

Application of mini-invasive surgical instruments in transaortic myectomy for hypertrophic obstructive cardiomyopathy: A single-center experience with 168 cases

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Abstract

Background: Septal myectomy has been a standard treatment option for patients with hypertrophic obstructive cardiomyopathy (HOCM) and drug refractory symptoms. However, there are only a few experienced myectomy centers in the world so far, mainly because of high technical difficulty of myectomy. From our clinical experience, the use of the mini-invasive surgical instruments during myectomy may be beneficial to reduce the technical difficulty. This study reports the preliminary experience regarding transaortic septal myectomy using mini-invasive surgical instruments for the treatment of patients with HOCM and drug refractory symptoms, and evaluates the early results following myectomy.

Methods Between March 2016 and March 2019, consecutive HOCM patients were included in this analysis who underwent isolated transaortic septal myectomy using the mini-invasive surgical instruments. Intraoperative, in-hospital and follow-up results were analyzed.

Results A total of 168 eligible patients (83 males, mean 56.8 ± 12.3 years) were included. Midventricular obstruction was recorded in 7 (4.2%) patients. All included patients underwent transaortic septal myectomy with a mean aortic cross-clamping time of 36.0 ± 8.1 minutes. Nine (5.4%) patients received repeat aortic cross-clamping during surgery. Surgical mortality was 0.6%. Five (3.0%) patients developed complete atrioventricular block and required permanent pacemaker implantation. The median follow-up time was 6 months. No follow-up deaths occurred with a significant improvement in New York Heart Association functional status. The maximum gradients decreased sharply from the preoperative value (11.6 ± 7.4 mmHg vs. 94.4 ± 22.6 mmHg, $p < 0.001$). The median degree of mitral regurgitation fell to 1.0 (vs. 3.0 preoperatively, $p < 0.001$) with a significant reduction in the proportion of moderate or more regurgitation (1.2% vs. 57.7%, $p < 0.001$).

Conclusions The use of the mini-invasive surgical instruments may be beneficial to reduce the technical difficulty of transaortic septal myectomy procedure. Transaortic septal myectomy using the mini-invasive surgical instruments may be associated with favorable results.

1. Introduction

Septal myectomy, which effectively relieves left ventricular outflow tract (LVOT) obstruction, reliably reduces mitral regurgitation (MR), and thus substantially relieves symptoms and greatly improves quality of life, has been a standard treatment option for patients with hypertrophic obstructive cardiomyopathy (HOCM) and drug refractory symptoms [1-6]. However, there are only a few experienced myectomy centers in the world so far, mainly because myectomy requires relevant operator and institutional experience, which makes it difficult to develop standard surgical approaches to the treatment of this disease [7-11]. Also, septal myectomy requires appropriate depth and adequate length of septal excision through limited surgical exposure, which may expose patients to serious complications, such as iatrogenic free wall rupture as well as septal perforation, complete atrioventricular block, or recurrent obstruction [12, 13]. High

technical difficulty of myectomy has stimulated further studies regarding the improvement of myectomy approaches.

High technical difficulty of myectomy is mainly posed by appropriate depth and adequate length of septal excision under difficult exposure conditions. Also, an adequate length of septal excision has been reported to be extremely important to surgical effect^[14]. During the past several years, mini-invasive surgical instruments including long-handled forceps and scissors have been used during septal myectomy in this center. From our clinical experience, the use of the mini-invasive surgical instruments during myectomy may ensure an adequate length of resection; the small operational radius of the mini-invasive surgical instruments may be beneficial to reduce the difficulty of myectomy under difficult exposure conditions. The current study reports the preliminary experience regarding transaortic septal myectomy using mini-invasive surgical instruments for the treatment of patients with HOCM and drug refractory symptoms, and evaluates the early results.

