American Journal of Medicine and Medical Sciences 2025, 15(8): 2621-2625
DOI: 10.5923/j.ajmms.20251508.43

Comparative Evaluation of Structural and Geometrical Parameters of the Heart in Patients with Mitral Valve Stenosis after Balloon Mitral Valvuloplasty Depending on the Type of Imaging

Zufarov M. M., Khamdamov S. K., Im V. M.

Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov, Uzbekistan

Abstract **Introduction.** At present, echocardiography is an effective non-invasive method for assessing the degree of heart chamber remodeling and prognosis during balloon mitral valvuloplasty (BMV). **Objective.** The aim of our study is to analyze the structural and geometrical parameters of the heart in a comparative aspect with angiocardiographic examination during BMV in patients with mitral valve stenosis. **Materials and Methods.** The results of the examination of 87 patients with mitral stenosis are presented. The patients were divided into two groups: Group I consisted of 39 patients who underwent BMV under fluoroscopic guidance using the Inoue technique under local anesthesia; Group II included 48 patients who underwent BMV under echocardiographic guidance, with fluoroscopic control minimized and used mainly in technically difficult situations. **Results.** After BMV, both groups showed positive dynamics in the restoration of atrial geometry, which significantly lagged behind the recovery of the ventricles. In the postoperative period, the ventricles returned to normal values, whereas atrial parameters, despite positive remodeling dynamics, remained significantly above the normal range. As a result, the heart chamber ratio improved, but the index of chamber proportion did not return to normal. The remodeling index increased significantly, but its values remained reliably below the lower limit of normal. **Conclusion.** The above allows us to conclude that echocardiographic guidance during BMV in patients with mitral valve stenosis is a promising technique.

Keywords Echocardiography, Mitral stenosis, Balloon mitral valvuloplasty, Cardiac chamber remodeling, Angiography

1. Introduction

Structural and geometrical changes in the heart chambers include processes of hypertrophy and dilation, leading to impaired systolic and diastolic function. Pathological alterations in the structure and geometry of the heart chambers, referred to as “remodeling” of the heart in response to overload or loss of viable myocardium, often precede the clinical manifestation of heart failure. These changes can independently exacerbate cardiac dysfunction and negatively affect the quality of life and prognosis in diseases of the mitral valve of rheumatic origin.

Modern non-invasive diagnostic methods make it possible to assess morphological, structural-geometrical, and hemodynamic parameters of cardiac function with high reliability. Among these modern methods, echocardiography stands out, providing high-quality imaging of the heart chambers and intracardiac hemodynamics [1-4].

Currently, echocardiography (EchoCG) is the most commonly used and widely accessible method for diagnosing valvular heart disease. It is more cost-effective than magnetic resonance imaging and offers better assessment of the valvular apparatus. An important advantage is its non-invasive nature, in contrast to cardiac catheterization [4-7]. Among effective minimally invasive methods for treating mitral stenosis (MS) is balloon mitral valvuloplasty (BMV) using the Inoue technique [6,8-12]. This procedure is performed with the aid of catheters and specialized intravascular tools introduced via the femoral vessels, far from the target site. Visualization is achieved via fluoroscopy, which displays the instruments over the outline of the heart but does not provide a precise spatial representation of catheter position relative to cardiac chambers. Therefore, intervention effectiveness is assessed indirectly—mainly by measuring pressure in the heart chambers. During fluoroscopic imaging, the interatrial septum (IAS), particularly the region of the fossa ovalis, is not clearly visible. Anatomical changes caused by mitral stenosis and other concomitant conditions (e.g., other valvular defects, atrial fibrillation) further complicate orientation during the procedure. Echocardiography allows for precise identification of catheter position, instrument relationships, guidance during transseptal puncture, and

Received: Jul. 16, 2025; Accepted: Aug. 3, 2025; Published: Aug. 7, 2025
Published online at http://journal.sapub.org/ajmms

placement of the balloon catheter and its dilation [9,11,13,14].

The aim of our study is to assess the structural and geometrical parameters of the heart in a comparative context using echocardiographic versus angiocardiographic guidance during BMV in patients with mitral valve stenosis.

2. Materials and Methods

This study presents the results of an examination of 87 patients with rheumatic mitral stenosis (MS) who underwent balloon mitral valvuloplasty (BMV) using the Inoue technique at the Department of Interventional Cardiology, Arrhythmology, and Endovascular Surgery of the Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov.

