Surgical management of diastolic heart failure after septal myectomy for obstructive hypertrophic cardiomyopathy

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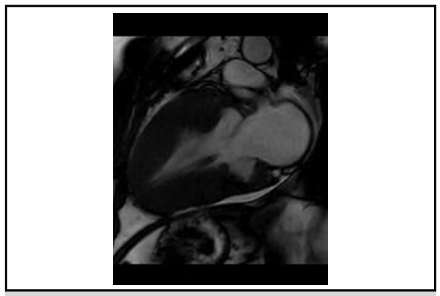
ABSTRACT

Objective: Some patients with obstructive hypertrophic cardiomyopathy may remain limited after surgical relief of the subaortic obstruction. In this report, we describe experience in surgical management of patients with advanced diastolic heart failure symptoms after adequate transaortic septal myectomy for obstructive hypertrophic cardiomyopathy.

Methods: We identified adult patients who presented with heart failure symptoms after previous transaortic septal myectomy for obstructive hypertrophic cardiomyopathy and underwent repeat sternotomy for transapical myectomy to enlarge a small left ventricular cavity. Functional recovery after hospital dismissal was assessed through a questionnaire-based survey.

Results: Six patients with previous septal myectomy presented with New York Heart Association functional class III symptoms. Preoperative transthoracic Doppler echocardiography confirmed adequate relief of subaortic outflow tract obstruction with only trivial or mild mitral valve regurgitation; left atrial volume index was increased at 46 mL/m^2 (range, 44-47 mL/m^2). Following transapical myectomy, the left ventricular diameter was enlarged from 23 mm (range, 21-27 mm) to 29 mm (range, 27-31 mm) at end-systole and from 40 mm (range, 38-42 mm) to 43 mm (range, 42-50 mm) at end-diastole. All the patients were alive after a median follow-up of 0.6 years (range, 0.4-3.5 years), and 5 patients responded to a postoperative survey and indicated improvement in their heart condition compared with functional status before the repeat myectomy.

Conclusions: Patients with diastolic heart failure after septal myectomy for obstructive hypertrophic cardiomyopathy may present with systolic cavity obliteration due to excessive myocardial hypertrophy. Repeat transapical myectomy can enlarge the left ventricular chamber and augment the diastolic volume, which results in improved physical capacity and patient-perceived functional status. (JTCVS Techniques 2022;11:21-6)



Diastolic LV morphology before repeat operation for transapical myectomy.

CENTRAL MESSAGE

Patients with diastolic heart failure after septal myectomy for obstructive hypertrophic cardiomyopathy may benefit from repeat transapical myectomy to enlarge the LV diastolic volume.

PERSPECTIVE

Patients with diastolic heart failure after septal myectomy for obstructive HCM may present with systolic cavity obliteration due to excessive myocardial hypertrophy. Repeat transapical myectomy can enlarge the LV chamber and augment the diastolic volume, which results in improved physical capacity and patient-perceived functional status.

See Commentaries on pages 27 and 29.

Video clip is available online.

Approximately 70% of symptomatic patients with hypertrophic cardiomyopathy (HCM) have left ventricular outflow tract (LVOT) obstruction and may benefit from pharmacological treatment.[1] If patients are severely limited and do not respond well to medical therapy, septal reduction by surgical myectomy may be recommended to eliminate or reduce dynamic LVOT obstruction and associated exertional symptoms. In previous studies, approximately 80% to 96% of patients reported improvement in heart failure

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Abbreviations and Acronyms

AF = atrial fibrillation
EF = ejection fraction
HCM = hypertrophic cardiomyopathy
LV = left ventricular
LVOT = left ventricular outflow tract
TTE = transthoracic echocardiography

symptoms postprocedure.[2-4] However, some patients remain limited despite relief of the subaortic obstruction.

Persistent symptoms after adequate relief of LVOT obstruction may result from residual midventricular obstruction, increased chamber stiffness due to increased muscle stiffness, or the burned-out phase of HCM.[5-7] Limited physical capacity in patients with HCM and preserved systolic function may also be explained by increased chamber stiffness due to decreased left ventricular (LV) end diastolic volume as occurs in some patients with the apical HCM phenotype and patients with LV cavity obliteration.[6,8,9] Such patients with nonobstructive HCM and diastolic heart failure may benefit from transapical myectomy to enlarge the LV diastolic volume as well as stroke volume and reduce end-diastolic pressure.[10,11] In this report, we describe our experience in surgical management of patients with advanced heart failure symptoms after adequate transaortic septal myectomy for obstructive HCM.

