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**ORIGINAL ARTICLE**

# A retrospective clinical study of transaortic extended septal myectomy for obstructive hypertrophic cardiomyopathy in China

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## Abstract

**OBJECTIVES**: The aim was to assess the early and mid-term clinical effects of transaortic extended septal myectomy (TAESM) on obstructive hypertrophic cardiomyopathy (HCM) in China.

**METHODS**: Ninety-three consecutive patients [57 men; mean age 45.8 ± 13.4 (11–74) years] with obstructive HCM underwent TAESM in Fuwai hospital. Their clinical data were analysed retrospectively. All the patients had drug-refractory symptoms and left ventricular outflow tract (LVOT) obstruction with a resting or physically provoked gradient of ≥50 mmHg. Preoperative transthoracic, intraoperative transoesophageal and postoperative transthoracic echocardiography was performed to assess LVOT gradients, septal thickness, LVOT diameter, mitral valve function, etc. Systolic anterior motion (SAM) of the anterior mitral valve leaflet had been detected in all preoperatively.

**RESULTS**: All the surgical procedures of the 93 patients were technically successful. The average length of postoperative stay was 7.8 ± 3.7 days. The 30-day and in-hospital mortality was 0%. Initial postoperative transoesophageal echocardiography (TEE) demonstrated marked reduction in LVOT gradient (91.76 ± 25.08 to 14.34 ± 13.44 mmHg, $P < 0.0005$) and significant improvement in mitral regurgitation (MR; $P < 0.0005$). Concomitant surgical procedures were carried out in 37 (39.8%). Complete atrioventricular block occurred in 3, complete left bundle branch block in 44, intraventricular conduction delay in 18, complete right bundle branch block in 2, transient renal dysfunction in 2 and transient intra-aortic-balloon-pumping was needed in 2. No other complications were observed during hospital stay. During a follow-up of 10.72 ± 11.02 (1–24) months, there were no readmissions or deaths, and all patients subjectively reported an obvious decrease in limiting symptoms and a significant increase in physical ability. At the latest follow-up, the New York Heart Association functional class decreased from 3.09 ± 0.60 (2–4) preoperatively to 1.12 ± 0.32 (1–2) ($P < 0.0005$); the LVOT gradient remained low at 14.78 ± 14.01 mmHg; MR remained absent (51) or at mild-(41)-to-moderate-(1) levels and SAM resolved completely in 98.9% (92 of 93) patients.

**CONCLUSIONS**: TAESM provides excellent relief from LVOT obstruction in HCM patients, with a conspicuous clinical and echocardiographic outcome at early and mid-term follow-up. For obstructive HCM and cardiac comorbidities, concomitant cardiac procedures with TAESM can be performed with low risk and satisfactory results.

**Keywords:** Hypertrophic cardiomyopathy • Surgical myectomy • Concomitant procedures

## INTRODUCTION

Hypertrophic cardiomyopathy (HCM) is known as a relatively common genetic cardiovascular disease with an incidence of about 0.2% [1] among the overall population in America and 0.16% in China [2], presenting in all age groups. Although with diverse clinical presentations and courses, HCM generally includes obstructive and non-obstructive haemodynamic forms. As an important part of the pathophysiology of obstructive HCM, obstruction of the left ventricular outflow tract (LVOT) occurs because of multiple interrelated factors. Surgical septal myectomy has been proposed as the the therapeutic gold standard for the treatment of drug-refractory disabling symptoms in HCM caused by LVOT obstruction. This procedure can relieve haemodynamic disorders and has an acceptable surgical risk when performed on appropriate patients and in experienced centres [1, 3, 4]. In this

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paper, our latest experience of treating obstructive HCM by transaortic extended septal myectomy (TAESM) is reported.

## MATERIALS AND METHODS

The objective of this study was to analyse the efficacy and durability of TAESM for obstructive HCM and introduce our clinical strategy. The clinical data were analysed retrospectively.

### Patient sample

This study was carried out in 93 consecutive obstructive HCM patients treated surgically in Fuwai Hospital (Beijing), National Center for Cardiovascular Diseases, China, from October 2009 to December 2011.

