Intraoperative Assessment for Mitral Valve Competency in a Beating Heart Under Retrograde Coronary Perfusion

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SUMMARY

Intraoperative assessment of a repaired mitral valve is of paramount importance for reparative mitral surgery. From September 2010 through November 2012, 20 consecutive patients underwent mitral valve plasty for mitral regurgitation. The patients who underwent surgery after June 2012 received assessment of the repair with the heart beating (HB group, $n = 10$), and the patients who underwent the operation before May 2012 were assessed for the repair only under cardioplegic heart arrest (non-HB group, $n = 10$). Intermittent cold retrograde blood cardioplegia was used in all patients. In the HB-group, after completion of the procedures, pump blood without a crystalloid additive was delivered into the coronary sinus. The function of the mitral valve was assessed under beating conditions. There were no differences between the two groups in aortic cross clamp time and operation time, although operative and concomitant procedures were slightly more complicated in the HB group than in the non-HB group. Postoperative echocardiography revealed none or mild mitral regurgitation in all the patients in both groups. Reopening of the closed left atrium for additional repair was necessary only in one patient in the HB group and 3 patients in the non-HB group. In conclusion, the method of perfusing the myocardium retrogradely via the coronary sinus with warm blood is safe and effective for assessing the competency of the mitral valve in a beating heart. (*Int Heart J* 2013; 54: 192-195)

Key words: Mitral valve, Intraoperative assessment, Beating, Repair

Intraoperative assessment of the repaired mitral valve has been suggested by a number of surgeons.¹⁻⁵⁾ To inspect mitral valve function directly while the heart is filled and actively beating, we perfused the coronary artery retrogradely via the coronary sinus under aortic cross-clamping. We reviewed our own experience in a contemporaneous patient group.

METHODS

The time frame for this review was September 2010 through November 2012. Altogether, the records for 20 consecutive patients with pure mitral regurgitation were analyzed. Analysis was based on retrospective chart review. All patients were classified as having mitral regurgitation resulting from degenerative disease. Patients with mitral regurgitation associated with ischemic disease, rheumatic disease, or endocarditis were excluded. None of the patients in this group had undergone previous cardiac surgical procedures. The patients who underwent mitral valve plasty after June 2012 received assessment of the repair with the heart beating (HB group, $n = 10$), and the patients who underwent the operation before May 2012 were assessed for the repair under cardioplegic heart arrest (non-HB group, $n = 10$).

Repair was considered for all patients. The basic techniques for repair included triangular resection and reconstruction for posterior leaflet defects, ring annuloplasty with a flexible ring, suture annuloplasty, and implantation of an artificial chordae. Intermittent cold retrograde blood cardioplegia was used in all patients for myocardial protection during the aortic cross-clamp period. The heart was exposed routinely by median sternotomy and pericardiotomy. Cardiopulmonary bypass was established by separate caval cannulation and arterial flow into the ascending aorta. The systemic temperature was reduced to 28° to 30°C. A double-lumen cardioplegic needle is placed in the ascending aorta and connected with both the pressure line and the cardioplegia line. With the heart empty and beating, the aorta was cross-clamped, and high-potassium cold blood was delivered by means of the aortic root into the coronary arteries. Once cardiac arrest was induced, the right atrium was opened under total caval occlusion and a retrograde cardioplegia catheter was inserted into the coronary sinus and secured to the right atrial wall with a 4-0 pursestring suture and snigger. After this, cold blood cardioplegia was delivered intermittently through the coronary sinus. The mitral valve was then exposed through a left atriotomy. Reparative procedures of the mitral valve were performed as appropriate. Competency of the repaired valve was assessed by infusing cold saline into the left ventricular cavity through the mitral valve orifice.

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under cardioplegic arrest.

In the HB-group, after completion of the procedures, pump blood without the crystalloid additive was delivered through the cardioplegia line into the coronary sinus at a rate of $5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. The heart usually began to fibrillate within 10 minutes and could be defibrillated with a DC shock. Thus, the function of the mitral valve was assessed under beating conditions. The left ventricular cavity was filled with blood through the aortic root or the thebesian veins. Retraction of the interatrial septum should be done with great care to avoid distortion of the mitral valve, which leads to overestimation of mitral regurgitation. When residual mitral regurgitation was confirmed and additional repair was needed, cardiac arrest was reinduced and sustained by intermittent infusion of cold blood cardioplegia. The alternation of cardiac arrest and beating could be achieved by switching the infusion of cold blood cardioplegia and pump blood through the coronary sinus. After the intracardiac procedures were completed, the retrograde cardioplegia catheter was extracted, and the aortic cross-clamp was released. Cardiopulmonary bypass was then terminated, and the remaining operative procedures were completed in the usual fashion.

Nominal data were calculated with the χ^2 test and Fisher's exact test for the qualitative data. Comparisons between the two groups were made by the *t*-test for independent samples in the case of normal data distribution and the Mann-Whitney *U* test in the case of non-normal data distribution. A *P*-value of < 0.05 was regarded as significant. The SPSS statistical software package 11.0 was used for statistical testing.

