Ultrasound in Med. & Biol., Vol. 40, No. 6, pp. 1096–1103, 2014

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2013.12.005

● *Original Contribution*

ANALYSES OF LONGITUDINAL AND OF TRANSVERSE RIGHT VENTRICULAR FUNCTION PROVIDE DIFFERENT CLINICAL INFORMATION IN PATIENTS WITH PULMONARY HYPERTENSION

Silvia Pica,* Stefano Ghio,* Gianni Tonti,† Rita Camporotondo,* Annalisa Turco,* Anna Sara Pazzano,* Laura Scelsi,* Claudia Raineri,* and Luigi Oltrona Visconti*

*Division of Cardiology, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy; and †Department of Cardiology, ASL L'Aquila, L'Aquila, Italy

(*Received* 3 *June* 2013; *revised* 3 *December* 2013; *in final form* 6 *December* 2013)

Abstract—We tested the hypothesis that analysis of longitudinal right ventricular (RV) function and analysis of transverse RV function by echocardiography provide different clinical information in patients with pulmonary hypertension (PH). Indices of longitudinal and transverse RV function were obtained with different echocardiographic techniques in 30 patients with idiopathic pulmonary arterial hypertension, 28 patients with systolic left ventricular dysfunction and PH (sLVD PH), 27 patients with sLVD and normal pulmonary pressure (sLVD no PH) undergoing right heart catheterization and 20 healthy patients. Indices of RV transverse function were significantly worse in patients with PH than in patients without PH and did not statistically differ between patients with normal and those with reduced cardiac index; RV diameter shortening at mid-segment correlated best with mean pulmonary artery pressure ($h = 0.63, p < 0.001$). Indices of longitudinal function were poorly related to severity of PH, but a tricuspid annular plane systolic excursion <15 mm predicted a cardiac index <2.5 L/min/m^2 with 80% sensitivity and 93% specificity (area under curve = 0.85). In conclusion, in patients with PH, reduced transverse RV function is a reliable indicator of the presence of high pulmonary artery pressure, whereas reduced RV longitudinal function is associated with impairment of cardiac function. (E-mail: s.ghio@smatteo.pv.it) © **2014 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Right ventricle, Pulmonary hypertension, Echocardiography.**

INTRODUCTION

A thorough evaluation of the performance of the right ventricle is of utmost clinical relevance in the evaluation of patients with suspected or known pulmonary hypertension (PH). In patients with idiopathic pulmonary arterial hypertension (IPAH), survival depends on the ability of the right ventricle to adapt to the chronically elevated pulmonary artery pressure (D'Alonzo et al. 1991; McLaughlin et al. 2002; Sitbon et al. 2002). *Guidelines for the Diagnosis and Treatment of Pulmonary Hypertension* (hereafter referred to as Guidelines) also recommend that the echocardiographic assessment of right ventricular (RV) shape and function should support the estimation of pulmonary artery pressures in the diagnostic assessment of patients with suspected PH (Task Force 2009). In patients with systolic dysfunction of the left ventricle, it is the coexistence of PH and reduced RV ejection fraction that allows identification of those at higher risk (Ghio et al. 2001). However, although the most recent echocardiographic guidelines provide a very comprehensive overview of all views and all measures of right heart structure and function that can be obtained with ultrasound, the most clinically useful approach to the assessment of RV function in patients with PH has not been completely standardized (Rudski 2010; Voelkel et al. 2006). M-Mode provides prognostic data, but allows assessment only of the longitudinal component of RV function (Forfia et al. 2006; Ghio et al. 2010). Two-dimensional echocardiography relies on geometric assumptions that may reduce the accuracy of the method (Eysmann et al. 1989; Sebbag et al. 2001). Speckle-tracking echocardiography permits the angle-independent evaluation of myocardial strain and could therefore allow assessment of RV function also in the transverse direction, but this possibility has

Address correspondence to: Stefano Ghio, Divisione di Cardiologia, Policlinico S. Matteo, Piazza Golgi 1, 27100 Pavia, Italy. E-mail: s.ghio@smatteo.pv.it

not yet been fully explored (Chow et al. 2008; Jamal et al. 2003; Kittipovanonth et al. 2008; Meris et al. 2010; Puwanant et al. 2010). Most importantly, no data have been published concerning the relative clinical usefulness of the echocardiographic parameters describing longitudinal and transverse RV function in patients with PH, an issue that has recently been discussed in a cardiac magnetic resonance study (Kind et al. 2010).

