Med. J. Cairo Univ., Vol. 90, No. 6, September: 1875-1880, 2022
www.medicaljournalofcairouniversity.net

Impact of the Type of Annuloplasty Prosthesis on Hemodynamic Status after Mitral Valve Repair in Egyptian Patients

YOSRY M. THAKEB, M.D.* and KHALED N. LEON, M.D., FSCAI**

The Departments of Cardiac Surgery and Cardiology**, National Heart Institute, Egypt*

Abstract

Background: There is no consensus regarding the selection criteria for the annuloplasty rings, although some publications have addressed this issue. Usually, complete rigid rings are preferred to treat functional MR, under-sizing the prosthesis to overcome leaflet tethering, while flexible or semirigid rings, either complete or partial, are more often used to treat degenerative.

Aim of Study: Evaluation of the mitral valve competency and gradient after mitral valve repair comparing rigid annuloplasty ring vs flat physio II ring.

Patients and Methods: Between October 2018 and October 2021, thirty-three (33) patients underwent mitral valve repair by flat physio ring and saddle shaped annuloplasty ring for degenerative and ischemic mitral valve disease respectively. Correlation between postoperative mitral hemodynamics was evaluated, the ischemic patients were fully revascularized.

Results: Only (2) patients had a significant MR from the degenerative by using flat physio II ring while 3 patients developed a significant increase in mean Diastolic Gradient on the mitral valve.

Conclusion: Selection of mitral valve ring should be differ according to the type of the pathology.

Key Words: *Mitral valve repair – Degenerative disease – Ischemic mitral valve disease diastolic gradient – Mitral regurgitation – Functional mitral stenosis.*

Introduction

THE standard procedure of Mitral regurgitation is the mitral valve repair (MVr) for both functional and degenerative types. Either recurrence of MR or functional mitral stenosis (FMS) according to the reduction of the mitral effective orifice area (EOA), and elevation of the trans-mitral pressure gradient (TMPG), is the main concern.

There is a high incidence of FMS with a mitral valve area less than 1.5cm^2 or a mean TMPG more than 5mmHg after surgical mitral annuloplasty for both ischemic or degenerative MR **[1-3]**. this may lead to development of NYHA and/or atrial fibrillation **[4-6]**.

The type of annuloplasty either saddle shape rigid ring or complete semirigid flat ring were reported as predictors of FMS, following valve repair. Compared to a physio ring, the postoperative TMPG was greater in patients with a saddle shaped ring prosthesis **[5]**.

On the other hand, a larger annuloplasty prosthesis is expected to reduce TMPG. Based on these backgrounds, the aim of this study is to evaluate mitral valve hemodynamics and competency of the repair.

There is no consensus regarding the selection criteria for the annuloplasty rings, although some publications have addressed this issue **[7]**. Usually, complete rigid rings are preferred to treat functional MR, under-sizing the prosthesis to overcome leaflet tethering, while flexible or semirigid rings, either complete or partial, are more often used to treat degenerative MR. Fig. (2).

Patients and Methods

It is a retrospective comparative study for evaluation of mitral valve hemodynamic status by trans-thoracic echocardiogram immediate post operative (2 weeks). Thirty-four (34) patients underwent mitral valve repair with annuloplasty prosthesis at the National Heart Institute of Egypt, between October 2018 and October 2021.

After excluding one (1) patient with significant mitral regurgitation ≥ moderate underwent mitral valve replacement, the remaining thirty-three (33) patients were enrolled.

Correspondence to: Dr. Yosry M. Thakeb, The Department of Cardiac Surgery, National Heart Institute, Egypt

Fifteen (15) patients had degenerative pathology Fig. (1) had the flat ring annuloplasty, the remaining had functional mitral regurgitation (FMR) due to ischemic pathology, the saddle shape ring was implanted concomitant with CABG.

The goal was to evaluate the correlation between type of annuloplasty prosthesis and mitral valve hemodynamics. Consent for using patients' data was obtained from all patients.

In this cohort, seven (7) of patients underwent minimally invasive mitral repair via a right mini thoracotomy. The main technique of mitral repair included resection in four (4) patients, artificial chorda in three (3) patients, folding plasty in five (5) patients, and augmentation in one (1) patient. The prolapse lesion included four (4) anterior, seven (7) posterior, and seven (7) bi-leaflet.

Transthoracic echocardiography was done to all patients with estimation of left ventricular ejection fraction (LVEF), end-diastolic and systolic dimensions, and tricuspid regurgitation pressure gradient (TRPG) were obtained from the official echocardiographic report **[8]**.

