Echocardiographic Measures Associated With Early Postsurgical Myocardial Dysfunction in Pediatric Patients With Mitral Valve Regurgitation

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Background: The assessment of left ventricular (LV) systolic function using conventional echocardiographic measures is problematic in the setting of mitral regurgitation (MR) given that altered loading conditions can mask underlying ventricular dysfunction. The purpose of this study was to characterize LV function and deformation before and after effective mitral valve repair or replacement to determine echocardiographic measures associated with early postoperative myocardial dysfunction.

Methods: Baseline LV function was assessed retrospectively by conventional echocardiography and speckle-tracking strain analysis pre- and postoperatively in patients diagnosed with MR between January 2000 and March 2013, excluding patients with less than mild to moderate MR preoperatively, left-sided obstructive lesions, large septal defects, or more than mild MR postoperatively.

Results: Forty-six pediatric patients were evaluated (average age, 8.2 ± 6.4 years). Thirteen patients had normal preoperative ejection fractions but significant postoperative dysfunction (defined as an ejection fraction < 50%). Compared with the 33 patients with normal postoperative function, age (11.5 ± 7.1 vs 7.3 ± 5.7 years, $P = .04$), global circumferential strain (−13.2 ± 5.6% vs −17.1 ± 4.6%, $P = .02$), and global circumferential strain rate (−0.94 ± 0.40 vs −1.36 ± 0.42 sec^{-1}, $P = .004$) were found to be statistically different. Using receiver operating characteristic curves, an older preoperative age (area under the curve, 0.67; $P = .03$), lower global circumferential strain magnitude (area under the curve, 0.74; $P = .007$), and lower global circumferential strain rate magnitude (area under the curve, 0.80; $P = .0004$) were determined to be factors associated with early postoperative LV dysfunction after surgical repair of MR.

Conclusions: Strain measurements may be useful as part of the echocardiographic assessment of patients with MR and can guide timing for surgical repair in the pediatric population. (J Am Soc Echocardiogr 2014;■:■-■.)

Keywords: Speckle-tracking strain, Myocardial dysfunction, Mitral valve regurgitation, Pediatric mitral valve surgery

Mitral regurgitation (MR) is a common finding in the pediatric congenital and acquired heart disease population, with varying etiologies.[1] In patients with MR, assessment of left ventricular (LV) systolic function is problematic given that altered loading conditions can mask underlying ventricular dysfunction.[2] Thus, conventional measurements of function such as ejection fraction may not reflect true myocardial contractility.[3]

Myocardial deformation evaluation is often used in adults as an additional measure of LV function.[4] Speckle-tracking-derived myocardial strain assessment is useful in that it provides an angle-independent measure of global and regional myocardial deformation, which has been shown to correlate with normal and abnormal ventricular function.[5]

Identifying LV dysfunction early is crucial to allow timely surgery to prevent early postoperative dysfunction and improve survival after surgical correction.[6] The purposes of this study were to characterize LV function and deformation using conventional measures of function and strain analysis using speckle-tracking echocardiography before and after effective mitral valve repair or replacement and to determine preoperative echocardiographic measures associated with postoperative myocardial dysfunction. We hypothesized that global and regional measurements of strain before valvular repair or replacement would be decreased and can identify patients at risk for ventricular failure, which may be helpful in guiding the timing of surgical intervention.

METHODS

Patient Population

The Lucile Packard Children's Hospital Heart Center database was queried to retrospectively identify all eligible patients diagnosed

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0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2014.11.010

Abbreviations

GCS = Global circumferential strain

GCSr = Global circumferential strain rate

GLS = Global longitudinal strain

GLSr = Global longitudinal strain rate

LV = Left ventricular

LVEDD = Left ventricular end-diastolic dimension

LVEDV = Left ventricular end-diastolic volume

LVEF = Left ventricular ejection fraction

MR = Mitral regurgitation

ROC = Receiver operating characteristic

TTE = Transthoracic echocardiography

VCFc = Velocity of circumferential fiber shortening

WSc = Circumferential wall stress

with MR between January 2000 and March 2013. Patients with less than mild to moderate MR preoperatively, coexistent left-sided obstructive lesions such as mitral or aortic stenosis, large septal defects, or more than mild MR postoperatively were excluded from this study. Criteria for inclusion were thus pediatric patients ≤21 years of age with at least mild to moderate MR preoperatively and adequate imaging for analysis on preoperative and initial postoperative transthoracic echocardiography (TTE).

