FAILURE OF AN IMPLANTABLE LEFT VENTRICULAR ASSIST DEVICE: A DISTINCTIVE ELECTROCARDIOGRAPHIC PATTERN BEFORE MALFUNCTION

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Long-term implantable left ventricular assist devices (LVADs) have revolutionized the care of patients with heart failure who are awaiting transplantation.^{1,2} The HeartMate Vented Electric (VE) (Thermo Cardiosystems Inc., Woburn, Mass.) Left Ventricular Assist System (LVAS) consists of an implanted LVAD with a percutaneous drive line that connects the internal pump to the external power supply and controller, as well as providing a vent for the internal chamber to the atmosphere. The system is capable of supplying full circulatory support for the left ventricle and is currently being evaluated both as a bridge to transplantation and as a permanent alternative to transplantation in patients with irreversible heart failure.

We report a case of primary pump failure that was heralded by a distinctive pattern on the electrocardiogram (ECG). Although device-related failures with currently available implantable LVADs have been extremely uncommon, we believe the ECG findings described, which occurred before device failure, may serve a predictive function and thereby avoid a catastrophic outcome.

Clinical summary. The patient was a 60-year-old man who had an acute anterior wall myocardial infarction approximately 4 months before evaluation at our institution. Despite timely thrombolytic therapy and urgent coronary balloon angioplasty of an occluded left anterior descending coronary artery, the infarction progressed and the patient was left with severe residual left ventricular dysfunction, with an estimated left ventricular ejection

fraction of approximately 20% by radionuclide ventriculography. After his referral to our institution, he was rehospitalized on two subsequent occasions for decompensated heart failure, which was responsive only to parenteral inotropic agents and diuretics. Despite aggressive medical support, his hemodynamic status continued to deteriorate and he was listed for heart transplantation. Seven months after the infarction, right heart catheterization revealed the following pressures while the patient was maintained on a continuous milrinone infusion: right atrium 8 mm Hg, pulmonary artery 75/39 mm Hg (mean 55 mm Hg), pulmonary artery wedge 40 mm Hg, cardiac index $1.3 \text{ L} \cdot \text{min}^{-1} \cdot \text{m}^2$, and systemic blood pressure 75/50 mm Hg. The patient was judged to have heart failure refractory to maximal medical therapy and the decision was made to proceed with implantation of an LVAD as a bridge to transplantation. The patient's blood type was O+ and the preoperative panel reactive antibody level was 68%.

The device was implanted in the standard fashion with the LVAD positioned in a preperitoneal subcostal pocket with the inflow catheter placed in the left ventricular apex and the outflow graft anastomosed to the proximal ascending aorta. The combined power and control cable exited percutaneously above the left iliac crest in the left lower quadrant of the abdomen. The postoperative course was unremarkable and the patient quickly resumed his preoperative activity level with physical therapy. Anticoagulation consisted of 325 mg of aspirin per day. LVAD flow rates remained at 5 to 6 L/min off all cardiac medications. Renal and pulmonary function remained normal.

On postoperative day 82, the patient reported a vague feeling of generalized uneasiness, and the LVAD flow rates indicated on the external console demonstrated a decrease to approximately 3 L/min. Systemic blood pressure remained within normal ranges. An intravenous bolus of normal saline solution was administered, after which the LVAD flow rates returned to baseline and the patient's symptoms transiently resolved. A 12-lead ECG was obtained (Fig. 1). Approximately 45 minutes later, the patient became acutely unresponsive with minimal mea-

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Fig. 1. Standard 12-lead ECG obtained prior to device failure demonstrating current bursts in synchrony with the LVAD. Native QRS complexes are noted (*arrows*).

Fig. 2. **A,** LVAD motor chamber showing clotted blood over the stator, the magnet, and cams, as well as over and under the retaining screw. The hardened blood clot effectively adheres the movable magnet and cams to the motor chamber housing and stator, thus impeding any rotation of the cams (0.5 $\times$). **B,** Back surface of the pusher plate showing clotted dry blood on the plate and ramps (0.5 $\times$).

surable LVAD flow and no palpable pulse. The LVAD was immediately disconnected from the external electric power source and manual mechanical pumping of the LVAD was initiated, but without achieving a palpable peripheral pulse. Despite vigorous resuscitative efforts with intravenous inotropic/vasopressor agents, a pulse could not be restored and the patient died.

Postmortem examination revealed markedly dilated right and left ventricular chambers consistent with the preoperative diagnosis. All suture lines were intact with no evidence of hemorrhage, perforation, or infection. The valved conduits and pump chamber were intact without evidence of thrombus or valve disruption. The pump chamber that houses the electric motor and cam assembly

was encased with dried blood, which effectively prevented the pusher plate from functioning. Careful examination of the drive line failed to identify a site of perforation through which blood may have entered the system (Fig. 2).

Comment. Implantable LVADs have progressed technologically to a point where they can provide improved survival for patients awaiting transplantation and will also provide a long-term alternative to heart transplantation. The need for this therapy is increasing every year as the number of patients with refractory heart failure increases. Currently available implantable LVADs are either electrically or pneumatically driven, with the former providing greater patient mobility. The HeartMate pneumatic LVAD has been extremely reliable, with few reported device-related failures. These have included a loosening of the outflow connector and erosion of the Dacron fabric within the inflow conduit, both of which have been rectified by design modifications.³⁻⁵ This level of device reliability contributed greatly to the Food and Drug Administration's approval of the pneumatic HeartMate LVAD as a bridge to transplantation.

The VE HeartMate System operates on 12 volts of direct current and draws approximately 1 ampere of current under normal load conditions. However, with increased resistance to pumping, the motor can draw up to 5 amperes of current in bursts. The pattern of high-current bursts observed on this patient's ECG in synchrony with the pump before device failure may be explained by two possible mechanisms. First, the increased resistance encountered by the motor and cam assembly as blood entered the chamber may have resulted in an increased power draw reflected on the external ECG

pattern. Alternatively, blood in the motor compartment may have resulted in a current leak reflected on the ECG. Regardless, the pattern observed on this patient's ECG before device failure correlates clinically with the finding of blood within the actuating mechanism with resultant malfunction. To our knowledge, this finding has not been previously reported and, when observed, should alert the clinician to potential impending device failure. It is suggested that the presence of this finding in a patient supported on the HeartMate VE System should prompt immediate interrogation of the device by means of the external console. Further, consideration should be given to urgent surgical intervention.

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