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Posterior chordal preservation with anterior artificial neochord reconstruction in rheumatic mitral valve replacement

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ABSTRACT

Introduction: Following mitral valve replacement, adaptation of left ventricle depends upon the annulo-ventricular continuity. Artificial chordal reconstruction has been mentioned as means to maintain annulo-ventricular continuity in patients in whom total chord preservation is not feasible.

Objective: This study aimed to compare the difference in left ventricle internal diameter in diastole and systole, ejection fraction and pulmonary artery systolic pressure after six months of surgery, in patients undergoing posterior chords preserving mitral valve replacement with mitral valve replacement with posterior chord preservation and neochord reconstruction at the anterior mitral annulus.

Methodology: A comparative observational study was conducted from 2019 December to 2020 December) at Manmohan Cardiothoracic and Vascular and Transplant Centre after ethical approval using convenience sampling. A total of 30 patients were divided into two groups: Posterior preservation and artificial neochord reconstruction (Group I) versus Posterior Chord preservation (Group II). Echocardiographic measurement of left ventricle internal diameter in diastole and systole, ejection fraction, pulmonary artery systolic pressure was done preoperatively, after seventh post-operative day, and sixth post-operative month.

Result: Left ventricle internal diameter in diastole in Group I and Group II were 43 ± 2.96 mm and 48.93 ± 4.94 mm (p = 0.01) and in systole in Group 1 and Group 2 were 29.26 ± 2.96 mm and 35.93 ± 5.23 mm (p=0.01) at six months. There were no significant differences in left ventricle ejection fraction and pulmonary artery systolic pressure after six months of surgery.

Conclusion: Mitral valve replacement with artificial neochord reconstruction resulted in decrease in left ventricle internal diameter in diastole and systole after six months of surgery.

Keywords: heart valve disease; mitral regurgitation; mitral stenosis; ventricular ejection fraction.

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INTRODUCTION

Chordal preservation during mitral valve replacement (MVR) concept was introduced to reduce incidence of post-operative low cardiac output.[1] Later annulo-ventricular continuity concept was proposed, stating that dynamic interaction between mitral annulus and left ventricle (LV) wall defines left ventricle function.[2-4] This interaction allows for LV distension during diastole and wall tension during systole. When papillary muscles contract during isometric phase of cardiac cycle, closed mitral valve is drawn into LV cavity thus

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reducing longitudinal axis of LV and increasing short axis.[5] This interaction stretches myocardium, leading to greater contraction and increase in stroke volume. During systole, ventricle undergoes counterclockwise torsional deformation of apex with respect to base; during isometric relaxation and in early diastole, this is reversed (diastolic recoil).[6] Disruption of papillary-annular continuity impairs this torsional deformation thereby causing abnormal diastolic function and disruption of normal LV stress-strain patterns.[7] Artificial chordal reconstruction technique maintains annulo-ventricular continuity in situations not favouring chordal preservation. This study compared difference in LV internal diameter in diastole (LVIDd) and systole (LVIDs), LV ejection fraction (EF), left atrium (LA) size, tricuspid annular plane systolic excursion (TAPSE), pulmonary artery systolic pressure (PASP) in patients undergoing MVR with posterior chord preservation and neochord reconstruction at anterior mitral annulus and conventional posterior chords preserving MVR.

METHODOLOGY

A comparative observational study was conducted from 2019 December to 2020 December at Manmohan Cardiothoracic Vascular and Transplant Centre (MCVTC) after receiving the ethical approval (Reference number: 294/(6-11)E[2]/076/077) from the Institutional Review Committee of Institute of Medicine, Tribhuvan University, Maharajgunj, Kathmandu, Nepal. All rheumatic heart disease patients with severe mitral stenosis (MS), mitral regurgitation (MR) or both, with or without tricuspid regurgitation, with or without diabetes mellitus, hypertension, hyperthyroidism or hypothyroidism were included in this study using convenience sampling method. Patients with acute mitral valve pathology, repairable MR, comorbidities other than mentioned above and mitral valve disease associated with severe aortic valve pathology were not included in the study.

