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Original Article

Assessment of left and right atrial geometrical changes in patients with stable coronary artery disease: Left and right atrial strain and strain rate imaging study

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ABSTRACT

Objective: In patients with coronary artery disease (CAD), there are several studies that assessed the left ventricular (LV) function by strain (S) and strain rate (SR) imaging. The aim of this study is to evaluate the function of both atria in patients with CAD using strain and strain rate imaging, and to correlate this with the severity of CAD.

Methods: We conducted a prospective, single center case control study for 40 consecutive patients who presented to our department with chronic stable angina and were candidates for invasive coronary angiography. We enrolled patients from December 2013 to May 2014 and each patient was subjected to echocardiographic assessment of E/e′ of mitral valve, left atrial volume index (LAVI), right atrial volume index (RAVI), and peak atrial longitudinal strain (es) and strain rate (SR) during LV systole. This was followed by invasive coronary angiography for assessment of the severity of CAD using Gensini score. Patients were classified according to angiographic results into 3 groups: Group I (Gensini score = zero), Group II (Gensini score > 0 and < 20) and Group III (Gensini score $\geq$ 20).

Results: There was no statistically significant difference between the three groups in either LA volumes (V_{min}, V_{max}) and distensibility with p value of 0.272, 0.126, and 0.243 respectively or RA volumes and distensibility with a p value of 0.671, 0.183, and 0.259 respectively. On the other hand, LA & RA systolic S and SR were significantly lower among CAD patients in comparison with the group of normal coronaries. Mean LA S and SR was decreased in group III than group II (15.97 ± 3.73, 21.8 ± 6.75 % and 1.11 ± 0.30, 1.81 ± 1.23 s^{-1}) with p value of 0.005&0.041 respectively. RA systolic S and SR were significantly lower in the 2 groups with CAD than the group with normal coronaries with a p value of 0.001 and 0.002 respectively.

Conclusion: In patients with CAD and normal EF, borderline E/e′ ratio and normal atrial size, there are decreased LA and RA systolic S and SR parameters with no effect on atrial volumes or distensibility. Accordingly, this could prove that atrial wall deformation occurs early in CAD even before any changes in atrial volumes or dimensions.

1. Introduction

Coronary artery disease (CAD) is a major health problem worldwide as it carries high risk of developing heart failure, morbidity and mortality.[1] Left ventricular (LV) diastolic dysfunction is an early and sensitive marker of ischemia in patients with CAD, as it presents even before regional or global LV systolic dysfunction.[1,2] Furthermore, it is well known that the atrium has an important role in maintenance of LV stoke volume in the setting of LV dysfunction.[3] Evaluation of the LA function is emerging as an important component in assessing the effect of CAD on hemodynamics.[3] Despite its vital contribution in cardiac function, assessment of atrial function is usually neglected in our routine daily practice. During the cardiac cycle, the atria have three functions: reservoir, conduit and active contractile function.[4] Recently, several studies have shown that strain (S) and strain rates (SR)

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are powerful parameters of deformation; they directly reflect both global and regional systolic and diastolic myocardial function,[5,6] and can detect any early effects of CAD on LA functions.[7] The atrial reservoir function is reflected by systolic strain and strain rates, and the conduit and contractile functions are reflected by the early and late diastolic strain rate respectively.[8] Atrial remodeling and atrial disease are associated with major adverse cardiovascular outcomes especially atrial fibrillation, strokes and heart failure.[9,10] In this study we aimed to evaluate the function of both atria in patients with CAD using strain and strain rate imaging, and correlate this function with the severity of CAD.

2. Patients and methods

2.1. Study design and population

We conducted a prospective, single center case control study for 40 consecutive patients who presented to our department with chronic stable angina and were candidates for invasive coronary angiography. We enrolled patients from December 2013 to May 2014, Patients were classified according to the severity of CAD by coronary angiography into 3 groups; Group I with normal coronary arteries (Gensini score = zero), Group II with mild CAD (Gensini score >0 and <20) and Group III with severe CAD (Gensini score $\geq$ 20). All patients were subjected to the following, full history taking, clinical examination and routine laboratory investigations, all demographic data and risk factors of CAD were recorded; (age, sex, BMI, hypercholesterolemia (ongoing treatment of hypercholesterolemia or serum cholesterol level either fasting or non-fasting >200 mg/dl), diabetes mellitus (fasting serum glucose level >126 mg/d or diabetic medications) or current cigarette smoking.

