Apical Transverse Motion Is Associated with Interventricular Mechanical Delay and Decreased Left Ventricular Function in Children with Dilated Cardiomyopathy

Wei Hui, MD, Cameron Slorach, RDCS, and Mark K. Friedberg, MD, *Toronto, Ontario, Canada*

Background: Apical transverse motion (ATM) is associated with electromechanical dyssynchrony in adult dilated cardiomyopathy (DCM). Bundle branch block electromechanical dyssynchrony is uncommon in pediatric DCM, but ATM and its association with ventricular function have not been characterized.

Methods: Fifty-six children with DCM were retrospectively studied. Using echocardiography, ATM was assessed visually and by speckle-tracking longitudinal displacement of the interventricular septal and left ventricular (LV) lateral walls in opposite directions. Doppler tissue imaging–derived displacement and velocities were used to time the onset and peak LV and right ventricle motion, from which intra- and interventricular delays were calculated to assess their association with ATM. The timing of aortic valve opening and closure in relation to onset and peak LV displacement was used as a measure of LV mechanical efficiency.

Results: LV ATM was observed in 35 of 56 patients (62.5%), occurring in two patterns: 45% had ATM (interventricular septum displacing toward the lateral wall and lateral wall displacing toward the mitral annulus during systole), and 18% showed reverse ATM (r-ATM; lateral wall displaced toward the apex and interventricular septum displaced toward the septal annulus during systole). Both patterns were associated with increased interventricular but not intraventricular mechanical delay (controls: 2 msec, ATM 16 msec, r-ATM 8 msec, both $P < .05$ vs control subjects). Patients with ATM or r-ATM had lower LV ejection fractions (19% vs 29%, $P < .05$) and higher mechanical inefficiency compared with those without ATM. Survival was not statistically different in those with ATM or r-ATM compared with those without ATM or r-ATM.

Conclusions: In pediatric DCM, ATM is associated with LV dysfunction, mechanical inefficiency, and interventricular mechanical delay. (J Am Soc Echocardiogr 2018;■:■-■.)

Keywords: Pediatrics, Dilated cardiomyopathy, Echocardiography, Apical transverse motion, Mechanical delay

Apical transverse motion (ATM) or apical "rocking" or "shuffling" is a lateral motion of the left ventricular (LV) apex perpendicular to the LV long axis. In adults with heart failure, ATM has been reported in asynchronously contracting ventricles and predicts reverse remodeling following cardiac resynchronization therapy (CRT).[1-5] Thus ATM may be linked to dilated cardiomyopathy (DCM) prognosis and response to therapy. Pediatric DCM is associated with a worse prognosis than adult DCM,[6] and although our impression from clinical practice is that ATM occurs frequently in this population, the incidence of left bundle branch block electromechanical dyssynchrony in pediatric DCM is low.[7] Thus, the frequency and functional significance of ATM in pediatric DCM have not been defined. Accordingly, the aim of this study was to investigate ATM in relation to mechanical delay, ventricular function, and transplantation-free survival in children with DCM. We hypothesized that ATM is associated with increased mechanical delay, worse LV function, and consequently worse outcomes in children with DCM.

From the Division of Pediatric Cardiology, the Labatt Family Heart Center, Hospital for Sick Children and University of Toronto, Toronto, Ontario, Canada.

Conflicts of Interest: None.

Reprint requests: Mark K. Friedberg, MD, Labatt Family Heart Center, Hospital for Sick Children, 555 University Avenue, Toronto, ON M5G 1X8 (E-mail: mark.friedberg@sickkids.ca).

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METHODS

Patient Population

We retrospectively analyzed the functional echocardiograms, at presentation to our institution, of children 0 to 18 years of age diagnosed with idiopathic, genetic, or familial DCM. For the purposes of this study, the date of this echocardiographic study constituted the date of diagnosis, as the true onset of disease is unknown in many cases. Patients were identified from the institutional database. All available patients were included if they had LV ejection fractions (LVEFs) < 45% using the biplane Simpson method and LV end-diastolic dimension Z scores > 2. Patients with congenital heart disease, previous cardiac surgery, or paced or nonsinus rhythm were

Abbreviations

ATM = Apical transverse motion

CRT = Cardiac resynchronization therapy

DCM = Dilated cardiomyopathy

DTI = Doppler tissue imaging

LV = Left ventricular

r-ATM = Reverse apical transverse motion

RV = Right ventricular

excluded. Subject demographics were obtained from the medical record. To evaluate whether ATM is a pathologic phenomenon, we compared results with those from normal control subjects. Control subjects were healthy volunteers or children with innocent murmurs in whom echocardiographic findings were normal. Control subjects were matched by age and gender to patients with DCM in a 1:2 ratio. The study was approved by the institutional research ethics board.