Sample size of 9.33 ≈ 10 was calculated by using formula, $n = (r+1/r)\ \sigma^2\ (z\beta+z\alpha)/d^2$, where n was the sample size, r was the ratio of a small group to a smaller group (r = 1), σ^2 was the standard deviation of the outcome variable ($\sigma^2 = 0.6$), d was the difference in the mean (d = 0.6), $z\alpha$ was level of confidence level (1.96 at 95%), $z\beta$ (0.84) was the desired power of the study (80%). Values were taken from a previously published similar study.[8] For analysis ease later, in total 30 eligible patients were taken, with 15 alloted in each group: Posterior chord preservation and anterior annular neochord implantation in MVR (Group I) and posterior chord preservation in MVR (Group II). Informed written consent was obtained from all the patients.

The surgeon and his team, and the data collectors (enumerators) were aware of the division of patients into two groups. Echocardiography was done by the cardiologists and none of the cardiologists were aware of the division of the groups. Relevant information was filled in the proforma before and after the operation. Surgeries were performed by a single team.

Post-operatively patients underwent echocardiography on seventh post-operative day and sixth month post-operative period to measure the LVIDd, LVIDs, Left Ventricle EF, Left Atrium size (LA), PASP, TAPSE. All the variables were recorded in Microsoft Excel sheet and IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, N.Y., USA) was used for statistical analysis. Paired t-test, Wilcoxon signed rank test, independent sample t-test, and independent sample Mann-Whitney U test were used and $p < 0.05$ was considered significant statistically.

Surgical technique: All the patients underwent a median sternotomy. Heparin was administered at a dose of 400 units/kg. Activated clotting time was measured to monitor adequate heparinisation. Standard cardiopulmonary bypass (CPB) was initiated with aorto-bicaval cannulation. The LA was approached through the interatrial septum or interatrial groove. The mitral valve was excised preserving as much posterior chords as possible in both the groups. Mitral valve of appropriate size, was sutured to the mitral annulus by pledgetted sutures in interrupted fashion in both groups.

In group 1, continuity between the papillary muscle and mitral annulus was established by suturing one 5-0 expanded polytetrafluorethylene (ePTFE) neochord at five-o'clock position of anterior mitral annulus to tip of posterior papillary muscle and suturing another ePTFE neochord at 10 o'clock position at anterior mitral annulus to the tip of posterior papillary muscle. Here, mid-anterior annulus was considered to be 12 o'clock position. The ePTFE sutures were tied after the valve was implanted in place. Tricuspid valve repair was done as necessary.

After completion of valve implantation, the smooth opening of the valve leaflets was checked. The cardiac chambers were closed in a running fashion with polypropylene suture. Weaning from CPB, de-airing of the heart, protaminisation, decannulation, and chest closure were done in a standard fashion.

RESULT

This study included 30 patients undergoing the mitral valve replacement for rheumatic heart disease with severe mitral stenosis and/or mitral regurgitation. Each patient was followed up for a period of six months after the surgery, and none of the patients were lost to follow-up during the study period. There were 10 females and five males in Group I and 11 females and four males in Group II. The groups were comparable in relation to gender distribution, age, height, weight, CPB time, aortic cross clamp time (ACC), valve size, post-operative ventilation time, and drain output (Table 1). One patient in each group underwent re-exploration due to excessive bleeding. Superficial surgical site infection occurred in one patient in Group 1 and was managed conservatively. Stroke was not recorded in any of the patients.

In Group 1, there was a significant decrease in the LVIDd, LVIDs, LA size, and a significant fall in PASP at sixth month of surgery. However, no significant difference in EF and TAPSE were seen in this period (Table 2).

In Group 2, no significant difference in LVIDd, LVIDs, EF, and TAPSE was noted at sixth month post-operative period. However, significant decrease in LA size, PASP was noted in group 2 at sixth months of surgery in comparison to preoperative levels (Table 3).

A significant difference in LVIDd, LVIDs was noted and no difference in EF, LA size, TAPSE, PASP was noted between the two groups at six months post-operatively (Table 4).

There was a decrease in LVIDd after six months in both groups. However, Group 1 demonstrated a significant decrease in LVIDd (Figure 1).

There was decrease in LVIDs at six months post-operative period in Group 1 as compared to Group 2 (Figure 2).

