Artificial Organs

Temporary Right Ventricular Mechanical Support in High-Risk Left Ventricular Assist Device Recipients Versus Permanent Biventricular or Total Artificial Heart Support

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Abstract: Early planned institution of temporary right ventricular assist device (RVAD) support with the CentriMag (Levitronix LLC, Waltham, MA, USA) in left ventricular assist device (LVAD) recipients was compared with permanent biventricular assist device (BVAD) or total artificial heart (TAH) support. Between 2007 and 2011, 77 patients (age range: 25–70 years) with preoperative evidence of biventricular dysfunction (University of Pennsylvania score >50; University of Michigan score >5) were included. Forty-six patients (38 men; median age 54.5 years, range: 25–70 years) underwent LVAD placement combined with temporary RVAD support (group A); in 31 patients (25 men; median age 56.7 years, range: 28–68 years), a permanent BVAD or TAH implantation (group B) was performed. Within 30 days, 12 patients from group A (26.08%) and 14 patients from group B (45.1%) died on mechanical support ($P = 0.02$). Thirty patients (65.2%) in group A were weaned from temporary RVAD support and three (6.5%) underwent permanent RVAD (HeartWare, Inc., Framingham, MA, USA) placement. A total of 26 patients (56.5%) were discharged home in group A versus 17 (54.8%) in group B ($P = 0.56$). Three patients (8.5%) received heart transplantation in group A and six (19.3%) in group B ($P = 0.04$). In group A, 90-day and 6-month survival was 54.3% ($n = 25$) versus 51.6% ($n = 16$) in group B ($P = 0.66$). In group A, 1-year survival was 45.6% ($n = 21$) versus 45.1% ($n = 14$) in group B ($P = 0.81$). The strategy of planned temporary RVAD support in LVAD recipients showed encouraging results if compared with those of a similar permanent BVAD/TAH population. Weaning from and removal of the temporary RVAD support may allow patients to be on LVAD support only despite preoperative biventricular dysfunction. **Key Words:** Artificial heart—Biventricular failure—Left ventricular assist device support—Biventricular assist device support.

Left ventricular assist device (LVAD) support is a well-established and accepted treatment strategy for refractory end-stage heart failure patients. However, right ventricular failure (RVF) remains a major contributor to significant morbidity and mortality after LVAD placement (1–5).

First-generation pulsatile devices have been related to the incidence of RVF, mainly owing to the mechanical effects of left ventricular unloading and the need for extensive surgical dissections to accomodate the large pump, with consequent high risk of postoperative bleeding (3–5).

Early planned institution of a permanent biventricular support in the case of preoperatively predicted or documented RVF could be a radical solution to overcome the problem (6). However, biventricular assist devices (BVADs) or total artificial hearts (TAHs) have been demonstrated to have significant limitations due to their large size, limited durability, and lower quality of life (QOL) compared with the recent LVADs (1,3,7–11).

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The second- and third-generation implantable continuous-flow devices are small and durable. The avoidance of complete left ventricular unloading owing to maintenance of left ventricular end-diastolic volume, maintained septal position, and preservation of right ventricular mechanics makes such pumps effective to decrease the risk of RVF (1,3–5).

It is questionable whether even simultaneous temporary right ventricular assist device (RVAD) support at the time of continuous-flow LVAD implantation would help the function of the right ventricle (RV) in the early, most critical postoperative time and thus help to avoid a long-term BVAD or TAH implantation as previously advocated elsewhere (12,13).

The objective of this study was to evaluate the aforementioned strategy in implantable LVAD recipients initially judged to be at high risk of postoperative RVF and compare them with a similar patient population who underwent primary permanent BVAD or TAH support placement.

PATIENTS AND METHODS

Ventricular assist device evaluation and mechanical circulatory systems

All patients were evaluated concerning the risk of RVF using previously published scores (14–17) (Table 1).

