96
Haemoglobin value (g/dl)	9.9 ± 1.1	9.7 ± 0.9	0.50
WBC count (10^3/μl)	11 ± 6	11 ± 3	0.62
CRP (mg/dl)	18 ± 12	17 ± 9	0.86
Lactate value (mg/dl)	2.4 ± 1.7	1.8 ± 1.0	0.17
PH value	7.44 ± 0.08	7.44 ± 0.09	0.91
BE (mmol/l)	1.8 ± 4.3	4.6 ± 4.1	0.06
Norepinephrine (mcg/kg/min)	0.21 ± 0.34	0.08 ± 0.08	0.10
Epinephrine (mcg/kg/min)	0.08 ± 0.22	0.04 ± 0.04	0.38
Milrinon (mcg/kg/min)	0.02 ± 0.08	0.03 ± 0.10	0.83

AST: aspartate transaminase; ALT: alanine transaminase; aPTT: activated partial thromboplastin time; MELD: Model for End-stage Liver Disease; WBC: white blood cell; CRP: C-reactive protein; BE: base excess; VAD: ventricular assist device; CPB: cardiopulmonary bypass; SD: standard deviation; INR: international normalized ratio.
[a]Student's *t*-test, χ^2 test or Fisher's test as appropriate.

Table 3: Intraoperative parameters and postoperative outcome in both groups

Parameter	CPB (n = 23) Mean ± SD, N (%)	No CPB (n = 17) Mean ± SD, N (%)	P-value[a]
Total surgery time	315 ± 113	216 ± 79	0.12
CPB time	155 ± 57	0 ± 0	<0.001
Total chest tube blood loss (24 h)	2069 ± 1759	987 ± 889	0.03
Intraoperative blood transfusion requirement			
PRBC (units)	15 ± 15	8 ± 4	0.03
FFP (units)	8 ± 13	1 ± 2	0.03
Platelets (units)	6 ± 4	4 ± 3	0.18
NovoSeven (mg)	2.8 ± 6.0	0.46 ± 1.1	0.09
Postoperative outcome			
RVAD requirement	17 (74)	11 (65)	0.73
Resternotomy for bleeding	8 (35)	2 (12)	0.14
Respiratory failure	16 (70)	13 (76)	0.73
Renal failure	15 (65)	9 (53)	0.52
Liver failure	11 (48)	8 (47)	1.00

CPB: cardiopulmonary bypass; PRBC: packed red blood cell; FFP: fresh frozen plasma; RVAD: right ventricular assist device; SD: standard deviation.
[a]Student's t-test, χ^2 test or Fisher's test as appropriate.

Table 4: Characteristics, intraoperative parameters and postoperative outcome in matched groups

Parameter	CPB (n = 15) Mean ± SD, N (%)	No CPB (n = 15) Mean ± SD, N (%)	P-value[a]
Age (year)	49 ± 13	54 ± 12	0.23
BMI[a]	23 ± 5	26 ± 6	0.20
Creatinine (mg/dl)	1.3 ± 0.7	1.0 ± 0.4	0.30
INR	1.2 ± 0.1	1.2 ± 0.09	0.08
Total chest tube blood loss (24 h)	2469 ± 2067	1080 ± 941	0.05
Intraoperative blood transfusion requirement			
PRBC (units)	11 ± 5	7 ± 4	0.06
FFP (units)	4 ± 3	1 ± 2	0.02
Platelets (units)	5 ± 3	4 ± 2	0.18
NovoSeven (mg)	2.0 ± 5.4	0.55 ± 1.2	0.36

CPB: cardiopulmonary bypass; BMI: body mass index; INR: international normalized ratio; PRBC: packed red blood cell; FFP: fresh frozen plasma; RVAD: right ventricular assist device; SD: standard deviation.
[a]Student's t-test, χ^2 test or Fisher's test as appropriate.

in all patients except for 3 patients in the CPB group who became BerlinHeart Excor biventricular assist device (BVAD) (BerlinHeart GmbH, Berlin, Germany), Thoratec paracorporeal ventricular assist device (PVAD) (Thoratec, Inc., Pleasanton, CA, USA) and Thoratec HeartMate II, respectively.

Postoperative complications including RV failure requiring RVAD implantation and other end-organ damage was comparable between the two groups (Table 3). To preclude that the higher amount of bleeding and blood product usage in the CPB group was related to higher preoperative INR value, a propensity score matching was performed. Table 4 shows the results of propensity score matching after adjustment for INR value with 15 patients in each group. The total blood loss in the first 24 h after surgery (2469 ± 2067 vs 1080 ± 941 ml, P = 0.05) and the number of units of intraoperative fresh frozen plasma (FFP) required (4 ± 3 vs 1 ± 2, P = 0.02) remained higher in the CPB group compared with no-CPB group.