PATIENTS AND METHODS

Patient Population and Data Collection

The study population included adult patients who presented with heart failure symptoms after previous transaortic septal myectomy for obstructive HCM and underwent repeat sternotomy for transapical myectomy to enlarge the small LV cavity. Hemodynamic parameters before the initial septal myectomy were measured on 2-dimensional Doppler echocardiography and were obtained from clinical notes available from the index hospitalization. Hemodynamic parameters evaluated before and immediately after the repeat operation was collected from the electronic health record and our internally maintained cardiovascular surgery database. Functional recovery after hospital dismissal was assessed through a questionnaire-based survey initiated in October 2020. Patients were invited to report the extent of exertional symptoms postprocedure. Survey questions inquiring about level of physical activity and self-rated improvement in cardiac function included "Please mark the statement(s) that describe your level of physical activity" (answers included 1. Not limited, 2. Limited by something other than my heart, and 3. Limited by my heart) and "Compared with your heart condition before surgery, how much improvement in your heart function do you feel since your surgery" (answers included 1. A lot, 2. Quite a bit, 3. Some, 4. A little, and 5. Not at all). This study was approved by the Mayo Clinic Institutional Review Board (No. 21-003741, approved May 6, 2021). All patients consented and authorized use of their medical information for clinical research.

Operative Details

The transapical approach to myectomy has been detailed previously.[10,11] In brief, operations were performed through a standard secondary median sternotomy, and all patients were placed on cardiopulmonary bypass with central aortic cannulation. After dissection of the heart from surrounding adhesion and cardioplegic arrest, an apical ventriculotomy was made far enough lateral to the left anterior descending artery to allow closure without vessel compromise. The anterolateral and posteromedial papillary muscles were identified and protected, and septal resection was initiated along the distal ventricular septum and extended from the apical area cephalad. We extended the myectomy proximally to the point where we could easily identify the previous subaortic resection. Additional excision of hypertrophied muscle was removed anteriorly, and significantly hypertrophied papillary muscles were shaved where appropriate to minimize risk of midventricular obstruction. In 1 patient who had prior mitral valve replacement, the hypertrophied papillary muscles were excised to augment ventricular cavity volume.[12]

RESULTS

Patient Characteristics

Median age of the 6 patients (3 women) with HCM who underwent transapical myectomy was 46 years (range, 38-51 years), and the median (interquartile range [IQR]) age at initial operation was 33 years (IQR, 32-38 years) (Table 1). The median interval between the index operation and the repeat myectomy was 7.1 years (IQR, 3.6-9.6 years). Three of the 6 patients underwent the index operation at our clinic. The repeat myectomy procedures were performed between March 2013 and August 2020, with more than half (n = 4) performed during 2020. At the time of evaluation for repeat operation, all the patients had New York Heart Association functional class III symptoms; presenting complaints included exertional dyspnea (n = 6), fatigue (n = 4), and/or chest tightness (n = 3). Three patients aged 49, 51, and 55 years had a history of atrial fibrillation (AF) before transapical myectomy; all of them were women, and all had persistent AF. Two patients underwent concomitant pulmonary vein isolation, and the left atrial appendage was ligated in 1 patient.

Hemodynamic Parameters Before Index Transaortic Septal Myectomy

Hemodynamic data before the initial operation were available for 5 patients. The median (IQR) septal thickness was 21 mm (IQR, 20-22 mm), and the left ventricle was hyperdynamic in most patients (ejection fraction [EF], 75% (IQR, 71%-75%). Resting LVOT gradient was 50 mm Hg (IQR, 39-77 mm Hg), and the provoked LVOT gradient ranged from 56 to 104 mm Hg (n = 3). Mitral valve regurgitation was mild in 3 patients and moderate in the other 2. Imaging tests for comparison of cardiac morphology before the initial and the repeat myectomy were available in 3 patients as shown in the Video 1. Small left ventricle chamber size was not appreciated at the time of initial myectomy in any of the patients.

