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Original article

Mechanism of atrial functional mitral regurgitation in patients with atrial fibrillation: A study using three-dimensional transesophageal echocardiography

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ABSTRACT

Background: Functional mitral regurgitation (MR) can occur in patients with atrial fibrillation (AF) despite having preserved left ventricular (LV) systolic function. This MR is known as atrial functional MR. The aim of this study was to clarify the mechanism of atrial functional MR using real-time three-dimensional transesophageal echocardiography (3DTEE).

Methods: Sixty patients underwent transthoracic echocardiography and 3DTEE: 16 patients with AF and significant non-organic MR and preserved LV ejection fraction (>50%) constituted the AF-MR group, 20 patients with AF and no significant MR formed the AF-NSMR group, and 24 normal subjects comprised the control group.

Results: The left atrial volume index was significantly larger in the AF-MR group (95 ± 41 ml/m^2) than in the AF-NSMR group (38 ± 13 ml/m^2, $p < 0.05$) or the control group (21 ± 7 ml/m^2, $p < 0.05$). The 3D annular circumference was significantly longer in the AF-MR group than in the AF-NSMR group. The annular-anterior leaflet coaptation angle was smaller in the AF-MR group than in the AF-NSMR group ($11 \pm 6^\circ$ vs. $18 \pm 9^\circ$, $p < 0.05$). The annular-posterior leaflet coaptation angle was comparable between the two AF groups ($26 \pm 12^\circ$ vs. $28 \pm 10^\circ$), whereas the annular-posterior leaflet tip angle was larger in the AF-MR group than in the AF-NSMR group ($59 \pm 13^\circ$ vs. $44 \pm 11^\circ$, $p < 0.05$). The posterior leaflet bending toward LV cavity was therefore significantly larger in the AF-MR group than in the AF-NSMR group ($32 \pm 10^\circ$ vs. $18 \pm 15^\circ$, $p < 0.05$).

Conclusions: In patients with AF and significant functional MR occurring despite their preserved LV systolic function, the left atrium and mitral annulus were dilated and the anterior leaflet was flattened along the mitral annular plane, whereas the posterior leaflet was bent toward the LV cavity.

Introduction

A previous study has suggested that isolated mitral annular dilation in patients with lone atrial fibrillation (AF) does not usually cause functional mitral regurgitation (MR) [1]. In contrast, some other studies have shown that functional MR occasionally occurs in patients with AF and an enlarged left atrium (LA), despite having preserved left ventricular (LV) systolic function [2–4]. This MR is known as atrial functional MR [5]. Despite these earlier studies, the detailed mechanism of atrial functional MR has yet to be fully elucidated. Therefore, the purpose of this study was to clarify the mitral geometric changes in patients with atrial functional MR using real-time three-dimensional transesophageal echocardiography (3DTEE).

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Methods

Patients

We performed 3DTEE in 16 consecutive patients with persistent AF, preserved LV ejection fraction (EF) (>50%), and moderate or severe degrees of non-organic MR (AF-MR group). All of them had been referred to our echocardiography laboratories in Osaka City General Hospital or Shiroyama Hospital for diagnosis of the grading and etiology of their MR using transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE). After confirming LVEF > 50%, a moderate to severe MR grading, and a non-organic etiology with TTE, the patients were recruited into our study and TEE was performed. We excluded patients with significant elongation or calcification of their mitral valve leaflets, ruptured or apparently elongated mitral chordae tendineae, severe mitral annular calcification, other significant valvular heart diseases except secondary tricuspid regurgitation (TR), a history of coronary artery disease or regional LV wall motion abnormality suggesting myocardial ischemia or infarction, acute decompensated heart failure, or contraindication for TEE. Comparison was made with 20 consecutive patients with persistent AF, preserved EF, and no significant (none or mild) MR (AF-NSMR group), along with 24 consecutive sinus rhythm patients without apparent cardiac disease (control group). All of the patients in the AF-NSMR group and the control group were referred to our echocardiography laboratories for both TTE and TEE to rule out a cardiac embolic source or infective endocarditis. The Ethical Committees of the Osaka City General Hospital and Shiroyama Hospital approved the study, and written informed consent was obtained from all the patients.

Transthoracic echocardiography

TTE and TEE images were acquired using an iE33 or an EPIQ imaging platform with the S5-1 or X5-1 transducer for TTE and the X7-2t transducer for TEE (Philips Ultrasound, Bothell, WA, USA).