2. Methods

2.1 Patients

Between March 2016 and March 2019, consecutive HOCM patients aged ≥ 18 years who underwent septal myectomy using the mini-invasive surgical instruments in this center were reviewed. Inclusion criteria were the maximum LVOT gradients ≥ 50 mmHg at rest or with provocation and presence of severe limiting symptoms refractory to maximum pharmacologic therapy with non-vasodilating β -blockers and/or calcium channel blockers. Exclusion criteria included: (1) organic mitral valve (MV) lesions (rheumatic, degenerative, ischemic, infective, and mitral annulus calcification); (2) previous valvular surgery; (3) LVOT obstruction secondary to hypertensive heart disease or severe aortic stenosis; (4) concomitant coronary artery disease requiring bypass grafting; (5) concomitant modified Maze procedure; and (6) concomitant obstruction of right ventricular outflow tract requiring enlargement. Patients who underwent septal myectomy via the transseptal approach through right atrium or via the left atrial approach through interatrial sulcus were also excluded.

2.2 Preoperative evaluation

Preoperative transthoracic echocardiography (TTE) examination was performed to define (1) the location and magnitude of any left ventricular pressure gradient, both at rest and with provocation; (2) the distribution and severity of myocardial hypertrophy; (3) MV anatomy and function; (4) the presence of mitral subvalvular anomalies including abnormal chordae tendineae attached to the ventricular septum or free wall (false cords), fibrotic and retracted secondary chordae inserted on the anterior mitral leaflet body, and papillary muscle (PM) abnormalities (hypertrophy, and direct insertion into the anterior mitral valve leaflet); and (5) the presence of intrinsic MV disease including lesions of mitral leaflets and mitral annulus. Resting LVOT velocity was measured by continuous-wave Doppler of the outflow tract from an apical window, and the resting LVOT pressure gradient was estimated by using the modified *Bernoulli*

equation (i.e., gradient = $4v^2$, where v = peak LVOT velocity). In patients with resting LVOT gradients < 30 mmHg, maneuvers such as the Valsalva maneuver and stand-to-squat were frequently used. In addition, cardiac magnetic resonance was frequently used to measure basal septal thickness and for characterization of PM morphology and location within the left ventricular cavity, PM thickness, and PM mobility.

2.3 Study protocol

This study protocol was approved by the ethics committee of Zhongshan Hospital Fudan University and was consistent with the *Declaration of Helsinki*. All included patients signed an informed consent approved by the ethics committee. Data collection was performed by trained staff (two people). The trained staff, however, were not informed of the purpose of this study.

Baseline and surgical characteristics, intraoperative results, and in-hospital results were obtained from our institutional database and were reviewed using a standard data collection form. Intraoperative results included the incidence of repeat aortic cross-clamping (due to inadequate septal myectomy, iatrogenic free wall rupture, iatrogenic septal perforation, and iatrogenic aortic valve perforation) and transesophageal echocardiography data including the maximum LVOT gradient, interventricular septal thickness, systolic anterior motion (SAM), the severity of MR, and aortic regurgitation. In-hospital results were surgical death, complete atrioventricular block requiring permanent pacemaker, new-onset atrial fibrillation, complete left bundle branch block, new-onset cerebrovascular adverse events, prolonged mechanical ventilation (> 72 hours), redo for bleeding, and postoperative hospital stay. Surgical death included all deaths within 30 days of operation regardless where death occurred and all in-hospital deaths after 30 days among patients who had not been discharged after the initial operation.

Patients were regularly followed up at 3 and 6 months following myectomy and in 6-month intervals thereafter. Follow-up data were obtained through clinic visits or telephone interviews. Follow-up results included survival, reoperation for recurrent LVOT obstruction and/or symptomatic MR, New York Heart Association (NYHA) functional class at the latest follow-up, and echocardiographic data at the latest follow-up including residual obstruction (the maximum gradient \geq 30 mmHg), septal thickness, SAM, residual MR, and ventricular septal defect were also recorded.

2.4 Surgical procedures

Operations were guided by intraoperative transesophageal echocardiography (TEE), with particular attention paid to ventricular septal anatomy as well as thickness, MV anatomy as well as function, and mitral subvalvular anatomy. The patient was put in the reverse *Trendelenburg* and left lateral decubitus position. Under general anaesthesia, the heart and ascending aorta were exposed by a median incision with sternotomy, and cardiopulmonary bypass with ascending aortic and right atrial cannulation was established with a left ventricular vent placing via the right superior pulmonary vein. Through a low oblique aortotomy approximately 7-10 mm above the right coronary ostium, the aortic valve leaflets were pulled up to gain access to the outflow tract, the hypertrophic cardiac muscle, anterior MV leaflet, and

