Case Report

Successful Bi-Ventricular Abiomed Support in a Coronary Artery Bypass/Mitral Valve Replacement Patient

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ABSTRACT

The Abiomed Bi-Ventricular Support System is recommended for patients with post-cardiotomy ventricular dysfunction who have undergone successful cardiac surgery, and then subsequently develop low cardiac output, impairing hemodynamic stability. Stagnant blood flow from ventricular unloading increases the potential for thrombus formation on artificial surfaces of ventricular assist devices and mechanical valves. This case discusses the management of a patient successfully weaned from Abiomed bi-ventricular support following coronary artery bypass and mitral valve replacement with a mechanical prosthesis. We will also describe the management of a console failure that occurred before device explantation.

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INTRODUCTION

This unique case discusses the clinical course of a mechanical valve and coronary artery bypass grafting (CABG) patient who required Abiomed bi-ventricular assist devices (bi-VAD). The patient, a 69 year old female, experienced a stunned myocardium perioperatively. She could not be weaned from cardiopulmonary bypass (CPB) using an intra-aortic balloon pump (IABP) with conventional pharmacologic therapy and required bi-VAD support. The patient's management while on support and the response to a console failure that occurred during assist are outlined here.

CASE REPORT

A 69 year old female with known mitral valve disease presented with increased exertional dyspnea, easy fatigability, and congestive heart failure. Her past medical history included atrial fibrillation, hypertension, hyperlipidemia, cardiomegaly, and morbid obesity. Cardiac catheterization revealed severe triple vessel disease, 3+ mitral regurgitation, and an ejection fraction of 55%. She underwent mitral valve replacement with a 33 mm mechanical prosthesis and left anterior descending and posterior descending artery revascularization using saphenous vein grafts.

After 105 minutes on CPB and 75 minutes cross clamp time, termination of bypass failed twice. Bypass was resumed, 2 g calcium chloride was administered, an epinephrine drip was started at 0.03 mcg/kg/min and titrated to 0.175 mcg/kg/min, and an amrinone drip was begun at 10 mcg/kg/min following a 60 mg loading dose. Two units of packed red blood cells (PRBCs) were given for a 22% hematorcrit. Weaning was again unsuccessful and an intra-aortic balloon was inserted.

Despite pharmacological and IABP[a] support at 1:1, filling pressures remained greater than 20 mmHg, indicating left heart failure. The patient experienced atrial fibrillation and was treated with 500 mg procainamide and 0.5 mg digoxin. Trans-esophageal echocardiogram (TEE) demonstrated a normally functioning valve and severe global dysfunction of the left ventricle. These findings were consistent with the increased afterload associated with an MVR in the setting of a long standing significant MR and myocardial stunning. Based on the inability to wean the patient using conventional measures and the TEE findings, the patient was placed on Abiomed[b] left ventricular support.

While on CPB, inflow to the left ventricular assist device (LVAD) was established from the left atrium using a 36 French (Fr.) malleable cannula[b]. Outflow was established using a 46 Fr. wire reinforced arterial cannula[b] placed in the anterior aortic root. Once the patient was on LVAD support, weaning from bypass was still unsuccessful due to right ventricular failure.

Bypass was resumed and a right ventricular assist device (RVAD) was placed utilizing the same size inflow and outflow cannulas as on the left. Bi-ventricular assist was then initiated and the patient was weaned from bypass with a device output of 4.0 to 5.0 L/min bilaterally. Following bi-VAD initiation, the atrial fibrillation came under control, the systemic blood pressure was 85/53 mmHg, the pulmonary artery (PA) pressure was 39/16 mmHg, and the central venous pressure (CVP) was 16 mmHg. Intra-operative TEE showed minimal systolic left ventricular contractions which produced small ejections seen on the arterial waveform.

Once the patient's pressures stabilized, the heparin was fully reversed, in accordance with Abiomed recommendations, to ensure control of bleeding before beginning heparin therapy. However, 24 hours should not be exceeded without heparinization. Following heparin reversal, the activated clotting time (ACT) remained elevated (183 seconds), the hematocrit was 22%, and oozing was seen at the VAD insertion sites. This was treated with 10 units platelets, 2 units fresh frozen plasma (FFP), and 2 units PRBCs. After the bleeding diminished, attempts at closing the chest were unsuccessful due to visible heart edema and decreased blood pressure when the sternal edges were approximated. Consequently, the wound was packed with vancomycin soaked kerlix, the chest was left open, and a sterile dressing was applied. Ninety minutes after bi-VAD insertion, the patient was transferred to the Intensive Care Unit (ICU).