All the patients were diagnosed by transthoracic echocardiography (TTE). Surgery was performed to relieve obstruction of LVOT, and the patients were eligible for inclusion in surgical intervention if they met the following two criteria: (i) under Doppler TTE, a LVOT gradient of ≥50 mmHg at rest or with physiological provocation; (ii) unresponsive to maximum pharmacological therapy, including dyspnoea with New York Heart Association (NYHA) functional class II to IV and/or chest pain with Canadian Cardiovascular Society Angina class III or IV, and/or repetitive effort-related syncope despite prior appropriate medical therapy. The inclusion criteria were much the same as international common practice [1, 5, 6]. The baseline clinical variables of this group of patients are shown in Table 1.

Surgery was not performed in the patients who did not meet the criteria for surgery, which was insignificant LVOT obstruction or minimal symptoms, or medical therapy was effective already.

Preoperative and postoperative TTE were performed with commercially available equipment [7, 8]. The clinical symptoms, haemodynamic status and echocardiographic information [LVOT gradient, interventricular septum thickness, degree of mitral regurgitation (MR) and aortic regurgitation, etc.] of each patient were documented and analysed before and after TAESM. Moreover, TEE was done intraoperatively to assess and document relief from LVOT obstruction and MR after myectomy.

**Table 1:** Baseline clinical and demographic data ($n$ = 93)

| Parameter | Mean value (range) or number (%) |
|---|---|
| Age (years) | 45.78 ± 13.39 |
| Body weight (kg) | 67.83 ± 13.69 |
| Male | 57 (61.3%) |
| Preoperative symptoms | |
| Exertional dyspnea | 84 (90.3%) |
| Chest discomfort | 67 (72.0%) |
| Palpitation | 17 (18.3%) |
| Syncope/presyncope | 16 (17.2%) |
| Medical therapy | |
| Beta-blocker | 93 (100%) |
| Calcium blocker | 67 (72.0%) |
| Previous alcohol ablation | 3 (3.2%) |

LVOT: left ventricular outflow tract.

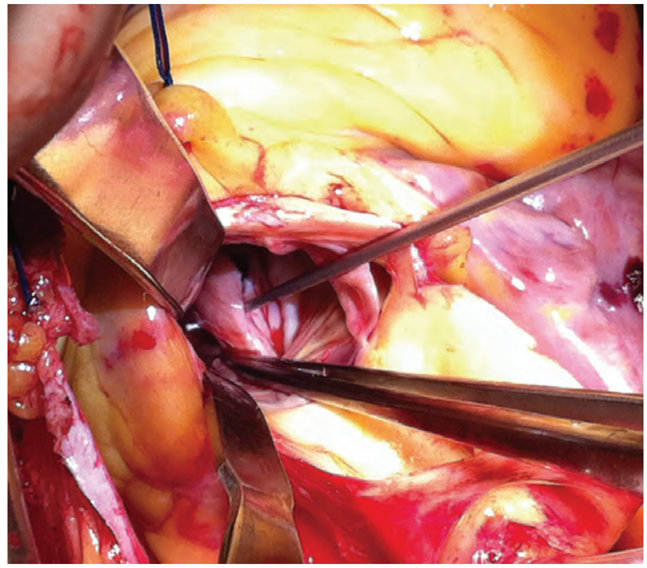

**Figure 1:** Abnormal muscle located between the anterior papillary muscle and the anterior leaflet of the mitral valve.