mitral subvalvular apparatus. A head lamp and loupe magnification were used to achieve better inspection of the left ventricular cavity. The mini-invasive surgical instruments (as shown in Figure 1) were used during the resection. Scalpel resection was usually started at the nadir of the right cusp, 5 mm below the aortic valve and extending leftwards to the left trigone. The area of septal excision was lengthened beyond the bases of PMs and toward the apex of the heart. The depth of resection was up to 50% of the basal thickness of the septum. The excision of the hypertrophic muscles as a whole mass was required. In addition, mitral subvalvular anomalies were also corrected, including false cords cutting, retracted secondary chordae cutting, and hypertrophic PM release and/or resection. After resections were completed, the bases of the PMs should be seen by looking through the incision of the aortic root. And then, the outflow tract, mitral and aortic valves were carefully and thoroughly reexplored.

TEE was used after weaning off bypass to measure the maximum gradients and the severity of MR following myectomy. Repeat aortic cross-clamping was immediately performed if there was residual obstruction and/or residual moderate or more MR or if a ventricular septal defect or a left ventricular free wall rupture was observed.

2.5 Statistical analysis

Statistical analysis was performed with the SPSS statistical package version 22.0 (SPSS Inc., Chicago, IL, USA). Categorical data were expressed as frequency distributions and single percentages and were compared between groups using *Fisher's* exact test if the expected frequency was < 5 or the *chi-square* test. Normally distributed continuous variables were expressed as the mean \pm standard deviation and were compared between groups using an independent-samples *t*-test; non-normally distributed continuous variables were expressed as median and interquartile range (IQR) and were compared between groups with the *Wilcoxon* rank sum test. A two-sided *p*-value less than 0.05 was considered statistically significant.

3 Results

3.1 Study population

A total of 208 adult patients who met the inclusion criteria were reviewed. Forty patients were excluded due to concomitant valvular heart disease requiring surgery (27 patients), concomitant Maze procedure (3 patients), concomitant enlargement of right ventricular outflow tract (2 patients), and undergoing septal myectomy via transseptal approach through right atrium (8 patients), which left 168 eligible patients for data analysis. There were 83 male patients and 85 female patients with a mean age of 56.8 ± 12.3 years. The baseline characteristics are listed in Table 1. Despite the fact that 39.9% of the population had a history of hypertension, it was not deemed severe enough to be the primary cause of ventricular hypertrophy. Nine (5.4%) patients underwent previous alcohol septal ablation. Atrial fibrillation and right bundle branch block were recorded in 14 (8.3%) patients and 4 (2.4%) patients, respectively. All patients manifested severe limiting symptoms, such as dyspnea, angina-like chest pain and syncope, with New York Heart Association (NYHA) functional class III and IV in 86.3% of the population.

TTE examination revealed a mean maximum LVOT gradient of 94.4 ± 22.6 mmHg with a mean interventricular septal thickness of 18.3 ± 3.1 mm. SAM was observed in all patients, of whom 97 (57.7%) were diagnosed with moderate or more MR. Importantly, midventricular obstruction was recorded in 7 (4.2%) patients. Mitral subvalvular anomalies were recorded in 45 (26.8%) patients, including false cords (11 patients), fibrotic and retracted secondary chordae (29 patients), and PM abnormalities (13 patients).

All patients underwent transaortic septal myectomy with a mean aortic cross-clamping time of 36.0 ± 8.1 minutes (median, 35.0 min). A total of 45 (26.8%) patients received mitral subvalvular procedures in addition to myectomy, including false cords cutting (11 patients), fibrotic and retracted secondary chordae cutting (29 patients), and M release and/or resection (13 patients).

3.2 Intraoperative results

The repeat aortic cross-clamping was recorded in 9 (5.4%) patients. Of them, 5 patients were identified as residual obstruction or moderate or more MR due to inadequate initial septal myectomy, and underwent a “more” extended myectomy in terms of depth and length and/or leftward direction from the left ventricular free wall toward the MV according to TEE findings (4 patients) and received transaortic mitral valve repair using the “edge-to-edge” technique (one patient); another 2 patients underwent repair of a left ventricular free wall rupture due to free wall rupture; and the remaining 2 patients underwent repairs of septal defect and aortic right valve due to iatrogenic perforation, respectively.

