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Chapter 3

Contemporary Surgical Treatment for Hypertrophic Cardiomyopathy

Takashi Murashita

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Abstract

Hypertrophic cardiomyopathy is the most common cause of sudden death in young athletes. Surgical septal myectomy is highly effective for the patients with hypertrophic obstructive cardiomyopathy, which is refractory to medical treatment. The perioperative mortality rate for isolated septal myectomy is less than 1% in high volume centers. The long-term outcomes have been reported to be outstanding with >90% of patients being free of significant symptoms and most being able to return to a normal lifestyle. There is a documented survival benefit after surgical septal myectomy. There is a wide variation of pathophysiology in hypertrophic cardiomyopathy including diffuse midventricular obstruction or subvalvular abnormalities. Several surgical approaches have been applied in accordance with the pathophysiology, such as transaortic, transapical, and transmitral septal myectomy. There is a controversy how to manage concomitant mitral valve regurgitation. The most recent Society of Thoracic Surgeons database showed that operative mortality of concomitant septal myectomy and mitral valve operations was double compared with isolated septal myectomy.

Keywords: hypertrophic cardiomyopathy, septal myectomy, surgical outcomes

1. Introduction

Hypertrophic cardiomyopathy is a genetic disorder of the heart muscle, resulting in a small left ventricular cavity and marked hypertrophy of the myocardium [1, 2]. Although many patients remain asymptomatic throughout life, some patients develop symptoms such as dyspnea,

angina, and syncope. Hypertrophic cardiomyopathy is the most common cause of sudden death in trained athletes [3].

The mainstay of therapy for hypertrophic cardiomyopathy has been the combination of lifestyle changes and medical therapy including beta blockers or calcium channel blockers. However, there remain patients who are refractory to medical treatment. For these patients, surgical septal reduction therapy, called septal myectomy, is indicated with class I indication [4]. When surgery is contraindicated because of serious comorbidities or advanced age, alcohol septal ablation is recommended with class IIa indication [4]. Dual-chamber pacing has also been used for the relief of outflow tract obstruction in patients whom both surgical septal myectomy and alcohol ablation are considered to have unacceptable risk. The treatment algorithm for the management of hypertrophic cardiomyopathy patients is shown in **Figure 1**.

Given the duration of experience and documented evidence of long-term outcomes, surgical septal myectomy is the preferred treatment for most patients who need invasive therapy. Operator and institutional experience is a key factor of successful surgical outcomes. The guidelines suggested that surgical treatment should be performed only by experienced operators, which were defined as an individual operator with a cumulative case volume of at least 20 procedures or an individual operator who is working in a dedicated hypertrophic cardiomyopathy program with a cumulative total of at least 50 procedures [4].

Compared with surgical septal myectomy in which the hypertrophic muscle is directly visualized and resected, successful alcohol ablation is dependent on the variable septal artery anatomy, which may not supply the targeted are of the septum in up to 20–25% [4].

