Symptomatic Exercise-Induced Left Ventricular Outflow Tract Obstruction without Left Ventricular Hypertrophy

Eyad K. Alhaj, MD, Bette Kim, MD, Deborah Cantales, RDCS, Seth Uretsky, MD, Farooq A. Chaudhry, MD, and Mark V. Sherrid, MD, *New York, New York*

Background: Left ventricular (LV) outflow tract obstruction (LVOTO) is most commonly seen in patients with hypertrophic cardiomyopathy. Postexercise dynamic LVOTO (DLVOTO) has been infrequently identified in symptomatic patients without LV hypertrophy, and its pathophysiology is not well established. The aim of this study was to identify echocardiographic abnormalities that might explain the dynamic development of systolic anterior motion, mitral-septal contact, and LVOTO in these patients.

Methods: Patients with DLVOTO and normal wall thickness were compared with 20 age-matched and gender-matched controls with normal stress echocardiographic findings. Two other groups were also compared: patients with DLVOTO and mild segmental hypertrophy (segmental wall thickness ≤15 mm) and patients with normal left ventricles but DLVOTO after dobutamine stress.

Results: Six symptomatic patients were identified (mean age, 48 ± 9 years; range, 37–60 years; five men) with normal wall thickness who developed DLVOTO after exercise during a 6-year period. Five had been hospitalized for cardiac symptoms. The mean postexercise LV outflow tract gradient caused by systolic anterior motion mitral-septal contact was 107 ± 55 mm Hg (range, 64–200 mm Hg). All patients had echocardiographic LV wall thicknesses in the normal range (≤12 mm). Structural abnormalities of the mitral valve were identified in all six patients. These were elongated posterior leaflets (2.0 vs 1.5 cm, $P < .0005$), elongated anterior leaflets (3.2 vs 2.6 cm, $P = .015$), increased protrusion height of the mitral valve beyond the mitral annular plane (2.6 vs 0.6 cm, $P < .00001$), and residual protruding portions of the mitral valve leaflets (0.85 vs 0.24 cm, $P < .005$). There was anterior positioning of the papillary muscles in the LV cavity, with a greater distance from the plane of the papillary muscles to the posterior wall (1.8 vs 1.3 cm, $P = .03$). In two patients, potentially provoking medications were stopped; two patients received β-blockers, with reductions of angina. Medium-term prognosis was good; no patient had died after 3.5 years. The mitral valve abnormalities in the 10 patients with DLVOTO and mild segmental hypertrophy were qualitatively and quantitatively very similar to those in patients with DLVOTO without hypertrophy. In contrast, the valves of patients with dobutamine stress DLVOTO were not elongated, but 50% had residual mitral leaflets that protruded past the coaptation point by ≥5 mm.

Conclusions: DLVOTO after exercise can occur in the absence of LV hypertrophy and may be associated with high gradients and cardiac symptoms. Elongated, redundant mitral valve leaflets with anterior position of the papillary muscles appear to cause the postexercise obstruction. (J Am Soc Echocardiogr 2013;26:556-65.)

Keywords: Left ventricular outflow obstruction, Left ventricular hypertrophy, Hypertrophic obstructive cardiomyopathy, Hypertrophic cardiomyopathy, Mitral valve disease

Systolic anterior motion (SAM) of the mitral valve and mitral-septal contact is the most common cause of left ventricular (LV) outflow tract (LVOT) obstruction (LVOTO) in hypertrophic cardiomyopathy (HCM).[1-4] It is characteristically provocable, with worsening obstruction related to a decrease in preload or afterload or an increase in contractility.[5-7] Exercise echocardiography has proved to be a useful tool in HCM, provoking increases in gradients in the large majority of patients and importantly in patients who would otherwise be deemed to have nonobstructive HCM.[5,7-12] LVOTO after exercise has been infrequently identified in symptomatic patients without LV hypertrophy (LVH), and its pathophysiology is not well established; the term "dynamic left ventricular outflow tract obstruction" (DLVOTO) is commonly used to describe this entity. In this case series, we analyzed six symptomatic patients who had structurally normal left ventricles with no LVH but who developed severe DLVOTO after exercise.

From the Division of Cardiology, Department of Medicine, St. Luke's-Roosevelt Hospital Center, Columbia University, College of Physicians and Surgeons, New York, New York.

Reprint requests: Mark V. Sherrid, MD, St. Luke's-Roosevelt Hospital Center, 1000 10th Avenue, New York, NY 10019 (E-mail: *msherrid@chpnet.org*).

0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2013.02.007

Abbreviations

CW = Continuous-wave

DLVOTO = Dynamic left ventricular outflow tract obstruction

HCM = Hypertrophic cardiomyopathy

LV = Left ventricular

LVH = Left ventricular hypertrophy

LVOT = Left ventricular outflow tract

LVOTO = Left ventricular outflow tract obstruction

SAM = Systolic anterior motion

METHODS

Adult inpatients and outpatients referred for the evaluation of cardiac symptoms underwent routine diagnostic stress echocardiography with symptom-limited Bruce protocol treadmill exercise, with imaging performed in the supine left lateral decubitus position immediately after the termination of exercise.[5,9,12] Views of the left ventricle from five imaging planes were digitized within 60 sec. If SAM was noted by the sonographer, continuous wave (CW) Doppler of the LVOT was acquired, first from the five-chamber and then from the three-chamber view. During this 6-year time period, we performed 9,475 stress exercise echocardiographic studies.