Table 1: Demographics and perioperative parameters of the two groups

Parameters	Group 1 (Mean ± SD)	Group 2 (Mean ± SD)	p-value
Age (years)	42.33 ± 12.03	41.47 ± 9.25	0.82
Height (cm)	160 ± 6.47	157 ± 6.31	0.23
Weight (Kg)	53.67 ± 7.54	53.80 ± 10.08	0.96
Valve size (mm)	27.93 ± 1.03	27.93 ± 1.28	0.87[b]
CPB time (mins)	69.73 ± 14.41	68.80 ± 15.86	0.86
Aortic cross clamp time (mins)	52.33 ±13.22	48.40 ± 12.42	0.40
Post-operative ventilation time (hours)	6.50 ± 2.41	7.07 ± 4.03	0.77[b]
Drain output (ml)	432 ± 217.90	522 ± 195.52	0.24

cm = centimetres; kg = Kilogram; CPB = cardiopulmonary bypass time; mm = millimetres; mins = minute; ml = millilitres; b independent sample Mann-Whitney U test.

Table 2: Comparison of parameters in Group 1 between the preoperative and sixth month post-operative period

Parameters	Preoperative Echocardiography parameters (Mean ± SD)	Sixth month post-operative Echocardiography parameters (Mean ± SD)	p-value
LVIDd (mm)	46.93 ± 5.93	43.06 ± 2.96	0.008[a]
LVIDs (mm)	33.33 ± 6.48	29.26 ± 2.96	0.008[a]
EF (%)	58.73 ± 4.68	58.66 ± 3.99	0.861[a]
LA (mm)	54.33 ± 6.63	42.13 ± 7.25	0.001
TAPSE (mm)	21.80 ± 2.00	21.46 ± 1.64	0.285[a]
PASP (mmHg)	55.40 ± 15.90	38.93 ± 4.74	0.01

LVIDd = left ventricle internal diameter in diastole; LVIDs = Left ventricle internal diameter in systole; LA = left atrium; TAPSE = Tricuspid annular plane systolic excursion; PASP = Pulmonary artery systolic pressure; mm = millilitres; mmHg = millilitres of mercury; % = percentage; a Wilcoxon Signed Rank Test.

Table 3: Comparison of parameters in Group 2 between the preoperative and sixth month post-operative period

Parameters	Preoperative Echocardiographic parameters in Group 2 (Mean ± SD)	Sixth months post-operative Echocardiographic parameters in Group 2 (Mean ± SD)	p-value
LVIDd (mm)	48.53 ± 5.68	48.93 ± 4.94	0.361[a]
LVIDs (mm)	37.26± 7.21	35.93 ± 5.23	0.623[a]
EF (%)	56.33 ± 4.68	53.00 ± 8.40	0.137[a]
LA (mm)	52.13 ± 5.15	45.80 ± 6.66	0.003
TAPSE (mm)	21.73 ± 2.49	20.40 ± 1.59	0.07[a]
PASP (mmHg)	54.80 ± 11.97	41.73 ± 6.21	0.001

LVIDd = left ventricle internal diameter in diastole, LVIDs = Left ventricle internal diameter in systole, LA = left atrium, TAPSE = Tricuspid annular plane systolic excursion, PASP = Pulmonary artery systolic pressure, mm = millilitres, mmHg = millilitres of mercury, % = percentage, [a] Wilcoxon Signed Rank Test

Table 4: Comparison of parameters at sixth month post-operative period between patients in Group1 and Group 2

Parameters	Sixth month post-operative period Echocardiographic parameters in Group 1 (Mean ± SD)	Sixth month post-operative period Echocardiographic parameters in Group 2 (Mean ± SD)	p-value
LVIDd (mm)	43.06 ± 2.96	48.93 ± 4.94	0.001
LVIDs (mm)	29.26 ± 2.96	35.93 ± 5.09	0.001
EF (%)	58.66 ± 3.99	53.00 ± 8.40	0.81b
LA (mm)	42.13± 7.25	45.80 ± 6.66	0.16
TAPSE (mm)	21.46 ± 1.64	20.40 ± 1.59	0.116b
PASP (mmHg)	38.93 ± 4.74	41.73 ± 6.21	0.176

LVIDd = left ventricle internal diameter in diastole, LVIDs = Left ventricle internal diameter in systole, LA = left atrium, TAPSE = Tricuspid annular plane systolic excursion, PASP = Pulmonary artery systolic pressure, mm= millilitres, mmHg = millilitres of mercury, %=percentage, b independent sample Mann-Whitney U test.