The EOA, which was calculated with the continuity equation, the TMPG, the Doppler velocity index (DVI = VTIMV/VTILVOT), and the peak flow velocity were measured **[9-12]**.

Results

We enrolled thirty-three (33) patients in our study, all patients had sever MR candidate for MVr according to the ESC/EACTS Guidelines for the management of valvular heart disease 2021.

Implanted annuloplasty prostheses was the physio ring for fifteen (15) patients with degenerative mitral valve disease MVD and a saddle shape for eighteen (18) ischemic patients. Fig. (1).

Fig. (1): Showing competency of the mitral valve ring after implantation.

The overall mean patient age is higher with degenerative valve disease 54.68±4.5 (44-71) years versus 50.11±4.66 (38-66) years with ischemia 14 males 19 females the full demographic data is shown in Table (1).

Table (1): Demographic DATA number of patient, age, sex and BMI.

	All	Saddle	Physio II	*p*-value
No	33	18	15	
Age		50.11±4.66 (38-66)	54.68±4.5 (44-71)	0.01
Smoking	17	6	11	0.02
Sex:				
Male	14	9	5	0.33
Females	19	9	10	
BMI:				
<18	5	1	4	0.31
18.5-24.9	8	4	4	
25-29.9	10	6	4	
>30	10	7	3	
Previous cardiac conditions:				
Yes	9	9	0	0.001
No	24	9	15	
Previous cardiac conditions:				
AF	1	1		
MI	3	3		
CHF	2	2		
Pacemaker	0	0		
Previous PCI	3	3		

Four (4) of the ischemic patients had low LVEF only one (1) patient with degenerative valve disease.

The ischemic patients won in the no. of dilated LV EDV also the elevated PA pressure Table (2).

Table (2): Preoperative Echocardiographic finding most of the patients had good EF.

	All	Saddle	Physio II	*p*-value
LVEF:				
<30%	2	2	0	0.35
30-50	3	2	1	
>50%	28	14	14	
LV EDV:				
More than 6.5	5	3	2	1.0
Less than 6.5	28	15	13	
PA pressure		40.22±9.16	34.13±3.23	0.02
PA pressure More than 60	2	2	0	0.49
Degree of MR:				
Mild	3	2	1	1.0
Moderate	2	0	2	
Sever	0	0	0	1.0
AF	2	1	0	0.48
Mean Diastolic Gradient		3.33±1.71	3±0.65	

Techniques:

Table (3): We notice up-sizing the ring in annuloplasty for degenerative valve disease, downsizing in IMR.

	All	Saddle	Physio II	*p*-value
Ring Size (mean ± SD)		30.67±2.28	33.07±1.83	0.002
Ring size:				
26	1	1	0	0.12
28	3	3	0	
30	8	6	2	
32	10	5	5	
34	9	3	6	
36	2	0	2	
Chordal placement	3	1	2	0.58
Resection	4	0	4	0.03
Augmentation	0	0	0	1.0

From Table (3) we can notice that we up-sized the ring in annuloplasty for degenerative valve disease to decrease the incidence systolic anterior motion (SAM) as insertion of a small prosthetic ring may lead to this pathology, we did downsizing in the IHD, only two (2) patients had a significant MR from the degenerative by using flat physio II ring while three (3) patients developed a significant increase in mean Diastolic Gradient on the mitral valve **[13].**

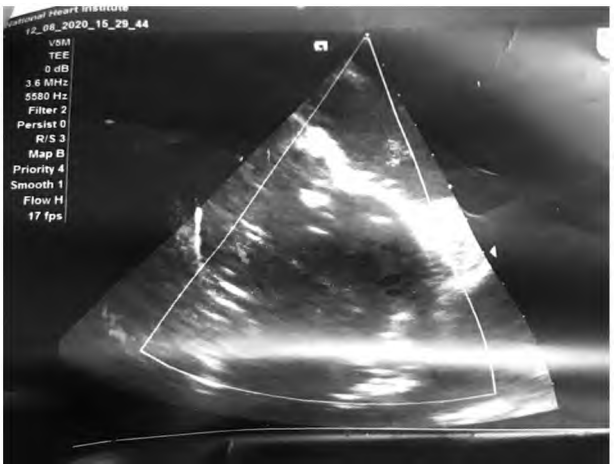

Fig. (2): Intra-operative TEE for evaluation of mitral valve competency after ring implantation.

There is a great postoperative improvement of both LV EDV, PA pressure and LVFF (Table 4).