Each patient's diagnosis, gender, date of birth, height, weight, body surface area (calculated using the formula of Du Bois and Du Bois), dates of surgical procedure, types of surgical procedure, period between surgery and postsurgical TTE, and type of prior surgical intervention were obtained from the electronic medical record. Postsurgical TTE included analysis both initially and, if available, 4 to 15 weeks postoperatively.

The etiology and duration of MR before surgical intervention were recorded, with the duration defined as either acute (present for <6 months) or chronic (present for ≥6 months). To account for the influence of varying surgical technique over the 13-year period, aortic cross-clamp time and number of cardioplegia doses were obtained. The percentage of patients with postoperative LV dysfunction was also measured for two different surgical eras, 2000 to 2006 and 2007 to 2013.

Echocardiographic Data

Echocardiographic studies were routinely performed in all patients as part of their pre- and postoperative evaluations. Images were acquired according to American Society of Echocardiography guidelines and stored on our institution's secure server.[7] The ultrasound equipment used for the echocardiographic studies was either the Siemens Sequoia C512 (Siemens Medical Solutions USA, Inc, Mountain View, CA) or the Philips iE33 (Philips Medical Systems, Bothell, WA).

For each patient, pre- and postoperative transthoracic echocardiographic studies were selected before and after mitral valve repair or replacement at our institution. The primary investigator made offline measurements using the syngo Dynamics workstation (Siemens Medical Solutions USA, Inc; syngo Dynamics Solutions, Ann Arbor, MI).

MR was graded by the vena contracta jet width, left atrial–to–aortic valve ratio, and pulmonary venous Doppler profile.[8] While blinded to each patient's clinical information, pre- and post-operative MR grading was conducted ≥30 days apart by a senior investigator. MR was graded as mild, moderate, or severe on the basis of defined criteria by the American Society of Echocardiography's Nomenclature and Standards Committee and the Task Force on Valvular Regurgitation.[9] Inclusion criteria for the final analyses were therefore patients with more than mild MR preoperatively with complete correction after surgery with no more than mild postoperative MR. Given the retrospective nature of the study, several studies were excluded for inadequate pre- and/or postoperative imaging.

LV ejection fraction (LVEF) was measured using the 5/6 area × length method.[10] LV end-diastolic volume (LVEDV), as derived by the 5/6 area × length method, was indexed to body surface area for further comparison. LV end-diastolic dimension (LVEDD), measured by M-mode echocardiography in the short-axis view, was reported with standard *Z* scores.[11] Velocity of circumferential fiber shortening (VCFc), circumferential wall stress (WSc), and meridional wall stress were calculated for all studies by the primary investigator. Wall stress calculations used noninvasive systolic blood pressure measurements performed at the time of echocardiography. Pre- and postoperative offline analyses were performed separately to maintain objectivity and reduce bias. An LVEF < 50% was defined as the threshold for ventricular dysfunction. Normal LVEF preoperatively was not a requirement for inclusion.

A second investigator performed measurements of LVEF by the same method on a randomly selected subset of 10 patients (using the random number generator in Microsoft Excel; Microsoft Corporation, Redmond, WA) to determine interobserver variability and reproducibility. The second reader was blinded to the initial analysis, the two measurements were separated by ≥30 days, and the reader was free to independently choose images for analysis within the designated study date.

The highest quality apical four-chamber and parasternal short-axis view images were identified to perform systolic strain measurements using Velocity Vector Imaging version 2.0 (Siemens Medical Solutions USA, Inc). This software provides vendor-independent deformation analysis using a speckle-tracking algorithm to provide angle-independent two-dimensional velocity, strain, and strain rate.[12,13] The average frame rates for the apical four-chamber and parasternal short-axis views were 44 and 45 Hz, respectively. The primary investigator performed all strain measurements. The endocardial border was manually traced and automatically tracked by the Velocity Vector Imaging software, producing graphs of strain and strain rate of six segments of myocardium in the parasternal short-axis view and four segments of myocardium in the apical four-chamber view over time (Figure 1). The apical segments in the four-chamber view were excluded from longitudinal strain calculations because of the poor tracking capability of these segments. Therefore, global longitudinal strain (GLS), global circumferential strain (GCS), global longitudinal strain rate (GLSr), and global circumferential strain rate (GCSr) measurements were the average of basal and midsegment values, while regional measurements were the average of basal and midsegment values of the lateral or septal wall.

Statistical Analysis

All continuous data are presented as mean ± SD. Parametric testing was used to compare data with normal distributions, such as age, body surface area, and echocardiographic indices. All unpaired comparisons were performed with Student *t* tests, while paired *t* tests were used to compare echocardiographic indices before surgery, immediately after surgery, and at 4 to 15 weeks postoperatively.