Hemodynamic Parameters During Repeat Transapical Myectomy

Figure 1 and Figure 2 show the LV morphology during systole and diastole for each of the 6 patients before

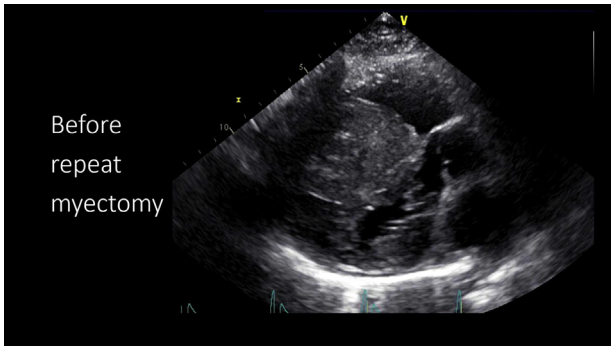
TABLE 1. Characteristic features of the 6 patients

		Index transaortic myectomy				Repeat transapical myectomy					
Patient	Sex	Age (y)	Septal thickness (mm)	EF (%)	Interval (y)	Age (y)	EF (y)	AF	Preoperative LVEDD (mm)	Postoperative LVEDD (mm)	Functional improvement*
1	Male	22	45	80	2	24	84	N	30	43	Unknown
2	Male	33	21	75	3	37	76	N	41	52	Some
3	Female	46	20	75	5	51	65	Y	38	43	A lot
4	Male	33	18	68	9	42	70	N	50	53	A lot
5	Female	39	/	/	10	49	67	Y	38	42	Some
6	Female	31	22	71	24	55	63	Y	42	41	Some

EF, Ejection fraction; *Interval*, interval years between index septal myectomy and repeat transapical myectomy; *AF*, atrial fibrillation; *LVEDD*, left ventricular end-diastolic dimension. *Functional improvement was defined as the extent of functional improvement from survey results as described in the Methods.

transapical myectomy. None of the patients had residual LVOT obstruction at the time of repeat operation. On preoperative transthoracic echocardiography (TTE), the median LV diameter was 23 mm (IQR, 21-27 mm) at end-systole and 40 mm (IQR, 38-42 mm) at end-diastole. Systolic function of the left ventricle was at or above the upper range of normal (EF, 69%; IQR, 66%-75%). The stroke volume index was 43 mL/m^2 (IQR, 34-46 mL/m^2) and the cardiac index was 2.8 L/min/m^2 (IQR, 2.4-3.3 L/min/m^2). Mitral valve regurgitation was mild in all patients except 1, in whom the regurgitation was trivial. The median left atrial volume index, however, was 46 mL/m^2 (IQR, 44-47 mL/m^2) and an apical pouch was identified and repaired in 2 patients.

Postoperatively, the LVEF on TTE decreased to 64% (IQR, 62%-65%) before hospital dismissal. The LV end-systolic diameter was enlarged to 29 mm (IQR, 27-31 mm), and the LV end-diastolic diameter was 43 mm (IQR, 42-50 mm). The extent of mitral valve regurgitation remained mild in 3 patients and was reduced to trivial in the other 3.



VIDEO 1. Comparison of cardiac morphology before the initial and the repeat myectomy available in 3 patients. Video available at: https://www.jtcvs.org/article/S2666-2507(21)00744-6/fulltext.

Surgical Outcomes and Functional Recovery

Surgical specimens were examined by cardiovascular pathologists as described previously.[13] The median weight of muscle specimens was 9.8 g (IQR, 9.2-13.6 g). Myocyte hypertrophy was moderate in 1 patient and severe in the other 5. Four patients were found to have moderate or severe interstitial fibrosis, and in the other 2 patients, interstitial fibrosis was mild. No coexisting infiltrative pathologies were identified.

The median crossclamp time for the repeat operation was 26 minutes (IQR, 18-37 minutes) and the median cardiopulmonary bypass time was 46 minutes (IQR, 29-59 minutes). Patients stayed in the hospital for a median of 6.0 days (IQR, 6.5-7.8 days). No patient had sternal wound infection, reoperation for bleeding, pneumonia, renal failure, or permanent pacemaker implantation during the hospital stay postprocedure.

At a median follow-up of 0.6 years (IQR, 0.4-3.5 years), all the patients were alive. Five patients responded to the survey described above. Four of these 5 patients were surveyed 2 to 8 months after the transapical myectomy. Compared with the functional status before the repeat myectomy, patients reported some (n = 3) or a lot (n = 2) of improvement in their heart condition postprocedure, but 2 patients remained limited with shortness of breath on walking 2 blocks or less. Overall, 1 patient reported no physical limitation, and another patient was limited by a noncardiac condition. In the other 3 patients, physical capacity was perceived to be limited by the heart; all of these patients had a preoperative history of persistent AF.