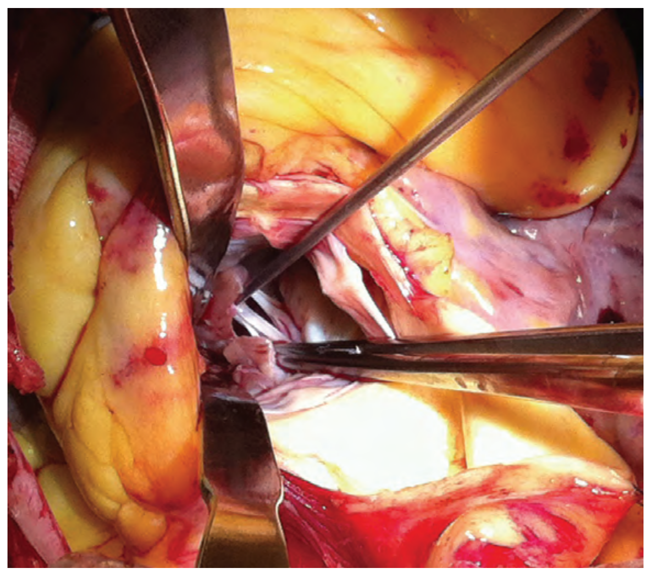

**Figure 2:** The abnormal muscle bundle was cut off.

### Transaortic extended septal myectomy

Under general anaesthesia, the heart and ascending aorta were exposed by a median incision with sternotomy, and cardiopulmonary bypass was performed using ascending aortic cannulation. Through a transverse aortotomy, the aortic valve was exposed totally after cardiac asystole induced with cold blood cardioplegia. The aortic leaflets were retracted by the assistant so as to inspect the LVOT, the hypertrophic cardiac muscle and anterior mitral valve leaflet. For better exposure through the aortic incision, we used two long retractors and a suction pump that could suck the blood in the LV and retract the aortic valve simultaneously (Figs 1–3). It is also important for the surgeon to have a head lamp. Moreover, it is usually necessary to use a medical gauze ball as a depressor to press the hypertrophic muscle from outside the heart, so better exposure can be gained and resection carried out more easily. Additionally, two homemade long-handled scalpels (one sharp, the other bush-hook) with a length of ~30 cm and a long pair of surgical forceps (~32 cm long) were used during the resection.

The aim was to open the LVOT and reduce the gradient to <30 mmHg, which often required resection of the hypertrophic muscle until the thickness of the LV wall and interventricular septum became nearly normal by visual inspection. By looking through the incision of the aortic root, we could often see the papillary muscles' bases after TAESM was completed. Accordingly, the extended septal myectomy in this cohort was a much more extensive resection (Figs 4–6) compared with the original Morrow procedure described almost half a century ago [9]. To some extent, one of the most important tips of our surgical technique was to define the resection border precisely and try to resect the hypertrophied muscles as a whole mass (Fig. 6). The extent of resection could be distally to or sometimes beyond the level of the mitral papillary muscles towards the apex (Fig. 4). The most distal portion of the obstruction must be resected completely despite the difficulty in exposing the distal part of the LV cavity [10]. In order to open the LVOT thoroughly, aberrant muscle bundles must be resected, which might be located around the root of papillary muscles, between the apex and the left ventricular free wall, or between papillary muscles and free wall, etc (Fig. 5). To obtain a more posterior position, partial excision of the papillary muscles off the left ventricular wall was necessary. Moreover, mitral valve repair, such as anterior leaflet folding when redundancy existed, was another important procedure in special patients who had slack chordae and leaflets, which might result in systolic anterior motion (SAM). The adequacy of the resection was evaluated by direct inspection, and intraoperative TEE evaluation was carried out immediately after the patient was weaned from cardiopulmonary bypass. Some concomitant surgical procedures had been administrated to the patients who had cardiac comorbidities, including coronary artery bypass grafting (CABG), modified Maze procedure, valve repair, plasty or replacement surgery, enlargement of right ventricular outflow tract (RVOT) and cardiac tumour resection.

After the operation, temporary pacing wires were placed on the LV as a routine procedure.

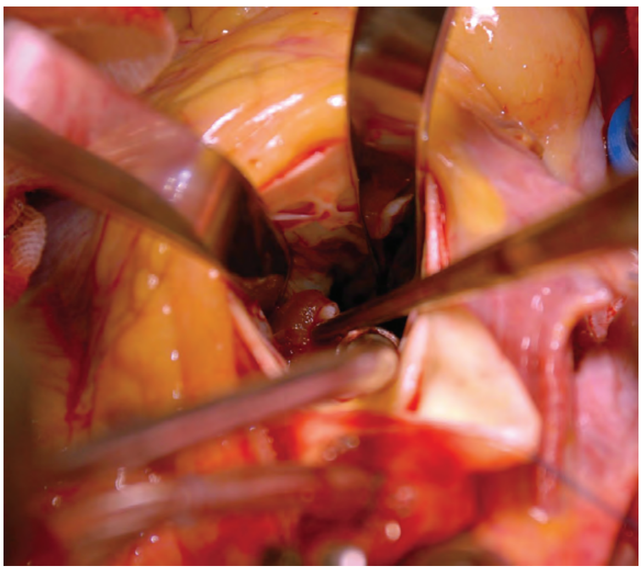

**Figure 3:** Hypertrophic IVS was partially resected.

## Follow-up

We aimed to perform follow-up at 3 and 12 months after TAESM, and yearly thereafter. The recommended measures included physical examination and TEE. Postoperative complications and the early and mid-term outcomes after surgery were recorded. The follow-up study was carried out by subsequent clinic visits to the outpatient departments and telephone interviews with the patients and their relatives.