TEE examination showed that the maximum LVOT gradients following myectomy fell to 10.8 ± 6.3 mmHg with the interventricular septal thickness of 13.8 ± 2.1 mm, both of which were significantly lower than the preoperative values ($p < 0.001$). No residual obstruction was recorded. SAM was observed in 16 (9.5%) patients, of whom one was identified as moderate MR. No instances of more than moderate MR were observed.

3.3 In-hospital outcomes

One patient died of cerebral hernia on the fourth day postoperatively, which may be associated with acute cerebral infarction determined by skull computed tomography examination, and surgical mortality was 0.6%. Five (3.0%) patients developed complete atrioventricular node block and required permanent pacemaker implantation. Note that among the 5 patients, 3 had right bundle branch block prior to surgery. Another 4 (2.4%) patients developed new-onset atrial fibrillation, but all the 4 patients returned to sinus rhythm following electrical cardioversion. The other postoperative complications are listed in Table 2. A total of 167 patients were discharged, and the median length of postoperative hospital stay was 6 days.

3.4 Follow-up results

A total of 161 (95.8%) patients received a follow-up visit with a median duration of 6 (IQR, 6-13) months. During the follow-up periods, the clinical manifestations disappeared, and no deaths or re-interventions were observed. As shown in Figure 2, NYHA functional class significantly improved from the preoperative values, with no patients being class III or IV.

TTE examination at the latest follow-up showed the maximum LVOT gradients were significantly lower than the preoperative values (Figure 3). Three patients were identified as residual obstruction with the maximum gradients of 34 mmHg, 39 mmHg, and 42 mmHg, respectively. However, the 3 patients did not receive repeat surgery or alcohol septal ablation. As summarized in Table 2, moderate MR at the latest follow-up was recorded in 2 (1.2%) patients with no symptoms, which was significantly lower than the preoperative value (1.2% vs. 57.7%, $p < 0.001$). There were no cases of severe MR at follow-up. Note that one patient who developed iatrogenic septal perforation intraoperatively was found to have one 2-mm asymptomatic ventricular septal defect during follow-up. The patient was categorized as NYHA class I, and dynamic evaluation was continued.

4 Discussion

In the 1960s, Morrow et al have reported transaortic resection of a small amount of muscle from the proximal ventricular septum, a technique generally described as classic Morrow operation. Over the next decades, myectomy has evolved from the classic Morrow operation to a more extended septal myectomy guided by preoperative cardiovascular magnetic resonance and intraoperative TEE [15-18]. High technical difficulty, however, limited clinical application of the extended septal myectomy procedure. In 2015, Ferrazzi et al proposed the transaortic secondary chordae cutting in addition to a shallow septal myectomy for the treatment of HOCM [8]. It was reported to be associated with favorable results [8, 19]. However, such an approach remained controversial because the secondary chordae maintains ventricular geometry and enhances wall thickening, which may be helpful in the presence of left ventricular dilation and systolic dysfunction [20]. In this study, using the mini-invasive surgical instruments, transaortic septal myectomy was performed in 168 patients with HOCM and drug refractory symptoms. Favorable results were achieved, including a low surgical mortality (<1%) with no occurrences of deaths or re-interventions at follow-up, a significant improvement of quality of life with recovery from symptoms and NYHA functional class I and II, an effective relief of LVOT obstruction, and a reliable reduction of MR. The observed good survival and a significant improvement in NYHA functional status coincided with an effective relief of LVOT obstruction and a reliable reduction of MR, which confirmed the safety and efficacy of transaortic septal myectomy using the mini-invasive surgical instruments in the treatment of symptomatic HOCM.

In this series including 168 transaortic myectomy procedures with the aid of the mini-invasive surgical instruments, the mean duration of aortic cross-clamping was 36.0 ± 8.1 minutes (median, 35.0 min), which was significantly lower than the value (median, 68 min) reported from a famous and experienced myectomy center in the same country [21]. The reason for shorter aortic cross-clamping time in this series may be that the application of the mini-invasive surgical instruments, regarding that the small operational radius of the mini-invasive surgical instruments may be beneficial to reduce the difficulty of myectomy under difficult exposure conditions, and then shorten operation time.