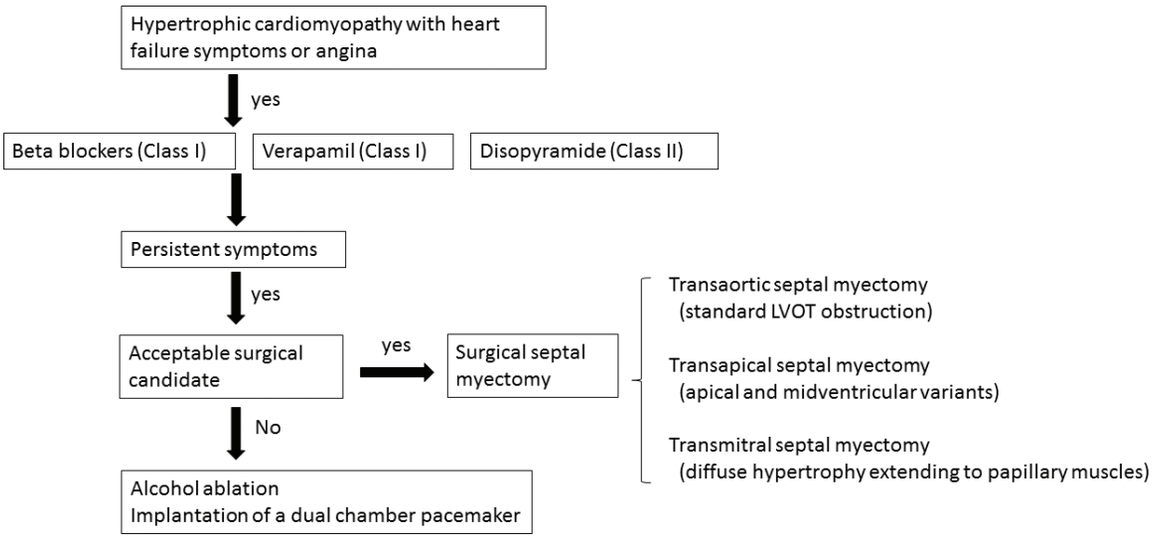

Figure 1. Treatment algorithm for the management of hypertrophic cardiomyopathy patients. LVOT, left ventricular outflow tract. **Figures 2–5** were cited from the study of Price et al, but **Figure 1** was not cited from them.

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2. Surgical septal myectomy

2.1. Historical perspective of septal myectomy

The attempts of surgical correction for HCM were started in the late 1950s. One of the earliest septal myectomy was performed by Cleland and colleagues in 1958. They reported a series of 12 cases of septal myectomy in 1964, and there were three operative deaths [5].

Septal myectomy is also called Morrow operation, as it was reported by Morrow and Brockenbrough in 1961 [6]. They reported two cases of successful subaortic ventriculomyotomy via a transaortic approach for severe symptomatic hypertrophic subaortic stenosis.

Kirklin and Ellis reported two cases of successful surgical relief of diffuse subvalvular aortic stenosis via a left ventriculotomy in 1961 [7].

2.2. Transaortic septal myectomy

The initial technique reported by Morrow and colleagues involved excising a rectangular segment of the septal myocardium beneath the right coronary cusp with approximately 3–4 cm long, 1 cm wide, and 1.5 cm deep [8].

In recent years, the standard transaortic procedure has evolved into an extended septal myectomy. Following the initiation of cardiopulmonary bypass, exposure of the left ventricle is obtained via an oblique aortotomy. The completed myectomy extends from the subaortic level, about 5 mm below the aortic annulus to the midventricular level, opposite the base of the anterior papillary muscle of the mitral valve, for a total length of about 7 cm (**Figure 2**).

Ashikhmina et al. reported the importance of direct intraoperative measurement of pressures in the left ventricle and aorta [9]. After cannulation of the aorta, a 2.5 inch, 22-gauge spinal needle is placed into the aorta close to the aortic cannula and another 3.5 inch, 22-gauge spinal needle is placed into the left ventricle through right ventricular free wall and septum.

Nguyen et al. reported that transaortic septal myectomy can be achieved for relatively thin ventricular septum (<18 mm) with low risk of iatrogenic ventricular septal defect (0.3%) [10]. Brown et al. reported that septal thickness or left ventricular mass was not associated with death [11].

2.3. Transapical septal myectomy

Apical hypertrophic cardiomyopathy is a relatively rare form of hypertrophic cardiomyopathy. Eriksson et al. reported that this type of hypertrophic cardiomyopathy is not associated with sudden cardiac death and has a benign prognosis; nevertheless, one of third of these patients experience cardiovascular complications such as myocardial infarction and arrhythmias [12].

For these patients, transaortic septal myectomy is not always effective. Schaff et al. described a technique for resection of hypertrophic apical myocardium via an apical ventriculotomy

