CASE REPORTS

HeartMate II Ventricular Assist Device Thrombosis—An Echocardiographic Approach to Diagnosis: Can Doppler Evaluation of Flow Be Useful?

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A 68-year-old man was admitted to the hospital 4 months after HeartMate II ventricular assist device implantation, because his clinical status had deteriorated and his levels of lactate dehydrogenase and free hemoglobin had increased. Transthoracic echocardiography performed at admission revealed decreased basic diastolic continuous flow velocity with a pulsatile increase in flow velocity during ventricular contraction in both inflow and outflow cannulas. Twelve hours after beginning lytic therapy, basal diastolic continuous flow velocity had increased, and the amplitude between diastolic and systolic flow velocity had decreased. The clinical status of the patient improved, and his lactate dehydrogenase decreased. A decrease in basal diastolic flow may be a valuable marker of flow disturbance in continuous flow ventricular assist devices. (J Am Soc Echocardiogr 2011;24:350.e1-350.e4.)

Keywords: Ventricular assist device, Echocardiography, HeartMate II

CASE PRESENTATION

A 68-year-old man was admitted to our hospital 4 months after HeartMate II (Thoratec Corporation, Pleasanton, CA) continuous flow ventricular assist device implantation because his clinical status had deteriorated. His clinical course was uneventful until approximately 1 month before admission, when heart failure symptoms became apparent and a transient increase in the power consumption of the device was reported. Transthoracic echocardiography was performed repeatedly during this hospital stay: at admission, after medical treatment, after thrombolytic treatment, and prior to discharge. The outflow cannula could be examined from the second right parasternal intercostal space. The device data, laboratory findings, and selected echocardiographic measurements are presented in Table 1. On the admission exam, the left ventricle was enlarged, and consistent partial systolic opening of the aortic valve was observed during systole (Figures 1A and 2B, Video 1). Mild aortic insufficiency was noted only during diastole, and high-grade mitral valve insufficiency was also present (Figure 2B, Video 2). No signs of inflow cannula malposition or thrombus could be seen. Color Doppler showed laminar flow in both inflow and outflow cannulas. Diastolic flow velocity in both cannulas was low, and large differences between basal diastolic and pulsatile systolic flow velocities were observed (Figures 3A and 3B). The next examination, performed after the optimization of medical therapy and increasing the speed of the pump, did not differ significantly. Neither the transesophageal examination nor contrast-enhanced computed tomography improved the diagnosis. Because the patient's clinical state did not improve, thrombolysis was performed. The patient's condition improved rapidly, and 12 hours later, transthoracic echocardiography was performed. We noted a reduction in left ventricular diameter, and mitral insufficiency decreased. The aortic valve remained closed during systole, and aortic insufficiency was seen in both diastole and systole (Figures 1B, 2C, and 2D, Video 3). We observed a change in the flow velocity pattern in both inflow and outflow cannulas (Figures 3C and 3D, Video 4). Diastolic continuous flow velocity increased significantly, and the difference between diastolic and systolic flow velocity decreased. No important changes in mean arterial pressure were noted, as shown in Table 1.

DISCUSSION

Only a few cases of continuous flow device thrombosis have been reported, and the only contribution of echocardiography to the diagnosis in these cases was to evaluate the position of the inflow cannula as well as to exclude the presence of evident thrombi.[1-5] In one case, a complete occlusion of the outflow cannula was demonstrated with a transesophageal approach.[2] Because the direct evaluation of the pump is not possible using echocardiography, the diagnosis of suspected pump thrombosis must be established indirectly. Echocardiographic signs suggesting device malfunction include dilatation of the left ventricle, consistent opening of the aortic valve during systole, and interventricular septal shift to the right, suggesting insufficient unloading of the left ventricle.[6,7] Lack of improvement after the adjustment of pump speed indicates the device's dysfunction. The detailed role of Doppler flow measurements in detecting continuous flow device malfunction has not been reported. Normal flow across the cannula consists of basal, constant flow caused by the pump itself, augmented by systolic increase of the flow velocity caused by the contraction of the left ventricle. The velocity of diastolic flow is dependent mainly on the rotational

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Table 1 Device data, laboratory findings, and selected echocardiographic measurements

Variable	At admission	After medical treatment	After thrombolysis	At discharge
Mean BP (mm Hg)	70	68	71	75
Rotation speed (rpm)	9,200	9,600	9,600	9,400
Free hemoglobin (mg/L)	150	450	400	100
LDH (U/L)	2,700	3,243	1,152	900
LV EDD (mm)	69	68	56	58
LV ESD (mm)	65	61	49	55
AV amplitude (mm)	10	9	0	0
LV ET (ms)	170	135	0	0
AI grade	I	I	I	I
AI	Diastole	Diastole	Diastole/systole	Diastole/systole
MI grade	III	III	I/II	I/II
Inflow diastole (cm/sec)	40	20	70	60
Inflow systole (cm/sec)	70	80	138	140
Outflow diastole (cm/sec)	10	15	80	70
Outflow systole (cm/sec)	140	160	150	160