DISCUSSION

Septal myectomy is useful to relieve LVOT obstruction and improve both pulmonary hypertension and LV filling in patients with obstructive HCM.[14-16] But reducing the basal septal thickness and associated LVOT obstruction may not improve health status in some patients with HCM.[2] In this report, we describe a cohort of patients with persistent or recurrent symptoms after conventional

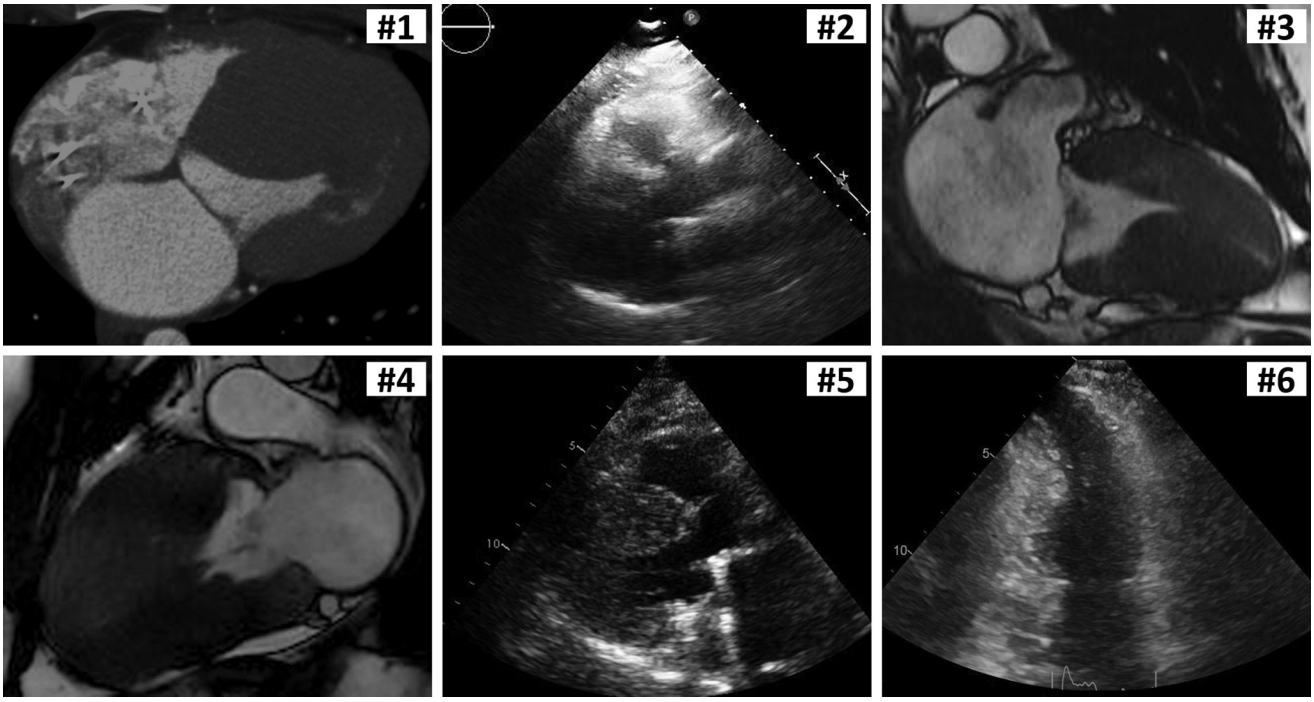


FIGURE 1. Left ventricular morphology during systole for each of the 6 patients before repeat transapical myectomy.

transaortic septal myectomy who appeared to have reduced LV volume due to excessive myocardial hypertrophy beyond the basal segment. Transapical myectomy to enlarge the LV cavity led to clinical improvement in the majority of patients.