The patient arrived in ICU on 1.0 mcg/kg/min nitroglycerin, 0.18 mcg/kg/min epinephrine, and 0.05 mcg/kg/min norepinephrine with a systolic blood pressure in the high 90s. The ACT upon arrival in ICU was 123 seconds, and a heparin drip was started at 700 units per hour (u/hr) and titrated to maintain the ACT between 200 and 250 seconds (Figure 1). Packed red cells were ordered as needed to sustain a hematocrit above 27%. The epinephrine was weaned 0.003 mcg/kg/min every two hours as long as the systolic BP remained 95 mmHg or greater. Minimal left ventricular ejection was necessary to prevent thrombus formation by continuously washing the mechanical valve while allowing the heart to rest. The CVP and PA diastolic pressures were kept between 10-18 mmHg using hetastarch and crystalloid to maintain this ejection as evidenced by small arterial waveforms. No specific target pulse pressure limit was set or measured.

Within the first two hours postoperatively, there was 1,230 ml of bloody chest tube drainage. The ACT was 173 seconds at that time. Four units PRBCs, 10 units platelets, 4 units FFP, and 50 mg protamine were given to treat the bleeding (Table 1). While on bi-VAD support, a mediastinal exploration was performed in the ICU. Mild bleeding from the pulmonary artery cannulation site was found and controlled with pledgeted sutures. The wound was irrigated with thrombin solution and packed with antibiotic soaked laparotomy sponges. The vein grafts were

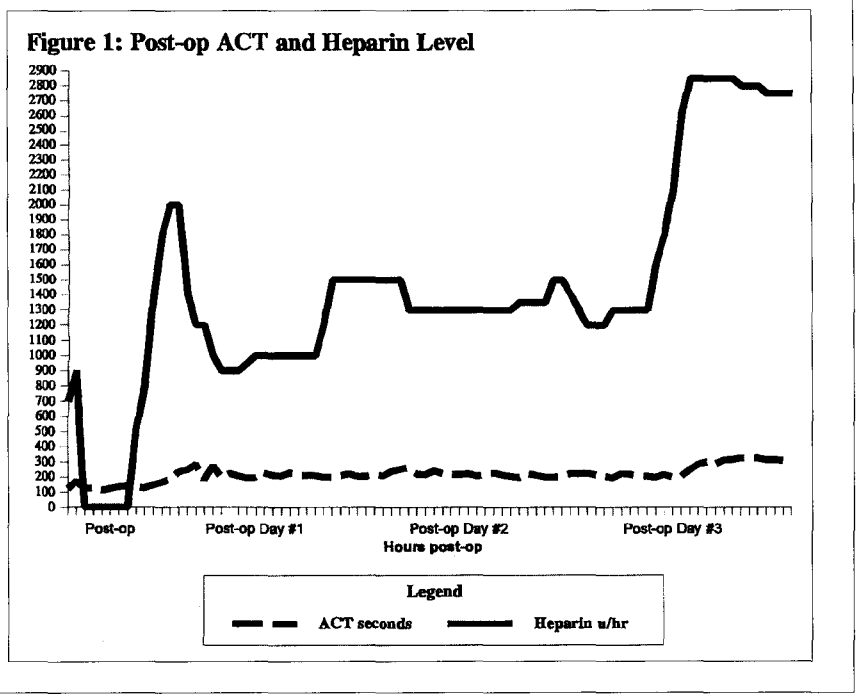
a Datascope Corp., Montvale, NJ 07645
b Abiomed Cardiovascular, Inc., Danvers, MA 01923

patent and the heart was visibly contracting better than immediately following surgery. The heparin drip was stopped during the procedure and restarted six hours later after the chest tube drainage was less than 50 ml per hour.

The following day, a chest x-ray showed right upper lobe atelectasis. A fiberoptic bronchoscopy revealed a blood clot obstructing the right upper lobe. The clot was removed and the remainder of the lung appeared normal.