TABLE 1. *Demographic and preimplant clinical parameters of LVAD plus temporary RVAD population (group A) vs. BVAD/TAH population (group B)*

	LVAD + temporary RVAD ($n = 46$)	BVAD or TAH ($n = 31$)	P
Age (years)	54.5 (25–70)	56.7 (28–68)	0.21
Male gender (n, %)	38 (59.7)	25 (40.2)	0.06
BSA (m^2)	1.87 (1.75–1.88)	1.91 (1.7–2.3)	0.29
Etiology			
Idiopathic DCMP (n, %)	25 (54.3)	19 (61)	0.06
Ischemic DCMP (n, %)	14 (30.4)	10 (32.2)	0.23
Valvular DCMP (n, %)	5 (10.8)	2 (6.4)	0.07
Postmyocarditis DCMP (n, %)	2 (4.3)	—	—
Previous cardiac operation (n, %)	9 (19.5)	4 (12.9)	0.55
LVAD change (n, %)	6 (13.04)	—	—
INTERMACS level	2.3 (2–4)	2.5 (2–4)	0.32
MODS score*	8.4 (3–16)	8.7 (3–18)	0.20
SAPS II score*	30.5 (24–41)	31.2 (28–47)	0.75
Inotropic score*	28.5 (18–45)	30.1 (20–50)	0.73
IABP (n, %)	35 (76.08)	17 (54.8)	0.05
mSAP (mm Hg)	63.2 (50–70)	62.9 (48–65)	0.55
SvO_2 (%)	48 (40–55)	45.1 (40–55)	0.39
CI ($L/min/m^2$)	1.9 (1.2–2.8)	2.1 (1–3.1)	0.49
RVSWI (mm Hg/mL/m^2)	325.5 (265–396)	310.4 (248–385)	0.49
mPAP (mm Hg)	25.5 (14–50)	26.8 (16–55)	0.34
PVR (dynes/sec/cm^5)	221.6 (198–690)	235.5 (210–790)	0.20
CVP (mm Hg)	18.5 (12–24)	18.2 (12–26)	0.75
PCWP (mm Hg)	22.1 (18–32)	21.1 (18–30)	0.70
TAPSE (mm)	9.8 (8–13.1)	9.2 (8–14.4)	0.20
RVEDD (mm)	34.5 (25–48)	36.6 (27–50)	0.24
RV S/L ratio (14)	0.65 (0.58–0.70)	0.67 (0.60–0.75)	0.29
RV/LV ratio (15)	0.72 (0.66–0.77)	0.74 (0.68–0.80)	0.97
Moderate to severe TR (n)	46 (100%)	31 (100%)	0.17
RVEF (%)	25.4 (20–35)	22.4 (18–36)	0.73
LVEF (%)	20.5 (10–25)	20.5 (10–25)	0.20
Moderate to severe MR (n)	46 (100%)	31 (100%)	0.17
NT-proBNP (pg/mL)	12 610 (10 130–16 250)	13 820 (10 180–18 250)	0.19
Michigan score (16)	5.1 (4.0–5.8)	5.9 (4.0–6.4)	0.27
Pennsylvania score (17)	51.2 (46.5–65)	54.5 (49.5–65)	0.24
Berlin score (14,15)	BVAD	BVAD	—

*Definition is given by the present authors elsewhere (1,13,14).

All values are presented as median and range or as percentage.

BSA, body surface area; BTT, bridge to transplantation; CI, cardiac index; CVP, central venous pressure; DCMP, dilative cardiomyopathy; IABP, intraortic balloon pump; LVEF, left ventricular ejection fraction; mPAP, mean pulmonary arterial pressure; mSAP, mean systolic arterial pressure; MODS, multiple organ dysfunction score; MR, mitral regurgitation; NT-proBNP, N-terminal pro-B-type natriuretic peptide; PCWP, pulmonary capillary wedge pressure; PVR, pulmonary vascular resistance; RVEDD, right ventricular end-diastolic dimension; RVEF, right ventricular ejection fraction; RVSWI, right ventricular stroke work index; RV/LV ratio, right to left ventricular end-diastolic diameter ratio; SAPS, simplified acute physiology score; SvO_2, mixed venous oxygen saturation; TAPSE, tricuspid annulus plane systolic excursion; TPG, transpulmonary gradient; TR, tricuspid regurgitation.