Echocardiography

Echocardiography was performed using a GE Vivid 7 or E9 (GE) ultrasound system. Probe frequencies were chosen according to the size of the patient. Images were obtained following a standardized institutional functional protocol. Two-dimensional LV apical four-, three-, and two-chamber views were recorded at frame rates of 50 to 90 frames/sec to analyze LV apical displacement using speckle-tracking technology (EchoPAC version 112; GE Vingmed Ultrasound, Horten, Norway). Color Doppler tissue imaging (DTI) was obtained at frame rates of ≥150 frames/sec. Pulsed-wave DTI was obtained from an apical four-chamber view at the lateral mitral, septal, and lateral tricuspid annuli.

Assessment of ATM

The interventricular septum and LV lateral wall normally displace longitudinally in the same direction: toward the apex in systole and toward the base in diastole. ATM was defined as longitudinal systolic displacement of the interventricular septal and LV lateral walls in opposite directions (Figure 1).[5] ATM was assessed from the apical four-chamber view by visual assessment of a rocking apical motion and confirmed by longitudinal two-dimensional speckle-tracking displacement performed on the apical third of the LV lateral and septal walls (Videos 1 and 2, available at www.onlinejase.com, Figure 1). As part of this visual assessment, to evaluate the possible impact of right ventricular (RV) motion on apical rocking beyond the measured interventricular mechanical delay, we undertook qualitative visual assessment of the motion of the RV lateral wall and septum in relation to the motion of the LV apex and LV lateral wall using a slow-motion replay loop and sequential frame-by-frame analysis of cardiac "cine" clips (Videos 1 and 2, available at www.onlinejase.com, Figure 1). A reverse-ATM (r-ATM) pattern was defined when speckle-tracking analysis showed systolic LV lateral wall displacement toward the apex and interventricular septal displacement toward the septal annulus.

Timing of Cardiac Events and Assessment of Intra-LV and Interventricular Delay

To determine the possible impact of intraventricular and interventricular mechanical delays on ATM, color DTI velocities and displacement were used to measure the time to onset and peak systolic motion at the basal RV, interventricular septal, and LV lateral walls using electrocardiographic q-wave onset as a reference (Figure 2). The time difference between onset and peak velocity and displacement between the lateral and septal mitral annulus constituted the intra-LV mechanical delay. The time difference between the lateral mitral and tricuspid annulus constituted the interventricular mechanical delay. Timing intervals were corrected for heart rate and expressed as a percentage of the corresponding electrocardiographic R-R interval, displayed simultaneously on the echocardiographic monitor. The timing of aortic valve opening and closure in relation to the time of onset and peak LV DTI displacement was used as a measure of LV efficiency (Figure 2). The timing of aortic valve opening and closure was determined by the time to onset and termination of pulsed Doppler flow at the aortic valve. In addition to further explore the association of ATM with inefficient LV patterns of contraction and dysfunction as defined previously by our group, we investigated the relationship of ATM to patterns of abnormal regional motion described by Forsha *et al.*[8] and to the tissue Doppler–derived systolic-to-diastolic (S/D) ratio as described by Friedberg and Silverman[9] and Mondal *et al.*[10] in children with DCM. In brief, on the basis of regional strain curve patterns, LV "global" contraction patterns were classified as homogenous, septal hypokinesis, LV wall hypokinesis, apical sparing, chaotic paradoxical timing dispersion or late timing dispersion.[8] For calculation of the S/D duration ratio, systolic and diastolic duration were derived from pulsed tissue Doppler curves sampled at the lateral mitral annulus, where systolic duration was measured from the QRS onset to termination of the s′ wave, and diastolic duration was measured between termination of the s′ wave to onset of the next QRS complex.

Statistical Analysis

Continuous data are reported as median (range) and categorical parameters as proportions (percentage). The Mann-Whitney test was used to compare groups, including patients with versus without ATM. The Wilcoxon rank test was used to test within-group differences in timing of ventricular displacement and aortic valve opening and closure. The χ^2 test was applied to test differences in the incidence of death or heart transplantation between patients with versus without ATM or r-ATM. Kaplan-Meier survival curves were constructed to compare transplantation-free survival in patients with ATM or r-ATM versus those without ATM. The log-rank test was used to compute the power of Kaplan-Meier survival analysis to detect a significant difference between survivors and nonsurvivors and the sample size needed to detect such a difference at the .05 significance level.

Intra- and Interobserver Agreement

All studies were assessed after 6 months by the same observer to derive intraobserver agreement and by a second observer to assess interobserver agreement for the diagnosis of ATM and its direction (whether ATM or r-ATM). Cohen's κ was applied to calculate intra- and interobserver agreement. Statistical analysis was performed using SPSS Statistics version 20.0 software (IBM, Armonk, NY). P values < .05 were considered to indicate statistical significance.

RESULTS

Fifty-six children with DCM were included. Patient characteristics and those of 28 age-matched control subjects are presented in Table 1. Age at presentation was 0.62 years (range, 0–17.7 years). Six patients (11%) died and 26 patients (45%) underwent heart transplantation during the mean follow-up period of 0.3 years (range,