Limited exercise capacity in many patients with HCM correlates with inability to increase LV stroke volume and cardiac output.[17,18] Because patients with HCM generally have higher than normal LVEF, the ability to increase LV end-diastolic volume is important in augmentation of stroke

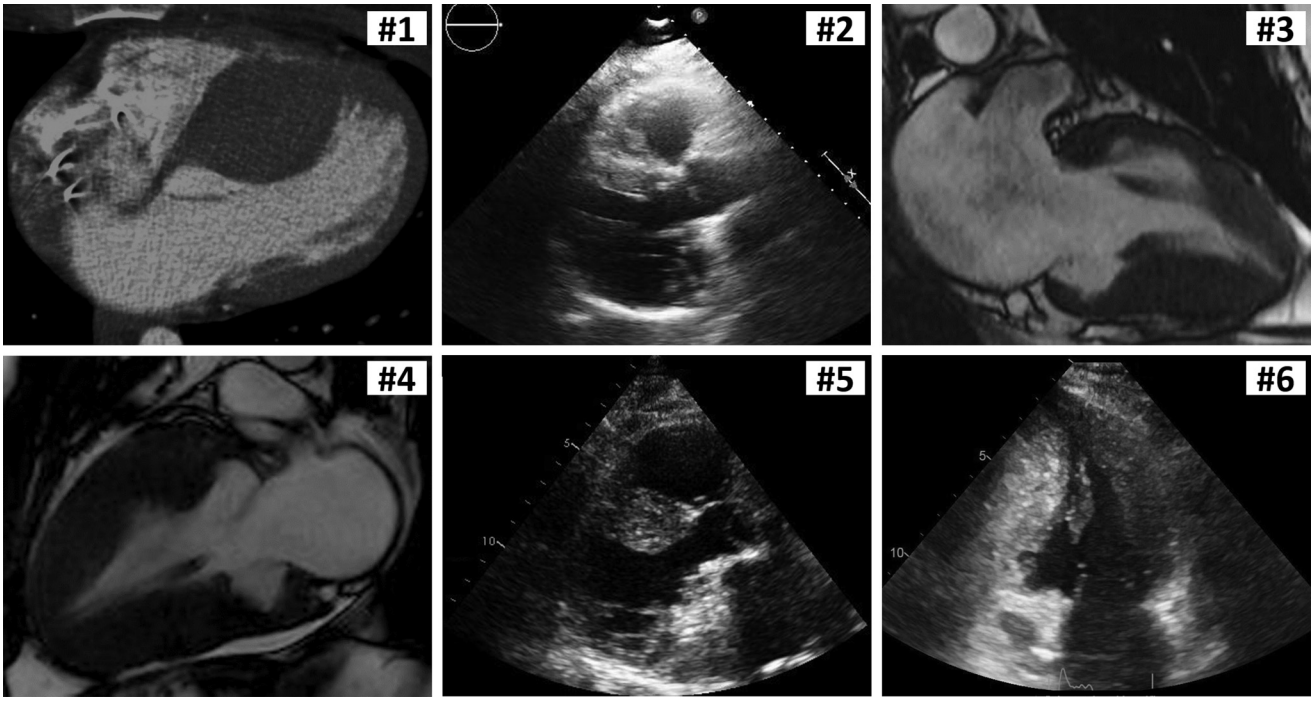


FIGURE 2. Left ventricular morphology during diastole for each of the 6 patients before repeat transapical myectomy.

volume.[18] However, increased myocardial hypertrophy in HCM may result in decreased LV diastolic volume, which leads to chamber stiffness reflected by a leftward shift of the LV diastolic pressure-volume curve compared with normal controls.[19] Chamber stiffness may be influenced by intrinsic muscle stiffness, but this appears to be less important than the volume-mass effect in HCM.[19] Nevertheless, pathological assessment of the surgical specimens suggested that the proportions of moderate or severe myocardial hypertrophy (100%) and interstitial fibrosis (66.7%) seemed slightly greater in the present study than previously reported in patients with obstructive HCM (myocardial hypertrophy 97.3% and interstitial fibrosis 32.4%),[13] and the influence of myocardial stiffness in patients with nonobstructive HCM remains to be elucidated.

Previously we reported that apical myectomy can augment LV stroke volume and improve symptoms in 76% to 98% of patients with nonobstructive HCM and diastolic heart failure.[10,11] In agreement with previous findings, all patients in the present study reported self-perceived improvement in cardiac function. However, 3 female patients who had a preoperative history of persistent AF considered themselves to be limited by their hearts. Indeed, AF is a significant predictor of severe symptoms at clinical evaluation, and patients with nonobstructive HCM are more susceptible to AF than patients with the obstructive phenotype.[20] Klarich and colleagues[21] found that the likelihood of having AF was 2.3 times as high at baseline and 1.8 times as high during follow-up in women with nonobstructive HCM.[21] The confounding effect of cardiovascular comorbidities on symptom improvement after myectomy needs further investigation.

