ORIGINAL ARTICLE

Predictors of transient left ventricular dysfunction following transcatheter patent ductus arteriosus closure in pediatric age

Hala Mounir Agha [a,*], Hala S. Hamza [a], Alyaa Kotby [b], Mona E.L. Ganzoury [b], Nanies Soliman [b]

[a] Department of Pediatrics, Pediatric Cardiology Division, Specialized Pediatric Hospital, Cairo University, Cairo
[b] Department of Pediatrics, Pediatric Cardiology Division, Specialized Pediatric Hospital, Ain Shams University, Cairo

[a,b] Egypt

Objectives: To evaluate the left ventricular function before and after transcatheter percutaneous patent ductus arteriosus (PDA) closure, and to identify the predictors of myocardial dysfunction post-PDA closure if present.

Interventions: Transcatheter PDA closure; conventional, Doppler, and tissue Doppler imaging; and speckle tracking echocardiography.

Outcome measures: To determine the feasibility and reliability of tissue Doppler and myocardial deformation imaging for evaluating myocardial function in children undergoing transcatheter PDA closure.

Patients and methods: Forty-two children diagnosed with hemodynamically significant PDA underwent percutaneous PDA closure. Conventional, Doppler, and tissue Doppler imaging, and speckle-derived strain rate echocardiography were performed at preclosure and at 48 hours, 1 month, and 6 months postclosure. Tissue Doppler velocities of the lateral and septal mitral valve annuli were obtained. Global and regional longitudinal peak systolic strain values were determined using two-dimensional speckle tracking echocardiography.

Results: The median age of the patients was 2 years and body weight was 15 kg, with the mean PDA diameter of 3.11 þ 0.99 mm. M-mode measurements (left ventricular end diastolic diameter, left atrium diameter to aortic annulus ratio, ejection fraction, and shortening fraction) reduced significantly early after PDA closure ($p < 0.001$). After 1 month, left ventricular end diastolic diameter and left atrium diameter to aortic annulus ratio continued to decrease, while ejection fraction and fractional shortening improved significantly. All tissue Doppler velocities showed a significant decrease at 48 hours with significant prolongation of global myocardial function ($p < 0.001$) and then were normalized within 1 month postclosure. Similarly, global longitudinal strain significantly decreased at 48 hours postclosure ($p < 0.001$), which also recovered at 1 month follow-up. Preclosure global longitudinal strain showed a good correlation with the postclosure prolongation of the myocardial performance index.

Conclusion: Transcatheter PDA closure causes a significant decrease in left ventricular performance early after PDA closure, which recovers completely within 1 month. Preclosure global longitudinal strain can be a predictor of postclosure myocardial dysfunction.

Keywords: Global myocardial function, Longitudinal strain, Patent ductus arterious, Tissue Doppler imaging, Transcatheter

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* Corresponding author at: Pediatric Department, Pediatric Cardiology Division, Specialized Pediatric Hospital, Faculty of Medicine, Cairo University, Kasr Al Aini Street, Cairo 11562, Egypt.
E-mail address: halaazza@gmail.com (H.M. Agha).

P.O. Box 2925 Riyadh – 11461KSA
Tel: +966 1 2520088 ext 40151
Fax: +966 1 2520718
Email: sha@sha.org.sa
URL: www.sha.org.sa

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Introduction

The left to right shunting through hemodynamically significant patent ductus arteriosus (PDA) causes pulmonary overcirculation with resultant left ventricle (LV) volume overload and remodeling. The left ventricle compensates by increasing stroke volume, but in patients with greater shunts, it causes symptoms of congestive heart failure [1,2]. Transcatheter PDA closure is a well-established, safe, and effective procedure. It has become the treatment of choice, with closure rate exceeding 90–95%. Success rate is improving over time owing to device modifications, advancement of novel techniques, and increased operator skill [3]. Theoretically, PDA closure is supposed to alter the LV volume overload and remodeling with improvement of systolic and diastolic heart function gradually. However, some reports demonstrate an immediate deterioration in LV systolic performance, which recovers within a few months [1]. This study was conducted to evaluate the LV systolic and diastolic function before and after PDA closure in children using conventional two-dimensional, Doppler, tissue Doppler, and speckle-derived strain echocardiography, as both speckle tracking echocardiography and tissue Doppler imaging (TDI) have demonstrated the ability to detect early myocardial dysfunction in different diseases [4–6]. Furthermore, we have tried to determine the predictors of LV dysfunction following percutaneous transcatheter PDA closure.

Abbreviations

PDA	patent ductus arteriosus
LVEDD	left ventricular end diastolic diameter
LVEDV	left ventricular end diastolic volume
LA/AO ratio	left atrium to aortic diameter ratio
EF	ejection fraction
FS	fraction shortening
GLS	global longitudinal strain
TDI	tissue Doppler imaging
S	peak systolic annular velocity
E	peak early diastolic annular velocity
A	peak late diastolic annular velocity
MPI	myocardial performance index
PW	pulsed wave
ICT	isovolumetric contraction time
IVRT	isovolumetric relaxation time
BSA	body surface area
CI	confidence interval
ROC	receiver operating character
AUC	area under the curve

Patients and methods

Patient characteristics

Forty-two children diagnosed with PDA and planned for percutaneous transcatheter ductal closure were enrolled in this study. This was a prospective collaborative study between Cairo University and Ain Shams Specialized Pediatric Hospitals. The interventional work of this study was performed at the Pediatric Cardiology Catheterization Laboratory of Cairo University. Patients were reviewed during the period from February 2012 till June 2014. The indication for PDA closure was a hemodynamically significant shunt causing the LV volume overload. The exclusion criterion was the coexistence of other hemodynamically significant congenital heart diseases or irreversible pulmonary vascular disease. An informed consent was obtained from the patients or their legal guardians after approval of the Ethical Committee of Ain Shams University of Medical Science. The work complies with the principles of the Declaration of Helsinki in 1964.

Transthoracic echocardiographic study

All patients who were scheduled for transcatheter PDA closure underwent two-dimensional (2D) echocardiography, Doppler imaging, TDI, and speckle tracking imaging. The echocardiographic studies were obtained preclosure (within 1 week prior to ductal closure), early (within 48 hours postclosure), and then at 1 month and 6 months postclosure. Transthoracic echocardiography was performed by an expert pediatric cardiologist, with patients in the supine position, using VIVID 9 General Electronics (GE Ultrasound, Horten, Norway) with a 3–7 MHz phased-array transducer. The M-mode measurements included interventricular septum, and LV internal and LV posterior wall diameters in systole and diastole. Ejection fraction (EF) and fraction of shortening (FS) were all measured in the parasternal long-axis view. In addition, the aortic and left atrial diameters were measured in parasternal long-axis view at the end of diastole. Two-dimensional echocardiographic measurement included the PDA size at the pulmonic end in the high parasternal ductal view in the preclosure echocardiography. Pulsed wave tissue Doppler velocities were obtained at the cardiac base in the apical four-chamber orientation from two locations: the lateral mitral annulus and the interventricular septum. Peak systolic annular velocity (S'), peak early diastolic annular velocity (E'), and peak late diastolic annular velocity (A') were measured. Calculation of the global myocardial

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