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RESEARCH ARTICLE

Computed Tomography Assessment of the Left Atrium and Left Ventricle as Components of the Mitral Valve Complex in Patients with Functional Mitral Regurgitation: Implications for TMVR Planning

Leyla Musayeva*

Central Clinic Hospital, Baku, Azerbaijan

Corresponding Author: *Leyla Musayeva, Email: leyla.musayeva@gmail.com*

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Abstract

Background: Functional mitral regurgitation (FMR) is associated with structural remodeling of the left atrium (LA) and left ventricle (LV). Accurate preprocedural imaging is essential for transcatheter mitral valve replacement (TMVR). The objective of this study was to evaluate LA volume, LV geometry, and LA–LV axis orientation using Multislice CT (MSCT) in patients with FMR compared with healthy controls.

Methods: Fifty subjects underwent contrastenhanced cardiac CT: 25 controls and 25 patients with FMR. LA volume, LV volumes, LV sphericity index, and LA–LV axis angle were assessed and indexed to body surface area.

Results: LA volume index was significantly higher in the FMR group (81 ± 19.8 ml/m^2) than in controls (41 ± 9.9 ml/m^2; $p < 0.0001$). The LA–LV axis angle was more obtuse in FMR patients (157.5 ± 6.4° vs. 151 ± 6.4°; $p < 0.01$). LV remodeling and reduced LVEF were also observed in the FMR cohort.

Conclusion: MSCT provides comprehensive assessment of LA and LV geometry in FMR and supports anatomical evaluation for TMVR planning.

Keywords: Mitral valve, Functional mitral regurgitation, Left atrium, Computed tomography, Transcatheter mitral valve replacement.

Introduction

Mitral valve disease remains a major cause of cardiovascular morbidity (1). The mitral valve apparatus consists of the annulus, leaflets, subvalvular structures, left atrium (LA), and left ventricle (LV) (2). Dysfunction of any component may impair leaflet coaptation and lead to mitral regurgitation (MR) (3). MR may be ischemic or nonischemic, and primary or secondary (functional), and may present acutely or chronically (4, 5).

Acute MR results in abrupt elevation of LA and pulmonary venous pressures due to the absence of compensatory remodeling (6, 7). Chronic MR allows progressive enlargement of the LA and LV, contributing to annular dilation and heart failure (6, 8, 9).

Many patients with MR are unsuitable for surgery, making transcatheter mitral valve replacement (TMVR) an important alternative (9). Despite the development of several devices, widespread clinical adoption has been restricted by anatomical limitations and frequent need for transapical access. TMVR, however, shows significant promise for high-risk patients.

Successful TMVR requires detailed anatomical assessment, including evaluation of the annulus, subvalvular apparatus, and LV geometry (10, 11). LA is a key component of the mitral complex and plays a central role in pulmonary pressure regulation (7). New TMVR devices with atrial fixation further highlight the importance of LA anatomy (12).

This study aimed to evaluate LA volume, LV geometry, and LA–LV axis orientation using MSCT in patients with FMR, with the broader goal of advancing pre-procedural planning for TMVR therapies.

Determining the optimal treatment for MR is crucial. Many patients are unsuitable for surgery due to high operative risks, making transcatheter mitral valve replacement (TMVR) an appealing alternative (13, 14).

This study aims to assess the left atrium using CT imaging as part of the mitral valve complex in patients with functional mitral regurgitation (FMR), with the broader goal of advancing pre-procedural planning for TMVR therapies.

Methods

This retrospective study was approved by the local ethics committee (EA4/095/18). 50 cardiac CT examinations were analyzed retrospectively: 25 healthy controls (control group) and 25 patients with functional mitral regurgitation (FMR group) (≥ grade II confirmed by prior echocardiography). All scans were performed using retrospective ECG gating with dose modulation techniques. Images were reconstructed from 0% to 90% of the cardiac cycle in 10% increments. Data were analyzed using syngo.via (Siemens AG). Post-processing involved reviewing static and cine images in multiple cardiac planes. LV volumetric analysis was conducted using dedicated CT software (syngo.via Circulation, Siemens AG) with a three-dimensional threshold-based segmentation algorithm. End-diastolic and end-systolic phases were automatically identified and manually corrected if necessary.

LA volume was calculated using the biplane area–length method. The LA cavity was manually traced in end-systolic two-chamber (A1) and four-chamber (A2) views, and LA length (L) was measured (Figure 1).

The final LA volume was computed using the established biplane area–length formula (15):

$$LA\ volume = \frac{0.85 \times A1 \times A2}{L}$$

Left ventricular end-diastolic (LVEDV) and end-systolic (LVESV) volumes were derived from the volumetric analysis, and the left ventricular ejection fraction (LVEF) was calculated as the difference between LVEDV and LVESV, divided by LVEDV.