## Statistical analysis

Data were collected during hospital stay and by outpatient services, and were put together in an Excel document. By using SPSS 17.0, the data were analysed through a retrospective method. The data for continuous variables were expressed as mean ± SD or as ranges. Value changes from pre- to postoperative were compared using the Wilcoxon test for paired samples. Significance was defined with a $P$-value of $\leq 0.05$.

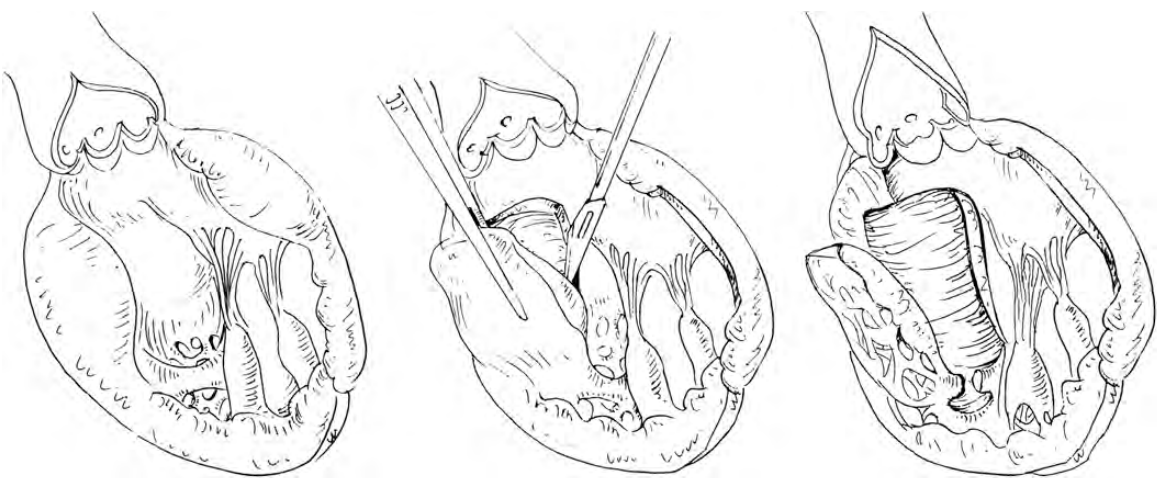

**Figure 4:** The drawings show the extent of resection. We often try to resect the hypertrophied muscles as a whole mass.

**Figure 5:** The drawings show the extent of resection, including abnormal muscles that are located between the anterior papillary muscle and the anterior leaflet of mitral valve.

