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# An international multicenter experience of biventricular support with HeartMate 3 ventricular assist systems

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Abstract

Significant right ventricular failure accompanying left ventricular failure was treated by implantation of the fully magnetically levitated centrifugal HeartMate 3 ventricular assist device as bi-ventricular support in 14 patients in 6 medical centers worldwide. The clinical details of this first multi-center experience are described, with 9 of these patients (64%) being alive as of January 1, 2018 - 8 of them ongoing on BiVAD support for 95 - 636 (mean 266) days, 7 of them at home, and one successfully transplanted after 98 days of support.

Clinically significant right ventricular failure remains a major Achilles heel in the success of left ventricular assist device implantations. Although its true incidence is still widely disputed [1,2], there is no doubt that a definite, albeit small, number of patients with progressive heart failure need long-term biventricular mechanical support. The only currently approved device for chronic biventricular support, the Syncardia total artificial heart, is limited by its relatively large size and by the lesser quality of life it may provide compared with continuous flow pumps, and therefore over the last years there has been an ever-growing off-label use of two HeartWare ventricular assist devices as biventricular assist device (BiVAD) support [3,4]. In the last report from the INTERMACS registry, there are 618 cases of implantation of continuous flow BIVADs [5]

Since its first implantation [6], the introduction of the HeartMate 3 fully magnetically levitated ventricular assist device, with its improved clinical features as compared to previous generation pumps [7-11], has generated an interest in using it also in a BiVAD configuration. Following the publication of the first two clinical experiences with the HeartMate 3 BiVAD by the German Heart Center Berlin group [12], there have been 12 additional cases performed globally, and it is the aim of this report to summarize the first multicenter experience with this modality.

Case presentations

Fourteen patients were each implanted with two HeartMate 3 ventricular assist devices in a BiVAD configuration in six medical centers worldwide: four patients at the German Heart Center Berlin, three patients each at The Alfred in Melbourne, Australia, and at the Heart Center of the University of Leipzig, two patients at the Hannover Medical School and one case each at the Medical University of Vienna, Austria, and the Heart Center of the Sheba Medical Center in Israel.

Patients' preoperative characteristics are detailed in Table 1. Seven of the 14 patients were diagnosed with dilated cardiomyopathy and 9 were in INTERMACS level 2.

In 8 patients the right ventricular assist device (RVAD) was implanted simultaneously with the LVAD: in 6 patients the RVAD implantation was planned preoperatively, due to severe clinical right heart failure accompanied by elevated central venous pressures (22 to 28 mmHg) and severely reduced right ventricular function by echocardiography (below 10%), and in 2 patients - following failure to wean from cardiopulmonary bypass following LVAD implantation. Five patients were implanted and supported first with a temporary RVAD using CentriMag or Levitronix pumps for 9 – 112 (mean 45.6) days following LVAD implantation due to failure to wean from cardiopulmonary bypass, before being subsequently implanted with the HeartMate 3 RVAD. All of these patients failed repeated attempts to wean from the temporary RVADs, using a combination of catecholamines, milrinone, levosimendan and a variety of pulmonary vasodilators, including sildenafil, iloprost and nitric oxide. In one patient the HeartMate 3 RVAD was implanted 76 days after the LVAD, without a temporary RVAD, due to late onset of right heart failure and deterioration of right ventricular function which did not respond to maximal medical therapy.