Note that 7 HOCM patients in this series suffered from midventricular obstruction and underwent transaortic septal myectomy using the mini-invasive surgical instruments. Favorable results suggested

that the application of the mini-invasive surgical instruments made it easy to remove the myocardium at the base of PMs, even to extend to the apex of the left ventricle. The surgical comfort of the operator is essential for a surgeon, especially for an inexperienced surgeon who performs septal myectomy procedures. These may attribute to the small operational radius of the mini-invasive surgical instruments, which is very important in case of limited surgical exposure. Moreover, the application of the mini-invasive surgical instruments is beneficial for an adequate length of septal excision, which is extremely important to surgical effect ^[14].

Complete atrioventricular block, left ventricular free wall rupture, aortic valve injury and iatrogenic septal perforation were the main complications of septal myectomy. In the present cohort, the incidence of pacemaker implantation (3.0%) was greater than expected based on other large series ^[22, 23]. This elevated incidence was attributed to the excessive subaortic resection to the side of the noncoronary valve when the incision beginning just to the right of the nadir of the right aortic sinus was made. More than 41.0% of patients developed complete left bundle branch block after myectomy, which allowed the adoption of conservative surgical strategies in patients with preoperative right bundle branch block. In this series, left ventricular free wall rupture, a rare complication after myectomy, occurred in 2 (1.2%) patients, and was successfully treated under cardiopulmonary bypass and cardioplegic arrest with a double-armed 3-0 polypropylene suture with a pledget placed in a horizontal mattress fashion, similar to the technique described to control a stab wound to the heart in close proximity myectomy to a coronary artery. Although abnormal papillary muscles were corrected, left ventricular free wall rupture was indicated via operative exploration to not be associated with the excision of muscle bundles. Left ventricular free wall rupture may be associated with excessive subaortic resection to the mitral anterior commissure when the incision that began just to the right of the nadir of the right aortic sinus was made. In principle, aortic valve injury and iatrogenic septal perforation were prone to occur in young patients with small aortic roots and old patients without severe septal hypertrophy, respectively. In this series, ventricular septal perforation occurred in one female patient aged 70 years with a preoperative septal thickness of 17.0 mm. Although the perforation was repaired using a bovine pericardium patch, a residual ventricular septal defect was observed during follow-up and may be associated with the thin myocardium surrounding of the perforation and the small patch that was not large enough to extend beyond the edge of the perforation at a certain distance.

This study had some potential limitations. First, this was a single-center, single-armed observational study with a limited sample size, which may have influenced the generalizability of the results. A control group including patients undergoing myectomy without the aid of the mini-invasive surgical instruments was not established, and the number of patients is relatively small, implying some weakness of the results. Second, only a minor part of patients received cardiac magnetic resonance imaging, as it did not serve as a regular examination modality in the early times at our institution. Third, a functional capacity assessment tool, such as the 6-minute walking test, and a quality of life assessment tool, such as the SF-36 questionnaire, were not utilized in this study. Finally, the duration of follow-up was relatively short. It needed longer observation to confirm our findings.

5 Conclusion

The use of the mini-invasive surgical instruments may be beneficial to reduce the technical difficulty of transaortic septal myectomy procedure. Transaortic septal myectomy using the mini-invasive surgical instruments may be associated with favorable results.

Abbreviations

LVOT, left ventricular outflow tract; MR, mitral regurgitation; HOCM, hypertrophic obstructive cardiomyopathy; MV, mitral valve; TTE, transthoracic echocardiography; PM, papillary muscle; NYHA, New York Heart Association; SAM, systolic anterior motion; TEE, transesophageal echocardiography.

Declarations

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Availability of data and materials: The datasets used in the current study are available from the corresponding author or the first author on reasonable request.

Authors' contributions: (I) Conception and design: C Wang and L Xia; (II) Administrative support: C Wang; (III) Provision of study materials or patients: Q Ji, Y Wang, Y Yang; (IV) Collection and assembly of data: Q Ji, Y Wang, H Lai, W Ding; (V) Data analysis and interpretation: Q Ji, Y Wang, Y Yang, W Ding, L Xia; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Competing interests: The authors declare that they have no competing interests.