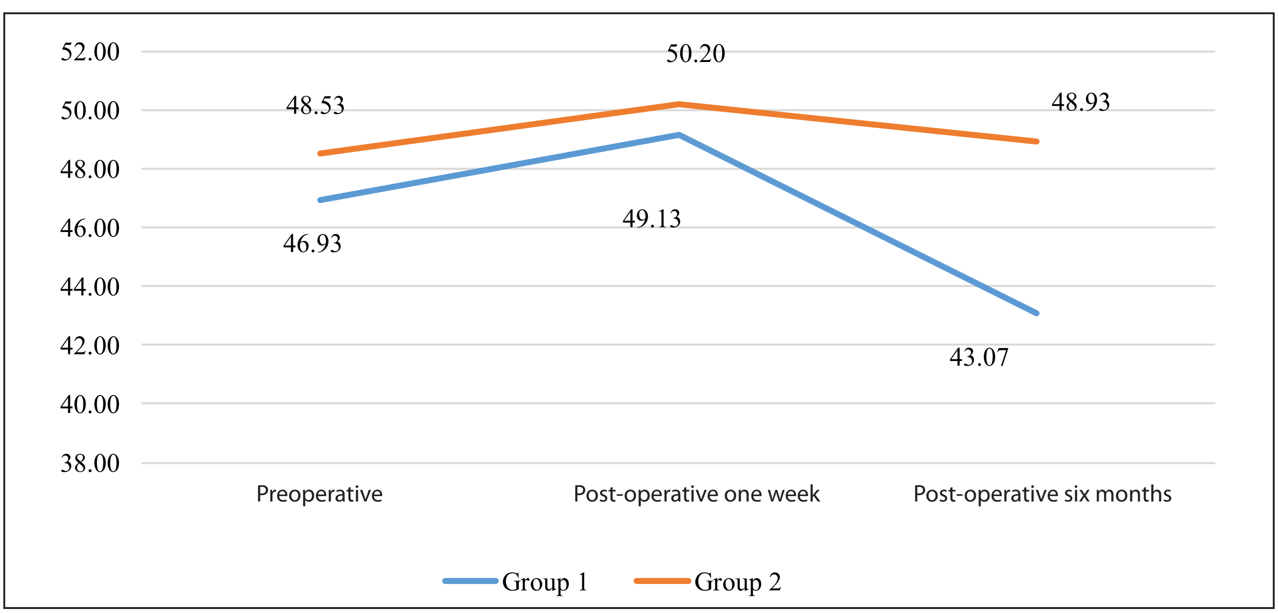

Figure 1: Graphical representation of mean LVIDd (mm) during study period

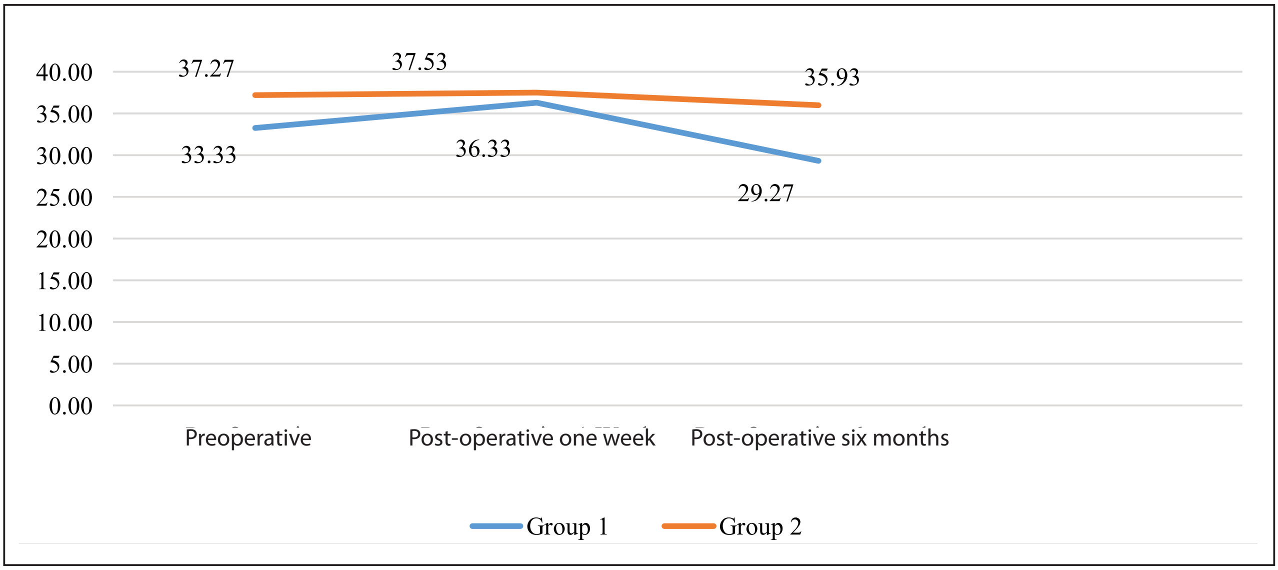

Figure 2: Graphical representation of mean LVIDs (mm) during study period

DISCUSSION

Mitral valve surgery aims to provide a competent, non-obstructed valve without deteriorating the left ventricle function. These aims are met with valve conservation and repair rather than valve replacement. However, not all patients will have a mitral valve feasible for repair and these groups of patients do require mitral valve replacement. As the awareness of the deleterious effects of the loss of annulo-ventricular continuity has increased, chordal preservation has gained popularity and is now a standard procedure during MVR. Sometimes when the valve and chords are severely affected and the preservation of both anterior and posterior chords may not allow the placement of a bigger size valve and at times it can affect the proper opening of the valve disc. In such case anterior leaflet and chordal resection followed by two neochord insertion at the anterior annulus can preserve annulo-ventricular continuity and left ventricle function. So, we opted for the latter approach and conducted a study to see the outcome in patients undergoing MVR with this approach.

In this study, the mean age in Group 1 and Group 2 was 42.33 ± 12.03 (range 20-60) years and 41.47 ± 9.25 (range 20-60) years, (p = 0.827) respectively. The height of the patients in Group 1 and Group 2 was 160 ± 6.47 cms and 157 ± 6 cms (p=0.230). The weight of the patient in Group 1 and Group 2 was 53.67 ± 7.54 Kgs and 53.80 ± 10.08 Kgs (p=0.968).

Soga et al., used the oblique technique of neochord reconstruction at MVR in nineteen patients with mitral stenosis and found that in the 12 months post-operative period, there was a significant increase in the EF, a significant decrease in LVIDd, and a significant decrease in LVIDs in the artificial neochord reconstruction group.