Patients were divided into two groups:

- **Group I** included 39 patients who underwent BMV under fluoroscopic guidance using the Inoue technique under local anesthesia.
- **Group II** included 48 patients who underwent BMV under echocardiographic guidance, with fluoroscopy minimized and used only in cases of technical difficulty.

The initial stages of BMV involved catheterization of the right heart chambers and transseptal puncture of the interatrial septum. Right heart catheterization was performed for diagnostic purposes and did not differ from standard intracardiac catheterization techniques. However, the transseptal puncture had to be performed precisely at the fossa ovalis, as it served as the access point for surgical catheter intervention. Transseptal puncture was performed using a J. Endrys (USA) transseptal needle inserted into the catheter and advanced to the opening of the superior vena cava. It was then directed into the right atrium, with the proximal control flag of the needle rotated dorsally at 45° relative to the sagittal plane of the patient. This maneuver oriented the needle tip toward the left atrium. Continuing advancement of the catheter and needle allowed engagement with the fossa ovalis after sliding off the muscular ridge defining its superior edge. A quick, forward piercing motion enabled puncture of the interatrial septum, followed by a "give" into the left atrial cavity. The catheter was then advanced into a stable position within the left atrium.

An ultrasound system (GE VIVID S70) was positioned to the patient's left, at the head of the operating table. The ultrasound specialist stood next to the machine and manipulated the probe with the left hand, allowing repeated imaging without interfering with the surgeon, who stood on the patient's right.

Prior to intracardiac intervention, baseline intracardiac hemodynamic parameters were established. Determining the catheter position during transseptal puncture was a mandatory step. The surgeon and imaging specialist worked simultaneously. Standard parasternal imaging in the second to fourth intercostal spaces was not feasible during fluoroscopy, as the probe obstructed the field of view. Therefore, echocardiographic imaging was performed from the apical window in a four-chamber view. It was crucial to help the surgeon guide the needle tip to the fossa ovalis, adjusting maneuvers based on ultrasound imaging.

Once the transseptal puncture was completed, the catheter position was confirmed. If the catheter could not be visualized from the apical window, the procedure was temporarily paused and imaging was switched to the standard parasternal position. Immediately afterward, the pericardial cavity was examined to exclude hemopericardium. If fluid was detected, serial assessments were performed every 3–5 minutes to monitor the rate of blood accumulation and signs of cardiac tamponade. Parameters such as chamber dimensions, interventricular septal motion, respiratory variations in atrioventricular flow, and ventricular wall motion were analyzed. Accumulation of ≥200 mL of blood or evidence of tamponade necessitated emergency percutaneous drainage. If no complications occurred, pericardial control was repeated after 15 minutes [9,13,14].

In cases of difficulty advancing the catheter through the narrowed mitral orifice (MO), the EchoCG specialist assisted the surgeon by monitoring catheter position in real time. These assessments were also performed from the apical view to avoid interrupting the procedure [6,8,13].

Mitral orifice dilation was performed gradually by stepwise balloon inflation. After each series of balloon inflations, the balloon was retracted into the left atrium, and transmitral blood flow was evaluated using Doppler echocardiography. When the peak transmitral pressure gradient decreased to 5–9 mmHg, the procedure was concluded. The mitral orifice area was calculated based on the pressure half-time using an apical view aligned with the transmitral flow. From this same view, the dynamics of mitral regurgitation were assessed. The emergence or worsening of regurgitation to grade 2 was considered an indication to stop the procedure. Final mitral orifice area measurements were performed in the short-axis view at the end of the procedure.

The effectiveness of mitral valve dilation was confirmed by intraoperative echocardiographic findings: reduction of the transmitral pressure gradient, increase in the mitral orifice area, and absence of worsening mitral regurgitation [6,13,14].

Throughout the procedure, both standard and specific echocardiographic parameters were analyzed to assess structural and geometrical remodeling using established remodeling index calculations.

Statistical analysis was conducted using Microsoft Excel, calculating arithmetic means and standard errors. Statistical significance was determined using Student's t-test, with a significance level of $p<0.05$ considered statistically meaningful. Differences were interpreted as significant at $p<0.05$ (95% confidence), $p<0.01$ (99% confidence), and $p<0.001$ (99.9% confidence).

3. Results and Discussion

To evaluate the outcomes of structural and geometrical heart parameters, patients were divided into two groups:

- **Group I:** 39 patients who underwent BMV under fluoroscopic guidance.
- **Group II:** 48 patients who underwent BMV under echocardiographic guidance, with minimal use of fluoroscopy.