In group A, the following systems were used: HeartMate II (Thoratec Corp., Pleasanton, CA, USA; $n = 24$), HeartWare HVAD (HeartWare, Inc., Framingham, MA, USA; $n = 18$), Incor (Berlin Heart GmbH, Berlin, Germany; $n = 3$), and DuraHeart (Terumo Heart, Inc., Ann Arbor, MI, USA; $n = 1$). The biventricular support systems used in group B were: Thoratec (Thoratec Corp.) paracorporeal ($n = 10$) and implantable VAD ($n = 1$), HeartWare HVAD (HeartWare, Inc.; $n = 8$), Berlin Heart Excor (Berlin Heart GmbH; $n = 6$), and SynCardia TAH (SynCardia Systems, Inc., Tucson, AZ, USA; $n = 6$).

Patient consent

Written informed consent was obtained from all patients. This study was approved by our Institutional Review Boards.

Operative technique

Operations were performed by different surgeons through median sternotomy on standard cardiopulmonary bypass. The implantation site used for the long-term LVAD inflow cannula was the left ventricular (LV) apex; for the outflow graft, an ascending aorta anastomosis was performed (3). In three cases the descending aorta was alternatively used for the outflow, in redo operations.

In group A, the outflow cannula of the temporary CentriMag (Levitronix LCC, Waltham, MA, USA) RVAD was directly inserted into the pulmonary artery trunk ($n = 32$) or prolonged by usage of a 10 mm Dacron graft and then sutured to the pulmonary artery ($n = 14$) (12,13). The inflow cannula was directly placed into the RA ($n = 38$) even using a Dacron graft in two cases, or indirectly placed through the femoral vein ($n = 6$).

Tricuspid valve repair procedures, in group A, included two De Vega tricuspid annuloplasties performed with 3-0 polypropylene single mattress sutures supported by pledgets of autologous pericardium to reduce the annular size with a diameter of the residual valve ostium never smaller than 25 mm, and two ring annuloplasties (28 mm, GoreTex band).

Once the "temporary biventricular support" procedure was performed in group A, intraoperative transesophageal echocardiography was carried out to assess left/right heart contractility and geometry, arterial valve function, and to identify any intracardiac shunt. Optimal pump speed was set to ensure that no interventricular septum shift occurred, unloading of the left and right ventricles was sufficient, and periodic aortic valve opening was possible, as already described elsewhere (3–5,12). These settings were adjusted regularly during the daily patient visits in the intensive care unit (ICU).

In group B, for permanent BVAD implantation, the right atrium (RA) or RV and pulmonary artery were connected with cannulas, and TAH implantation was performed as already described elsewhere (7–11).

Statistical analysis

Demographic and clinical patient characteristics in the two groups were compared with Student's *t*-tests for continuous variables and chi-square tests for categorical variables. Group differences in intraoperative and postoperative variables were evaluated using the same methodology. Fisher's exact test was used for comparisons of categorical variables. Statistical evaluations were performed with SPSS, version 16.0 (SPSS, Inc., Chicago, IL, USA). A $P < 0.05$ was considered significant.

RESULTS

Study population

Between 2007 and 2011, 556 long-term LVAD and 178 long-term BVAD/TAH implantations were performed overall at our institutions. A total of 77 patients (age range: 25–70 years) with moderate to severe right ventricular failure (RVF) associated with refractory end-stage left ventricular failure were included in this study. Forty-six patients (38 men and 8 women, median age 54.5 years, range: 25–70 years) underwent LVAD combined with temporary RVAD support (group A); in 31 patients (25 men and 6 women, median age 56.7 years, range: 28–68 years), a permanent BVAD or TAH implantation (group B) was performed. Group A was divided into two populations depending on the time of temporary RVAD implantation: 35 patients had simultaneous LVAD and temporary RVAD placement (group A1); 11 LVAD patients received a temporary RVAD support within 48 h after their arrival in the ICU (group A2).

Baseline characteristics and preoperative clinical parameters of the two groups (Table 1) were similar.