Accordingly, we used different echocardiographic techniques and obtained several indices of longitudinal and transverse RV function to test the hypothesis that analysis of longitudinal RV function and analysis of transverse RV function provide different clinical information in patients affected by PH.

METHODS

Patients

The study population comprised 30 patients with IPAH, 28 patients with systolic left ventricular dysfunction and PH (sLVD PH), 27 congestive heart failure patients with sLVD and normal pulmonary pressures (sLVD no PH) and 20 otherwise healthy patients as controls. IPAH was diagnosed after excluding all other causes of PH, according to Guidelines recommendations (Task Force 2009). Patients with sLVD were included if they had a left ventricular ejection fraction $\leq$ 35% and an etiology of either ischemic/hypertensive heart disease or idiopathic dilated cardiomyopathy. Exclusion criteria were: organic valvular heart disease, previous cardiac surgery, myocardial infarction or unstable angina in the previous 6 mo, history of pulmonary embolism or chronic obstructive pulmonary disease and implantation with RV pacing devices. Patients underwent echocardiographic examination within 24 h of a clinically indicated right heart catheterization. All patients signed an informed consent agreement approved by the institutional review board of Fondazione IRCCS Policlinico San Matteo for longitudinal, non-pharmacologic, non-sponsored studies and in compliance with Italian legislation (Codex on the Privacy, D. Lgs. 30 giugno 2003, n. 196).

Echocardiographic examination

The echocardiographic examination (using commercially available equipment: Vivid 7, GE Healthcare) and off-line analysis were performed by two echocardiographers blinded to the clinical data of the patients; disagreement was solved by consensus with a senior investigator. The following M-mode and 2-D parameters describing the right ventricle were measured/calculated: systolic displacement of the lateral portion of the tricuspid annular plane (TAPSE), measured on the M-mode tracing under 2-D-echo guidance; RV free wall thickness; RV end-diastolic (RVEDA) and end-systolic (RVESA) areas measured in an apical four-chamber view modified to optimize visualization of the entire right ventricle; RV fractional area change (RVFAC) calculated as [(RVEDA–RVESA)/RVEDA) $\times$ 100]; RV transverse diameters measured in the same apical view at basal and mid-levels; RV diameter shortening calculated as the percentage change between end-diastole and end-systole. Color-coded tissue Doppler images of the right ventricle in apical view were acquired during three cardiac circles, at a frame rate set at 150–180 frames/s; off-line analysis was performed using dedicated software (EchoPac BT08, GE Vingmed Ultra-sound, Horten, Norway). Longitudinal peak systolic velocity (*S*) and peak systolic strain were measured at the basal and mid-levels of the RV lateral wall. Two-dimensional echocardiographic gray-scale images of the right ventricle in apical view were acquired at a frame rate of 70–80 frames/s during three cardiac cycles and digitally stored for off-line analysis using dedicated speckle-tracking software (Vector Velocity Imaging Technology, Siemens Medical Solutions, Mountain View, CA, USA). Peak systolic displacement, velocity and strain were recorded at the basal and mid-levels of the RV lateral wall in both longitudinal and transverse directions. Transverse shortening at the basal and mid-levels was calculated using vector velocity imaging as [diastolic diameter – (diastolic diameter – transverse displacement)]/diastolic diameter.

Right heart catheterization

Right heart catheterization was performed with a balloon-tipped catheter. The following hemodynamic parameters were measured or calculated: pulmonary capillary wedge pressure (PCWP); mean (mPAP), systolic and diastolic pulmonary artery pressures; cardiac output (CO, calculated by thermodilution or the Fick method); cardiac index (CI), obtained by dividing cardiac output by body surface area; right atrial pressure; pulmonary vascular resistance (calculated as (mPAP – PCWP)/CO). According to the Guidelines, PH was defined as a mPAP $\geq$ 25 mm Hg; a low CI was defined as $<$2.5 mL/min/m^2.

Statistical analysis

Data are described as means and standard deviations or medians and 25th–75th percentiles if continuous and counts and percentages if categorical. Differences between groups were analyzed either with the Student t-test or Mann-Whitney *U*-test (depending on their distribution) or with an analysis of variance with Tukey's honest significant difference test for comparison among groups. Associations between continuous variables were measured with Spearman's test, yielding the coefficient ρ and a *p*-value. Receiver operating characteristic (ROC) curve analysis was used to determine the most