Substantially compromised LV volume may not be apparent in some patients with obstructive HCM undergoing septal myectomy. Alternatively, late development of systolic cavity obliteration may reflect late LV remodeling.[22] Progression of LV hypertrophy in HCM is usually reported in children and adolescents and anecdotally in adults. With up to 7 years of follow-up, Maron and colleagues[23] observed 6 to 23 mm increase in the LV wall thickness among 22 patients aged 4 to 15 years.[23] In adult patients, Flett and colleagues[24] reported a 47-year-old male with progressively increased wall thickness from 12 mm to 18 mm during 6 years of follow-up, which was accompanied by a continuously elongated length of apical obliteration from 25 mm to 41 mm.[24] It should be noted that patients in our current report were considerably younger at index operation in comparison to the overall population who have undergone transaortic septal myectomy for obstructive HCM at our clinic.[25] It appears that the chance of LV remodeling is greater in younger adults with HCM compared with older patients.

In other patients, examination of the cardiac images suggested that a small LV cavity was present at the time of the index transaortic septal myectomy. In the retrospective review, we observed apposition of the papillary muscles and the hypertrophied interventricular septum in the distal LV chamber during systole, but obstructive gradients at the mid ventricle were barely detectable. In contrast to the typical midventricular variant of HCM, maximum instantaneous midventricular gradients at the time of myectomy, if present, were <30 mm Hg with provocation in all the patients in this report. The small LV cavity was recognized in all but 1 patient on TTE before transapical myectomy, and LV end-diastolic diameter was below the lower limit of normal range in 4 patients. Indeed, given the apical predominant hypertrophy of this cohort and known heterogeneous distribution of LV hypertrophy in HCM, LV end-diastolic diameter alone may not be sufficient to define a small LV cavity. Furthermore, imaging the apex is sometimes challenging through standard echocardiogram. Hence, advanced imaging techniques such as cardiac magnetic resonance imaging or cardiac computed tomography may be useful to appreciate the anatomical structure of the distal LV and aid in the measurement of LV volume.

Arguably, heart failure symptoms in most patients with obstructive HCM can be more readily ascribed to LVOT obstruction than small LV cavity. However, if abnormalities in the stroke volume and/or diastolic function can be simultaneously recognized as a result of excessive myocardial hypertrophy, prophylactic LV enlargement in addition to the subaortic septal resection may be beneficial.[26]

Several limitations of the current report should be acknowledged. First, this patient review is subject to the limitations and biases commonly present in every retrospective study. Patients included in this series underwent repeat transapical myectomy before the study was initiated. Therefore, available cardiac evaluation and imaging tests were limited only if clinically necessary. Postoperative follow-up was conducted through direct mail and phone contact. The response rate can be influenced by patient characteristics, geographical differences, and changes in phone number or physical location. LV volumes are difficult to quantify in patients with the phenotypes we have described. Linear measurement of the LV dimension on echocardiography is completed at the tips of mitral leaflets,[27] which may not capture the extent of volume obliteration near the apex. Identification of LV cavity obliteration is largely subjective but is well recognized.[7,28] Estimated stroke volume and cardiac index at rest may not provide comprehensive insight into the mechanism of physical limitation. Our observations are limited by the small sample in this series, but the experience has led to increasing use of combined transaortic and transapical myectomy in our practice and may be useful to other surgeons who encounter patients with obstructive HCM. This study illustrates a newly recognized patient cohort who may benefit from transapical myectomy after standard transaortic septal myectomy.

The majority of patients underwent the repeat procedure within a year before this study was initiated, which results in limited length of follow-up.

CONCLUSIONS

Patients with diastolic heart failure after septal myectomy for obstructive HCM may present with reduced LV stroke volume and systolic cavity obliteration due to increased chamber stiffness with excessive myocardial hypertrophy. Repeat transapical myectomy can enlarge the LV chamber and augment the diastolic volume, which results in improved physical capacity and patient-perceived functional status.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: hypertrophic cardiomyopathy, diastolic heart failure, repeat operation, transapical myectomy