VAD evaluation

For all patients, preoperative scores evaluating the risk for RVF were calculated (14–17). The scores indicated high risk for LVAD implantation (Table 1). BVAD implantation was planned for all 77 patients, but 46 patients refused permanent BVAD or TAH implantation (group A). However, they agreed to LVAD implantation and temporary RVAD placement in the first place, to be followed by permanent BVAD implantation only if the initial treatment

TABLE 2. *Outcome of LVAD plus temporary RVAD population (group A) versus BVAD/TAH population (group B)*

	LVAD + temporary RVAD ($n = 46$)	BVAD or TAH ($n = 31$)	P
ICU time (days)	22.4 (15–50)	25.2 (3–60)	0.94
Ventilation time (days)	10.2 (3–50)	13.5 (1–60)	0.75
Hospital stay (days)	44.2 (25–98)	46.5 (18–101)	0.56
Died (in hospital) on biventricular support	12 (26.08%)	14 (45.1%)	0.02
Weaned from temporary RVAD	30 (65.2%)	—	—
Time of temporary RVAD support	16.2 (2–50)	—	—
Secondary permanent RVAD support*	3 (6.5%)	—	—
Weaned from permanent RVAD	—	5 (45.4%)†	—
Discharged on VAD support	26 (56.5%)	17 (54.8%)	0.56
Discharged on LVAD-only support	25 (54.3%)	—	—
Bridge to HTx	3 (8.5%)	6 (19.3%)	0.04
CVVH	7 (15.2%)	8 (25.8%)	0.08
CVVH time (days)	7.3 (5–11)	8.1 (6–14)	0.54
Bleeding/tamponade	20 (43.4%)	14 (45.1%)	0.10
Transfusion	46 (100%)	31 (100%)	0.10
PRBCs	20.5 (3–52)	23.2 (3–60)	0.82
PLTs units	15.9 (6–48)	16.5 (6–52)	0.51
FFP (1000 mL/unit)	5.6 (2–15)	6.1 (2–20)	0.43
Pulmonary hemorrage	4 (8.6%)	4 (9.6%)	0.63
PLTs count	125.6 (40–198)	133.6 (88–177.5)	0.48
Haptoglobin (mg/dL)	49.9 (26–168)	46.5 (18–155)	0.77
PFH (mg/dL)	8.1 (4.9–13)	7.1 (6.8–13)	0.66
MOF	7 (15.2%)	8 (25.8%)	0.08
Sepsis	7 (15.2%)	8 (25.8%)	0.08
Brain death (cerebral hemorrage)	1 (2.1%)	2 (6.4%)	0.51

*HeartWare HVAD (HeartWare Inc., Framingham, MA, USA).
†RVAD removal refers to the BVAD population.
All values are presented as median and standard deviation or as percentage.
CVVH, continuous veno-venous hemofiltration; FFP, fresh frozen plasma; HTx, heart transplantation; IABP, intraortic balloon pump; MOF, multiple organ failure; PFH, plasma free hemoglobin; PLTs, platelets; PRBCs, packed red blood cells.

failed. Under these circumstances, temporary mechanical RV support was allowed.

Outcome

Within 30 days, 12 patients from group A (26.08%) and 14 from group B (45.1%) died on mechanical support, thus revealing a significant statistical difference ($P = 0.02$), as shown in Table 2. The causes of mortality in the patients in group A were multiple organ failure (MOF) and sepsis ($n = 7$), bronchial bleeding ($n = 4$), and cerebral hemorrage ($n = 1$). In group B, the causes of death were MOF and sepsis ($n = 8$), bronchial bleeding ($n = 4$), and cerebral hemorrage ($n = 2$).

Median length of hospital stay was 44.2 days (range: 25–98 days) in group A versus 46.5 days (range: 18–101 days) in group B ($P = 0.56$). The duration of ICU stay was 22.4 days (range: 15–50 days) versus 25.2 days (range: 3–60 days) ($P = 0.94$). All patients of both groups needed transfusions and there were no significant statistical differences in terms of number of units of packed red blood cells, fresh frozen plasma, or platelets required.