[9] Similar decrease in LVIDd and LVIDs was noted in this study, however the EF remained similar in both cases at seven days and six months after the surgery. This may be due to the limited and short time duration of follow-up in this study as compared to Soga et al study. The preoperative LVIDd increased from 45.6 mm to 47.0 mm in the early post-operative period in patients undergoing MVR with total chord preservation. Similarly, LVIDs increased from 28.9 to 31.5 mm, EF decreased from 65.3% to 61.4% in the early post-operative period.[9] Similar results were seen in this study at seventh post-operative day.

In a study by Garcia et al., LVIDd decreased from 50 mm to 47 mm in the chordal transection group and from 52.2 mm to 46 mm in the total chord preservation group, which was a significant decrease from the pre-operative period.[10] However, they concluded that both groups showed a similar decrease in LVIDd in the post-operative period and no method of MVR was superior to others. Similarly, LVIDs decreased from 32.4 to 31.1 in six months in the chordal transection group and from 33.7 to 32.0 in the total chord preservation group as compared to preoperative values. No significant difference between the two groups was noted, indicating neither methods could be regarded as superior to each other. EF increased significantly in both groups as compared to the pre-operative value from 63% to 67% and 62% to 67%, in chordal transection and total chordal preservation group respectively, however, no difference in EF between the two groups was noted in this study. In this study, LA size progressively decreased in both Group1 and Group 2 after seven days and after six months of surgery. This decrease suggested that both method of MVR resulted in similar reverse remodeling of LA. PASP decreased significantly in both groups in the study by Garcia et al, from the early period and similar results were observed in this study. CPB time and ACC times were 124 mins and 99 mins, in the chordal transection group and 111mins and 93 mins in the chordal preservation group. The clamp time was significantly less in the chordal preservation group as compared with the chordal transection group. In this study CPB time was 69.73 and 68.80 minutes, and ACC time was 52.33 and 48.40 minutes respectively and was not significantly different between the two groups.