A **control group** of 37 healthy individuals was used for comparison.

In addition to structural and geometrical parameters, we also performed a comparative analysis of **radiation exposure** received during BMV.

The patient groups were comparable in terms of disease severity and duration.

As shown in the presented data (Table 1), the left atrial volume (cm) before surgery was 6.2±1.16 in Group I and 5.85±0.18 in Group II. After surgery, the values decreased to 5.3±0.85 in Group I and 5.62±0.17 in Group II. In the control group, the left atrial volume was 8.5±1.6 (P<0.05). The left atrial area in Group I was 47.9±9.47, and in Group II, it was 46.8±8.52. After surgery, the values were 24.8±4.2 in Group I and 30.52±6.54 in Group II, compared to 8.5±1.6 in the control group (P<0.01). The left atrial pressure (mmHg) in Groups I and II before surgery was 1.28±0.15 and 1.27±0.18, respectively, while after surgery the values were 1.17±0.07 in Group I and 1.32±0.11 in Group II. The values of the indexed left atrial pressure (cm/m²) were 90.61±13.81 in Group I and 88.9±10.52 in Group II. After surgery, these values decreased to 57.62±11.23 in Group I and 62.85±9.85 in Group II, which were significantly higher (P<0.001 compared to the control group). The fraction of left atrial volume change (%) before surgery was 22.0±4.38 in Group I and 25.69±3.23 in Group II; after surgery, these values changed to 19.48±4.52 in Group I and 16.3±4.89 in Group II.

Comparative analysis of the structural and geometric parameters of the left atrium before surgery did not reveal any significant differences between the groups based on the conducted studies (Table 2).

Table 1. Structural and Geometrical Parameters of the Left Atrium Before and After Surgery

Parameters	Control Group	Group I		Group II	
		Before	After	Before	After
LA diameter (cm)	4.1±0.1	6.2±1.16**	5.3±0.85	5.85±0.18**	5.62±0.17*##
LA area (cm²)	8.5±1.6	47.9±9.47***	24.8±4.2***	46.8±8.52***	30.52±6.54***#
LA sphericity index	1.09±0.08	1.28±0.15**	1.17±0.07*	1.27±0.18**	1.32±0.17***#
Indexed LA volume (cm³/m²)	30.8±8.6	90.61±13.81***	57.62±11.23**	88.9±10.52***	62.85±9.85**#
LA emptying fraction (%)	39.7±4.5	22.0±4.38*	19.48±4.52**	25.69±3.23*	16.3±4.89***#

Notes: *- p<0.05, **- p<0.01, ***- p<0.001 vs control group; - p<0.05, ## - p<0.01 between groups after surgery.*

Table 2. Structural and Geometrical Parameters of the Left Ventricle Before and After Surgery

Parameters	Control	Group I		Group II	
		Before	After	Before	After
LV ESV index (mL)	25.46±8.51	30.85±8.78*	41.25±2.56***	28.87±6.52*^	31.25±5.69*##
LV EDV index (mL)	63.46±12.25	58.72±8.54*	61.23±11.24	56.8±5.68*	59.65±4.35*#
LVEF (%)	59.12±6.35	49.4±1.85***	56.23±5.69*	51.32±1.68**	52.36±1.89**#
LV remodeling index	4.12±0.38	0.59±0.18***	0.89±0.35**	0.60±0.17***	0.75±0.23***##

Note: * - data reliability compared to the control group (*-P<0.05; ** - P<0.01; *** - P<0.001); ^ - data reliability between groups before surgery (^ - P<0.05); # - data reliability between groups after surgery (# - P<0.05; ## - P<0.01).

Table 3. Structural and Geometrical Parameters of the Right Atrium Before and After Surgery

Parameters	Control	Group I		Group II	
		Before	After	Before	After
RA area (cm²)	11.12±1.55	27.23±2.16**	20.78±1.65**	26.35±2.18***	23.12±2.17**#
RA sphericity index	1.11±0.09	1.42±0.15**	1.17±0.12*	1.37±0.18**	1.28±0.19*#
Indexed RA volume (cm³/m²)	42.87±12.24	63.31±14.71**	46.58±10.33*	62.9±8.48**	52.72±6.35**#
RA emptying fraction (%)	37.41±6.53	28.15±3.41**	22.34±3.42**	29.34±2.85*	23.32±3.56**#

Note: * - data reliability compared to the control group (*-P<0.05; ** - P<0.01; *** - P<0.001); # - data reliability between groups after surgery (# - P<0.05).

