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CASE REPORT

Artificial Heart (Clinical)

Conversion from long-term AB-5000 to EVAHEART using a combined left thoracotomy and sternotomy approach

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Abstract Because of the extreme donor shortage in Japan, waiting times for heart transplantation exceed 2 years. Since 1980s in Japan, device availability has also been an issue, with only a few paracorporeal ventricular assist devices (VADs) available as a bridge to transplantation or recovery. However, two implantable VADs became commercially available in 2011. Given these constraints in our healthcare system, we report a relatively rare case of bridge-to-bridge use of an implanted EVAHEART after having used a paracorporeal AB-5000 support for an extended period of time. We successfully employed a combined left thoracotomy and median sternotomy approach as a conversion technique.

Keywords Ventricular assist device · Bridge to bridge · AB-5000 · EVAHEART

Introduction

Paracorporeal ventricular assist devices (VADs) are commonly indicated for short-term use as a bridge to decision, candidacy, and recovery for adult patients. However, they are occasionally used as a long-term support for several reasons.

Because of the extreme shortage of donor hearts in Japan, the average waiting time for a heart transplant exceeds 2 years. Until recently, 80 % patients waiting for a heart transplant were supported by paracorporeal VADs. However, the outlook is changing because of the introduction of two types of commercially available implantable VADs in 2011, following approval by the Japanese Ministry of Health, Labor and Welfare. In consideration of this history, we relate the relatively rare case of the bridge-to-bridge usage of an implantable VAD after patients had received paracorporeal VAD support for an extended period of time. A combined left thoracotomy and median sternotomy approach was successfully employed as a conversion technique.

Institutional approval for this clinical report has been waived.

Case report

A 55-year-old male diagnosed with dilated cardiomyopathy required frequent admissions despite taking optimal medications over 2 years. He was eventually transferred to our hospital while on intravenous inotropes and underwent an implantation of AB-5000 VAD (ABIOMED, Inc., Danvers, MA), which was available as part of a clinical trial in Japan. He was subsequently listed as a candidate for heart transplantation. Consecutive echocardiography revealed reverse remodeling of the left ventricle (Fig. 1a), and approximately 12 months later, hemolytic anemia developed, which gradually worsened. Chest radiography revealed that the direction and position of the inflow

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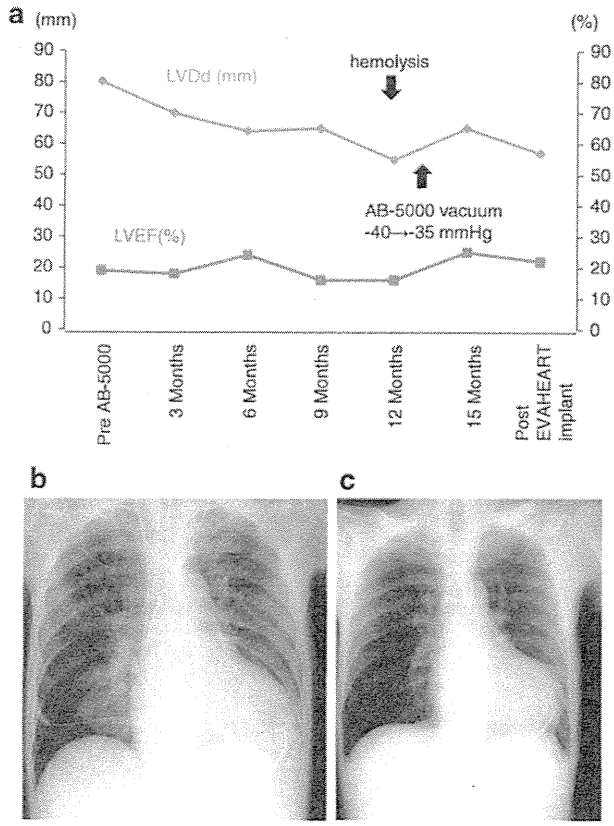