On post-op day #2 , the patient's platelet count was less than 100,000/ml, the hematocrit had fallen to 28% from 32% the day before, and she had nearly a liter of bloody chest tube drainage out over the previous 24 hours. Platelets (10 units) and PRBCs (2 units) were given and a mediastinal exploration was done in the ICU to look for bleeding at the VAD insertion sites. The heparin drip was continued during the procedure, which revealed no active bleeding.

Figure 1: Post-op ACT and heparin level



By post-op day #3, while still on full bi-VAD support, the bleeding had stabilized. The patient's hemodynamics had also stabilized with a blood pressure around 100/70 mmHg, and the epinephrine and norepinephrine were off. Pulmonary artery pressure and CVP were within normal limits, and increased native ejection seen on the monitor indicated myocardial recovery. For these reasons, weaning was begun. The RVAD was weaned first, as per Abiomed recommendations. The flow was decreased 500 ml every four hours until a 2.0 L/min was reached. Once the RVAD was at 2.0 L/min, the ACT range was increased to 275-325 seconds. The patient tolerated this flow with a systemic systolic pressure in the 120's, PA pressures 20s/10s, and CVP in the low to mid-teens. With the RVAD at 2.0 L/min, LVAD weaning was begun at 500 ml every four hours. This lower flow allowed more volume to return to the heart and caused increased ejection. This was tolerated well, and explantation was scheduled for the following day.

At 2:00 a.m., the Abiomed console audibly alarmed, indicating that it had switched to battery power. Despite changing wall outlets, turning the device off and restarting it, and biomedical engineering checking the circuits and console, AC power could not be restored. Considering that the battery operates for only one hour, the patient was in stable condition and was scheduled for explantation, the surgeon was informed of the failure and emergency explantation was performed in the routine fashion.

In the operating room (OR), after the packing and blood clots around the heart and mediastinum were removed, the RVAD inflow, then outflow, were clamped and the patient's hemodynamics were monitored. The patient tolerated this well. Next, the left pump inflow was clamped, followed by the outflow, and the patient tolerated this as well. The cannulae were then removed and the chest was closed in the usual fashion.

The patient returned to the ICU with stable hemodynamics on 0.05 mcg/kg/min epinephrine and 0.5 mcg/kg/min nitroglycerin. Her ICU stay was complicated by respiratory failure but she was extubated seven days after her CABG/MVR. One week later, post-op day #14, she was transferred to in-patient rehabilitation. On post-op day #22 the patient was discharged home from rehab with no visiting nurses or out-patient rehabilitation recommended.

DISCUSSION

The Abiomed blood pump is a disposable dual chamber (atrial and ventricular) system separated by tri-leaflet valves. It fills by gravity and requires no vacuum. The atrial chamber permits continuous blood flow from the patient into the top (atrial) chamber and is expelled from the bottom (ventricular) chamber by a console using a pneumatic drive system to compress room air to drive the blood pumps. The system is automated to adjust systole, diastole, rate and flow of each pump automatically and independently, thereby eliminating the need for the operator to "set" a certain flow rate for either pump except during weaning. The rate of each is dependent upon the volume it receives and the afterload it is pumping against (1).

Thrombus and emboli formation are inherent risks of blood and artificial surface interactions (2). This, coupled with the risk of stagnant flow by diversion of blood from the heart to an assist device, increases the chance of thrombus formation on a mechanical valve (3,4). In this case, these complications were

Table 1: Post-op VAD flows, blood loss, lab work, and blood products

Table 1: Post-op VAD flows, Blood loss, Lab work, and Blood Products

Left Flow	Right Flow	Chest Drainage	Lab Values	Blood Products
Post-op Day of Surgery				
4.1-4.6	4.3-4.9	1,445cc	On Arrival in ICU: H/H=10.2/29.9 Platelets=132 PT/PTT=15.7/47.0 0400: H/H=10.1/29.8 Platelets=137 PT/PTT=15.1/>150	2u FFP 4u PRBCs 10u Platelets
Post-op Day #1				
3.9-4.6	4.0-5.1	950	H/H=10.8/31.6	
Post-op Day #2				
3.9-4.4	4.4-4.8	120	H/H=9.8/28.3 Platelets=82,000 PT/PTT=14.8/>150	2u PRBCs 10u Plat.
Post-op Day #3				
Begin wean	Begin wean	420	H/H=9.2/28.3 Platelets=87,000 PT/PTT=13.2/129	2u PRBCs

minimized by maintaining adequate anticoagulation and by keeping filling pressures at a level which allowed a small amount of left ventricular ejection throughout the patient's course.