Concerning other secondary endpoints, no differences were seen regarding postoperative liver dysfunction ($P = 0.08$), continuous veno-venous hemofiltration need and times ($P = 0.08$ and $P = 0.54$, respectively), or ventilation time ($P = 0.75$) (Table 2).

A total of 26 patients (56.5%) were successfully discharged home in group A versus 17 (54.8%) in group B ($P = 0.56$). Three patients (8.5%) received heart transplantation in group A and six (19.3%) in group B ($P = 0.04$). Eight patients of group A are still in hospital for rehabilitation.

Regarding LVAD recipients as primary temporary RVAD patients (group A1) or secondary temporary RVAD patients (group A2), within 30 days, seven (20%) died on support in group A1 versus five (45.4%) in group A2 ($P = 0.02$), as shown in Table 3. The causes of death were mainly MOF and sepsis.

Twenty-five patients (71.4%) in group A1 were weaned from temporary RVAD support versus five (45.4%) in group A2 ($P = 0.01$). In group A1 three (8.5%) patients underwent permanent RVAD (HeartWare, Inc.) placement. Two of these patients died due to MOF after 9 and 58 days, respectively, of BVAD support, and one is at home and still on support after 352 days (18).

A total of 20 patients (57.1%) were successfully discharged home on LVAD support in group A1 versus 5 (45.4%) in group A2 ($P = 0.04$). Two (5.7%) patients of group A1 received heart transplantation

TABLE 3. *Outcome of LVAD plus primary temporary RVAD population (group A1) versus LVAD + secondary temporary RVAD population (group A2)*

	LVAD + primary temporary RVAD ($n = 35$)	LVAD + secondary temporary RVAD ($n = 11$)	P
ICU time (days)	20.4 (14–46)	23.7 (15–50)	0.81
Ventilation time (days)	9.8 (3–46)	10.7 (5–50)	0.77
Hospital stay (days)	40.2 (25–87)	46.1 (26–98)	0.59
Died (in hospital) on temporary BVAD support	7 (20%)	5 (45.4%)	0.02
Weaned from temporary RVAD	25 (71.4%)	5 (45.4%)	0.01
Time of temporary RVAD support	15.8 (2–50)	16.9 (2–27)	0.21
Secondary permanent RVAD support*	3 (8.5%)	—	—
Discharged on LVAD-only support	20 (57.1%)	5 (45.4%)	0.04
Bridge to HTx	2 (5.7%)	1 (9.09%)	0.07
CVVH	3 (8.5%)	4 (36.3%)	0.04
CVVH time (days)	6.7 (5–11)	7.9 (6–11)	0.62
Bleeding/tamponade	15 (42.8%)	5 (45.4%)	0.14
Transfusion	35 (100%)	11 (100%)	0.14
PRBCs	19.8 (3–50)	21.8 (4–52)	0.55
PLTs units	14.8 (6–45)	15.9 (7–48)	0.91
FFP (1000 mL/unit)	5.1 (2–11)	6.6 (4–15)	0.74
Pulmonary complications	3 (8.5%)	1 (9.09%)	0.55
PLTs count	135.1 (70–188)	120.4 (40–198)	0.89
Haptoglobin (mg/dL)	46.1 (28–168)	43.1 (26–125)	0.51
PFH (mg/dL)	7.8 (4.9–10)	8.9 (5.1–13)	0.66
MOF	3 (8.5%)	4 (36.3%)	0.04
Sepsis	3 (8.5%)	4 (36.3%)	0.04
Brain death (cerebral hemorrage)	1 (2.8%)	—	—

*HeartWare HVAD (HeartWare, Inc., Framingham, MA, USA).
All values are presented as median and standard deviation or as percentage.
CVVH, continuous veno-venous hemofiltration; FFP, fresh frozen plasma; HF, heart failure; HTx, heart transplantation; IABP, intraortic balloon pump; MOF, multiple organ failure; PFH, plasma free hemoglobin; PLTs, platelets; PRBCs, packed red blood cells.

versus one (9.09%) in group A2 ($P = 0.07$). There were no statistically significant differences between the subgroups A1 and A2 concerning the remaining endpoints, as shown in Table 3.