Considering the risk of stroke, 2 patients in the CPB group had perioperative stroke within days after VAD implantation and 1 patient had stroke complications after 31 days of support. In the no-CPB group, 3 patients developed postoperative stroke (1 ischaemic and 2 intracerebral bleeding). The cerebral bleeding events were related to thrombolysis therapy for pump thrombosis in 1 patient and to phenprocoumon overdose in another patient.

Interestingly, LVAD implantation on VA-ECMO without CPB had no impact on the survival. The survival rate was comparable between both groups (P = 0.591) (Fig. 1).

DISCUSSION

The main findings of this study can be summarized as follows:

(i) Implanting a permanent VAD in a patient with VA-ECMO is feasible without technical issues.
(ii) Patients undergoing VAD implantation on VA-ECMO have a shorter total procedure time and less total blood loss in the first 24 h after surgery, require lower number of blood products and have a trend towards lower RVAD implantation rate. However, survival rate remains comparable regardless if the

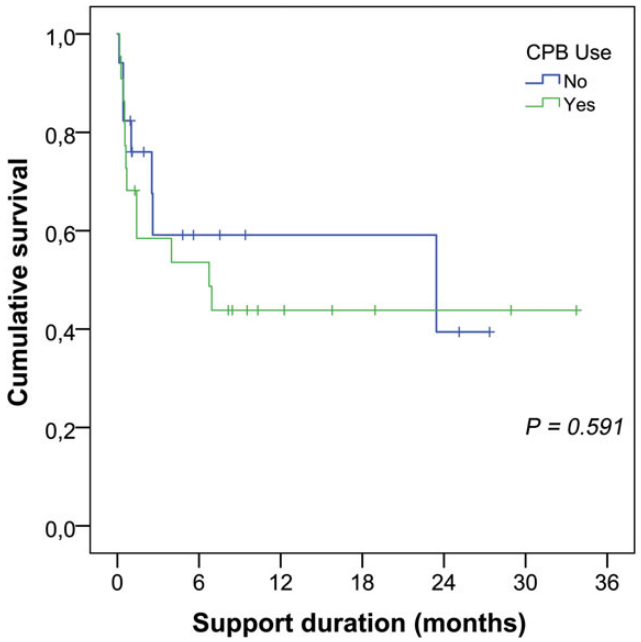

Figure 1: The Kaplan–Meier survival curve of the patients. CPB: cardiopulmonary bypass.

CPB machine was used at the time of VAD implantation surgery or not.

Mechanical circulatory support systems are regarded as a reliable treatment option for patients with end-stage heart failure who are non-responsive to the conventional medical therapies [6–8]. Long-term assist device implantation is inevitable in patients who fail to show adequate recovery of the ventricular function on VA-ECMO considering issues of organ shortage and resulting extended waiting times for heart transplantation. The most challenging task is to adequately select patients for long-term VAD support early after VA-ECMO implantation to avoid unnecessary resource utilization by patients who otherwise may not survive the VAD implantation surgery due to the severity and/or irreversibility of end-organ damage. Basically, the main goal after VA-ECMO implantation at our institution is to wean the patient off the mechanical support. Previous study from our group showed that Model of End-Stage Liver Disease (MELD) score is among the most reliable parameters predicting outcome after permanent VAD implantation in patients on VA-ECMO [9]. Currently, a VA-ECMO patient is considered for permanent VAD implantation at our institution after failure of the weaning trials from the ECMO and adequate neurological evaluation and in the presence of a low MELD score (<20).

There is a tremendous difference in the characteristics and functional status of patients undergoing VAD implantation after VA-ECMO support [9]. These patients are sicker, and a majority of them have a history of cardiopulmonary reanimation, are on ventilator support prior to VAD surgery, and have the so-called acute lung injury on VA-ECMO with respiratory dysfunction [10], a higher rate of RV dysfunction and most importantly a higher bleeding tendency due to VA-ECMO-induced derangement of the coagulation system. It is therefore intuitive to expect a higher postoperative complication rate in these patients compared with other patients without VA-ECMO at the time of VAD surgery. Any attempt to reduce the intraoperative trauma might be helpful to prevent the postoperative complications. We believe that performing the surgery on ECMO without CPB may improve the postoperative outcome.

The majority of patients with end-stage heart failure have some degree of mitral and/or tricuspid valve insufficiency at the time of LVAD implantation. Recent studies did not show any advantage of performing mitral and/or tricuspid valve procedures at the time of LVAD implantation [11, 12]. We do not perform mitral and/or tricuspid valve repair procedures for our LVAD candidates. However, it is the policy of our institution to perform aortic valve replacement if there is more than moderate aortic valve insufficiency prior to LVAD implantation. Notably, none of the VA-ECMO patients included in this study had relevant aortic valve insufficiency. Further, all of these patients underwent VAD implantation only and the decision to use CPB was not related to the necessity of performing other intracardiac procedures.

