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ORIGINAL RESEARCH

Role of Echocardiography in Patients With Intravascular Hemolysis Due to Suspected Continuous-Flow LVAD Thrombosis

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OBJECTIVES This study sought to characterize the echocardiographic findings of patients presenting with intravascular hemolysis (IVH) due to suspected continuous-flow left ventricular assist device (LVAD) pump thrombosis.

BACKGROUND LVAD patients who develop pump thrombosis often present with IVH. Echocardiography may be able to detect device dysfunction in this setting.

METHODS Continuous-flow LVAD patients presenting with IVH due to suspected pump thrombosis were identified. Patients underwent echocardiography with cannula Doppler flow velocity interrogation. Findings were compared with baseline and follow-up studies, and with 49 stable LVAD control patients.

RESULTS Of 145 patients, 14 (10%) had IVH due to suspected pump thrombosis. The mean age was 55 ± 15 years, 93% were men, and 50% received LVAD as destination therapy. Mean duration between implantation and IVH was 231 ± 218 days. Eleven (79%) patients presented with hemoglobinuria, 9 (64%) with jaundice, and 5 (36%) with acute heart failure. Reduced cannula diastolic flow velocity and increased systolic/diastolic (S/D) flow velocity ratio were the only echocardiographic parameters significantly different from controls (outflow cannula 0.3 ± 0.2 m/s vs. 0.8 ± 0.3 m/s, $p = 0.03$, and 5.9 ± 2.8 vs. 1.7 ± 0.7, $p < 0.01$, respectively), and were worse for IVH patients with acute heart failure compared with those without (outflow cannula 0.2 ± 0.1 m/s vs. 0.5 ± 0.2 m/s, $p = 0.04$, and 7.2 ± 3.3 vs. 5.3 ± 2.0, $p = 0.02$, respectively). Outflow cannula diastolic flow velocity and S/D flow velocity ratio changed significantly from baseline ($p = 0.01$ and $p < 0.01$, respectively) in IVH patients, whereas systolic flow velocity did not change ($p = 0.59$). Odds ratios for outflow cannula diastolic flow velocity and S/D flow velocity ratio for predicting IVH were 0.60 (95% confidence interval [CI]: 0.51 to 0.73), $p = 0.02$, and 2.45 (95% CI: 2.37 to 2.52) $p < 0.01$, respectively. Corresponding inflow cannula values were similarly significant. Pump thrombosis was confirmed in 7 (50%) patients after LVAD retrieval.

CONCLUSIONS Reduced cannula diastolic flow velocity and increased S/D flow velocity ratio identified continuous-flow LVAD dysfunction in patients with IVH due to suspected pump thrombosis better than other echocardiographic parameters. (J Am Coll Cardiol Img 2013;6:1129–40) © 2013 by the American College of Cardiology Foundation

Continuous-flow left ventricular assist devices (LVAD) provide circulatory support and improve survival for patients with advanced heart failure (HF) (1–3). These devices have demonstrated improved durability and outcomes compared with older pulsatile LVADs, and currently are the preferred device model for patients with indications for LVAD implantation (1). Initially implanted as a bridge to transplantation (BTT), LVADs are increasingly used for the purpose of destination therapy (DT) (1).

Pump thrombosis is increasingly recognized as an important complication in patients supported by continuous-flow LVADs, and is associated with a high degree of morbidity and mortality (1,2,4). Patients with pump thrombosis frequently present with signs and symptoms of intravascular hemolysis (IVH) (1). Pump thrombosis may be associated with LVAD dysfunction impairing left ventricular (LV) unloading and circulatory support, and can lead to clinical HF and/or hemodynamic instability.

ABBREVIATIONS AND ACRONYMS

BTT = bridge to transplantation
DT = destination therapy
IAS = interatrial septum
IVH = intravascular hemolysis
IVS = interventricular septum
LAP = left atrial pressure
LVAD = left ventricular assist device
PI = pulsatility index
RAP = right atrial pressure
S/D = systolic/diastolic

Pump thrombosis is often diagnosed in the presence of clinical and biochemical signs of IVH, accompanied by changes in device parameters such as increased power levels. Echocardiography is an important tool for the evaluation of device and cardiac function in LVAD-supported patients (5), and echocardiographic parameters associated with adverse outcomes have been previously described (6). The role of echocardiography in the evaluation of patients presenting with IVH due to suspected pump thrombosis is poorly defined. The purpose of this study was to characterize the echocardiographic findings of patients presenting with IVH due to suspected continuous-flow LVAD pump thrombosis.

METHODS

Study population. We retrospectively reviewed the records of all patients with prior implantation of a HeartMate II continuous-flow LVAD (Thoratec Corporation, Pleasanton, California) followed at our center between January 2008 and December 2012. Patients implanted with an LVAD as either BTT or DT were included. Of 158 patients, we excluded 13 who died at the time of implantation or in the perioperative period, for a final study population of 145. All patients provided written informed consent granting access to their medical records for research purposes. The Mayo Clinic Institutional Review Board approved this study.

Intravascular hemolysis due to suspected LVAD pump thrombosis. Patients presenting with IVH due to suspected pump thrombosis were selected for further analysis. This was defined as an acute rise in serum lactate dehydrogenase ≥2-fold above the stable baseline level while on LVAD support in conjunction with elevated free plasma hemoglobin (>12 mg/dl) in the absence of other causes of hemolysis, accompanied by at least 1 of the following: 1) left-sided HF in the absence of other causes; or 2) acute or gradual increases in pump power of ≥2 W above the stable baseline level. Patients presenting with IVH due to suspected pump thrombosis were initially treated with intensified anticoagulation and then monitored for evidence of persistent or worsening IVH and/or end-organ dysfunction. Surgical device exchange or urgent heart transplantation was recommended for patients with signs of clinical or hemodynamic instability or worsening IVH and/or end-organ dysfunction. Intensified anticoagulation consisted of intravenous unfractionated heparin and intensified antiplatelet therapy with increased aspirin dose and/or addition of an oral platelet $P2Y_{12}$ receptor blocker. An intravenous glycoprotein IIb/IIIa inhibitor was added for patients with persistent clinical and/or biochemical IVH who remained stable without end-organ dysfunction.

Clinical and demographic data. The routine surveillance follow-up protocol after LVAD implantation at our institution has been previously described (6). Briefly, all patients underwent monthly clinical outpatient follow-up for the first 3 months after discharge from hospital, and then every 3 to 4 months thereafter unless otherwise indicated. Comprehensive clinical, laboratory, device, and echocardiographic data were collected at each surveillance encounter, and these data were also collected at the time of presentation with IVH due to suspected pump thrombosis. Device data included pump speed, power, flow, and pulsatility index (PI) (a measure of the magnitude of blood flow pulses

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