In group A, 90-day and 6-month survival was 54.3% ($n = 25$) versus 51.6% ($n = 16$) in group B ($P = 0.66$). In group A, 1-year survival was 45.6% ($n = 21$) versus 45.1% ($n = 14$) in group B ($P = 0.81$) (Fig. 1).

Routine transthoracic echocardiography was performed in each patient 30 days and thereafter monthly after LVAD implantation in group A. At the latest follow-up (15.2 ± 6.3 months, range: 6–25 months), the LVAD outpatients ($n = 25$) showed by echocardiographic evaluation an RV ejection fraction (RVEF) >35%, a tricuspid regurgitation <grade 2, a systolic pulmonary arterial pressure >40 mm Hg, a tricuspid annulus peak systolic velocity >8 cm/s by tissue Doppler analysis, an RV short/long axis ratio (S/L ratio) <0.55, and an RV-to-LV end-diastolic diameter ratio (R/L ratio) <0.65, thus confirming a stable RV function after previous weaning from temporary RVAD (14,15).

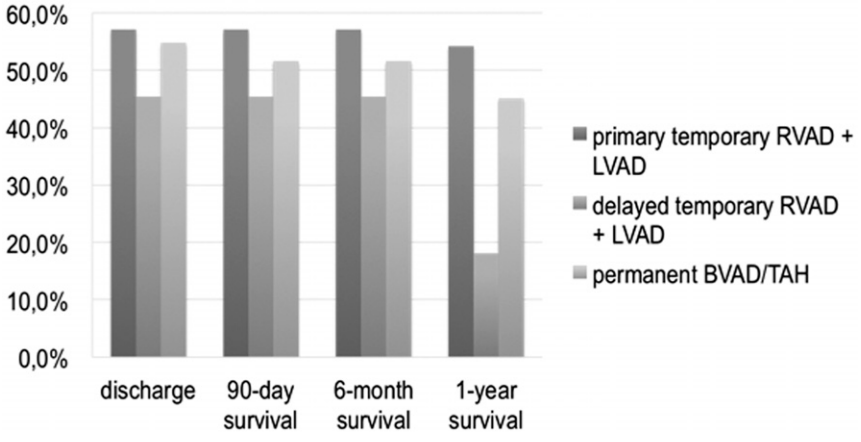

FIG. 1. Outcome of temporary RVAD plus long-term LVAD and permanent biventricular (BVAD/TAH) support populations.

DISCUSSION AND CONCLUSIONS

RVF requiring RVAD placement is the most significant risk factor for morbidity and mortality in LVAD recipients (1–5). The published literature identifies several potential predictors (14–17,19–21).

The Berlin group identified severe tricuspid regurgitation, RVEF <30%, right ventricle end-diastolic diameter >35 mm, RA >50 mm, and, in terms of RV geometry, S/L ratio >0.65, and R/L ratio <0.72 as risk factors for RVF (14,15). Applying the Berlin algorithm in similar populations of patients, the incidence of RVF was reduced to 10–12% in both Berlin and Rome institutions, which is considerably lower than the 13% to 44% given in previous reports where no similar systematic preselection of patients was performed (1–17,19–21). Puwanant et al. (22) suggested tricuspid annular plane systolic excursion <7.5 mm as a transthoracic echocardiographic predictor of RVF after LVAD implantation. Moreover, Matthews et al. and Fitzpatrick et al. (16,17) created RVF risk score models which have been herein adopted.

All these studies establish that it is possible to preoperatively identify patients who require biventricular mechanical circulatory support and it is plausible that early planned institution of biventricular support will result in better outcomes than delaying insertion of the RVAD as stated by the University of Pennsylvania (6).