The CPB activates the haemostatic system through contact system stimulation, platelet activation, inflammation and fibrinolysis. The contact system stimulation occurs once the CPB is initiated as the blood flows through the artificial CPB circuit [13, 14]. Contact with artificial materials such as glass, silicone and polyethylene leads to the activation of factor XII to FXIIa, which in turn activates prekallikrein to kallikrein, which activates more FXII and produces bradykinin from high molecular weight kininogens. The elevated bradykinin levels stimulate the secretion of tissue plasminogen activator that plays a major role besides fibrin in increasing the fibrinolytic activity, resulting in a hyperfibrinolytic state [15]. Moreover, the systemic inflammatory response syndrome may occur as a result of CPB [16]. The contact of blood with the CPB circuit activates the leucocytes to bind to it, resulting in more tissue factor expression and thrombin production. Furthermore, the CPB system decreases protein C activation. The platelets bind to the artificial surface of the CPB circuit, resulting in their activation and thrombin formation [17].

Meanwhile, the VA-ECMO system negatively impacts the coagulation system of the patients. Through a complex inflammatory response the VA-ECMO activates the coagulation pathway, thrombin and blood elements including platelets and leucocytes [18]. The red blood cells are mechanically destroyed by the pump and the artificial surface of the circuit [19]. Furthermore, the contact of blood with the ECMO circuit and the shear stresses lead to platelet activation and aggregation via GPIb receptors, resulting in platelet consumption and reduction of the platelet count.

In this study, we were able to show that implanting a VAD system in a patient with VA-ECMO is feasible and has the advantages of minimizing additional blood trauma induced by the CPB circuit. The amount of blood loss is less and a lower total number of blood transfusions were necessary when no CPB circuit was used. It has been well documented that a higher morbidity and mortality rate are well correlated with the number of red blood cell transfusions in cardiac surgery [20, 21]. We should therefore expect lower complication rates when less blood transfusion is required. Notably, the pre-VAD surgery characteristics of the patients in both groups (CPB versus no CPB) were comparable. However, patients in the no-CPB group have also a trend towards a lower rate of RVAD implantation. We might speculate that lower incidence of RVAD use might be also correlated to lower transfusion requirements in the no-CPB group.

Notably, patients in the CPB group had a higher INR rate prior to VAD surgery, possibly due to more extensive liver damage compared with the no-CPB group. Needless to say, this finding *per se* may explain the higher rate of red blood cell transfusion in this

group of patients. However, after propensity score matching and adjusting for the preoperative INR value, the total blood loss in the first 24 h after surgery (2469 ± 2067 vs 1080 ± 941 ml, $P = 0.05$) and the number of intraoperative FFPs required (4 ± 3 vs 1 ± 2, $P = 0.02$) remained higher in the CPB group compared with the no-CPB group (Table 4). This means that avoiding the CPB circuit seems to be protective against bleeding in these patients. Notably, another possible explanation of the lower bleeding tendency in the no-CPB group might have been related to our learning curve. Back in 2012, our cardiac surgery department with the clinic for anaesthesiology and the haemostaseology department initiated a special pilot project of targeted substitution of blood products and factors based on individual patients' needs. This programme was not available early in our experience. This may also explain higher blood usage early in our experience. Notably, the CPB group included 2 patients with extracorporeal VAD (Berlin Heart Excor and Thoratec PVAD). These pumps are known for their haemolytic and bleeding tendencies. Thorough data inspection of these 2 patients showed preoperative characteristics and postoperative values that are comparable with the rest of the patients in the CPB group. More importantly, these 2 patients were not matched and therefore excluded from Table 4, which includes only propensity-matched patients. Therefore, including these 2 patients in the primary analysis would not influence the study results.

Disadvantages of performing VAD surgery on VA-ECMO include the inability to visually inspect the left ventricle and thereby theoretically increasing the possibility of thromboembolic complications. However, the transoesophageal echocardiogram is nowadays a reliable tool to exclude any relevant thrombus formation within the left ventricle. We obviously consider using CPB once any thrombus is suspected within the left ventricle. The stroke rate was comparable between both groups in our cohort. Other disadvantages include the inability to perform simultaneous valve procedures.

This technique is not new and has been described before with earlier-generation extracorporeal pumps or as anecdotal case reports [4, 5]. Our study includes 40 patients who underwent VAD implantation after VA-ECMO implantation. Moreover, this is to our knowledge the first study comparing the outcome between patients who underwent VAD surgery with or without the use of CPB.

Limitations of this study include the retrospective nature of the study and the number of subjects included. The study includes two sequential different groups of patients. The majority of patients in the CPB group underwent VAD implantation early in our experience. The experience of our group is improving and might *per se* explain the reduced need for blood materials in the no-CPB group.

In conclusion, this study demonstrates that the CPB machine can be safely omitted when a long-term VAD is implanted on VA-ECMO support. Blood loss in the first 24 h after surgery was less and a significantly lower number of blood products were necessary in these patients compared with patients in whom the CPB machine was used. However, no significant difference in the survival rates between these two groups was observed.

Conflict of interest: none declared.

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