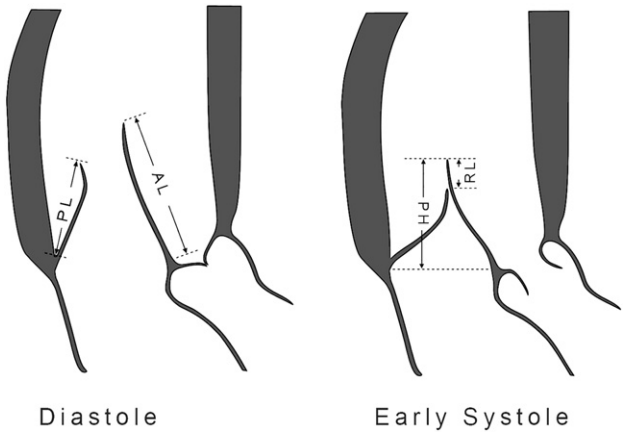

Figure 1 Line drawing of an apical three-chamber view from a representative patient with DLVOTO showing elongated mitral leaflets, increased protrusion height above the mitral annular plane, and increased residual leaflet length. The locations of echocardiographic measurements are shown. (*Left*) Diastole, showing measurements of anterior leaflet length (AL) and posterior leaflet length (PL). (*Right*) Early systole at the moment of coaptation, showing residual leaflet length (RL) and protrusion height (PH) of the most protruding leaflet measured from the mitral annulus to the top of the most protruding leaflet.

Inclusion and Exclusion Criteria

Patients were included in this case series if they (1) had no LVOTO at rest but developed de novo mitral-septal contact on two-dimensional imaging and LVOTO on CW Doppler after exercise and (2) had normal LV wall thicknesses. Over a 2-year period, we also identified patients who had no significant resting gradients but DLVOTO ≥30 mm Hg after exercise and who had mild segmental LVH, with all segments ≤15 mm. We also indentified patients with normal left ventricles but who developed SAM mitral-septal contact and LVOTO after dobutamine stress. Patients with any wall motion abnormalities at rest or after exercise were excluded. Meticulous care was taken to avoid measuring mitral regurgitant jets by angling the transducer medially away from the left atrium. Only CW jets that started after isovolumetric systole and were concave to the left in contour were accepted as LVOT gradient jets.[3-5,7] Moreover, we excluded patients with jets from complete systolic emptying of the left ventricle and patients with mid-LV obstruction. We only accepted jets for which color Doppler acceleration and aliasing occurred at the point of mitral-septal contact and not in the body of the left ventricle.[13]

Mitral Valve and LV Measurements

We compared patients with DLVOTO without LVH with 20 age-matched and gender-matched controls with normal results on stress echocardiography. At end-diastole, using parasternal long-axis and short-axis two-dimensional views, we measured with digital calipers the LV end-diastolic diameter just below the mitral tips and the LV segmental wall thickness of four LV wall segments, the anterior septum, posterior septum, posterior wall, and anterolateral wall, as described previously.[14] In the parasternal long-axis view, we also measured LV end-systolic diameter. On the parasternal long-axis view, at the moment of systolic mitral coaptation, we measured the diameter of the LVOT, the distance from the anterior mitral valve tip to the septum, and the distance from posterior mitral valve tip to the LV posterior wall. From the short-axis view at end-diastole, we measured the perpendicular distance from a line bisecting the papillary muscles to the septum and also to the posterior wall. From the apical three-chamber view, we measured structural variables of the mitral valve as shown in Figure 1. In diastole, we measured the length of the anterior leaflet, from the tip of the leaflet to the insertion of the noncoronary aortic leaflet; this measurement includes the intervalvular fibrosa but offers easily identified landmarks for measurement. We also measured the length of the posterior leaflet. At the moment of coaptation in early systole, we measured the residual portion of the anterior mitral leaflet that extends past the coaptation point and is thus untethered and protruding into the LV cavity,[15] and we measured the protrusion height of the mitral valve, the distance from the plane of the mitral annulus to the tip of most protruding mitral leaflet. This quantifies the protrusion of the mitral leaflets into the LV cavity. Chordal SAM was excluded from all measurements by observing full cine loops in multiple views and excluding patients without exercise LVOT gradients. From two-chamber and four-chamber views, we measured biplane LV end-diastolic and end-systolic volumes using Simpson's rule and calculated ejection fractions.

Cardiac magnetic resonance imaging was performed as clinically indicated. Wall thicknesses were measured in the same four LV wall segments described above,[14] and the presence of gadolinium delayed hyperenhancement was noted. The position, thickness, and number of papillary muscles were noted, as well as their potential to contribute to SAM and LVOTO, as previously reported.[2,16-20]

Patients' medical records were examined, and follow-up was performed by clinic visits and phone. Pharmacologic management was determined by the referring physicians. Abstract of medical records for research purposes was approved by the institutional review board of St. Luke's-Roosevelt Hospital Center.

Statistical Analysis

Continuous variables are reported as mean ± SD. One-way analysis of variance was used to carry out an omnibus test of differences