2.2. Exclusion criteria

To minimize the effect of some medical conditions on the atrial function, we excluded the following groups of patients:elderly patients >65 y of age, Obese patients with BMI $\geq$ 30 kg/m^2, acute coronary syndrome, any history of prior coronary artery revascularization (either surgical or through percutaneous catheterization), hypertensive patients (blood pressure >140/90 or being on antihypertensive medications), diabetes mellitus, patients with EF <55%, patients presenting with heart failure symptoms, any form of valvular heart diseases, any conduction system abnormality or rhythm other than sinus rhythm, severe renal or liver dysfunction and suboptimal echocardiographic images.

2.3. Echocardiography

All patients were subjected to full echocardiographic examinations at rest, in the left lateral position using (Vivid E9 dimension; General Electric Medical Systems, Horten, Norway) equipped with 2.5-MHz variable-frequency transducer). Standard 2 D views, including, apical 4, apical 2-chamber and parasternal long-axis views were obtained and apical views were obtained also with color TDI modes. For data acquisition, 3 cardiac cycles were collected and stored in a cine-loop format, to be processed using a software (Echo Pac, GE Vivid E9 echocardiography system version 113), for off-line measurements of TDI-based strain. Simpson method were obtained for assessment of global LV systolic function, E/e′ ratio were obtained by Doppler assessment of the mitral valve, E (early diastolic peak trans mitral flow velocity) divided by e′ which was measured through colour-coded TDI of the apical 4-chamber view, using PW Doppler sample placed at the septal and lateral mitral annulus, then the average of both values was taken.[11]

1. *Calculation of Left and right atrial volume by biplane area length method:*
   - LA volume = (0.85 × Area 4ch × Area 2ch)/(Longest LA length). Both the LA long axis and LA area were measured in apical 2 and apical 4 chamber views at end of ventricular systole. The LA area was obtained: by tracing the endocardial border of the atrium excluding pulmonary veins, LA appendage and sub annular plane, and LA long axis was measured as a line extending perpendicular from the back wall of LA to the mitral annular plane.[12]
   - RA volume = (0.85 × area 4ch × area 4ch)/(RA length) where both RA length and RA area were measured in apical 4 chamber view at the end of ventricular systole. RA area was obtained by tracing endocardial border of the right atrium excluding tricuspid subannular plane, RA appendage, IVC and SVC), and RA long axis was measured as a line extending from back wall of RA perpendicular to the annular plane of the tricuspid valve.[13]

   All atrial volumes were indexed to the body surface area (BSA). BSA is calculated by Mosteller formula: BSA (m^2) = (Height (cm) × Weight (kg)/3600)^{½}.[14]

   - Calculation of LA and RA distensibility using the following formula:

$$(V_{max}) - (V_{min}) \times 100/(V_{min}).$$

(V_{max}) = maximal volume of the atrium at the end of the systole (T wave on ECG) & (V_{min}) = minimum volume of the atrium at the end of the diastole (R wave on ECG).[12]

2. *Strain and strain rate imaging of the left and right atrium:*
   2D color-coded Tissue Doppler imaging (TDI), using standard apical 4 & apical 2 chamber views, at a high frame rate (>180 fps) and the narrowest possible sector angel possible (30°) images were be stored for off-line analysis using Echo Pac, GE 113, Atrial longitudinal systolic Strain S and SR were measured by placing a 2 mm sample volume (because of thin atrial wall) at the mid segment of : the LA septal wall, LA lateral wall, RA free wall (using the apical 4 chamber view), and LA inferior wall and LA anterior wall (using the apical 2 chamber view).[15,16] The studied segments were kept at the center of the U/S sector to insure the accuracy, and strain S /SR velocity curves were obtained and analyzed offline with dedicated software, atrial reservoir function during ventricular systole, represented by the interval between mitral valve closure (MVC) and mitral valve opening (MVO), peak positive systolic strain and strain rate were calculated from the extracted curves over 3 recorded cardiac cycles to obtain mean strain and strain rate values of the studied segment.[17]

2.4. Coronary angiography

Diagnostic coronary angiography was done to all patients through either femoral or radial approach according to local protocol. Gensini score was used to assess the severity of CAD by an experienced cardiologist, blinded to the echocardiographic data of the patients. Gensini score was calculated through multiplication of score used for grading the luminal narrowing of the main coronary artery by a factor which takes into account the site and importance of the lesion. The score of luminal narrowing was 1 for $\leq$25% stenosis, 2 for 26–50% stenosis, 4 for 51–75% stenosis, 8 for 76–90% stenosis, 16 for 91–99% stenosis and 32 for total occlusion. The factor of location was 5 for left main, 2.5 for the proximal lesion of either LAD (left anterior descending) or LCX (left circumflex), 1.5 for mid lesion, 1 for distal LAD, mid-distal LCX or RCA (right coronary artery). Then the sum of scores of all coronary arteries was used to express the total Gensini score.[18]

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