Enlargement of left ventricular outflow tract using an autologous pericardial patch for anterior mitral valve leaflet and septal myectomy through trans-mitral approach for the treatment of hypertrophic obstructive cardiomyopathy

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Abstract

Objective: Modified Morrow procedure is the gold standard of surgical intervention for hypertrophic obstructive cardiomyopathy (HOCM). However, there are certain cases without complete relief of obstruction through trans-aortic approach, we, therefore, described an unusual technique. We aimed to retrospectively analyze this series of patients to reveal its safety and efficiency.

Methods: We retrospectively analyzed a total of 247 consecutive HOCM patients in our center from January 2016 to December 2019. Sixteen of them who underwent enlargement of left ventricular outflow tract (LVOT) using an autologous pericardial patch for anterior mitral valve leaflet and septal myectomy through trans-mitral approach were recruited in this study. Baseline characteristics, perioperative data, and the outcomes were studied.

Results: Of the 16 patients, there was no operative mortality. No permanent pacemaker implantation and ventricular septal defects formation were observed. The peak pressure gradient of LVOT decreased from $97.56 \pm 23.81$ mmHg to $7.56 \pm 2.13$ mmHg ($p < .01$) after operation and $10.19 \pm 2.93$ mmHg ($p < .01$) 3 months later. The average septal thickness decreased from $18.38 \pm 3.56$ mm to $10.00 \pm 2.74$ mm ($p < .01$). During a mean follow-up of $34.25 \pm 12.85$ months (range, 15–57), no patient required cardiac reoperation. At the last follow up, the mean peak pressure gradient of LVOT was $10.12 \pm 2.03$ mmHg and no patient had more than moderate mitral regurgitation.

Conclusion: Enlargement of LVOT using an autologous pericardial patch for anterior mitral valve leaflet and septal myectomy through trans-mitral approach is feasible and reliable for the treatment of certain types of HOCM cases.

Keywords
autologous pericardial patch, hypertrophic obstructive cardiomyopathy, septal myectomy, surgical treatment, trans-mitral approach

Hongqiang Zhang, Kai Zhu, and Fanshun Wang contributed equally to this study.
1 | INTRODUCTION

Hypertrophic cardiomyopathy is one of the most common heritable heart diseases with an incidence of about one in 500 individuals.\(^1\) The morphologic and functional feature differs according to the site of the hypertrophic lesions, including the left and/or right ventricular. Hypertrophic obstructive cardiomyopathy (HOCM) is one form of hypertrophic cardiomyopathy with specific pathophysiological characteristic, that is the obstruction of the left ventricular outflow tract (LVOT) with/without concomitant mitral regurgitation (MR), caused by the thickened septal muscle and systolic anterior motion (SAM) of anterior mitral leaflet.\(^3\)\(^-\)\(^5\)

For patients with obstruction of LVOT and/or mitral valve regurgitation, symptomatic signs just like dyspnea, chest pain, and syncope are more likely occurred and these patients often do not respond adequately to drug therapy, such as beta-blockade, diiltiazem, and so forth. Therefore, these patients remain significantly symptomatic and have a dissatisfactory long-term prognosis, which means high mortality and morbidity than hypertrophic cardiomyopathy patients without the obstruction of LVOT.\(^2\)\(^,\)\(^6\) Current invasive treatments include alcohol septal ablation and surgical myectomy, especially surgical myectomy of the thicken LVOT muscle has been approved to have the most satisfactory results.\(^7\)\(^,\)\(^8\) For a long time, the modified Morrow procedure has been the gold standard of surgical treatment, which was performed through the trans-aortic approach. In fact, in addition to modified Morrow operation through the trans-aortic approach, there are other approaches, including the trans-apical and trans-mitral approach.\(^9\)\(^-\)\(^13\) In clinical practice, we found many special cases, such as the aortic valve annulus is very small, the angle between the aortic valve annulus and the mitral valve annulus is less than 120 degrees, the anterior mitral leaflet is too long, and so forth. It is difficult for these cases to completely resolve the obstruction of LVOT and SAM of anterior mitral leaflet by only resecting the hypertrophic LVOT muscle through trans-aortic approach without mitral valve replacement. Thus, we prefer trans-mitral approach to perform septal myectomy and mitral valves repair. In this study, we aimed to review the results and experiences of these cases in our center.