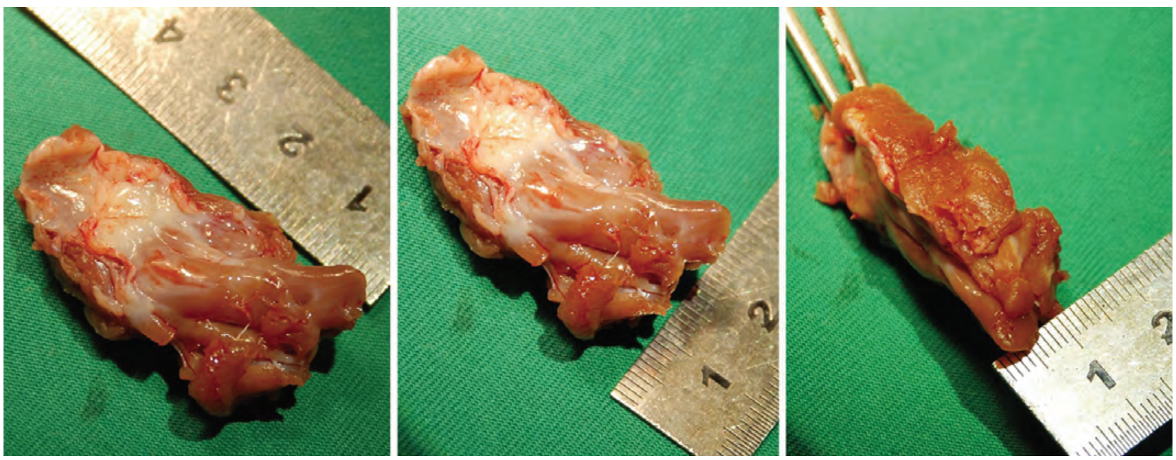

**Figure 6:** The resected muscle sample weighed 6.2 g (about 4 cm × 2 cm × 1.5 cm).



## RESULTS

The clinical data of the 93 consecutive obstructive HCM patients (57 men) with a mean age of 45.78 ± 13.39 (range 11–74) years who underwent TAESM in Fuwai hospital were collected and analysed. Preoperative TTE showed the peak LVOT gradient to be 91.76 ± 25.08 (13–171) mmHg at rest (all >50 mmHg after physical provocation). The mean interventricular septal thickness was 25.39 ± 6.30 mm (15–46). SAM was identified in all (100%) and MR in 73 patients (73 of 93, 78.5%), of whom 41 were moderate level or more.

All the patients underwent TAESM in Fuwai Hospital, and all the surgical procedures of the 93 patients were technically successful. Initial intraoperative TEE showed a decrease in the LVOT gradient in all (pre- vs intraoperatively, 91.76 ± 25.08 vs 14.34 ± 13.44 mmHg, $P < 0.0005$) and a significant improvement in MR (disappeared or mild). Six patients (6 of 93) had a LVOT gradient of 13–50 mmHg at rest and 74–124 mmHg after provocation, all of whom had drug-refractory symptoms after activity. They also underwent myectomy and all had a very good outcome. Further resection was carried out in two patients (2.2%) because intraoperative TEE showed a high LVOT gradient after the initial resection. Six patients had mitral valve replacement (MVR) because of obvious pathological changes of the mitral valve, such as damage by subacute bacterial endocarditis. Besides, another four cases underwent MVR after failed mitral valve plasty (MVP). Finally, SAM disappeared completely in 92 patients; only one (1.1%) still had mild SAM but without mitral-septal contact. Some concomitant surgical procedures were performed in 37 cases (37 of 93, 39.8%), including MVR in 10, MVP in nine, aortic valve replacement in six, tricuspid valve plasty in two, CABG in 18, Modified Maze procedure in three, cardiac tumour resection in two and RVOT reconstruction in one. Twelve patients had more than one concomitant procedure.

The average length of the postoperative stay was 7.8 ± 3.7 days. The 30-day and in-hospital mortalities were 0%. Complete atrioventricular block occurred in three cases (so permanent pacing was needed), complete left bundle branch block in 44, intraventricular conduction delay in 18, complete right bundle branch block (RBBB) in two, transient renal dysfunction in two (so hemodialysis was needed) and transient intra-aortic-balloon-pumping was needed in two. No other severe complications were observed during hospital stay.

**Table 2:** Parameters measured pre- and postoperatively, expressed as mean value (range) or number (%)

| Parameter | Preoperatively | Postoperatively | *P*-value |
|---|---|---|---|
| LVOT peak gradient (mmHg) | 91.76 ± 25.08 | 14.78 ± 14.01 | <0.0005 |
| Mean MR level | 1.35 ± 0.97 | 0.46 ± 0.52 | <0.0005 |
| None (0/4) | 20 | 51 | |
| Mild (1/4) | 32 | 41 | |
| Moderate (2/4) | 30 | 1 | |
| Moderately severe (3/4) | 10 | 0 | |
| Severe (4/4) | 1 | 0 | |
| SAM (*n*, %) | 93 (100%) | 1 (1.1%) | <0.0005 |
| NYHA class | 3.09 ± 0.60 | 1.12 ± 0.32 | <0.0005 |
| I (1/4) | 0 | 81 | |
| II (2/4) | 13 | 12 | |
| III (3/4) | 59 | 0 | |
| IV (4/4) | 21 | 0 | |

Mean mitral regurgitation (MR) levels are scored as 0–4, to define no (0), mild (1), moderate (2), moderately severe (3) or severe regurgitation (4). NYHA class are scored as 1–4, to define classes I–V, respectively.