However, it is now well recognized that permanent BVAD or TAH recipients have higher morbidity and mortality rates than LVAD recipients in nearly all categories. Farrar and coworkers (7) reported a 58% transplantation rate with Thoratec BVADs compared with a 74% transplantation rate among Thoratec LVAD recipients. Kormos and colleagues (8) had BVAD recipients who survived to transplantation in only 40% of cases. Magliato and associates (9) showed 59% survival to transplantation among their Thoratec BVAD recipients. The most robust experience published to date with the SynCardia TAH is the multicenter PMA trial experience (10,11) which reported a survival to transplantation of 79% versus 46% of BVAD controls and a treatment success in 69% of the TAH patients versus 37% of controls. The recent option of two miniaturized implatable rotary BVAD supports showed encouraging QOL results when compared with the SynCardia TAH but the success rate was 50% at 6 months according to the Berlin report (18) and similar results exist concerning the adoption of two axial flow pumps (23).

Thus we hypothesized that high-risk LVAD support recipients may get improved outcome by early planned temporary CentriMag RVAD insertion as opposed to delayed conversion of LVAD to permanent BVAD support or even to primary planned permanent BVAD or TAH support as partially described elsewhere (12,13).

Before adopting such a different strategy, we analyzed the data of our instutions, and found that 37.5% of long-term LVAD-only patients with similarly poor preoperative RV function died in hospital due to MOF despite maximal pharmacological support, correct volume balance management, and implantation of an RVAD support (paracorporeal Thoratec or Berlin Heart Excor) which was late and not beneficial (late being defined as more than 72 h after patients' arrival in the ICU).

In our study, the temporary CentriMag RVAD support in long-term LVAD recipients provided encouraging results compared with the permanent BVAD/TAH population (Table 2, Fig. 1). The strict monitoring and management of RVF at the time of LVAD placement, initially by rapid installation of a temporary RVAD and secondly, at the time of weaning from RVAD, by adequate pharmacological therapy (inhaled nitric oxide and moderate dosage infusion of intravenous inotropic support by adrenaline or milrinone) even during the follow-up (sildenafil daily, 25 mg/12 h orally for 3–6 months) (12) and without left ventricular over-unloading (5) may provide stable hemodynamics and right ventricular function during the overall time of LVAD support only.

Moreover, simultaneous intraoperative temporary RVAD installation at the time of long-term LVAD placement seems to be more effective and to provide better outcome compared with the delayed temporary RVAD installation (Table 3).

At latest follow-up, the LVAD outpatients ($n = 25$) showed an acceptable RV function and geometry in echocardiographic studies, thus confirming the success of the previous weaning from temporary RVAD (14,15). These results support the hypothesis of an eventual improvement of RV myocardial function during long-term LVAD-only support (24–27).

Currently, permanent BVAD or TAH support remains the gold standard for treatment of severe refractory biventricular failure (1,6,11,18,27). According to the data we have reported, a rapid or even simultaneous temporarily mechanical RV support installation may so far be the best option we reccommend in the case of long-term LVAD recipients at high risk for RVF (12–15,18,24,27). The weaning from and removal of the temporary RVAD support might allow patients to be on LVAD support only despite preoperative biventricular dysfunction. However, further scrutiny and longer follow-up times

are still necessary to provide robust conclusions because our study has limitations.

Study limitations

This is not a prospective or randomized study but the report of a retrospective analysis. The number of patients is small but well selected, which limits statistical power to discriminate multivariable analyses. In view of the number of patients, the TAH and BVAD populations were not separated as the study was intended to focus only on permanent biventricular support necessity versus "temporary biventricular support" adoption. In addition, all VADs were implanted at two institutions and our results may reflect some institutional bias. All VAD types used in the study period in our institutions were included because we believe that the physiological status of the patient, rather than the device type, is the primary determinant of the need for biventricular support. The risk scores for right heart failure were mainly validated in pulsatile devices, whereas in this study mostly continuous flow devices were used.

No QOL instrument was used in our study. It is clear that QOL may improve in the case of implantable continuous flow LVAD-only support if compared with permanent BVAD/TAH support in terms of device size, equipment, noise, location, and durability (1,3,11,18,23–27).

Nevertheless, if these findings can be confirmed by others, they would have important implications for LVAD or BVAD implantation decision making.

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