Immediately after bi-VAD initiation, the heparin was reversed with protamine, as per Abiomed recommendations, to ensure reasonable control of bleeding before heparin therapy initiation; however, 24 hours should not be exceeded without heparinization (1). Once heparin therapy is initiated, Abiomed recommends maintaining ACTs between 180-200 seconds (5). In this case, with the presence of a mechanical valve, that level was increased to 200-250 seconds.

In the ICU, anticoagulation was diligently monitored. Activated clotting times were measured hourly, if the ACT was within ordered parameters, and every 15 to 30 minutes after heparin changes until the ACT was in range. Two hours postoperatively, the heparin was discontinued in ICU, for six hours, due to excess chest tube drainage of undetermined origin. Due to the acute nature of the bleeding, it was more important to treat and find the cause quickly, than to order and wait for lab work. Platelets, FFP, PRBCs, and protamine were given. Exploratory surgery was done in ICU while on full bi-VAD support. By keeping the bi-VADs pumping, the potential for stagnant flow and thrombus formation within the circuit was reduced. The heparin was restarted once the chest tube drainage had diminished to less than 50 ml per hour.

By post-op day #3, because the patient's hemodynamics and hemostasis had stabilized, weaning was begun. First, the RVAD flow was decreased 500 ml every four hours until 2.0 L/min was reached. Then the ACT range was increased to 275 to 325 seconds and LVAD weaning was begun in the same manner. The patient remained stable and explantation was scheduled for the next day.

Equally important to thrombus prevention as adherence to an ACT regime was the maintenance of adequate filling pressures and minimal native ejection. No "set" amount of native ventricular ejection was ordered to ensure this. By keeping the CVP and PAD between 10-18 mmHg with volume therapy, minimal ejection was maintained, as evidenced by the arterial waveform. As support continued, more frequent native ejections were observed on the monitor between VAD ejections, indicating myocardial recovery. This continuous flow minimized the possibility of thrombus formation on the mechanical valve and was instrumental in preventing thrombo-embolic events during support. Because explantation was done emergently, no TEE was performed prior to VAD removal. However, postoperatively, a transthoracic echocardiogram showed a normally functioning valve with no apparent clot formation.

Several hours before explantation was scheduled, the console audibly alarmed that it had switched to battery power. Despite efforts by biomechanical engineering, AC power could not be reinstituted. The battery power lasts only sixty minutes so emergency explantation was performed. According to the Abiomed field service manager, the failure resulted from two separate problems.

The first problem was a blown F6 charger fuse which prevented the battery from receiving a charge. No cause for this was found, but it was believed to have been the result of a power surge. The F6 fuse is internal and not readily accessible, but by installing an external surge protector, a similar circumstance should be prevented.

The second, more complex problem, was failure of the AC to DC converter. When the system is in the AC mode, the converter provides the 24 volt source required to run the system. When the converter failed, the console automatically alarmed and switched to battery backup. The converter was returned to the manufacturer where it was reported that the CR25 diode had shorted causing a loss of the converter's 24 volt output. This failure was not believed to be a result of a power surge and an additional surge protector would not have prevented this failure. No explanation for this was found, but it is believed to be an isolated incident.

In the event these same circumstances should occur in the future, our biomedical engineering department, in conjunction with Abiomed, has designed a way to bypass the AC/DC converter and battery specifically for our institution. This bypass system powers the device by using a plug between the console battery socket and an external AC powered, 8 amp, 24 volt out-

put power supply. If it is ever necessary to utilize this system, it will be implemented by biomedical personnel only. If we had not been ready to explant the device and had depleted the battery, we would have used the backup footpump supplied with the device until another console was available.

Although the console failed, the patient suffered no deleterious effects and is now living independently and leading a lifestyle similar to pre-hospitalization with resolution of her congestive heart failure symptoms.

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