In 12 patients the RVAD had been implanted into the right atrium, using felt spacers glued to each other with Bioglue (CryoLife, Guildford, UK), underneath the sewing ring to decrease the intra-luminal length of the RVAD inflow cannula (Fig. 1). The RVAD pumps protruded from the pericardial sac into the right pleural space through a pericardial incision and were all covered by polytetrafluoroethylene patches. No surgical problems were encountered with RVAD implantation due to patient size or thoracic space dimensions. In one patient the RVAD was implanted into the diaphragmatic wall of the right ventricle, and in one patient both ventricles were excised and the HeartMate 3 BiVAD was configured as a total artificial heart. In five patients an 8 or 10 mm down-sized Hemashield graft was used as an RVAD outflow graft, but in the other 9 patients, down-sizing of the RVAD outflow graft diameter was not used. In 6

patients the RVAD outflow grafts were positioned lateral to the right side of the heart and crossed the aorta anteriorly to the pulmonary artery, and in 7 patients the grafts were routed along the diaphragmatic border of the right ventricle and then up the left side of the heart to the pulmonary artery. The initial LVAD flows ranged from 3.6 to 6.5 (mean 5.0) lit/min, with LVAD pump speeds of 5100 – 7000 (mean 5800) RPM, and RVAD initial flows were 2.4 – 5.4 (mean 4.0) lit/min, with RVAD pump speeds of 4400 – 6700 (mean 5200) RPM.

Nine of the 14 BiVAD patients (64%) were alive as of January 1, 2018: 8 patients were ongoing on BiVAD support for 95 - 636 (mean 266) days, 7 of them having been discharged home, and one was successfully transplanted after 98 days of support following an uneventful BIVAD explantation. In none of the patients in our series have there been attempts to wean from the HeartMate 3 RVAD. Five patients died after 10, 60, 83, 99 and 155 days of support. Causes of death were sepsis in three patients, hemorrhagic stroke in one and RVAD thrombosis in the patient in whom both pumps were used as a total artificial heart. A competing risks model using the R-package (cmprsk test) was used to estimate the risk of the competing outcomes of death, transplantation and continued support following BiVAD implantation. The model estimated that at 21 months following BiVAD implantation, the cumulative incidence of death was 45.5% and transplantation was 8.7% (Figure 2).

Other complications included blocking of the RVAD by a previously identified right atrial thrombus necessitating its replacement in one patient, sepsis in two patients, renal failure in one, gastrointestinal bleeding in one, epistaxis in one patient and drive line exit wound infection in one patient.

## Discussion

This small initial series of 14 patients suggests that the HeartMate 3 VAD may be used as a bi-ventricular support device. Although originally not designed and intended to be used as an RVAD, the HeartMate 3 pump was successfully utilized in this series for right sided support,

albeit with an improvised surgical approach, necessitating the shortening of the protruding length of the inflow cannula by using felt spacers underneath the right atrial sewing ring.

The low incidence of thrombosis recorded with the use of the HeartMate 3 as an LVAD so far [6-11], has been maintained in this series in the RVAD configuration too, as only one case in our series resulted in primary RVAD thrombosis, and this was the case in whom both pumps were used as a total artificial heart. The second case in our series in which RVAD replacement was necessary was due to embolization of a previously identified right atrial thrombus into the inflow cannula of the RVAD blocking the pump.

It is noteworthy that in 9 of the 14 cases in our series down-sizing of their RVAD outflow grafts diameter was not utilized. Downsizing the RVAD outflow graft diameter has been utilized in many previously reported cases of in which continuous flow devices were used as BiVADs, attempting to avoid pulmonary overflow by the RVAD, however this strategy has not been formally investigated. It is possible that due to the magnetically levitation of the impeller of the HeartMate 3 pump it may rotate and remain stable at a lower speed needed for balancing the RVAD flow to that of the LVAD, and thus there is no need to protect the lungs by downsizing the RVAD outflow graft diameter. In practice, the RVADs' mean pump speed in our series was lower by only 600 RPM compared to that of the LVADs (5200 vs 5800), and the lowest RVAD pump speed which has been utilized was 4400 RPM, considerably above the 3000 RPM minimal threshold provided by the pump controller. Lacking any compelling evidence for the need to perform downsizing of the RVAD outflow graft, it was performed in our series at the discretion of each surgeon.

The current need for dual peripherals is inconvenient for patients, although patients did cope with this onerous system. Future design modifications (of the pump and peripherals) will need to consider decreased burden to the patient.