AI, Aortic insufficiency; *AV*, aortic valve; *BP*, blood pressure; *EDD*, end-diastolic diameter; *ESD*, end-systolic diameter; *ET*, ejection time; *LDH*, lactate dehydrogenase; *LV*, left ventricular; *MI*, mitral insufficiency.

speed of the pump and the afterload. The velocity of systolic flow is dependent on the degree of unloading of the left ventricle, its rest systolic function, and afterload. Normal systolic flow velocity across the inflow and outflow cannula varies between 100 and 200 cm/sec.[5] Before treatment, we noted all indirect signs suggesting pump dysfunction; however, despite the laminar flow registered with color Doppler, we observed decrease of the flow velocities in both inflow and outflow cannulas as measured with pulsed-wave and continuous-wave Doppler. Diminished basal diastolic flow velocity was in our opinion caused by the obstruction of the outflow part of the pump. The obstruction resists the blood flow (a similar effect can be caused by the increase of afterload), and the flow velocity decreases, but the rotational speed of the pump remains constant.[8] The observed transitory increase in power consumption may suggest the transient impairment of propeller motion. On the contrary, the impairment of the inflow part of the device should cause an increase of the flow velocity in the inflow cannula. After thrombolytic therapy, an immediate change of flow velocity pattern was observed. The dissolving of the thrombus decreased afterload, and the basal flow increased. This change was concomitant with the improvement of the clinical status of the patient as well as with device parameters. We consider that rapid clinical improvement after thrombolysis confirms indirectly the diagnosis of thrombosis; however, because the device was not explanted, we do not have any direct proof of pump thrombosis.

The presented case shows the necessity of a routine spectral Doppler examination in patients after implantation of ventricular assist devices. In our experience, on transthoracic examination, visualization of the inflow cannula is almost always possible. The outflow cannula is more difficult to image and requires right parasternal views; however, it is possible in 60% to 70% of patients. During Doppler measurements, one must remember to align the ultrasound beam coaxial to the flow direction for accurate velocity estimation. It is often difficult, so nonstandard views and off-axis imaging are often necessary. Additionally, we strongly advise measuring arterial pressure during the echocardiographic examination, because device flow depends strongly on afterload. Flow velocities cannot be

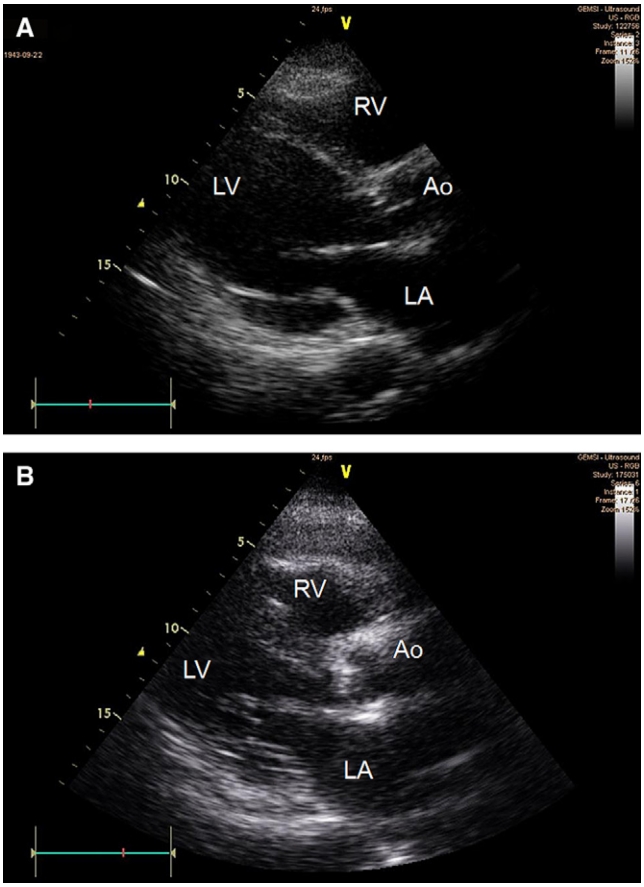

Figure 1 Two-dimensional echocardiographic examination, parasternal long-axis view, diastole. **(A)** Before thrombolysis; **(B)** after thrombolysis. Note decreased end-diastolic diameter of the left ventricle (LV) after thrombolysis compared with examination before the treatment. *Ao*, Aorta ascendens; *LA*, left atrium; *RV*, right ventricle.