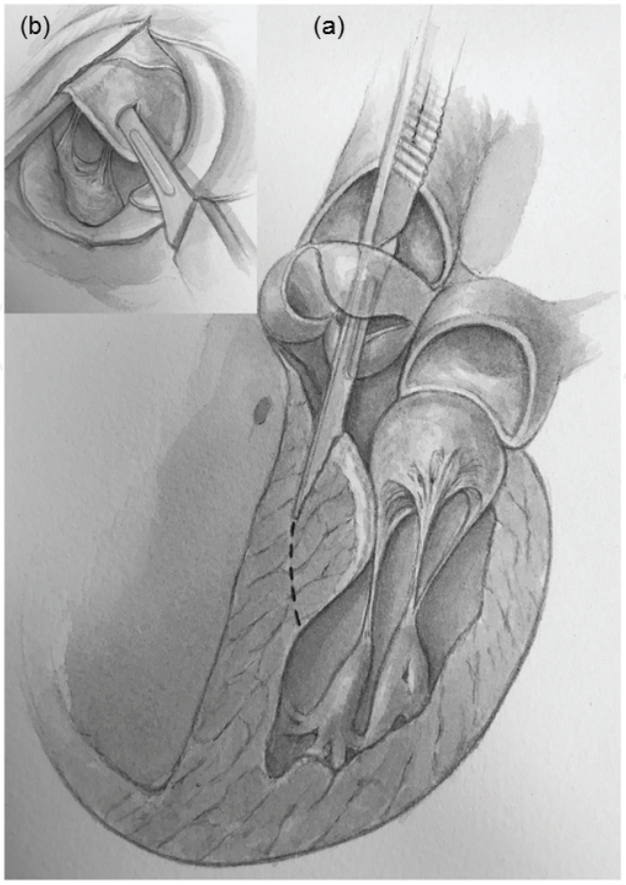

Figure 2. (a) Extended basal septal myectomy via supravalvular aortotomy. (b) Surgeon's view through the aortotomy, identifying the hypertrophic septum immediately inferior to the right coronary aortic valve cusp. Figure was cited from the study of Price et al. with their permission [49].

[13, 14]. A 6-cm longitudinal incision is made lateral to the left anterior descending artery beginning at the apical dimple. The goal of apical resection is to sufficiently enlarge the left ventricular cavity and shaving of the excess papillary muscle can be carried out if necessary (**Figure 3**).

Kunkala et al. reviewed 56 patients with midventricular obstruction [15]. Septal myectomy was performed through transaortic approach in 5, transapical approach in 32, and a combination of these in 19. There were no complications unique to the apical incision, and 5-year survival rate was similar to the expected one. Hang et al. also reported the effectiveness of combined transaortic and transapical approach to complex septal hypertrophy [16].

2.4. Transmitral septal myectomy

Transmitral septal myectomy was first described in 1963 by Lillehei and Levy [17]. This approach is indicated for patients with diffuse hypertrophy extending to or below the papillary muscles with mid-ventricular obstruction, which is not amenable to repair via a transaortic myectomy. Gutermann et al. reported 12 cases of transmitral septal myectomy with one mortality [18]. In the transmitral myectomy, the anterior mitral leaflet is widely detached

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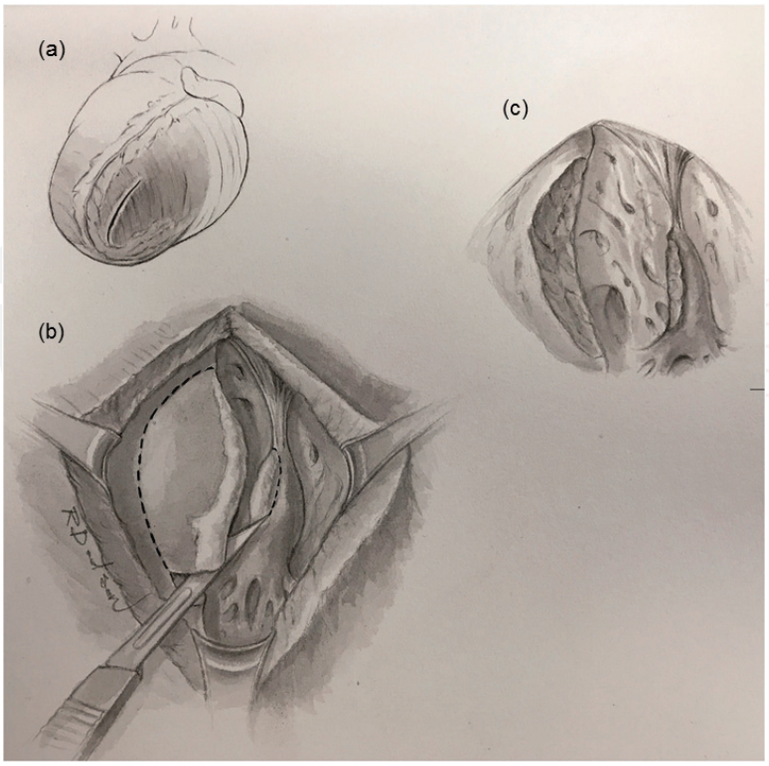

Figure 3. (a) Apical incision lateral to the left anterior descending coronary artery, ensuring there is enough myocardium remaining to leave the left anterior descending coronary artery uninvolved in the suture line. (b) Surgeon's view through the apical incision, identifying the hypertrophic myocardium and potentially hypertrophic papillary muscles. (c) Surgeon's view after resection, with an adequately resected left ventricular cavity. Figure was cited from the study of Price et al. with their permission [49].

from commissure to commissure, but the commissures are left intact. That allows an easy myectomy toward the base of the anterior papillary muscle, with mobility fully restored (**Figure 4**). The abnormal chordae from the septum to the anterior papillary muscle can be divided. After all intraventricular repairs are complete, the continuity of anterior mitral leaflet was restored either with continuous suture or with augmentation using an autologous pericardial patch.