Based upon our initial experience we conclude that the HeartMate 3 pump may be used as BiVAD in patients in need for a long-term bi-ventricular support. Further clinical experience with this modality is clearly needed before it can be recommended for routine use.

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The following authors wish to disclose their conflicts of interest:

Evgenij Potapov – Proctoring for Abbott and Medtronic; Jens Garbade, Jan Schmitto, Daniel Zimpfer - Scientific advisors for Abbott and Medtronic;

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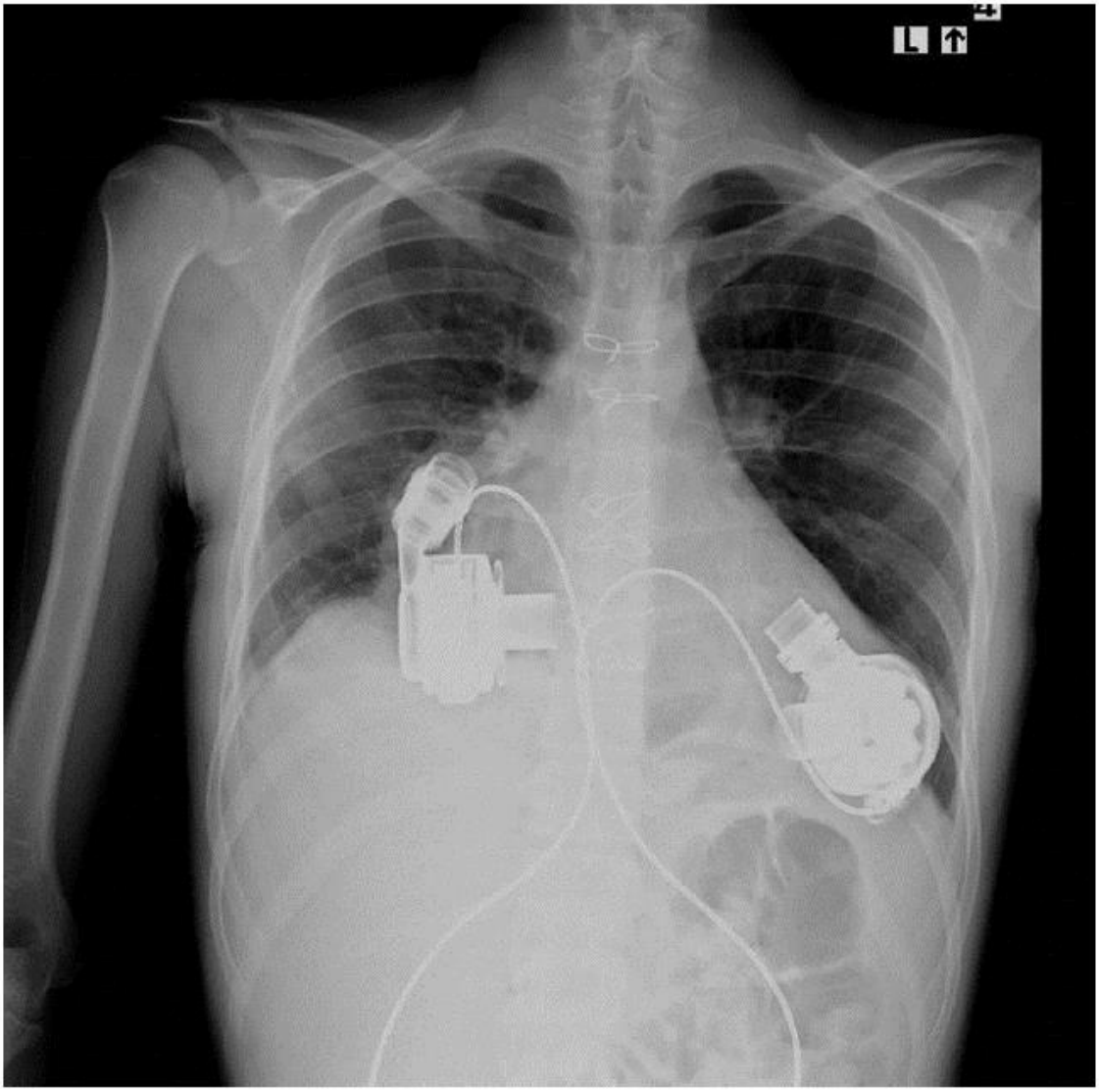