Table (4): Showing the post-operative echo data with no MR.

	All	Saddle	Physio II	*p*-value
LVEF:				
<30%	5	5	0	0.005
30-50	7	6	1	
>50%	21	7	14	
LV EDV:				
More than 6.5	12	10	2	0.01
Less than 6.5	21	8	13	
PA pressure More than 60	5	5	0	0.05
Degree of MR:				
Mild				
Moderate				
Sever				
AF	1	1	0	1.0

Post operative complications also shown in Table (5).

Table (5): Complication was in the form of PPM insertion, persistent AF and two patients had superficial wound infection.

	All	Saddle	Physio II	*p*-value
Complications	6	2	3	0.64
AF	1	1	0	
MI	0	0	0	
Pacemaker	1	1	0	
Stroke	1	0	1	
Wound	2	0	2	
Hospital stays		4-6 days	5-6 days	

Discussion

Previously to just preserve your repair you had to do mitral annuloplasty remodeling which was introduced by Carpentier **[14],** the optimal shape and flexibility of mitral annuloplasty rings were before controversial **[15].**

In this study, we select the flat ring for degenerative mitral valve disease and saddle-shaped mitral annuloplasty rings in the ischemic one from the concept of different regional force patterns of that suggest that the mitral valve annulus and its attached valvular and sub-valvular structures are applying torque onto the flat annuloplasty ring attempting to conform it into the saddle-shaped configuration in systole.

The saddle-shape of the mitral annulus apparently constitutes a low-force configuration in systole, and accordingly, the saddle-shaped annuloplasty ring provided a low-force condition of the mitral annulus in systole hence our result from the competency of the valve on this group. These observations may have important implications for annuloplasty rings' selections. Saddle-Shaped Mitral Valve Annuloplasty Rings Experience Lower Forces Compared With Flat Rings **[16]**.

The dynamics during cardiac cycle decreasing diastolic LV filling and systolic LV pressure by caval occlusion resulted in a reduction in the restraining forces of the anterior and commissural segments in the flat annuloplasty rings. This indicates that the restraining forces are load-dependent and coupled to myocardial contraction according to the Frank-Starling mechanism. Previous experimental studies have shown that annular shrinkage and shape change is initiated in end-diastole **[22]**.

This may lead to increased stress in the intertrigonal parts and the commissural segment induced by the flat ring may affect natural alignment of the papillary muscles and chords to the mitral leaflets and hereby have negative impact on leaflet coaptation geometry and leaflet stress distribution **[17-26]**.

Also, the selection of flat ring annuloplasty came from the concept of the increased danger of increasing the MPDG and development of SAM which may increase specially in downsizing also there is increasing evidence that identifies the disruption of mitral annular and aortic root dynamics as the primary cause of SAM after MV repair using leaflet resection and rigid rings (independent to leaflet size). This is supported by evidence from a large series of patients **[27]**.

We concluded that greater annuloplasty size had a potential to improve not only mitral hemodynamics, but also pulmonary hypertension obtained by resting echocardiogram; compared to a saddle shape ring, the flat can reduce the mean TMPG and increase the EOA.

In patients with larger annuloplasty prostheses if > (30mm), the type of annuloplasty prosthesis ring did not influence the mitral hemodynamics.

In comparative with Chan, et al., reported a slight elevation of mean TMPG (>3mmHg) which can lead to worse intracardiac hemodynamics **[5]**.

From previous studies we saw significant difference in mitral hemodynamic status among a variety of annuloplasty products, even if their sizes were equivalent. Also, in other studies, a smaller annuloplasty ring was associated with increased TMPG **[28,29]**.

Although EOA is a parameter calculated by reducing the influence of transmittal flow, EOA was correlated with LVSV (EOA = LVSV/MVVTI). Transmittal flow has less influence on the DVI, and the DVI had no significant correlation with size/type of annuloplasty prostheses and LV function. However, there was no significant correlation between the DVI and PASP; therefore, we may see left ventricular diastolic function and left atrial boost function when mitral hemodynamics are evaluated using EOA/TMPG; or the DVI may not be appropriate for the accurate evaluation of mitral hemodynamics. In either case, it is still difficult to detect the influencing factors on mitral hemodynamics after mitral repair using various techniques and products. Stress echocardiogram is a more effective option to obtain detailed information under loading status **[30,31,32]**.

Exercise-induced pulmonary hypertension (EIPH) is a cause of exercise intolerance and exertional dyspnea and worsens clinical outcomes for left ventricular dysfunction and MR **[33-36]**.