Fig. 1 Changes in left ventricular ejection fraction (LVEF) and diameter in diastole (LVDd). **a** Chest radiograph at POD 1; and **b** at POD 465; **c** at AB-5000 implantation, revealing there were no remarkable changes in the position and shape of the inflow cannula

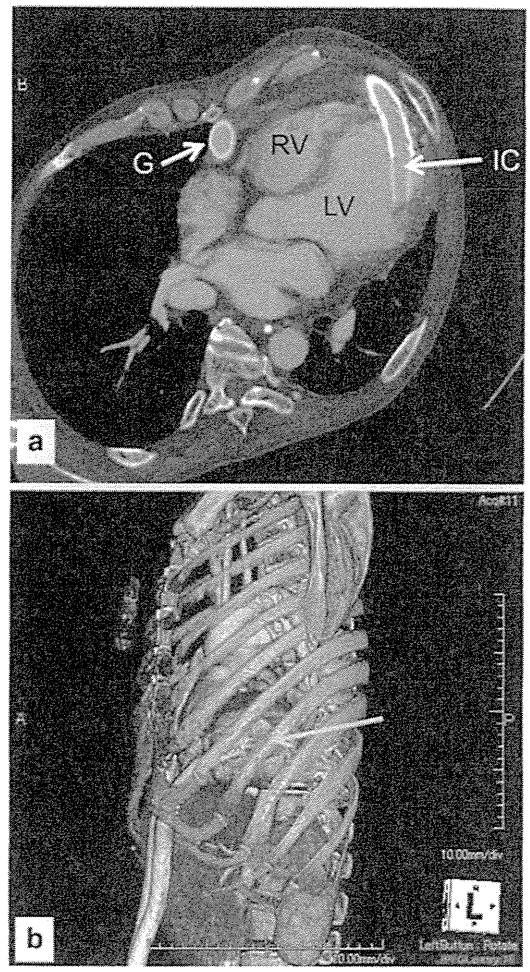

Fig. 2 Computed tomography images showing the following: the inflow cannula tip located close to the left ventricular posterior wall; **a** reconstructed two-dimensional image, **b** three-dimensional image and the inflow cuff of AB5000 (*yellow arrow*) located beneath the *left* lateral chest wall at the sixth intercostal level. *G* outflow graft, *IC* inflow conduit, *RV* right ventricle, *LV* left ventricle

cannula was unaltered (Fig. 1b, c), but computed tomography (CT) indicated the tip of the inflow cannula located close to the left ventricular posterior wall (Fig. 2a), and echocardiography revealed a high-velocity jet towards the tip. It may be possible that the location and direction of the inflow cannula changed following reverse remodeling of the left ventricle. Therefore, mobilization of the inflow cannula was necessary to resolve hemolysis. Coincidentally, new implantable VADs had been approved in Japan, and the patient desired to be discharged home following a future conversion from the paracorporeal VAD to an implantable VAD. Therefore, it was decided to convert the AB-5000 to an implantable centrifugal VAD, EVAHEART (Sun Medical Co., Nagano, Japan) [1]. However, sizes of inflow and outflow cannulae of EVAHEART were largely different compared with those of AB-5000, and it was necessary to exchange all parts of these devices. Echocardiography revealed that the inflow cuff was exceedingly laterally positioned from the midline. Preoperative CT assessment revealed that the inflow cuff was located beneath the left lateral chest wall at the sixth intercostal level (Fig. 2b). Accordingly, it was predicted that meticulous dissection around the left lateral side of the inflow cannula and the left ventricle would be technically challenging and also that re-dissection of the entire left ventricle for mobilization would impose additional adhesions before any foreseeable heart transplantation. Therefore, we elected to perform a combined left thoracotomy and median sternotomy approach for the conversion.