RESULTS

The ages of the patients ranged from 29 to 82 years (mean, 62.7 ± 14.4 years). Five patients were female. Table I shows the characteristics of the patients. There were no differences in age, gender, severity of mitral regurgitation, location of the mitral prolapse, stage of heart failure (based on NYHA classification), brain natriuretic peptide, or atrial fibrillation between the two groups.

As shown in Table II, there were no differences between the two groups in operative procedures, although they tended to be more complicated in the HB group than in the non-HB group; triangular resection of the posterior leaflet, 9 versus 9, triangular resection of the anterior leaflet, 1 versus 0, and reconstruction with artificial chordate, 4 versus 1, respectively. Concomitant procedures also tended to be more complicated in the HB group than in the non-HB group, although the differences were not significant; tricuspid annuloplasty: 3 cases in HB group versus one case in non-HB group, maze procedure: 3 cases in HB group versus one case (PV isolation only) in non-HB group, CABG: one case (3x) in HB group versus one

Table I. Characteristics of the Study Patients

Characteristics	HB group	non-HB group	<i>P</i>
<i>n</i>	10	10	
Age (years)	68.3 ± 9.4	58.7 ± 16.1	0.1
Gender			0.12
Male	6	9	
Female	4	1	
Preoperative MR (degrees)	3.7 ± 0.4	3.9 ± 0.3	0.29
4	7	9	
3	3	1	
Prolapsing leaflet			0.33
Anterior mitral leaflet	0	0	
Posterior mitral leaflet	6	8	
Both leaflets	4	2	
Etiology			
Barlow	0	0	
Marfan	1	0	0.31
NYHA (classification)	2.4 ± 0.7	2.5 ± 0.7	0.75
3	5	6	
2	4	3	
1	1	1	
BNP (pg/mL)	154.2 ± 108.7	94.9 ± 122.5	0.28
Rhythm			0.32
Sinus rhythm	6	8	
Chronic Af	2	0	
Paroxysmal Af	2	2	

MR indicates mitral regurgitation; NYHA, New York Heart Association; BNP, brain natriuretic peptide; and Af, atrial fibrillation.

Table II. Intraoperative Variables

Operative variables	HB group	non-HB group	<i>P</i>
Operative procedures			
Leaflet resection (AML)	1	0	0.31
Leaflet resection (PML)	8	9	0.53
Chordal reconstruction	4	1	0.12
Ring annuloplasty	10	10	
Concomitant procedures			
CABG	1 (3x)	1 (1x)	
TAP	3	1	0.26
Maze	3	1	0.26
PVI	0	1 (PVI only)	0.31
Operation time (minutes)	477 ± 69	474 ± 81	0.2
Aortic cross-clamp time (minutes)	208 ± 48	187 ± 59	0.4
Reopening of LA (times)	0.1 ± 0.3	0.5 ± 0.7	0.12
0	9	7	
1	1	2	
2	0	1	

AML indicates anterior mitral leaflet; PML, posterior mitral leaflet; CABG, coronary artery bypass grafting; TAP, tricuspid annuloplasty; PVI, pulmonary vein isolation; and LA, left atrium.

case (1x) in non-HB group. There were no differences between the two groups in aortic cross-clamp time and operation time. Reopening of the closed left atrium for additional repair of the mitral valve after assessment using transesophageal echocardiography (TEE) in the beating heart was necessary only in one patient in the HB group, compared with three patients (including one patient whose left atrium was opened three times) in the non-HB group.

In the HB group, the time to resume the heart beats after initiation of retrograde warm blood perfusion ranged from 3 to 24 minutes (mean, 11.8 ± 6.3 minutes) (Table III). Among 10 patients in the HB group, heart beats were resumed spontaneously in 3 while the others had to undergo DC shock. The pressure in the aortic root and coronary sinus at resumption of the heart beats ranged from 43 to 78 mmHg (mean, 64.4 ± 13.3 minutes) and from 20 to 67 mmHg (mean, 41.7 ± 15.5 minutes), respectively. The flow rate of retrograde warm blood at 34°C was 381.0 ± 101.3 mL/minute.

Additional repair after assessment in the beating heart was necessary in 6 patients. After the required procedures were performed under cardioplegic cardiac arrest, competency of the mitral valve was assessed again with the heart beating. This process was repeated until the repair became satisfactory. Assessment under beating conditions was performed only once in 4 patients, twice in 3 patients, 3 times in one, 4 times in one, and 5 times in one patient.

There was no operative or in-hospital mortality. No stroke was seen in either group. There were no differences between the two groups in postoperative CK-MB, duration of mechanical ventilation or postoperative hospital stay, severity of mitral regurgitation, location of the mitral prolapse, stage of heart failure (based on NYHA classification), brain natriuretic peptide, or atrial fibrillation (Table IV). Postoperative echocardiography revealed none or mild mitral regurgitation in all patients in both groups. Mitral regurgitation was judged as absent (no) in 9 patients in the HB group and in 7 patients in the non-HB group. Mitral regurgitation of grade 1 was observed in one

patient in the HB group and in 2 patients in the non-HB group. Only one patient in the non-HB group had grade 2 mitral regurgitation after repair.