2 | MATERIALS AND METHODS

2.1 | Patients and characteristics

Between January 2016 and December 2019, a total of 247 consecutive HOCM patients were operated in our center through different approaches. Sixteen of them underwent surgical enlargement of LVOT using an autologous pericardial patch for anterior mitral valve leaflet and septal myectomy through trans-mitral approach and were recruited in this study. Baseline characteristics were extracted from our hospital medical records. In this case series, seven of them were male, the average age was 47.94 ± 12.79 years. All patients were diagnosed via transthoracic echocardiography (TTE) before operation and transesophageal echocardiography (TEE) during operation. Preoperative and postoperative peak LVOT gradient, SAM sign, MR grade, and maximum thickness of septal were measured for each patient to evaluate surgical results. Postoperative TTE was performed for each patient 3 months after the operation and then every 6 months during follow-up until December 2020.

The surgical indication for these patients is the LVOT peak pressure gradient >50 mmHg with/without MR and symptomatic due to failed drug therapy. Patients indicated for modified Morrow procedure through trans-aortic approach were excluded from this series. The pathological features of each patient recruited in this series are listed in Table 1. Aortic cross-clamp time and postoperative complications were collected to evaluate surgical safety.

This study was approved by the ethics committee of Zhongshan Hospital Fudan University, all patients gave their informed consent.

2.2 | Operative technique

The surgery was conventional median sternotomy. Ascending aorta, superior and inferior vena cava were cannulated, after initiation of the cardiopulmonary bypass, aorta was cross-clamped and cold blood cardioplegia was introduced. We preferred a trans-right atrium and atrial septum approach to expose the anterior leaflet of mitral valve. The incision of mitral valve was at the root of the anterior leaflet, about 2–5 mm to the annulus, leaving an edge to repair. It usually

| TABLE 1 | Summary of operative details |
|---------|-----------------------------|
| Operative details | Values |
| Mortality | 0 |
| New-onset stroke | 0 |
| New-onset heart block | 0 |
| LBBB | 2 |
| AVB | 0 |
| New-onset atrial fibrillation | 0 |
| Left ventricular outflow gradient, mmHg | 7.56 ± 2.13 |
| Pathology | |
| Small aortic annulus/root | 3 |
| Small aortic and mitral annulus angle | 6 |
| Combined mitral valve lesion | |
| Anterior | 7 |
| Posterior | 4 |
| Mitral regurgitation | |
| Trace | 4 |
| Mild | 10 |
| Mild to moderate | 2 |
| SAM | 0 |
| Cross-clamp time, minutes | 54.56 ± 6.10 |
carried from the right fibrous trigone to the left without freeing the whole anterior leaflet. After this incision, the anterior leaflet attachments would be released, and the ventricular septum and bottom of the anterior papillary muscle could be exposed clearly. Septal muscle myectomy was carried from the nadir of the right aortic valve sinus to the left fibrous trigone, papillary muscle attachments were released at the same time. The depth of septal muscle resection was measured by TEE before operation and mainly depended on surgeons’ experiences. The resection should be carefully carried to avoid injuring the aortic valve, atrioventricular, and interventricular conduction beam. After septal myectomy, the anterior leaflet was reattached to the residual leaflet rim by using a prepared fusiform autologous pericardial patch (1% of glutaraldehyde solution, 10 min). The length of the patch could be measured according to the incision of the leaflet and the maximum width of the patch was usually about 10–15 mm to make sure allowing the leaflet billowing away from the septum and enlarging the LVOT completely. At last, we usually used a flexible band annuloplasty to increase the height of the leaflet coaptation to avoid the recurrence of MR.

2.3 | Statistical analysis

Continuous variables were expressed as mean ± standard error of the mean. Student t test was used to deal with group comparisons for analyses of continuous variables.