General anesthesia was conducted using a double-lumen endotracheal tube. The patient was positioned in the right lateral semidecubitus position, left side up. A left thoracotomy approach through the sixth intercostal space was made to obtain clear exposure of the cardiac apex and the inflow cuff of AB-5000 (Fig. 3a, b). The overlying pericardium was incised to a point sufficient to allow access to the left ventricular apex. Other cardiac structures and the outflow graft were dissected through the repeated median

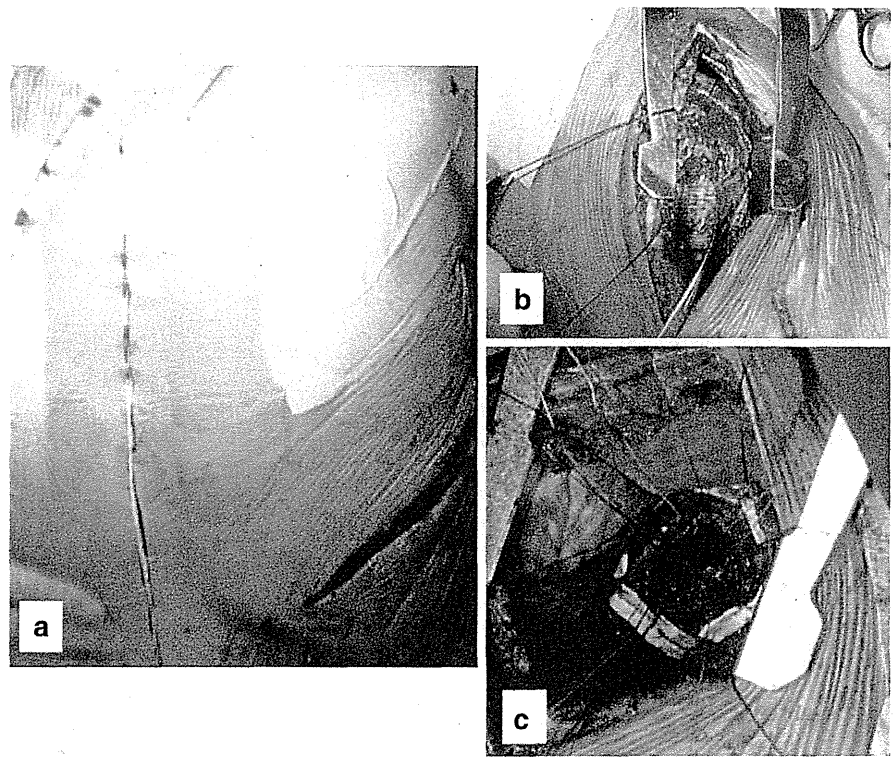

Fig. 3 **a** Re-median sternotomy incision made, **b** after meticulous dissection around the inflow cuff through the *left* anterior incision through the sixth intercostal space. **c** Eight pledgeted sutures to fix an EVAHEART inflow cuff were also placed through the sixth intercostal thoracotomy

sternotomy. No infectious findings were identified in the mediastinal space, and therefore, the pump pocket and driveline tunnel of EVAHEART were created in the preperitoneal space without undue concern. After the establishment of a cardiopulmonary bypass, AB-5000 was turned off. A partial occlusion clamp was placed across the ascending aorta to exclude the AB-5000 outflow graft. The previous outflow graft was removed, and an EVAHEART outflow graft was anastomosed on the aorta. The AB-5000 inflow cannula and cuff were removed, intraventricular thrombi along the inflow cannula were carefully removed, and eight pledgeted mattress sutures were placed in a ring-like fashion through the thoracotomy (Fig. 3c). After securing the EVAHEART inflow cannula to the left ventricular apex, the EVAHEART pump was connected with the cannulae and placed in the pump pocket. EVAHEART was able to run without any hemodynamic deterioration. The opened pericardium was repaired using an expanded polytetrafluoroethylene (ePTFE) sheet to prevent adhesion between the left ventricle and lung. The postoperative course was uneventful, hemolytic anemia resolved, and no infectious complications were reported. The patient was discharged home and resumed work. He underwent heart transplantation 19 months after EVAHEART support. We confirmed that no adhesion between the heart, EVAHEART, and lungs was observed during the heart transplantation.