Using TTE, LV end-diastolic dimension (LVDd), LV end-systolic dimension (LVDs), LV ejection fraction, LV mass index, and LA maximal dimension were measured [6]. The LA volume index was determined from the apical four-chamber view and the apical two chamber view using the method of discs [6]. The severity of the MR was defined using a multiparametric approach including an assessment of the vena contracta, the effective regurgitant orifice area using the proximal isovelocity surface area method, or the Doppler-derived volumetric method as appropriate in each patient [7]. The TR grade was classified according to the ratio of the color Doppler jet area to the right atrial area in mid-systole as follows: none (0), mild (1), moderate (2), or severe (3) [8–10]. Continuous wave Doppler was used to obtain the TR peak velocity (v, m/s) and transtricuspid systolic pressure gradient (mmHg), which was calculated as $4 \times v^2$. According to a previous study, we also measured the length of the inwardly bent basal segment of the LV as a parameter of the inward bend of the LV basal posterior wall caused by the backward dilation of the LA [11]. The length was measured from the posterior mitral annulus to the LA posterior wall contacting the pericardium at end systole (Fig. 1). For all TTE measurements, we carefully selected a beat occurring after two serial beats with average RR intervals [12].

Transesophageal echocardiography

In all patients, TEE was performed while under conscious sedation in a standard manner. The real-time 3D datasets were acquired from the mid-esophagus using the 3D zoom function. Sector width, gain, and depth settings were adjusted to ensure that the entire mitral valve annulus was included (a volume rate of 10 volume/s). We acquired two consecutive beats with a caution to select them occurring after two serial beats with average RR intervals [12]. Then, datasets were analyzed offline using computer software (QLab, Mitral Valve Quantification, Philips Healthcare, Andover, MA, USA) [13]. First, the mid-systolic frame was selected which is defined according to when the coaptation of mitral leaflets shifts most closely to the LA cavity side. We manually identified the anterior, posterior, and commissure points of the mitral annulus, and subsequently defined the hinge points of the leaflets in six more rotational planes. Then, the leaflets were manually traced in parallel slices across the valve. After these processes, the software automatically calculated the parameters described below. Anteroposterior (AP) and commissural (CC) diameters, 3D circumference, and annular height were calculated as the mitral annular parameters. Total leaflet surface area, total surface area of the anterior mitral leaflet (AML), total surface area of the posterior mitral leaflet (PML), longitudinal length of the middle AML (A2), longitudinal length of the middle PML (P2), coaptation area, coaptation length, and coaptation height were calculated as the parameters of the leaflets and coaptation size (Fig. 2). Coaptation length implies the three-dimensional transverse length of the coaptation line between the AML and PML, and coaptation height implies the shorter length from the coaptation line to the tip of the A2 or P2. In the present study, we also measured the AML annular-coaptation angle (αAML), the PML annular-coaptation angle (αPML), the AML annular-tip angle (βAML), and the PML

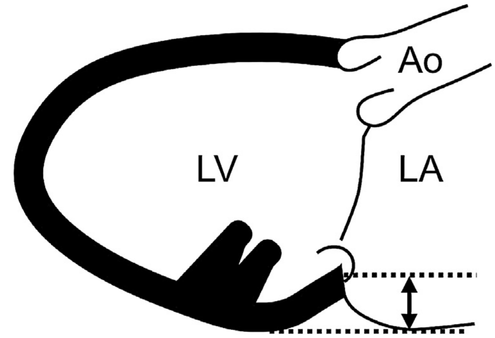

Fig. 1. The length of the inward bending basal segment of the left ventricle. The length was measured from the posterior mitral annulus to the left atrial posterior wall contacting the pericardium. Ao, ascending aorta; LA, left atrium; LV, left ventricle.

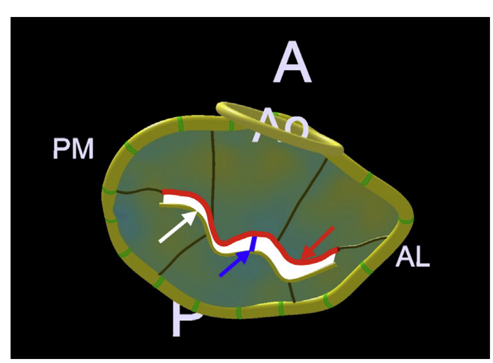

Fig. 2. The definition of the coaptation length, height, and area. (Red arrow): the red curved line indicates the coaptation line, which is defined as the basal line of the coaptation surface between the anterior mitral leaflet and the posterior mitral leaflet. (Blue arrow): the blue line indicates the coaptation height, which is defined as the shorter height of the coaptation surface between A2 and P2. (White arrow): the white area indicates the coaptation area, which is defined as the area of coaptation surface between the anterior mitral leaflet and the posterior mitral leaflet. A2, middle portion of anterior mitral leaflet; P2 middle scallop of posterior mitral leaflet. AL, anterolateral; Ao, ascending aorta; PM, posteromedial.

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