Statistics were performed with Stata 12.1 (Stata Corp.). A p value less than .05 was considered as the criterion for statistical significance.

3 | RESULTS

3.1 | Baseline characteristics

Of the 16 patients recruited in this series, seven were male, the mean age of the series was 47.94 ± 12.79 years (range, 16–65 years). The baseline characteristics were summarized in Table 2. All the patients recruited had severe symptoms and heart failure (NYHA II–IV) refractory to regular drug therapy. Preoperative atrial fibrillation was found in 3 (3/16, 18.75%) patients. No one had an invasive treatment (including alcohol septal ablation and surgical septal myectomy) before. The baseline preoperative peak pressure gradient of LVOT was 97.56 ± 23.81 mmHg (range, 70–156 mmHg), the maximum thickness of the septum was 18.38 ± 3.56 mm (range, 14–27 mm), SAM sign was observed in all patients by TEE before operation. Fifteen of the patients had more than moderate MR, only one patient had mild MR.

3.2 | Perioperative results

There was no patient who died in this series, the overall mortality rate of 0%. No new-onset atrial fibrillation or permanent pacemaker implantation was observed before being discharged from the hospital in our study, new-onset LBBB was observed in two patients. No new-onset stroke with symptoms was found during the hospital stay. The TEE examination intraoperatively revealed no ventricular septal defects, the peak pressure gradient of LVOT decreased from 97.56 ± 23.81 mmHg to 7.56 ± 2.13 mmHg (p < .001) and 10.19 ± 2.93 mmHg (p < .01) (Figure 1). The average septal thickness decreased from 18.38 ± 3.56 mm to

| TABLE 2 Baseline characteristics |
|----------------------------------|
| Preoperative variables | Values |
| Gender (male/female) | 7/9 |
| Age, years | 47.94 ± 12.79 |
| Atrial fibrillation (y/n) | 3/13 |
| Stroke (y/n) | 1/15 |
| Pacemaker (y/n) | 1/15 |
| NYHA functional class | |
| II | 2 |
| III | 13 |
| IV | 1 |
| LVEF, % | 63.00 ± 2.94 |
| Septal thickness, mm | 18.38 ± 3.56 |
| LVOT Peak gradient, mmHg | 97.56 ± 23.81 |
| SAM | 16 |

Mitrail regurgitation

- Mild | 1
- Moderate | 10
- Severe | 5

Abbreviations: LVEF, left ventricular ejection fraction; LVOT, left ventricular outflow tract; NYHA, New York Heart Association.

FIGURE 1 The LVOT peak gradient of preoperative (Pre), postoperative (Post) and 3 months after operation (Follow-up) significantly decreased from 97.56 ± 23.81 mmHg to 7.56 ± 2.13 mmHg (p < .001) and 10.19 ± 2.93 mmHg.
shown in Table 1. Seven patients had anterior mitral valve lesions, almost all the patients had no more than mild MR, except for one who eventfully in all cases according to TEE examination during operation, the mean peak pressure gradient of LVOT was 10.12 ± 2.03 mmHg treating with amiodarone. At the last follow up in December 2020, the trans-mitral approach via the aortic incision, the trans-mitral approach via the base of the anterior mitral leaflet provided a more clear panoramic exposure of the interventricular septum, making myectomy easily and avoiding heart block, through this approach, experienced surgeons could even identify the pale fibrous hinges subaortic hit caused by SAM. Also, this approach provided a wide vision of the anterior papillary muscles and its base. This allowed surgeons to completely address mitral valve abnormalities, release any abnormal papillary muscle, and chordae insertion to avoid postoperative SAM simultaneously. According to the literatures, more than half of the HOCM patients suffered from mitral valve regurgitation accompanied with obstruction of LVOT. Therefore, the trans-mitral approach enables surgeons to deal with this situation at the same time especially for patients with a structural abnormality of the mitral valve.