DISCUSSION

During reparative mitral operations, an intraoperative method for evaluating the competency of the mitral valve is of paramount importance. Although various methods have been reported for this purpose, most of them are performed in a nonbeating or fibrillating heart.¹⁻⁵⁾ To assess mitral valve function under direct vision with the heart filling and actively beating, thereby exposing the mitral valve to physiologic pressures, some surgeons have perfused both the left ventricle and the aortic root proximal to the cross-clamp separately under cardiopulmonary bypass.¹⁾ However, this technical maneuver has not been widely accepted, possibly because of the potential risks of perfusion failure and air embolism of the coronary arteries.

Direct visualization of mitral valve function under beating conditions is feasible by perfusing the myocardium retrogradely via the coronary sinus with warm pump blood. We have performed 10 cases of mitral valve repair using this method, with satisfactory results and no complications. The aortic cross-clamp time and operation time did not statistically differ between the groups, possibly because assessment of the repaired valve under beating conditions was repeated a couple of times as required in the HB group. However, operative procedures and concomitant procedures seemed to be more complicated in the HB group than in the non-HB group. Moreover, because the exact site of mitral regurgitation could be determined under beating conditions, reopening of the closed left atrium became less frequent in the HB group, which might lead to more satisfactory repair of the mitral valve.

The method of perfusing the myocardium retrogradely via the coronary sinus with warm blood was first introduced by Higami, *et al.*⁵⁾ During diastole, the left ventricle is filled with blood through the thebesian veins. During systole, the pressure within the left ventricle is elevated and blood flow through the thebesian veins is interrupted. We observed that the pressure within the left ventricle and the aortic root continued to be at the same level during the cardiac cycle. We also noticed by TEE that the aortic valve was kept closed even in systole. These findings suggest that the risk of air embolism of the coronary arteries might be very low using this method. However, when the mitral regurgitation disappears completely after repair, the chance of air embolism of the coronary arteries might be increased. Therefore, the pressure of the aortic root and the coronary sinus should be maintained at appropriate levels.

Intraoperative Doppler echocardiography has been proved to be an excellent modality for visualization of mitral valve competence during mitral valve repair.⁶⁻⁹⁾ However, when the repair is not satisfactory, the heart should be arrested and the left atrium opened again for additional procedure. The method described herein allows for alternation of assessment in the beating heart and repair in the cardioplegic arrested heart without closure and reopening of the left atrium. Indeed, in the HB group, we had to reopen the left atrium only once when significant mitral regurgitation was observed by TEE, although

Table III. Assessment of Mitral Valve Repair Using Retrograde Warm Blood Perfusion

Variable	HB group
Spontaneous beats (n)	3
Time to beat on (minutes)	11.8 ± 6.3
Aortic root pressure (mmHg)	64.4 ± 10.3
Coronary sinus pressure (mmHg)	41.7 ± 15.5
Retrograde blood flow (mL/minute)	381.0 ± 101.3
Assessment under beating (times)	2.2 ± 1.3

Table IV. Postoperative Results

Postoperative variables	HB group	non-HB group	P
CK-MB (ng/mL)	108 ± 22	101.6 ± 20.8	0.55
Intubation time (hours)	15.3 ± 7.2	12.2 ± 1.9	0.22
Hospital stay (days)	28.9 ± 22.1	18.6 ± 4.1	0.19
Postoperative MR (degrees)	0.1 ± 0.3	0.4 ± 0.7	0.23
0	9	7	
1	1	2	
2	0	1	

CK indicates creatine kinase and MR, mitral regurgitation.

repair under cardioplegic arrest and assessment with the heart beating was repeated a couple of times in some cases while the left atrium remained open.

A potential criticism is that the left ventricular cavity might be overdistended with the heart beating while the aortic valve is in closure position. Another concern is that elevated pressure in the coronary sinus and capillary beds might lead to myocardial edema. Although no histopathological study was performed in our patients, there was no significant difference in postoperative CK-MB levels between the groups. Over distention of the left ventricle seems to be unlikely, because intraventricular pressure rarely exceeded 100 mmHg during systole in our patients. Furthermore, in a beating heart, elevated venous pressure might not cause myocardial edema. Higami and coworkers used retrograde continuous cold blood cardioplegia and terminal warm blood cardioplegia. Their method might be less injurious to the myocardium with a theoretically decreased chance for myocardial ischemia or reperfusion injury, although to date we have not encountered any patients with serious low output syndrome.

The validity of our study is limited by its retrospective, nonrandomized nature. The operation periods of the 2 groups were different and the interval of the HB group was more condensed. Although there were no differences in the operative results, the effect of the learning curve should not be neglected. An additional limitation is the small study size, and as a consequence of this the results were not significant.

In conclusion, the method of perfusing the myocardium retrogradely via the coronary sinus with warm blood is safe and effective for assessing the competency of the mitral valve in a beating heart. We believe that the method would be of

great help for satisfactory mitral valve repair, because it allows for alternation of assessment in the beating heart and repair in the cardioplegic arrested heart with little risk of air embolism of the coronary artery while the left atrium remains open.

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