Left ventricular endocardial contours were delineated semiautomatically, considering papillary muscles as part of the LV cavity (Figure 2).

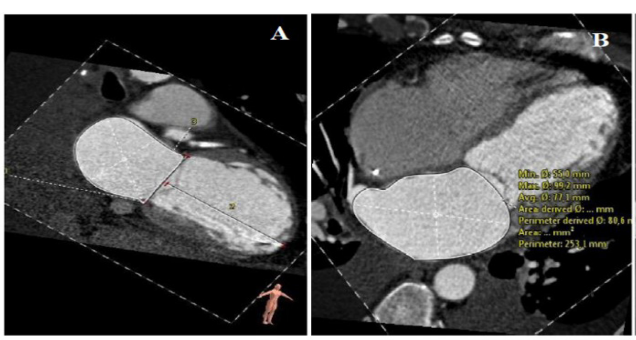

Figure 1: Manual tracing of the left atrial cavity area in endsystolic 2chamber (A) and 4chamber (B) reconstructed views

The left ventricular sphericity index (SI) in both systole and diastole was determined using end-diastolic and end-systolic LV volumes together with the LV long axis length measured in the two-chamber view. The SI was calculated using the established empirical formula (16).

$$SI = \frac{LV\ volume}{\left(LV\ long\ axis\right)^3 \times \frac{\pi}{6}}$$

The angle between the long axes of the left atrium and left ventricle was assessed in systole using three-chamber reconstructions by manually placing an angle measurement tool (Figure 3).

All quantitative parameters were indexed to body surface area (BSA).

Statistical Analysis

Data was analyzed using IBM SPSS Statistics, Version 22 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± SD. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess the normality of continuous data.

For normally distributed variables, comparisons between the control and FMR groups were made using the

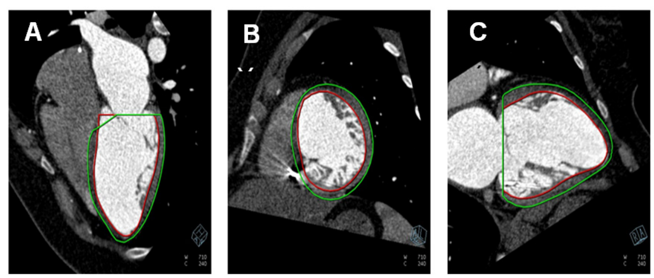

Figure 2: Evaluation of LV endocardial and epicardial borders in reformatted fourchamber (A), shortaxis (B), and twochamber (C) views

Figure 3: Reformatted 3chamber view illustrating the placement of the angle tool used to quantify the LA–LV axis.

independent samples t-test. For variables not following a normal distribution, the Wilcoxon rank-sum test was used. A pvalue <0.05 was considered significant.

Results

The analysis included 50 participants. The control group consisted of 25 subjects (19 men, 6 women; mean age 47 ± 11 years, range 24–70 years) who underwent coronary CT angiography for suspected coronary artery disease, which was subsequently ruled out. None had a history of cardiac disease, prior cardiac surgery, or interventional procedures. Left ventricular (LV) volumes, LV sphericity indices, and wall motion were all within normal limits. The mean BMI in this group was 26 ± 2.8 kg/m², and the mean LVEF was 72 ± 6%. The FMR group included 25 patients (18 men, 7 women; mean age 63 ± 7 years, range 50–75 years) with a mean BMI of 26 ± 3.5 kg/m² and a markedly reduced LVEF of 31 ± 9%.

Left atrial (LA) volume index was significantly elevated in patients with FMR compared to healthy controls (81 ± 19.8 ml/m² vs. 41 ± 9.9 ml/m²; $p < 0.0001$).

Table 1: Baseline characteristics of the study population

Variable	*Group 1 (n = 25)*	*Group (n = 25)*	*p-value*
Age, years	47 ± 11	63 ± 7	<0.0001
Gender, M/F	19/6	18/7	n/a
BMI, kg/m²	26 ± 2.8	26 ± 3.5	1

BMI - body mass index. M -male, F-female.

Full demographic and volumetric data are presented in Tables 1 and 2.

LV remodeling was evident in the FMR group, with increased sphericity indices and altered LV geometry.

The orientation between the left atrial and left ventricular long axes also differed significantly between groups. The LA–LV axis angle was more obtuse in the FMR cohort compared with controls (157.5 ± 6.4° vs. 151 ± 6.4°; $p < 0.01$). The observed ranges were 146–168° in the FMR group and 138–164° in the control group (Figure 4).