3.3 Follow-up results

All patients underwent routine TTE examination 3 months after the operation. The mean peak pressure gradient of LVOT was 10.19 ± 2.93 mmHg 3 months after the operation. No more MR was detected compared to the discharge status. One patient was rehospitalized for pericardial effusion and recovered uneventfully after receiving pericardiocentesis and drainage. All patients were alive during a mean follow-up of 34.25 ± 12.85 months (range, 15–57) from April 2016 to December 2020. Follow-up was complete in this cohort. No patient needed a second cardiac surgery. During follow up, one patient suffered a more than moderate mitral regurgitation with rapid atrial fibrillation. The mitral regurgitation decreased to mild to moderate after atrial fibrillation converted to sinus rhythm by treating with amiodarone. At the last follow up in December 2020, the mean peak pressure gradient of LVOT was 10.12 ± 2.03 mmHg and no one had more than moderate MR.

4 DISCUSSION

HOCM is common hereditary heart disease with nonspecific symptoms, just like dyspnea, chest pain, and syncope on exercise. For patients without relieving symptoms after regular drug treatment, surgical intervention is required. In this retrospective study, we described a trans-mitral approach through the base of the anterior mitral valve leaflet, with a special way to reattach the anterior mitral valve leaflet, for some special types of HOCM patients. The results confirmed that using this special technique to treat HOCM patients in this series is feasible and reliable.

Although there are many different surgical approaches and methods, the modified Morrow procedure through trans-aortic approach is still considered as the gold standard surgical treatment, showing a verified surgical result and good remission of symptoms for a long time. The trans-mitral approach was first described in 1963 by Lillehei and Levy. They chose this approach for HOCM patients just because of suboptimal exposure through the traditional trans-aortic approach. As we all know, a satisfactory procedure for HOCM consists of three major goals: completely thickened septal muscle resection, dealing with the anterior mitral valve leaflet to avoid postoperative SAM, and release of abnormal papillary muscle and chordae attachments. Compared with the traditional trans-aortic approach via the aortic incision, the trans-mitral approach via the base of the anterior mitral leaflet provided a more clear panoramic exposure of the interventricular septum, making myectomy easily and avoiding heart block. Also, this approach provided a wide vision of the anterior papillary muscles and its base. This allowed surgeons to completely address mitral valve abnormalities, release any abnormal papillary muscle, and chordae insertion to avoid postoperative SAM simultaneously. According to the literatures, more than half of the HOCM patients suffered from mitral valve regurgitation accompanied with obstruction of LVOT. Therefore, the trans-mitral approach enables surgeons to deal with this situation at the same time especially for patients with a structural abnormality of the mitral valve.

The limitation of our study was the small-sized patient population and lack of long-term follow up since the cohort of cases was rare. For each case, we planted a flexible band annuloplasty to increase the height of the leaflet coaptation to avoid the recurrence MR, and during a mean follow-up of 34.25 ± 12.85 months (range, 15–57), no patient had more than moderate MR, but the long-term prognosis accompany with the pericardial patch getting calcification is unknown.

Although modified Morrow procedure is still the gold standard surgical intervention for HOCM, enlargement of LVOT using an autologous pericardial patch for the anterior mitral valve leaflet and septal myectomy through trans-mitral approach is feasible and reliable for certain cases. Since the pathology of different HOCM forms...
varies in patients, a personalized procedure plan should be prepared and the one in our study could be a proper choice.

5 | CONCLUSIONS

Enlargement of LVOT using an autologous pericardial patch for the anterior mitral valve leaflet and septal myectomy through a trans-mitral approach is feasible and reliable for the treatment of certain types of HOCM cases.

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interests.

AUTHOR CONTRIBUTIONS

Hongqiang Zhang, Kai Zhu, and Fanshun Wang conceived and designed the manuscript, and collected and revised data. Hongqiang Zhang wrote the paper. Zhaohua Yang, Shouguo Yang, and Chunsheng Wang performed the procedure. Hongqiang Zhang and Chunsheng Wang reviewed and edited the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL

This study was approved by the ethics committee of Zhongshan Hospital Fudan University, written informed consent was obtained from the patient. All authors declare that they are responsible for obtaining permission to reproduce material from other sources.

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