Journal of Cardiac Failure Vol. 22 No. 4 2016

Brief Report

Characteristic Features on Morphologic and Topographic Findings of Pulmonary Vein Orifices in Transition From Diastolic Dysfunction to Heart Failure: A Computerized Tomography Study

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ABSTRACT

Background: Diastolic dysfunction (DD), a precursor to clinical heart failure (HF), has traditionally been evaluated by means of echocardiography. Data regarding morphologic descriptions of pulmonary vein (PV) orifices in transition from DD to HF have been lacking.

Methods and Results: We retrospectively studied 124 subjects with computerized tomography (CT)–derived PV parameters and echocardiography-derived diastolic indices. We categorized our subjects as 1) non-DD, 2) DD, or 3) heart failure with preserved ejection fraction (HFpEF) and observed a graded enlargement for 4 PV orifice areas across these groups. Positive linear relationship between the 4 PV orifice areas, echocardiography-derived mean pulmonary capillary wedge pressure (PCWP), and velocity of propagation (VP) were observed. Finally, maximum areas of left superior pulmonary vein (LSPV) and left inferior pulmonary vein (LIPV) significantly increased clinical diagnosis of HFpEF (likelihood-ratio χ^2: from 42.92 to 50.75 and 54.67 for LSPV and LIPV, respectively) when superimposed on left ventricular mass index, PCWP, and left atrial volume.

Conclusions: PV size measurements with the use of CT are feasible and further aid in diseases discrimination between preclinical DD and those progressed into HF, even with preserved global pumping. Our data suggest that CT-based PV measures may help to identify subjects at risk for HF. (*J Cardiac Fail 2016;22:316–320*)

Key Words: Diastolic dysfunction, heart failure with preserved ejection fraction (HFpEF), pulmonary vein, orifice areas.

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Manuscript received June 10, 2015; revised manuscript received December 8, 2015; revised manuscript accepted December 18, 2015.

1071-9164/$ - see front matter

http://dx.doi.org/10.1016/j.cardfail.2015.12.019

Heart failure (HF) with preserved ejection fraction (HFpEF) constitutes ~40%–50% of all cases of HF. The prevalence of atrial fibrillation (AF) ranges from 25% to 30% in HFpEF patients.[1] Recent evidence supports the concept that the severity of diastolic dysfunction (DD) may independently predict AF.[2] Therefore, a mechanistic link between DD and AF may be crucial from a primary prevention viewpoint.

Among all diastolic parameters, left atrial (LA) size has been recognized as a marker of DD, which may reflect the long-term elevated left ventricular (LV) filling pressure and increase of LV stiffness.[3] Echocardiography remains the most common bedside tool for LA structural/functional assessment in daily practice. However, echocardiography provides scant information for morphologic description of the pulmonary vein (PV) ostia. Instead, multidetector computerized tomography (MDCT) enables assessment of PV and PV ostia.

Data regarding the association among MDCT-characterized PV morphology, diastolic parameters, and LA remodeling in subjects presenting with DD or HFpEF remain largely undefined. We hypothesized that topographic and morphologic findings of PVs with the use of MDCT may be able to discriminate subtle differences in transition from non-DD, DD, and HFpEF.

Methods

Study Subjects

This study was approved by the Institutional Review Board of Mackay Memorial Hospital. From June 2010 to January 2011, we studied consecutive outpatients with HF, defined by New York Heart Association (NYHA) functional class II or III, with preserved LV ejection fraction (LVEF; HFpEF: n = 32) as assessed with the use of echocardiography (LVEF >50%) and evidenced by symptoms or signs from the Framingham criteria with preserved LVEF. The study settings were similar to those in our previous publications.[4] Another asymptomatic (NYHA functional class I) DD (n = 47) or non-DD (n = 45) group according to echocardiography was also enrolled. The main purpose for subjects receiving CT and echocardiographic studies was to characterize their coronary artery atherosclerotic conditions. Subjects with symptomatic critical coronary artery occlusion were excluded. All study participants presented no angina symptoms and no obvious myocardial ischemia according to functional stress tests for those with moderate-degree coronary artery stenosis according to CT.

Exclusion criteria included subjects with pacemakers, primary and severe valvular heart disorders after surgery, ongoing atrioventricular block or episodes, frequent cardiac arrhythmias, renal dysfunction (serum creatinine ≥2.5 mg/dL), and chronic obstructive pulmonary disease.

Computerized Tomography Methods

All patients underwent electrocardiography (ECG)–gated coronary CT angiography with the use of a CT scanner (Siemens Definition Dual-Source CT). An experienced radiologist retrospectively reviewed the images. All images were reconstructed at mid-diastolic phase (65% of cardiac cycle) and sent to a dedicated workstation (Aquarius 3D Workstation; Terarecon, San Mateo, California). The 4 PV measurements were obtained in short-axis view for each vein. The vascular analysis software was semiautomated. The user identified the outline of PVs, and the software provided the areas.

Echocardiography Methods

Transthoracic Doppler echocardiography (Vivid 7; GE-Vingmed) was carried out in all subjects equipped with a 2- to 4-MHz transducer (M4S). LA diameter, LV wall thickness, internal diameter, and LV mass were all determined from M-mode measurements based on American Society of Echocardiography criteria.[5] LV diastolic indices were determined with the use of several integrated parameters, including Doppler-based transmitral inflow early (E) and late-diastolic (A) filling velocities, deceleration time (DT) of E, and isovolumic relaxation time. Furthermore, tissue Doppler imaging (TDI) was used to determine the early-phase lateral mitral annular velocities, with both peak systolic (S′) and early diastolic (E′) data recorded. Color M-mode was used to acquire velocity of propagation (VP) and other load-independent diastolic indices from the apical 4-chamber view.[6,7] We also collected information regarding E/E′, which was estimated as the ratio of the early (E) transmitral Doppler velocity divided by TDI–derived early-diastolic lateral mitral annular diastolic velocity (E′).

We categorized the study cohort into non-DD, DD, and HFpEF based on integrated grading of diastolic abnormalities with the use of mitral inflow E/A patterns and DT and further aided by TDI as previously described.[8,9]

Results

Baseline Characteristics and Conventional Echocardiographic Measurements

The baseline characteristics of our study subjects were classified according to three groups (non-DD, DD, and HFpEF) and presented in Table 1. Across these 3 groups, significantly graded increase was noted in age, systolic blood pressure, body mass index, higher glucose, and worse renal function in terms of estimated glomerular filtration rate. Those with DD or HFpEF were more likely to have hypertension, diabetes, and hyperlipidemia.

Among the echocardiographic measures, compared with non-DD and DD groups, the HFpEF group had markedly increased LA size, greater LV wall thickness, and larger LV mass index, and worse mid-wall fractional shortening (all $P < .05$). More prolonged DT, reduced TDI S′ or E′, substantially elevated PCWP, and attenuated VP were observed in the DD and HFpEF groups (all $P < .05$).

Pulmonary Vein Measurements

The PV CT measurements showed significantly graded increase in PV orifice areas across non-DD, DD, and HFpEF categories (Table 1). Age-matched comparisons among groups (n = 29 non-DD; n = 31 DD; and n = 30 HFpEF) also showed similar trends (data not shown).

Associations Between Pulmonary Vein Measurements, Echocardiography-Derived Diastolic Parameters, and Circulating B-Type Natriuretic Peptide Levels

The correlations between PV measures and echocardiography-derived diastolic indices including DT, mitral E/A ratio, PCWP, VP, and B-type natriuretic peptide (BNP) levels are displayed in Table 2. A positive linear relationship was observed between PV orifice areas and PCWP and