During a mean follow-up of 10.72 ± 11.02(1–24) months, there were no instances of lethal arrhythmia, myocardial infarction, stroke or death. Until the latest follow-up, all the patients had a significant reduction in limiting symptoms (e.g. shortness of breath) and a significant increase in physical capacity. The mean NYHA functional class decreased from 3.09 ± 0.60 (2–4) preoperatively to 1.12 ± 0.32 at the time of latest follow-up ($P < 0.0005$). Eighty-two patients (NYHA class α, β or χ preoperatively) were free of limiting symptoms (NYHA class I) at the latest follow-up, and 11 (NYHA class β or χ preoperatively) had very mild limitations (NYHA class II). TTE identified that the LVOT turned to be widely patent throughout the cardiac cycle. Significant reductions to a mean level of 14.78 ± 14.01 mmHg were recorded by continuous-wave Doppler in peak instantaneous LVOT gradient. Mitral regurgitation remained absent (51) or at mild-(41)-to-moderate (1) levels. The main echocardiographic and NYHA data are shown in Table 2.

## DISCUSSION

Obstructive HCM is characterized by diastolic dysfunction, dynamic LVOT obstruction and rhythm troubles with risk of sudden death [11]. Generally speaking, the LVOT obstruction is often caused by the basal septum hypertrophy. Moreover, SAM of the mitral valve could result in mitral–septal apposition and incomplete leaflet apposition. As an important phenomenon in the mechanism of pathology, SAM may be caused by, as well as aggravate, the obstruction of LVOT, and would result in mitral valve apparatus distortion and MR. In this group, SAM was present in 100% of the patients preoperatively. Besides, anomalous papillary muscles can also contribute to MR and midcavity obstruction, usually by direct insertion into the mitral valve leaflets [12].

The diagnosis of obstructive HCM is often made by echocardiography and/or magnetic resonance imaging. Echocardiography has been considered the standard for diagnosis and assessment of LVOT obstruction [13]. The morphological features are that patients have a hypertrophied interventricular septum and left ventricle (usually >15 mm in adults, or the equivalent relative to body surface area in children and teenagers), but without any other diseases that may cause secondary hypertrophy. Additionally, the patients may also have other characteristics, such as typical symptoms (exertional dyspnea, palpitations and chest discomfort), electrocardiographic changes (arrhythmia) or positive family history of HCM. LVOT obstruction may be demonstrated by LVOT gradient under TTE or TEE.

The treatment strategy for obstructive HCM is significantly dependent on the degree of symptoms due to obstruction. The benefits and risks of each procedure should be analysed scientifically on the basis of current evidence. It is commonly accepted that medical therapy remains the first-line treatment in the majority of HCM patients [13], but if the peak instantaneous LVOT gradient is ≥50 mmHg (at rest or with provocation) and the symptoms cannot be managed with medications, septal reduction therapy is strongly recommended to avoid sudden death [5, 6]. In this retrospective study, we found that LVOT gradient was low (<50 mmHg) in six patients (six of 93) at rest but became much higher (>50 mmHg) after provocation. These patients all had drug-refractory symptoms after activity and underwent myectomy with a very good outcome. Therefore, some labile obstructive HCM patients also need surgical intervention. A provocation test is very important for patients in order not to miss the diagnosis of obstructive HCM [14].

Patients with persistent symptoms, despite optimal medical therapy, are usually considered candidates for septal reduction therapy. The surgical strategy has been often made depending on the patient's preference, physician's experience as well as some special status in a given situation. Compared with ablation, a longer period for recovery will be needed after TAESM because of thoracotomy and cardiopulmonary bypass. However, more and more experienced cardiac surgeons have reported encouraging results about TAESM during past years, which is considered the therapeutic gold standard in many prestigious cardiac centres today, even if alcohol septal ablation develops as another choice for high-risk patients [15–17]. TAESM can be performed safely with very low mortality and excellent long-term survival, which can be equivalent to general population, because the disease course of HCM has been changed thoroughly [6, 16].

In our opinion, one of the vital factors that directly determines the outcome of TAESM is the surgeon's clinical experience and anatomical knowledge of the LVOT. In experienced centres, the surgical outcome can be excellent [18]. As is mentioned in the 2011 guideline [1], extended Morrow procedure is a challenging operation in cardiac surgery, so there must be a learning curve before a surgeon can perform it perfectly. During the past 30 years, the largest group of Chinese obstructive HCM patients were treated in our institution. We have experienced a tough learning process and have gradually seen remarkable improvement by borrowing ideas from international communications and clinical exploration. According to our clinical practice, we had a morbidity of ∼7.4%, complete heart block (CHB) of ∼7.4% and MVR of 16.7% between 1996 and 2007. Moreover, the postoperative LVOT gradient was at an average level of 24 mmHg [19]. In the past few years, we have gradually improved the operating skills to tailor resection precisely, by properly increasing the extent of myectomy with precise discrimination, correction/resection of aberrant papillary muscles and mitral subvalvular apparatus abnormalities and using headlamps, long scalpels and forceps. This retrospective study shows that a much better clinical outcome, with a mortality of 0% (0/93), CHB rate of 3.2% (3 of 93), MVR of 10.8% and a mean postoperative LVOT gradient of 14.34 ± 13.44 mmHg, has been obtained since October 2009. Especially for the recent 20 cases, we have obtained results better than the average level, with a postoperative LVOT gradient of 1–9 mmHg.