Discussion

This study demonstrates significant LA enlargement and LV remodeling in patients with FMR. The elevated LA volume index aligns with previous findings (8, 17) and reflects the chronic volume overload characteristic of FMR. CTderived LA metrics may therefore contribute to risk assessment and TMVR planning.

LV sphericity indices and LA–LV axis orientation were also altered in FMR, consistent with progressive LV remodeling described in earlier studies (3, 16). These geometric changes may influence device selection and procedural strategy for TMVR.

MSCT provides high spatial resolution and comprehensive anatomical assessment, enabling evaluation of the mitral apparatus, LV geometry, and extracardiac structures in a single examination (18-20). CT also supports prediction of LVOT obstruction and identification of optimal access routes

Table 2: Volumetric parameters of the study population.

Variable	*Group 1 (n=25)*	*Group (n=25)*	*p-value*
LA volume, end systole, ml	79.9 ± 18.9	157.2 ± 46.6	<0.0001
LA volume index, ml/qm	41 ± 9.9	81 ± 19.8	<0.0001
LVEDD, mm	55.2 ± 5.6	81 ± 11.2	<0.0001
LVEDV, ml	138.6 ± 25.6	313.7 ± 100.8	<0.0001
LVESV, ml	40.5 ± 15.2	222.4 ± 92.4	<0.0001
SV, ml	97.8 ± 16. 7	91.3 ± 22	0.2627
LVEF, %	71.5 ± 5.8	31.2 ± 9.3	<0.0001
LVEDVI, ml/qm	70.5 ± 10.9	161.8 ± 47.5	<0.0001
LVESVI, ml/qm	20.2 ± 5.9	108 ± 48.5	<0.0001
SVI, ml/qm	50.4 ± 7.9	47.5 ± 10.3	0.2874
CO, l/min	7.2 ± 1.5	6.7 ± 2	0.3401
CI, l/min/qm	3.7 ± 0.8	3.5 ± 0.9	0.4292
LV-sphericity index, systole	0.2 ± 0.08	0.4 ± 0.1	<0.0001
LV-sphericity index, diastole	0.3 ± 0.07	0.5 ± 0.1	<0.0001

LA = left atrium, LVEDD = end-diastolic diameter of LV; LVEDV / LVESV = left ventricular end-diastolic / systolic volume; SV = stroke volume; LVEF = LV ejection fraction; LVEDVI, LVESVI = left ventricular end-diastolic / systolic volume index; SVI = stroke volume index; CO = cardiac output; CI = cardiac index; Values are expressed as the mean ± SD.

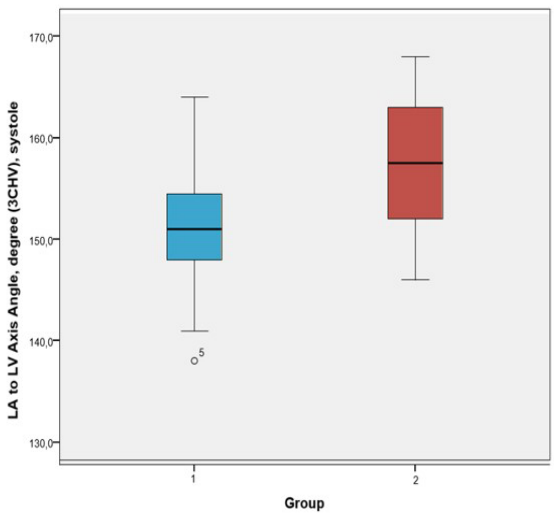

Figure 4: Intergroup comparison of the systolic LA–LV axis angle measured in the 3chamber reformatted view between healthy controls (Group 1) and patients with functional mitral regurgitation (Group 2)

(21). Although CT involves radiation and contrast exposure, modern protocols allow substantial dose reduction (22). Temporal resolution remains a limitation, particularly in arrhythmias, but dualsource systems provide adequate performance for most patients (23).

Limitations

This study is limited by its retrospective design and small sample size. The study focused primarily on establishing a pre-procedural CT post-processing workflow and clinical outcomes after TMVR were not evaluated.

Conclusion

CT has become an essential component of the TMVR workflow. It provides comprehensive anatomical and functional information necessary for patient selection, procedural planning, and risk assessment. With its ability to visualize the entire heart and thorax in multiple planes, CT enables detailed assessment of LA volume, LV geometry, and LA–LV axis orientation in patients with FMR. These parameters are relevant for TMVR planning and may support patient selection and procedural risk assessment. CT should be considered an essential imaging modality in the TMVR workflow.

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