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Original Article

Is mitral annular ascent useful in studying left ventricular function through left atrio-ventricular interactions?

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ABSTRACT

Background: The mitral annulus (MA) is a crucial structure that is in constant motion throughout the cardiac cycle. The main purpose of this study was to determine if M-mode evaluation of the longitudinal motion of the MA could be useful to examine atrio-ventricular interactions.
Methods: Echocardiographic data obtained from 150 patients (mean age 56 ± 16; 82 males) from the University of Cincinnati College of Medicine was evaluated to examine if any relationship exists between MA motion and measures of atrio-ventricular interactions.
Results: Even though left atrial size, left ventricular (LV) mass index, LV ejection fraction (LVEF) and degree of LV diastolic dysfunction (LVDD) were significant echocardiographic variables affecting MA motion; LVEF and the degree of LVDD were the main determinants of MA excursion during systole (MAPSE) and after atrial contraction (MAa). Our results confirm the surrogate value of MAPSE with regards to LVEF and also show that the extent of MA excursion during systole is the main determinant of MAa. The effect of LV diastolic function applies more strongly to MAPSE than to MAa. However, the maximal MAa amplitude varies in accordance to the type of LVDD.
Conclusions: We have shown for the first time that M-mode interrogation of the MA longitudinal motion appears useful to assess atrio-ventricular interactions. Since LV systolic and diastolic functions are so closely related; additional studies are now required to examine how this longitudinal measure correlates with known circumferential rotational data obtained with other imaging modalities.

1. Introduction

The mitral annulus (MA) is a crucial structure that plays an important role in mitral leaflet coaptation, unloading mitral valve closing forces, and promoting left atrial (LA) as well as left ventricular (LV) filling and emptying.[1] The three-dimensional saddle shape of the MA is well characterized in both animals and humans.[2] In fact, the systolic excursion of the MA has been correlated to LV systolic function.[3–7] During the cardiac cycle not only the MA is in constant motion, but also its excursion encompasses a volume that is part of the total LV volume change during both filling and emptying.[8]

Longitudinal myocardial function has attracted interest in recent years. Specifically, this interest was greatly advanced by the work of Torrent-Guasp that introduced the concept of the myocardial band, which explained the architecture of all cardiac chambers.[9] In addition, a 180° twist in the middle portion of this band has been implied as the responsible element for the twisting-untwisting motion of the LV.[10,11] This twisting-untwisting movement of LV myofibers from base and apex rotating in opposite directions, and their spatial and directional orientation changes during the cardiac cycle, have shown a close relationship between LV systolic and early diastolic function.[12,13] In fact impairment of this long-axis LV contraction and relaxation has been reported in experimental and clinical studies in the setting of coronary artery disease, myocardial infarction, LV hypertrophy, dilated cardiomyopathy, and hypertrophic cardiomyopathy.[14]

Our laboratory has previously shown that both mitral annular plane systolic excursion (MAPSE) and the mitral annular ascent

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(MAa) component, occurring during late ventricular diastole, were useful in identifying serial activation differences between the right and left heart.[4,5] We now hypothesized that closer inspection of the MA M-mode signal, with its excellent temporal resolution,[15,16] might be useful to examine atrio-ventricular interactions between the LA and LV.

2. Methods

2.1. Population studied

The University of Cincinnati IRB office approved the study (protocol number 12061302) and no written consent was needed since this was a retrospective study.

The echocardiographic database at the University of Cincinnati College of Medicine Main University Hospital Echocardiography Laboratory was queried for patients who had a complete transthoracic echocardiogram performed between July 1, 2013 and July 31, 2014 for any clinical indication meeting all of the following inclusion criteria.

Inclusion criteria for this study required that all patients at the time of the echocardiographic study were in normal sinus rhythm during the examination. In addition, there had to be good visualization of the LA and LV endocardium with complete M-mode tracing interrogation as well as tissue Doppler signal of the lateral portion of the MA. Furthermore, a complete spectral Doppler study to examine LV diastolic function had to be acquired as recommended by published guidelines.[17–19] Since interpretation of multiple echocardiographic parameters that vary with loading conditions might provide conflicting diagnostic information that could limit LV diastolic function characterization [20–22]; only echocardiographic studies with non-conflicting LVDD diagnostic criteria were included into the final analysis.

Finally, studies were excluded if patients had atrial fibrillation or rhythm abnormalities at the time of the study, mitral annular calcification, mitral valve stenosis, previous mitral valve repair or valvular replacement surgery.