Consent for publication: All authors have read and approved the content and agree to submit it for consideration for publication in your journal.

Ethics approval and consent to participate: Prior consent from all patients and approval from the ethics committee of Zhongshan Hospital Fudan University were obtained (No. Y2020-029).

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Tables

Table 1 Baseline and surgical characteristics

Variables	Value
Demographics	
Age (years)	56.8 ± 12.3
Gender (Females/Males)	85/83
Obesity (Body mass index >30 kg/m ²)	9 (5.4%)
Concomitant diseases	
Diabetes mellitus	16 (9.5%)
Coronary artery disease	7 (4.2%)
Hypertension	67 (39.9%)
Chronic obstructive pulmonary disease	13 (7.7%)
Cerebrovascular disease	9 (5.4%)
Family history of HCM	16 (9.5%)
Family history of sudden death	6 (3.6%)
Preoperative cardiac status	
NYHA class	
II	23 (13.7%)
III	120 (71.4%)
IV	25 (14.9%)
Previous alcohol septal ablation	9 (5.4%)
AF	14 (8.3%)
Left BBB	3 (1.8%)
Right BBB	4 (2.4%)
Preoperative TTE data	
Maximum LVOT gradient (mmHg)	94.4 ± 22.6
Interventricular septal thickness (mm)	18.3 ± 3.1
SAM	168 (100%)
Degree of MR (median, IQR)	3.0 (2.0-3.0)
Moderate or more MR	97 (57.7%)
Midventricular obstruction	7 (4.2%)

LVEF (%)	67.0 ± 4.2
LVEDD (mm)	44.6 ± 4.5
Mitral subvalvular anomalies	45 (26.8%)
False cords	11 (6.5%)
Retracted secondary chordae	29 (17.3%)
PM abnormalities	13 (7.7%)
Surgical characteristics	
ACC time (min)	36.0 ± 8.1
Transaortic myectomy	168 (100%)
Myectomy plus subvalvular procedures	45 (26.8%)
False cords cutting	11 (6.5%)
Retracted secondary chordae cutting	29 (17.3%)
PM release and/or resection	13 (7.7%)

Values are expressed as n (percent), mean ± standard deviation, or median (first quartile, third quartile).

HCM, hypertrophic cardiomyopathy; NYHA, New York Heart Association; AF, atrial fibrillation; BBB, bundle branch block; TTE, transthoracic echocardiography; LVOT, left ventricular outflow tract; SAM, systolic anterior motion; IQR, interquartile range; MR, mitral regurgitation; LVEF, left ventricular ejection fraction; LVEDD, left ventricular endo-diastolic diameter; PM, papillary muscle; ACC, aortic cross-clamping.

Table 2 Clinical outcomes and echocardiographic results

Variables	Value
Intraoperative	
Repeat aortic cross-clamping	9 (5.4%)
Inadequate septal myectomy	5 (3.0%)
Iatrogenic free wall rupture	2 (1.2%)
Iatrogenic septal perforation	1 (0.6%)
Iatrogenic AV perforation	1 (0.6%)
TEE data	
Maximum LVOT gradient (mmHg)	10.8 ± 6.3
Interventricular septal thickness (mm)	13.8 ± 2.1
SAM	16 (9.5%)
Degree of MR (median, IQR)	1.0 (1.0-1.0)
Moderate MR	1 (0.6%)
More than moderate MR	0
Moderate or more aortic regurgitation	0
In-hospital	
Surgical death	1 (0.6%)
CAVB	5 (3.0%)
Right BBB prior to surgery	3
New-onset AF	4 (2.4%)
Complete left BBB	69 (41.1%)
Cerebrovascular adverse events	2 (1.2%)
Prolonged ventilation (> 72h)	3 (1.8%)
Redo for bleeding	1 (0.6%)
Postoperative hospital stay (median, IQR; days)	6 (5-6)
Follow-up	
Number of patients	161 (95.8%)
Duration of follow-up (median, IQR; months)	6 (6-13)
Survival	161 (100%)

Reoperation	0
NYHA class at the latest follow-up	
I	127 (78.9%)
II	34 (21.1%)
TTE data at the latest follow-up	
Maximum LVOT gradient (mmHg)	11.5 ± 7.4
Residual obstruction	3 (1.9%)
Septal thickness (mm)	14.0 ± 2.5
SAM	9 (5.6%)
Moderate MR	2 (1.2%)
Ventricular septal defect	1 (0.6%)

AV, aortic valve; IQR, interquartile range; TEE, transesophageal echocardiography; CAVB, complete atrioventricular block.