As a significant advantage of TAESM, other associated cardiac diseases can be treated surgically. Patients with or without concomitant surgical procedures can benefit from the operation by means of improved life expectancy and performance status [20]. In this group, concomitant surgical procedures were carried out in 37 patients (39.8%, all for preexisting conditions), including MVP, MVR and CABG. In our clinical practice, coronary angiography was considered a preoperative routine examination for patients over 40, so as to detect coronary atherosclerotic heart disease and myocardial bridge, which might be associated with an unfavourable prognosis in HCM patients and should be treated empirically [21]. So, 18 patients were diagnosed with coronary disease and underwent on-pump CABG immediately after myectomy. All these patients had a good outcome during follow-up.

As mitral valve leaflets and subvalvular apparatus abnormalities play an important role in the pathologies of obstructive HCM, surgical management of the mitral valve has been considered a vital part of myectomy [22]. According to the analysis of preoperative echocardiography in this study, SAM was accessed in all and MR in 73 patients (78.5%), of whom 41 were more than moderate level. For many patients, SAM and MR could disappear or diminish automatically after myectomy. However, some patients had mitral valve abnormities, which also need special surgical treatment during the operations, or it would negatively influence the surgical outcome. For them, mitral valve repair or plasty is recommended as the priority choice [23]. According to our practice, MVR can be avoided in most patients with degenerative MR and HCM, and it is indicated only if the mitral valve cannot be repaired because of severe pathological changes such as endocarditis [24] or of other procedures have failed to relieve the LVOT gradient. In this group, SAM disappeared postoperatively including those who had MVP, except only one still had mild SAM but without mitral-septal contact. In this group, MVR was carried out in 10 cases (10 of 93). Six of them had severely damaged mitral valve, which could not be repaired. While for the other four cases, intraoperative TEE showed that the LVOT gradient and SAM had not been resolved perfectly after initial myectomy and MVP, so they had MVR thereafter.

TAESM can be successfully performed after a history of alcohol ablation treatment. In this group, three cases had histories of alcohol septal ablation performed in the previous 6 months to 4 years. Because the drug-refractory symptoms did not disappear after ablation or recurred later, myectomy was suggested to them when they were readmitted to hospital. They had a successful surgical procedure and uneventful recovery, of whom one had MVR after a failed MVP, the other two had a significant decrease in the LVOT gradient from a preoperative level of 67–133 mmHg (with physiological provocation) to 4–10 mmHg postoperatively. Consequently, a history of alcohol ablation may not adversely affect the surgical outcome of obstructive HCM, but a higher incidence of CHB than in the case of those who underwent only surgical myectomy was observed and reported in another study [10].

Electrocardiographic changes may be one of the main types of complications after TAESM, including left bundle branch block, intraventricular block and CHB. Unlike RBBB, which is more common after ablation, the left bundle branch block developed in nearly half of the septal myectomy patients [3]. Therefore, those who had complete RBBB preoperatively may have a higher risk of CHB after myectomy. In this retrospective study, three patients (3.2%) developed CHB after myectomy and permanent pacing was needed for them, of whom two had a previous history of complete RBBB. Pacing cannot be regarded as a primary treatment for obstructive HCM [25], but after TAESM, it may be needed with a very low probability in some special patients. Therefore, it is necessary to be alert when surgical myectomy is performed in obstructive HCM patients with RBBB.



## CONCLUSION

Excellent survival and very low morbidity were seen in this cohort of patients. TAESM can provide excellent relief from LVOT obstruction in HCM patients, with a good clinical outcome at early and mid-term follow-up. Concomitant cardiac procedures can be performed with TAESM for obstructive HCM and cardiac comorbidities, with low risk and satisfactory clinical results. Electrocardiographic changes may be one of the main types of complications after TAESM.

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