According to Natsuaki et al., post-operative EF did not change in the total chordal preservation group whereas the EF in the posterior chordal preservation group was significantly impaired as compared with preoperative values. The ratio of post-operative versus preoperative EF indicated that the post-operative EF in the chordal preservation group significantly improved than that in the chordal transection group.[11] Uzun et al., found that in patients with significant mitral insufficiency, all echocardiography measures improved significantly in the group with artificial chordal reconstruction group. LVIDd in both groups decreased from 56.0mm to 50mm ($p<0.001$) in the artificial neochord reconstruction group from 53.6 to 52.3 mm ($p<0.09$) in posterior preservation group.[8] However, in this study LVIDd decreased significantly only in Group 1 and not in Group 2. The ACC time was similar 55.25 and 59.15 mins but CPB times were significantly longer 90.44 and 78.64 in the patients of posterior chord preservation group from those with artificial neochord reconstruction group.[8] However, the difference was not significant in this study. This may be due to the fact that this study was a single centre study with same team doing the surgery as compared to multicentre study and various surgeons involved in the study by Uzun et al.

Yun et al., compared EF in a patient undergoing MVR with total chord preservation and partial chord preservation.[12] At discharge, EF was lower than preoperative values in both groups, but the decline was less than one half as much in the complete chord preservation group and concluded that complete preservation of the mitral sub-valvular apparatus during MVR confers a significant early advantage compared with that seen after partial chordal preservation. However, in this study early decrease in EF was seen in both groups and no significant difference between the groups was noted at seven days after surgery. The LV ejection performance continued to improve at one year as a result of improved remodeling, which was similar to this study.

Toktosunova et al., found that post-operative duration of ventilation was significantly less in total chordal preservation group (nine hours) as compared to posterior chord preservation group (14 hours), ($p=0.01$). In this study, no difference in extubation time was noted. According to Chowdhury et al., both groups demonstrated significant improvement ($p<0.05$) in left ventricle function immediately and late post-operatively, left ventricle end-systolic and end-diastolic volume was significantly decreased in the chordal preservation groups.[14] In a study by Pande et al., there was a significant reduction in LA size after mitral valve replacement.[15] The decrease was greater in patients with a left atrium >60mm in size. In this study, LA size reverse remodeling occurred after MVR in early as well as in 6 months in both the groups however, the difference between the two groups at 6 months was insignificant. Parvathy et al., studied regression pattern of PASP following the relief of MS at varying post-operative periods: hours to days, months, and years. Some stated that decrease of PASP and resistance occurred during the first few hours of procedure with no further decline, while others showed a progressive decline throughout the subsequent weeks or months.[16] In this study, PASP decreased in both the early and late period and continued to decrease in both groups but the decrease in PASP in group 1 and group 2 at six months was similar. Hence, both methods of MVR were equally efficient in decreasing PASP.

The limitation of this study was that it was a single centre study with a limited number of cases enrolled for a short-term study. A study with larger sample size and longer period of follow up is required to evaluate the changes in cardiac parameters as reverse remodeling of heart continues with time.

CONCLUSION

Mitral valve replacement with artificial reconstruction of neochords to maintain the annulo-mitral continuity resulted in decrease in left ventricle internal diameter in diastole and left ventricle internal diameter in systole at six months of surgery without increase in cardiopulmonary bypass and aortic cross clamp time, airway support time, and drain output. Mitral valve replacement with or without artificial neochord reconstruction resulted in similar ejection fraction, left atrial size, tricuspid annular plane systolic excursion, and pulmonary artery systolic pressure at six months.

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