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3D Morphological Changes in LV and RV During LVAD Ramp Studies

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ABSTRACT

OBJECTIVES The purpose of this study was to investigate the differential impact of the 2 most commonly available left ventricular assist device (LVAD) types on the right (RV) and left (LV) ventricles using 3-dimensional (3D) echocardiography-based analysis of ventricular morphology.

BACKGROUND LVADs have emerged as common therapy for advanced heart failure. Recent data suggest that the heart responds differently to speed settings in the 2 main devices available (HeartMate II [HMII], St Jude Medical, Pleasanton, California, and HVAD, HeartWare International, Framingham, Massachusetts). We hypothesized that 3D echocardiographic assessment of LV and RV volumes and shape would help describe the differential impact of the 2 LVAD types on the heart.

METHODS Simultaneous 3D echocardiography, ramp test, and right heart catheterization were performed in 31 patients with LVADs (19 with HMII and 12 with HVAD). Device speed was increased stepwise (8,000 to 12,000 for HMII and 2,300 to 3,200 revolutions per minute for HVAD). 3D echocardiographic full-volume LV and RV datasets were acquired, and endocardial surfaces were analyzed using custom software to calculate LV sphericity, conicity (perfect sphere/cone = 1) and RV septal and free-wall curvature (0 = flat; <0 = concave; >0 = convex).

RESULTS For both devices, cardiac output increased and wedge pressure decreased with increasing speed. In HMII, LV volumes progressively decreased (meanΔ = 127 ml) as the LV became less spherical and more conical, whereas the RV volume initially remained stable, but subsequently increased at higher speeds (meanΔ = 60 ml). Findings for the HVAD were similar, but less pronounced (LV:meanΔ = 51 ml, RV:meanΔ = 22 ml), and the LV remained significantly more spherical even at high speeds. On average, in HMII patients, the RV septum became more convex (bulging into the LV) at the highest speeds whereas in HVAD patients, there was no discernable change in the RV septum.

CONCLUSIONS The heart responds differently to pump speed changes with the 2 types of LVAD, as reflected by the volume and shape changes of both the LV and RV. Our study suggests that adding RV assessment to the clinical echo-ramp study may better optimize LVAD speed. Further study is needed to determine whether this would have an impact on patient outcomes. (J Am Coll Cardiol Img 2017;■:■–■) © 2017 by the American College of Cardiology Foundation.

Worldwide use of continuous-flow left ventricular assist devices (cfLVADs) is growing. Additionally, an increasing number of patients are being considered for destination therapy, and as a result, patients are being supported for increasingly longer periods of time (1,2). Accordingly, there is a growing need to find more optimal ways to manage these patients,

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ABBREVIATIONS AND ACRONYMS

2D = 2-dimensional

3D = 3-dimensional

cfLVAD = continuous-flow left ventricular assist device

HMII = HeartMate II

LV = left ventricle/ventricular

RPM = revolutions per minute

RV = right ventricle/ventricular

TTE = transthoracic echocardiography

one important facet being proper setting of device speed. Current recommendations for device speed adjustments are based on hemodynamics and echocardiographic parameters measured during "ramp" studies, in which cfLVAD speed is gradually increased over a range tolerated by the patient (3). Optimal speed is opined to be the one at which aortic valve opening is intermittent, the interventricular septum is midline, and mitral and aortic regurgitation are minimized together with pulmonary capillary wedge pressure <18 mm Hg and central venous pressure <12 mm Hg (3). Accordingly, one cannot rule out that additional factors may prove helpful in device speed optimization, and identifying them may have an impact on optimal use of these devices and thus on patient outcomes.

Two-dimensional (2D) imaging studies have shown that hearts supported with different types of cfLVADs (centrifugal vs. axial) respond differently to changes in speed from an anatomic perspective (4-6), raising the question whether different criteria need to be established for speed optimization in these 2 cfLVAD types. Invasive measurements have shown that both types of devices perform similarly in response to speed changes in terms of flow, and central and peripheral pressures (6). This has led to the hypothesis that perhaps device location, that is, intrathoracic (HVAD, HeartWare International, Framingham, Massachusetts) versus extrathoracic (HeartMate II [HMII], St Jude Medical, Pleasanton, California) has an anatomic impact on the native heart. If so, device location not only may impact how the left ventricle responds to changes in speed, but may also impact, via different effects on the septum, right ventricular (RV) geometry, size, and function (7-9). We hypothesized that 3-dimensional (3D) echocardiography-derived parameters of size and shape of the 2 ventricles may provide additional information in this context. We therefore performed 3D echocardiographic imaging during hemodynamic ramp studies in patients supported with either a centrifugal cfLVAD (HVAD) or an axial cfLVAD (HMII) to determine how device speed influences global left ventricular (LV) and RV sizes and shapes, including an analysis of septal geometry. Our aims were: 1) to determine how device speed influences LV and RV size and shape, including septal geometry; and 2) to test the feasibility of 3D echocardiographic analysis during the cfLVAD ramp study.

METHODS

We prospectively considered 63 consecutive ramp studies performed in patients with either a centrifugal (HVAD) or an axial (HMII) cfLVAD who were referred for a clinically indicated ramp test with right heart catheterization for LVAD speed adjustment. Patients with poor 2D and/or 3D image quality or who did not meet ramp study safety criteria (see the following text) or who were undergoing a ramp test for reasons other than speed optimization were excluded from the analysis. Thirty-five patients were thereby selected. Of these 35, 4 did not complete the full ramp protocol. The final cohort consisted of 31 patients, including 19 with an HMII and 12 with an HVAD (**Table 1**). The study was approved by the institutional review board, and all patients provided informed consent.

All tests were performed in the catheterization laboratory. The overall methods employed in this study for hemodynamic assessment have been detailed previously (6). At the initiation of the study, pump speeds were lowered to 2,300 revolutions per minute (RPM) in patients with HVAD and 8,000 RPM in patients with HMII pumps. After a 5-min stabilization period, echocardiographic, hemodynamic, and device flow, power, and pulsatility index values were taken. After completion of data acquisition, device speeds were increased by 100-RPM increments for HVAD patients and by 400-RPM increments for HMII patients. After a 2-min stabilization period, hemodynamic parameters were recorded. 3D echocardiographic images were acquired at every other speed setting, that is, at 200-RPM increments for HVAD patients and at 800-RPM increments for HMII patients. This procedure was repeated until 1 of the following occurred: 1) a maximum speed of 3,200 RPM was reached for HVAD patients or 12,000 RPM for HMII patients; 2) a suction event; or 3) a decrease in LV end-diastolic diameter to <30 mm. To simplify the graphical presentation and pooling of data, ramp speed settings were labeled from Stage I (lowest speed) to Stage V (highest speed).

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