Since our laboratory had previously shown significant differences with regards to LV systolic function and MAa using 75 patients,[5] for this study we targeted a total of 150 patients to analyze atrio-ventricular (LA and LV) interactions with an α value of 0.05 and desired power of 0.80.

Therefore, from a total number of 425 echocardiograms performed during that time frame, the first 150 consecutive echocardiograms that met all inclusion and none of the exclusion criteria were included in to the final analysis.

Calculation of body surface area was performed as previously described by Mosteller as follows [23]:

$$\text{BSA (m}^2) = ([\text{Height (cm)} \times \text{Weight (kg)}]/3600)^{1/2}$$

2.2. Echocardiographic studies

We utilized commercially available systems (Vivid 7 and 9; GE Medical Systems, Milwaukee, WI, USA) to perform two-dimensional echocardiographic studies. Images were obtained in the parasternal and apical views with the patient in the left lateral decubitus position and in the subcostal view with the patient in the supine position using a 3.5 MHz transducer. Standard two-dimensional, color, pulsed, and continuous-wave Doppler data were digitally acquired in gently held end-expiration, and saved in regular cine loop format for subsequent offline analysis.

Left ventricular end-diastolic and end-systolic volumes were traced from the apical four-chamber view in accordance to published data; while ejection fraction calculations were done using the Simpson's rule algorithm.[6]

Calculation of LV mass was performed according to the ASE-recommended formula using LV linear dimensions based on modeling the LV as a prolate ellipse of revolution using the following formula [6]:

$$\text{LV mass} = 0.8 \times \{1.04[(\text{LVIDd} + \text{PWTd} + \text{SWTd})3 - (\text{LVIDd})3]\} + 0.6\,\text{g}$$

Specifically, in this formula PWTd and SWTd correspond to posterior wall thickness at end diastole and septal wall thickness at end diastole, respectively.[6] Since this formula is appropriate for evaluating patients without major distortions of LV geometry such as patients with hypertension, it was appropriate for utilization in this study. Correction for BSA was then performed to express LV mass as LV mass index (LVMI) as g/m^2.

Measurement of LA volume was performed following the ASE guidelines using the area-length method from the apical 4-chamber and apical 2-chamber views at ventricular end systole (where LA size is largest) using the following formula [6,17]:

$$\text{LA Volume} = 8/3\pi\ [(\text{A1}) \times (\text{A2})/(\text{L})]$$

In this formula, L is measured from back wall to line across hinge points of mitral valve and is the shortest length from either the 4-chamber (A1) or 2-chamber (A2). To accurately correct for the effect of body habitus, LA volumes were corrected for BSA and consequently LA volumes were expressed as LAVI (mL/m^2).

Mitral inflow velocity was obtained using pulsed-wave Doppler examination at a sweep speed of 100 mm/s from the apical four-chamber view by placing the sample volume at the tips of the mitral leaflets.[17–19] Peak velocity in early diastole (E-wave, LV relaxation) and late diastole (A-wave, LA contraction) and deceleration time of the E-wave were measured as previously described.[17–19]

Since our laboratory has previously described that maximal MA excursion and MA ascent are better assessed when the lateral portion of the MA is interrogated,[4,5] pulsed-wave tissue Doppler imaging (TDI) was only performed on the lateral portion of the MA in order to perform direct ipsilateral correlations.

In terms of the lateral MA TDI, peak velocity in systole (S′), early diastole (E′), and late diastole (A′) were measured by placing the sample volume at the junction were the mitral valve plane intersects the left ventricular free wall using images obtained from the apical four-chamber view. As previously explained, for the purpose of this study LV diastolic pressure was estimated only using the E/E′ ratio obtained from the lateral MA E' velocity.[18,19] Finally, LV diastolic function was classified as normal, impaired relaxation, pseudonormal and restrictive pattern following published recommendations.[17]

Overall MA motion was examined by M-mode by placing the cursor in the same orientation as previously described for TDI. The resulting M-mode tracing generated a signal containing both MAPSE and MAa. Specifically, MAa was measured as the distance traveled by the lateral portion of the MA from the end of diastasis until the end of atrial contraction.[4,5] MAPSE was measured as the total excursion of the mitral annulus from the end of atrial ascent until the end of ventricular systole. A representative MA M-mode tracing showing both MAPSE and the MAa component is shown in Fig. 1.

2.3. Statistical analysis

The commercially available software Merge Cardio Workstation (Merge Healthcare) was used to calculate all echocardiographic measurements. All continuous data are presented as mean and standard deviation. Comparison between groups' baseline