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● *Original Contribution*

BI-ATRIAL FUNCTION BEFORE AND AFTER PERCUTANEOUS CLOSURE OF ATRIAL SEPTUM IN PATIENTS WITH AND WITHOUT PAROXYSMAL ATRIAL FIBRILLATION: A 2-D AND 3-D SPECKLE TRACKING ECHOCARDIOGRAPHIC STUDY

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Abstract—Our aim was to analyze atrial function with 2-D (2-D-STE) and 3-D (3-D-STE) speckle tracking echocardiography in patients with atrial septal devices and paroxysmal atrial fibrillation (PAF). One hundred sixteen patients and a subgroup of 22 patients who developed PAF after device insertion were studied. Left atrial and right atrial peak longitudinal strain and standard deviations of time to peak strain (TPS) were calculated using 2-D-STE. The left atrial/right atrial emptying fraction and expansion index were determined using 3-D-STE. By multivariate analysis, pre-closure 3-D right atrial expansion index, left atrial time to peak strain, and 3-D left atrial expansion index were independently associated with PAF. Compared with the other indices, receiver operating characteristic analysis revealed better diagnostic accuracy for the combination of pre-closure time to peak strain and 3-D expansion index in detecting PAF. Patients with atrial septal devices have pre-existing left and right atrial dilation and dysfunction as assessed by 2-D-STE and 3-D-STE that appear sensitive for the stratification of PAF risk in this population. (E-mail: vitar@tiscali.itcardiodiagnostica@gmail.com) **© 2018 World Federation for Ultrasound in Medicine & Biology. All rights reserved.**

Key Words: **Patent foramen ovale, Atrial septal defect, Echocardiography, Speckle tracking echocardiography, Left atrial function, Right atrial function.**

INTRODUCTION

Inter-atrial shunts can be caused either by atrial septal defect (ASD), accounting for nearly 10% of congenital heart disease, or patent foramen ovale (PFO), with an incidence of 20% to 35% of the general population (Humenberger et al. 2011; Saver et al. 2017). The treatment of PFO and ASD includes surgery and, more recently, transcatheter closure using atrial septal closure devices. The percutaneous procedure has been reported to be a safe technique in patients with suitable anatomy (Eeckhout et al. 2015; Vitarelli et al. 2014), but it was hypothesized (Johnson et al. 2011; Staubach et al. 2009) that device insertion could cause impairment of segmental atrial function and favor the development of paroxysmal atrial fibrillation (PAF).

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Tissue Doppler imaging (TDI) and, more recently, 2-D speckle tracking echocardiography (2-D-STE) represent new means of assessment of myocardial wall movement and deformation. The indexes derived from these technologies have been proposed as adjunctive tools in the evaluation of left ventricular (LV) and right ventricular (RV) function, are more sensitive than ejection fraction in detecting early ventricular dysfunction, and have also been used to quantify segmental atrial contraction (Boyd et al. 2009; Di Salvo et al. 2005; Moustafa et al. 2015; Sarvari et al. 2016; Vieira et al. 2014; Vitarelli et al. 2012). As 2-D-STE capability is limited by the difficulty in tracking speckles in different frames because of out-of-plane motion, 3-D speckle tracking echocardiography (3-D-STE) was designed to provide a quick and comprehensive quantitative assessment of ventricular and atrial strains and volumes in various heart diseases (Kleijn et al. 2011; Nagaya et al. 2013; Peluso et al. 2013; Perez de Isla et al. 2014; Toprak et al. 2016), but it has not been used in PFO and ASD before and after device insertion. Moreover, it

is known that reduced reservoir function is a risk factor for the development of atrial fibrillation (AF) (Toprak et al. 2016) and that atrial function is impaired especially in septal regions after placement of atrial septal occluders (Boyd et al. 2009; Di Salvo et al. 2005), but it is not known if mechanical irritation is the only cause of PAF.

Accordingly, the aim of the present study was to assess atrial function using 2-D-STE and 3-D-STE in PFO or ASD patients who had undergone device closure and developed PAF, as compared with patients with atrial devices and normal sinus rhythm and a group of normal controls. The purpose was twofold: We wanted, first, to establish whether these patients have a pre-existing risk for AF development and, second, to analyze which of the new echocardiographic indices can better predict PAF.