Study limitations:

There were several limitations.

First, this study was a retrospective observational study in a single center. Therefore, there was selection bias in deciding the techniques and products for mitral repair. Atrial fibrillation may influence on mitral hemodynamics, since left atrial boost function reduced.

Second, this cohort included physically small Egyptian patients, and therefore annuloplasty size selection may be different with a variant population. We have not the luxury for annuloplasty ring selection.

References

1- WILLIAMS M.L., DANESHMAND M.A., JOLLIS J.G., HORTON J.R., SHAW L.K. and SWAMINATHAN M.: Mitral gradients and frequency of recurrence of mitral regurgitation after ring annuloplasty for ischemic mitral regurgitation. Ann. Thorac. Surg., 88: 1197-1201, 2009.

2- KAINUMA S., TANIGUCHI K., DAIMON T., SAKAGUCHI T., FUNATSU T. and KONDOH H.: Does stringent restrictive annuloplasty for functional mitral regurgitation cause functional mitral stenosis and pulmonary hypertension? Circulation, 124: S97-S106, 2011.

3- MA W., SHI W., WU W., MA X., KONG Y., ZHU D. and ZHANG W.: Patient-prosthesis mismatch in mitral annu-

loplasty for degenerative mitral regurgitation: An ignored issue. Eur. J. Cardiothorac. Surg., 2019.

4- MAGNE J., SÉNÉCHAL M., MATHIEU P., DUMESNIL J.G., DAGENAIS F. and PIBAROT P.: Restrictive annuloplasty for ischemic mitral regurgitation may induce functional mitral stenosis. J. Am. Coll. Cardiol., 51: 1692-1701, 2008.

5- CHAN K.L., CHEN S.Y., CHAN V., HAY K., MESANA T. and LAM B.K.: Functional significance of elevated mitral gradients after repair for degenerative mitral regurgitation. Circ. Cardiovasc. Imaging, 6: 1041-1047, 2013.

6- MA W., SHI W., WU W., YE W., KONG Y., ZHU D. and ZHANG W.: Elevated gradient after mitral valve repair: The effect of surgical technique and relevance of postoperative atrial fibrillation. J. Thorac. Cardiovasc. Surg., 157: 921-927, 2019.

7- PAUL W.M. FEDAK, M.D., Ph.D., PATRICK M. MCCARTHY, M.D. and ROBERT O. BONOW, M.D.: Originally published, 19 Feb. 117: 963-974, 2008.

8- LANG R.M., BIERIG M., DEVEREUX R.B., FLACHSKAMPF F.A., FOSTER E. and PELLIKKA P.A.: Recommendations for chamber quantification: A report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group. J. Am. Soc. Echocardiogr., 18: 1440-1463, 2005.

9- SHIM C.Y., KIM S.A., CHOI D., YANG W.I., KIM J.M. and MOON S.H.: Clinical outcomes of exercise induced pulmonary hypertension in subjects with preserved left ventricular ejection fraction: Implication of an increase in left ventricular filling pressure during exercise. Heart, 97: 1417-1424, 2011.

10- GARGANI L., PIGNONE A., AGOSTON G., MOREO A., CAPATI E. and BADANO L.P.: Clinical and echocardiographic correlations of exercise-induced pulmonary hypertension in systemic sclerosis: A multicenter study. Am. Heart J., 165: 200-207, 2013.

11- CHEMLA D., HUMBERT M., SITBON O., MONTANI D. and HERVE P.: Systolic and mean pulmonary artery pressures: Are they interchangeable in patients with pulmonary hypertension? Chest, 147: 943-950, 2015.

12- LANG R.M., BADANO L.P., MOR-AVI V., AFIFILALO J., ARMSTRONG A. and ERNANDE L.: Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur. Heart J. Cardiovasc. Imaging, 16: 233-270, 2015.

13- Systolic anterior motion after mitral valve repair: where do we stand in 2015? Ottavio Alfieri, Elisabetta Lapenna European Journal of Cardio-Thoracic Surgery, Volume 48, Issue 3, September, Pages 344-346, 2015.

14- CARPENTIER A.: Cardiac valve surgery: The 'French correction'. J Thorac. Cardiovasc. Surg., 86: 323-337, 1983.

15- CARPENTIER A.F., LESSANA A., RELLAND J.Y., BELLI E., MIHAILEANU S., BERREBI A.J., PALSKY E. and LOULMET D.F.: The 'physio-ring': An advanced concept in mitral valve annuloplasty. Ann. Thorac. Surg., 60: 1177-1185, 1995.