The structural and geometric parameters (Table 2) of the left ventricle showed that the end-diastolic volume (EDV) (ml) before surgery was 30.85±8.78 in Group I and 28.86±6.52 in Group II. After surgery, these values increased to 41.25±2.56 in Group I and 31.25±5.69 in Group II ($P<0.05$, $P<0.01$). The baseline values of end-systolic volume (ESV) (ml) in Groups I and II were similar, at 58.72±8.54 and 56.8±5.68, respectively, and increased to 61.23±11.24 and 59.65±4.35 ($P<0.05$). The left ventricular ejection fraction (LVEF) (%) before surgery was 49.4±1.85 in Group I and 51.32±1.68 in Group II. These parameters increased to 56.23±5.69 and 52.36±1.89 after surgery, but did not reach the values of the control group, which were 59.12±6.35. The left ventricular remodeling index (LVI) was 0.52±0.18 in Group I and 0.61±0.17 in Group II before surgery, and after surgery, it was 0.89±0.35 and 0.75±0.23, respectively, which did not reach the values of the control group.

A similar trend was observed when evaluating the structural and geometric parameters of the right atrium (Table 3).

The area of the right atrium (cm^2) before surgery was 27.23±2.16 in Group I and 26.35±2.18 in Group II, both exceeding the control group value of 11.12±1.55. After surgery, it decreased to 20.78±1.65 in Group I and 23.12±2.17 in Group II but remained twice the normal value.

The dynamics of the sphericity index (SI) showed some improvement in the shape of the right atrium compared to baseline values. The positive dynamics of SI decreased from 1.42±0.15 to 1.17±0.12 in Group I and from 1.37±0.18 to 1.28±0.19 in Group II. As a result, the indexed right atrial area (cm^2/m^2) decreased from 63.51±14.71 to 46.58±10.33 in Group I and from 62.9±8.48 to 52.72±6.35 in Group II.

The fraction of right atrial volume change (FRAVC) decreased from 26.15±3.41 to 22.34±3.42 in Group I and from 29.34±2.85 to 23.32±3.56 in Group II.

Analysis of the structural and geometric parameters of the right ventricle (Table 4) showed that the end-systolic volume (ESV) in Group I was higher before and after surgery compared to the control group, which had a value of 18.35± 7.4, while Group I had values of 21.22±2.38 and 19.87±2.52, respectively, and Group II had 19.87±2.52. After surgery, ESV decreased to 20.25±1.48 in Group I and 20.16±3.55 in Group II. The end-diastolic volume (EDV) was 38.12±5.48 in Group I and 39.24±6.52 in Group II before surgery, and it increased to 41.26±6.23 and 40.28±3.35, respectively, after surgery ($P<0.05$). The left ventricular ejection fraction (LVEF) was 45.7±1.34 in Group I and 46.12±1.35 in Group II before surgery, and after surgery, it increased to 51.23± 4.23 in Group I and 48.52±2.36 in Group II. As a result, the remodeling index of the right ventricle was 1.02±0.14 and 1.01±0.17 before surgery, and 1.34±0.15 and 1.12±0.13 in Groups I and II, respectively, after surgery.

After performing balloon mitral valvuloplasty (BMV), both groups showed positive dynamics in the restoration of atrial geometry, although it lagged behind the recovery of the ventricles. Postoperatively, the ventricles returned to normal values, while the parameters of the atria, despite positive dynamics in remodeling, remained significantly above normal. As a result, the ratio of heart chamber sizes improved, but the restoration of the index of heart chamber ratio to normal values did not occur. The indexed right atrial volume significantly increased, but its values remained significantly below the lower limit of the normal range.

The above allows us to conclude that the use of echocardiographic methods in the performance of BMV for patients with mitral valve stenosis holds promise.

During the study, a comparative assessment of the radiological load on patients in both groups during BMV was conducted (Table 4).

Table 4. Radiation Dose During BMV Depending on Imaging Technique

Patient Group	Mean Radiation Dose (mGy)
Group I	32 ± 6.4 mGy
Group II	17 ± 5.1 mGy

General Findings

- Restoration of ventricular geometry occurred faster and more completely than atrial remodeling.
- Although the chamber ratios improved, the chamber proportion index did not normalize.
- The remodeling index (RI) increased but remained below normal limits.
- Use of echocardiographic control in BMV procedures significantly reduced radiation exposure to patients.