METHODS

Population

One hundred sixteen patients with atrial septal devices (PFO, n = 58; secundum ASD, n = 58) were prospectively studied and followed up for 6 mo after device implantation. All participants were younger than 50 y of age. Patients with coronary artery disease, valvular heart disease other than trace or grade 1 + regurgitation; congenital heart disease other than atrial septal defect; preprocedural PAF; heart failure; obesity (body mass index [BMI] ≥ 30 kg/m^2); parenchymal lung disease; or endocrinological, liver, kidney, or neoplastic diseases were excluded from the study. PAF was diagnosed when both AF and sinus rhythm had been documented on 2- to 7-d Holter monitoring or bedside electrocardiogram (ECG) monitoring. On the basis of definitions in the ACC/AHA/ESC guidelines, AF was considered paroxysmal if it was self-limited and resolved spontaneously (Johnson et al. 2011). Atrial septal aneurysm (ASA) was defined as a membrane excursion of the inter-atrial septum of at least 10 mm with a base diameter of the aneurysm of at least 15 mm (Vitarelli et al. 2014). Indications for ASD closure were isolated secundum ASD with a pulmonary/systemic flow (Q_p/Q_s) ratio ≥1.5:1 and signs of right ventricular volume overload. Indications for PFO closure were cryptogenic stroke and evidence of right-to-left shunt (Silvestry et al. 2015). The study was approved by the local institutional research committee. Patients were informed about the risks of the procedure and possible alternative treatment, after which they gave written consent. All of them were in sinus rhythm at the time of echocardiographic examination. Two-dimensional and 3-D STE was performed before device implantation and repeated on the day after the procedure (before PAF was detected) and after 6 mo of follow-up. Fifty-eight healthy patients without cardiovascular disease and with normal physical, electrocardiographic, and echocardiographic findings were recruited as part of the study and enrolled as controls.

2-D echocardiography

Examinations were conducted with patients in the left lateral decubitus position using a Vivid E9 commercial ultrasound scanner (GE Vingmed Ultrasound AS, Horten, Norway) with phased-array transducers. Gray-scale recordings were optimized at a mean frame rate of ≥50 frames/s. Measurements of cardiac chambers were made by transthoracic echocardiography according to established criteria (Lang et al. 2015). Left atrial (LA) area was measured just before mitral valve opening from the apical four-chamber view. LA maximal volumes (V_{max}), at the end of LV systole just before mitral valve opening, and LA minimal volumes (V_{min}), at the end of LV diastole at mitral valve closure, were measured from apical four-chamber and two-chamber views using a modified Simpson biplane method and were indexed to body surface area. LA emptying fraction (LA-EF) was calculated as [(LA-V_{max} – LA-V_{min})/LA-V_{max}] × 100. The LA expansion index (EI) was calculated as [(LA-V_{max} – LA-V_{min})/LA-V_{min}] × 100. Three measurements in each subject were averaged and used for analysis. Right atrial (RA) area was measured just before tricuspid valve opening from the apical four-chamber view, and RA maximal and minimal volumes were also obtained from the same views. Right ventricular systolic pressure was determined using standard Doppler practices (Rudski et al. 2010). Pulsed-wave Doppler mitral inflow was obtained, and peak E-wave and A-wave velocities, their velocity-time integrals and the atrial fraction (atrial velocity–time integral/total velocity–time integral) were determined. Mitral and tricuspid annulus velocities were measured on the transthoracic four-chamber views. Mitral and tricuspid E/E' ratios were measured at the lateral corner of the mitral and tricuspid annulus in apical views and were used as indices for LA and RA pressure.

2-D speckle tracking echocardiography

For 2-D-STE, images were recorded at a frame rate of 55–60 frames/s. The LA endocardial border was manually traced in both apical four-chamber and two-chamber views by a three-point-and-click approach. The software automatically tracked the epicardial contours on the subsequent frames, and adequate tracking was verified and corrected by adjusting the region of interest or manually correcting the contour. The software divides the region of interest into six segments and generates the longitudinal strain curves for each segment and a mean curve of all segments. Global strain was not derived in the presence of more than two uninterpretable segments in each view. An echocardiologist blinded to data of the study population performed all analyses offline. LA STE curves were