16- MORTEN O. JENSEN, M.Sc., HENRIK JENSEN, M.D., MORTEN SMERUP, M.D., Ph.D., ROBERT A. LEVINE, MD, AJIT P. YOGANATHAN, Ph.D., HANS NYGAARD, DMSc, J. MICHAEL HASENKAM, M.D., DMSc and STEN L. NIELSEN, M.D., DMSc: Saddle-shaped mitral valve annuloplasty rings experience lower forces compared with flat rings originally published 30 Sep. 2008 https://doi.org/10.1161/CIRCULATIONAHA. 107.74776Circulation, 118: S250-S255, 2008.

17- JIMENEZ J.H., SOERENSEN D.D., HE Z., HE S. and YOGANATHAN A.P.: Effects of a saddle shaped annulus on mitral valve function and chordal force distribution: An in vitro study. Ann. Biomed. Eng., 31: 1171-1181, 2003.

18- JENSEN M.O., LEMMON J.D., GESSAGHI V.C., CONRAD C.P., LEVINE R.A. and YOGANATHAN A.P.: Harvested porcine mitral xenograft fixation: Impact on fluid dynamic performance. J. Heart Valve Dis., 10: 111-124, 2001.

19- NIELSEN S.L., HANSEN S.B., NIELSEN K.O., NYGAARD H., PAULSEN P.K. and HASENKAM J.M.: Imbalanced chordal force distribution causes acute ischemic mitral regurgitation: Mechanistic insights from chordae tendineae force measurements in pigs. J. Thorac. Cardiovasc. Surg., 129: 525-531, 2005.

20- HASENKAM J.M., NYGAARD H., PAULSEN P.K., KIM W.Y. and HANSEN O.K.: What force can the myocardium generate on a prosthetic mitral valve ring? An animal experimental study. J. Heart Valve Dis., 3: 324-329, 1994.

21- KUNZELMAN K.S., COCHRAN R.P., VERRIER E.D., EBERHART R.C.: Anatomic basis for mitral valve modelling. J. Heart Valve Dis., 3: 491-496, 1994.

22- WILMER W. NICHOLS and MICHAEL F. O'ROURKE: Mcdonald's Blood Flow in Arteries: Theoretical, Experimental and Clinical Principles. Fifth Edition ed. Hodder Arnold, 2007.

23- GORMAN J.H., III, GUPTA K.B., STREICHER J.T., GORMAN R.C., JACKSON B.M., RATCLIFFE M.B., BOGEN D.K. and EDMUNDS L.H. Jr.: Dynamic three-dimensional imaging of the mitral valve and left ventricle by rapid sonomicrometry array localization. J. Thorac. Cardiovasc. Surg., 112: 712-726, 1996.

24- CARPENTIER A.: Cardiac valve surgery: The 'French correction'. J. Thorac. Cardiovasc. Surg., 86: 323-337, 1983.

25- CARPENTIER A.F., LESSANA A., RELLAND J.Y., BELLI E., MIHAILEANU S., BERREBI A.J., PALSKY E. and LOULMET D.F.: The 'physio-ring': An advanced concept in mitral valve annuloplasty. Ann. Thorac. Surg., 60: 1177-1185, 1995.

26- TIMEK T.A., GREEN G.R., TIBAYAN F.A., LAI D.T., RODRIGUEZ F., LIANG D., DAUGHTERS G.T., INGELS N.B. Jr. and MILLER D.C.: Aorto-mitral annular dynamics. Ann. Thorac. Surg., 76: 1944-1950, 2003.

27- BRAUN J., CIARKA A., VERSTEEGH M.I., DELGADO V., BOERSMA E., VERWEY H.F., et al.: Cardiac support device, restrictive mitral valve annuloplasty, and optimized medical treatment: A multimodality approach to nonischemic cardiomyopathy, J. Thorac. Cardiovasc. Surg., Vol. 142, 2011.

28- DOI K., YAMANO T., OHIRA S., YAMAZAKI S., NUMATA S. and YAKU H.: Annuloplasty ring size determines exercise-induced mitral stenosis severity after valve repair. J. Heart Valve Dis., 24: 744-51, 2015.

29- KAWAMOTO N., FUJITA T., FUKUSHIMA S., SHIMAHARA Y., KUME Y., MATSUMOTO Y., YAMASHITA K., ASAKURA K. and KOBAYASHI J.: Functional mitral stenosis after mitral valve repair for Type II dysfunction: Determinants and impacts on long-term outcome. Eur. J. Cardiothorac. Surg., 54: 453-459, 2018.