4. Conclusions

1. Structural and geometrical parameters of the heart, as assessed by echocardiographic examination, reflect the severity of the pathological process in mitral valve stenosis.
2. The remodeling outcomes observed using traditional angiographic and echocardiographic assessments were found to be comparable.
3. The degree of geometric recovery of the heart depends on its baseline structural state prior to the intervention, which in turn influences the improvement of intracardiac hemodynamics in the postoperative period.
4. A comparative analysis of the two patient groups demonstrated that performing BMV under echocardiographic guidance significantly reduces patient radiation exposure.

REFERENCES

[1] Bokeria L.A., Kosareva T.I., Makarenko V.N. Types of pathological remodeling of the heart in patients with acquired mitral valve defects // Clinical Physiology of Circulation. 2011. P. 31–36. (In Russian)

[2] Bokeria L.A., Kosareva T.I., Makarenko V.N. The index of the remodeling of the volumes: a new method of estimating heart geometry in acquired mitral valve disease. *Bakoulev Journal for Cardiovascular Diseases*. 2018; 19(4): 512–521.

DOI: 10.24022/1810-0694-2018-19-4-512-521 (In Russian)

[3] Gheorghe L.L., Mobasseri S., Agricola E., et al. Imaging for Native Mitral Valve Surgical and Transcatheter Interventions. *JACC Cardiovasc Imaging*. 2021; 14(1): 112–127. doi:10.1016/j.jcmg.2020.11.021.

[4] Lang R.M., Badano L.P., Mor-Avi V., et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *European Heart Journal - Cardiovascular Imaging*. 2015; 16(3): 233–271. https://doi.org/10.1093/ehjci/jev014.

[5] Tereshina O.V., Dmitriev O.V. Novel and conventional echocardiographic parameters for choosing management tactics in patients with degenerative mitral valve disease. *Russian Journal of Cardiology*. 2022; 27(8): 5138. doi:10.15829/1560-4071-2022-5138 (In Russian).

[6] Abukar M.A., Erik J.S., Packer T.R.O., Vasiliki K., Stig Urheim, Sahrai Saeed. Echocardiography Assessment of Rheumatic Heart Disease: Implications for Percutaneous Balloon Mitral Valvuloplasty. *Current Problems in Cardiology*. 2023; 48: 102021.

[7] ESC/EACTS Scientific Document Group. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. *Russian Journal of Cardiology*. 2022; 27(7): 5160. doi:10.15829/1560-4071-2022-5160. (In Russian)

[8] Shilenko P.A., Tsoi M.D., Patlai I.I., Kotsienko A.S., Pavlov A.A., Sigareva A.A., Kotov S.N., Shneider Yu.A. Mitral valve balloon valvuloplasty in acute coronary syndrome. *Russian Journal of Cardiology and Cardiovascular Surgery*. 2019; 12(1): 66–69.https://doi.org/10.17116/kardio20191201166 (In Russian)

[9] Badheka A.O., Shah N., Ghatak A., et al. Balloon Mitral Valvuloplasty in the United States: a 13-Year Perspective. *The American Journal of Medicine*. 2014. https://doi.org/10.1016/j.amjmed.2014.05.015.

[10] Mahfouz R.A., Elawady W., Goda M., Moustafa T. Redo Scoring for Prediction of Success of Redo-Percutaneous Balloon Mitral Valvuloplasty in Patients with Mitral Restenosis. *J Heart Valve Dis*. 2017; 26(5): 537–546.

[11] Otto C.M., Nishimura R.A., Bonow R.O., et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2020; 143(5): e72–e227. doi:10.1161/CIR.0000000000000923.

[12] Reyes V.P., Raju B.S., Wynne J., et al. Percutaneous balloon valvuloplasty compared with open surgical commissurotomy for mitral stenosis. *New England Journal of Medicine*. 1994; 331: 961–967.

[13] Zufarov M.M., Im V.M., Khamdamov S.K. Modern aspects of balloon mitral valvuloplasty of mitral valve stenosis of rheumatic etiology. Methodical recommendations. Tashkent, 2024. 31 p. (In Russian)

[14] Tarasov R.S., Protopopov A.V., Bokhan N.S., et al. Endovascular valvuloplasty in a patient with critical mitral stenosis and massive left atrial thrombosis. *Complex Issues of Cardiovascular Diseases*. 2018; 7(3): 134–139. DOI: 10.17802/2306-1278-2018-7-3-134-139 (In Russian).