**Figure 1.** Chest X ray of the patient displaying both VADs

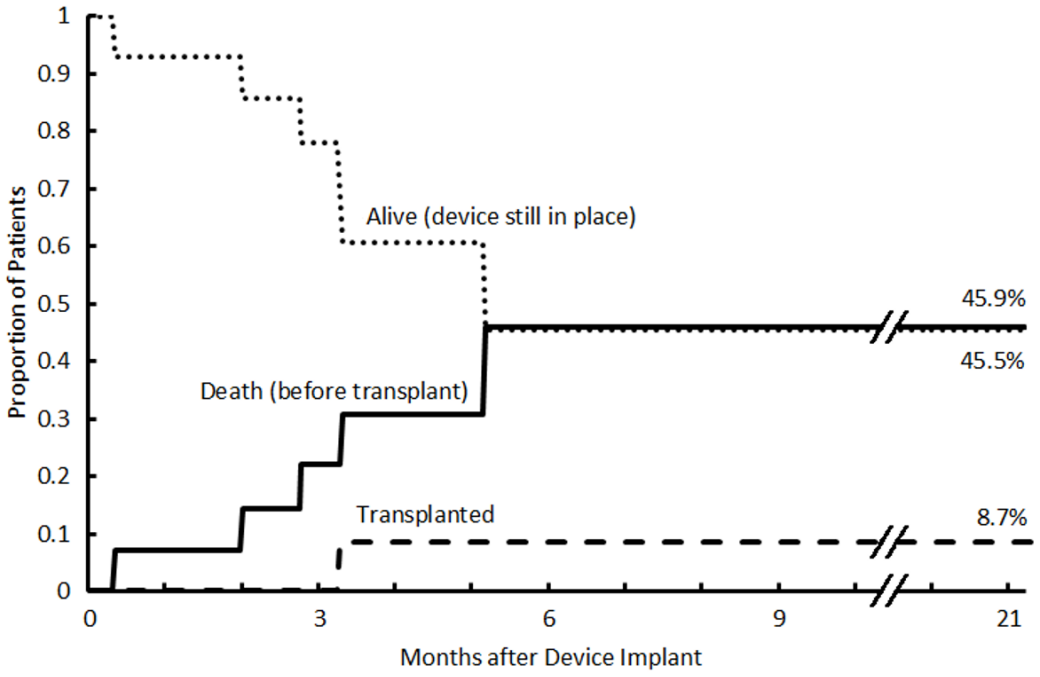


**Figure 2.** Competing outcomes for the 14 patients implanted with HeartMate 3 BIVAD, depicting patients alive on the device, dead before transplant and the one transplanted patient.

Table 1. Preoperative patients' characteristics

| | N = 14 |
|---|---|
| Male / Female | 13 / 1 |
| Age (mean) (years) | 17 – 73 (48.5) |
| Weight (mean) (Kilograms) | 61 – 137 (84.1) |
| Heart failure etiology: | |
| Dilated cardiomyopathy | 7 |
| Ischemic cardiomyopathy | 4 |
| Familial cardiomyopathy | 1 |
| Failed correction of type A aortic dissection | 1 |
| Doxorubicin induced cardiomyopathy | 1 |
| INTERMACS: | |
| Level 1 | 2 |
| Level 2 | 9 |
| Level 3 | 3 |
| Previous surgery: | |
| CABG | 3 |
| Ascending aorta and arch replacement, | 1 |
| Aortic valve sparing root replacement | 1 |