Figures



Figure 1

Mini-invasive surgical instruments. Special surgical instruments include long surgical forceps (the left) and long arm surgical scissors (the right).

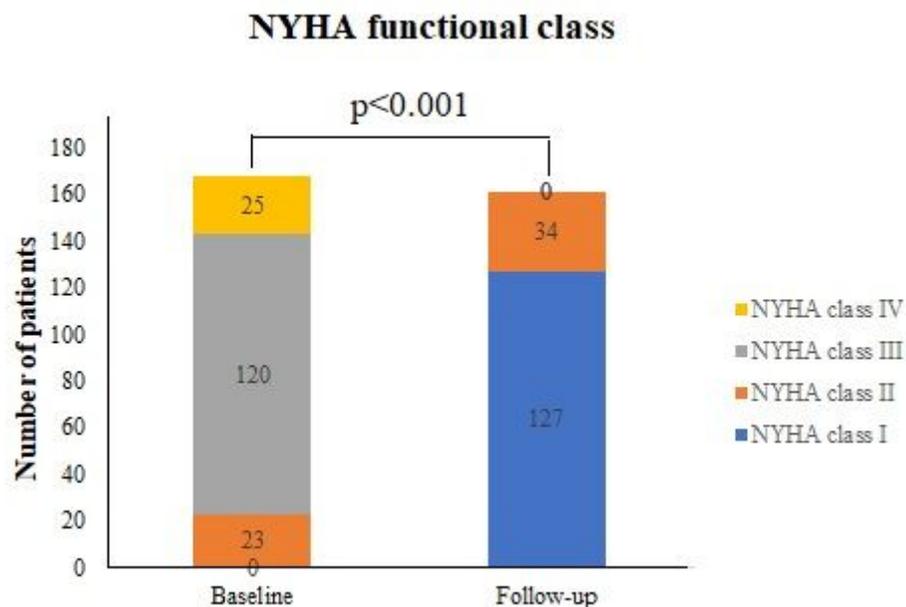


Figure 2

Pre- and post-operative NYHA functional class. $P < 0.001$, NYHA functional class prior to myectomy vs. NYHA functional class at the latest follow-up.

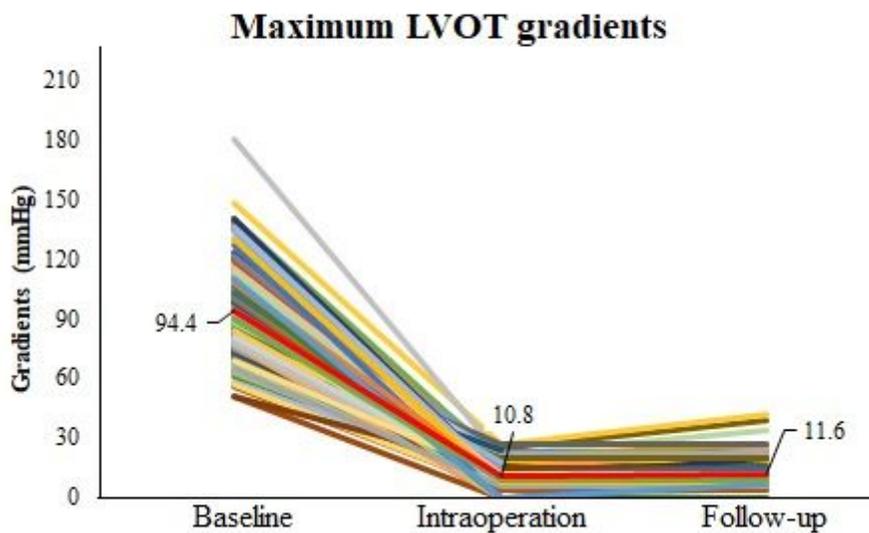


Figure 3

Pre- and post-operative maximum LVOT gradients. The values of the red line represent the mean maximum gradients. LVOT, left ventricular outflow tract.