Discussion

Some patients who could be considered for VAD implantation as a bridge to transplantation are unfortunately too ill to be identified as candidates for cardiac transplantation. Temporary mechanical support devices, primarily paracorporeal types, provide immediate support in such cases [2]. Once the general condition of patients has improved and they can be identified as candidates for cardiac transplantation, the replacement of the device with implantable VADs is considered, and this usually is performed within a month.

However, paracorporeal VAD was the sole available device for all bridging purposes in Japan until 2011. A situation where a paracorporeal VAD originally designed for intermediate-term use is utilized for a prolonged period of time is extremely exceptional.

In this study, reverse modeling of the left ventricle had gradually advanced, and the positional relationship between the left ventricular shape and the cannula shape had altered. It was evident that the AB-5000 inflow cannula had been so malleable that its location had altered during ventricular remodeling. After 1 year of support with AB-5000, the diameter of the left ventricle had become 55 mm, but the ejection fraction was still low. After vacuum pressure had changed from −40 to −35 mmHg to improve hemolysis, which was the weakest negative

pressure possible with this device, the ejection fraction of the left ventricle was still <30 %. We did not challenge the application of a bridge to recovery strategy in this case.

With regard to technical modifications, we elected an approach using a combined lateral thoracotomy with median sternotomy because chest radiography revealed the previously placed inflow cannula to be far offset to the left, and CT revealed that the inflow cuff was located just beneath the left lateral chest wall. It may be possible that replacing the inflow cuff through a left thoracotomy would minimize the exposure range of the left ventricle, particularly for the posterior wall, and that if the inflow cuff replacement was performed through the median sternotomy alone in this patient, the exposure of the entire surface of the heart would be needed to lift the left ventricle for inflow cuff replacement, which may increase the risk of bleeding. We considered that another advantage of this approach was that perpendicular visualization could facilitate an inspection of the inside of left ventricle and thus meticulous removal of the wedge thrombus. Recently, reports related to replacement of implantable LVAD using a thoracotomy or a thoracotomy and subcostal approach (as less invasive approaches) have been published [3, 4]. In our case, it was necessary to additionally use a re-median sternotomy because the outflow graft was far from the thoracotomy. The AB-5000 outflow cannula comprised a short (10 mm) Hemashield graft and a plastic tube reinforced by spiral wire. The EVAHEART outflow graft consisted of a 16-mm ePTFE graft. The discrepancy in graft size and the differences of graft flexibility would have caused kinking of the outflow graft to the graft anastomosis. Therefore, we removed the entire AB-5000 outflow graft and directly anastomosed the EVAHEART outflow graft to the aorta.

We have now performed additional four surgeries using the same approach and no patient has complained of pain at the point of thoracotomy incision, and no infection has been reported associated with the thoracotomy. However, this case is the only one that has reached the stage of heart transplantation so far, and no severe adhesions between the heart, device, and lungs were observed. We do not think that this approach should be considered in all conversion cases, and we have not used this approach in cases where cardiomegaly has been significantly improved. We have only used the re-median sternotomy to access the device because this approach is more suitable for patients on long-term VAD as it sustains ventricular dilatation. We believe that further study is required to establish criteria whereby this approach can be employed using CT images.

In conclusion, we report our experience with replacement of a long-term paracorporeal VAD with an implantable VAD. It is considered that an approach using both left thoracotomy and repeated median sternotomy ensures that the procedure is safer, particularly for patients with a dilated heart.

Conflict of interest Kenji Yamazaki serves as a consultant to Sun Medical Corporation. Other authors declare no conflict.

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