30- KUBOTA K., OTSUJI Y., UENO T., KORIYAMA C., LEVINE R.A., SAKATA R. and TEI C.: Functional mitral stenosis after surgical annuloplasty for ischemic mitral regurgitation: Importance of subvalvular tethering in the mechanism and dynamic deterioration during exertion. J. Thorac. Cardiovasc. Surg., 140: 617-623, 2010.

31- BERTRAND P.B., VERBRUGGE F.H., VERHAERT D., SMEETS C.J., GRIETEN L., MULLENS W., GUTERMANN H., DION R.A., LEVINE R.A. and VANDERVOORT P.M.: Mitral valve area during exercise after restrictive mitral valve annuloplasty: Importance of diastolic anterior leaflet tethering. J. Am. Coll. Cardiol., 65: 452-461, 2015.

32- SAMIEI N., TAJMIRRIAHI M., RAFATI A., PASEBANI Y., REZAEI Y. and HOSSEINI S.: Pulmonary arterial pressure detects functional mitral stenosis after annuloplasty for primary mitral regurgitation: An exercise stress echocardiographic study. Echocardiography, 35: 211-217, 2018.

33- TUMMINELLO G., LANCELLOTTI P., LEMPEREUR M., D'ORIO V. and PIERARD L.A.: Determinants of pulmonary artery hypertension at rest and during exercise in patients with heart failure. Eur. Heart J., 28: 569-574, 2007.

34- MARECHAUX S., PINCON C., LE TOURNEAU T., DE GROOTE P., HUERRE C. and ASSEMAN P.: Cardiac correlates of exercise induced pulmonary hypertension in patients with chronic heart failure due to left ventricular systolic dysfunction. Echocardiography, 25: 386-393, 2008.

35- MAGNE J., LANCELLOTTI P. and PIERARD L.A.: Exercise pulmonary hypertension in asymptomatic degenerative mitral regurgitation. Circulation, 122: 33-41, 2010.

36- LANCELLOTTI P., MAGNE J., DULGHERU R., ANCION A., MARTINEZ C. and PIERARD L.A.: Clinical significance of exercise pulmonary hypertension in secondary mitral regurgitation. Am. J. Cardiol., 115: 1454-1461, 2015.

مقارنة وتقييم كفاءة وديناميكية إصلاح الصمام اللميترالى بواسطة نوعين من حلقات الصمام الحلقة الكاملة الصلبة فى مقابل الحلقة الأقل صلابة المسطحة فى نوعين مختلفى الباثولوجيا من أنواع الارتجاع

فبين أكتوبر ٢٠١٨ و أكتوبر ٢٠٢١، خضع ثلاثة وثلاثون (٣٣) مريضاً لإصلاح الصمام الميترالى عن طريق الحلقة المسطحة والحلقة الصلبة لمرض ارتجاع الصمام الميترالى نتيجة اضمحلال الصمام أو نقص الامداد الدموى على التوالى.

تم تقييم العلاقة بين ديناميكا الدم بعد العملية الجراحية بواسطة الموجات الصوتية، وتم إعادة تروية مرضى نقص تروية الدم بالكامل.

تم استخدام الحلقة المسطحة لخمسة عشر (١٥) مريضاً يعانون من مرض الصمام الميترالى نتيجة اعتلال الصمام ذاته وتم استخدام الحلقة الصلبة لثمانية عشر (١٨) مريضاً مصابون بارتجاع نتيجة نقص التروية لعضلة القلب.

وجد أن هناك عدد (٢) من المرضى لديهم ارتجاع كبير بعد استخدام الحلقة المسطحة بينما تأثرت الديناميكية الخاصة بالصمام فى بالنقص فى (٣) مرضى بعد استخدام الحلقة الصلبة.

نستنتج من ذلك أنه يجب أن يتم اختيار حلقة الصمام الميترالى وفقاً للنوع المرضى.

وقد خلصنا إلى أن الحجم الأكبر للحلقة لديه القدرة على تحسين ليس فقط ديناميكا الدم، و لكن أيضاً ارتفاع ضغط الشريان الرئوى الناتج عن ارتجاع الصمام، بالمقارنة مع حلقة الصلبة ولكن من مميزات الحلقة الصلبة عدم ظهور أى مريض ارتجاع ولكن ظهور ضيق وتأثر فى الديناميكية لـ ٣ مرضى فقط.