Transmitral approach may provide excellent exposure to septal hypertrophy in patients with a narrow aorta which limits the transaortic view [19].

There are several case reports of minimally invasive transmitral septal myectomy through right thoracotomy, either with video-assisted methods or robotic platform [20–23].

2.5. Surgical outcomes and complications

Maron et al. reported the operative mortality data from five high-volume centers in North America [24]. Over the 15-year period, 3700 isolated septal myectomy operations were performed, and operative mortality was only 0.4%. In the meantime, it is expected that the surgical expertise of the high-volume centers would be passed down to regional multidisciplinary centers as well [25].

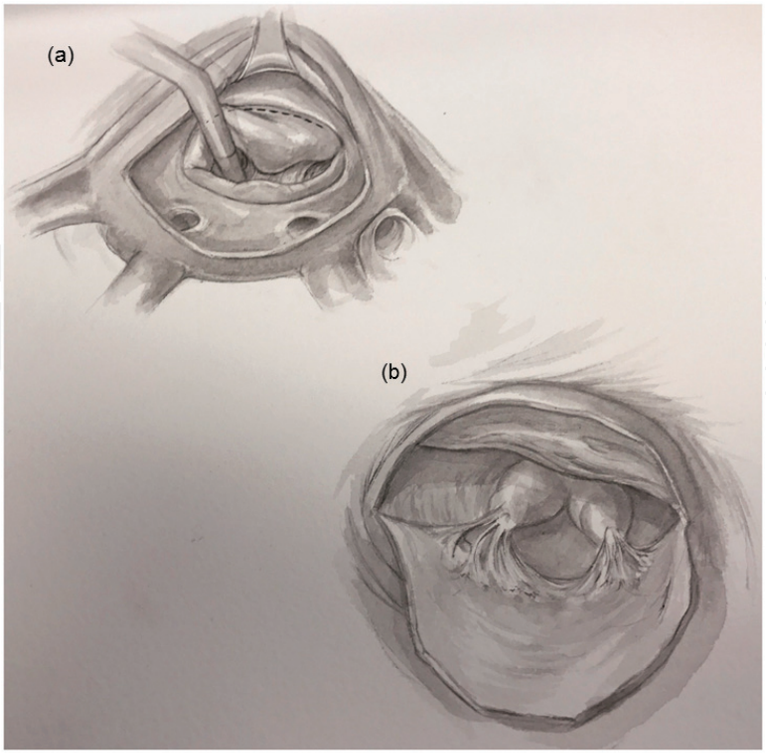

Figure 4. (a) View of the atrial surface of the mitral valve, with the dashed line representing the incision line in the anterior mitral valve leaflet. (b) Following incision and release of the anterior mitral valve leaflet, a broad view of the interventricular septum, down to the left ventricular apex, is obtained. Figure was cited from the study of Price et al. with their permission [49].

Kotkar et al. reviewed over two decades of surgical experience at Mayo Clinic [26]. More than 3000 patients underwent septal myectomy, and risk of hospital death after isolated septal myectomy was <1%. Postoperative complications such as iatrogenic ventricular septal defect and complete heart block requiring permanent pacemaker occurred infrequently (0.3 and 2%, respectively).

Parry et al. reviewed one surgeon's experience of septal myectomy for 211 patients at Toronto General Hospital [27]. The in-hospital mortality was 0.5% and 5-year survival rate was 98.1%.

According to the Society of Thoracic Surgeons database, 3452 septal myectomy operations were performed from July 2014 through December 2016, in the United States. Emergency status, endocarditis, aortic stenosis, and planned aortic valve operations were excluded, but concomitant coronary artery bypass was included. In the final cohort of 2038 patients, 1315 (65%) received septal myectomy alone, and 723 (35%) had septal myectomy with concomitant mitral operations. The median number of annual cases per center was 2 (range 1–435). Operative mortality and major morbidity were lower in isolated septal myectomy group than septal myectomy plus mitral operations (1.5% vs. 3.0%, $p = 0.03$; and 10.6% vs. 21.4%, $p < 0.001$, respectively). Postoperative iatrogenic ventricular septal defect and complete heart block requiring permanent pacemaker were rare (0.8 and 3.4%, respectively in isolated septal myectomy, and 1.8 and 4.1% in septal myectomy plus mitral operations) [28].

2.6. Long-term outcomes of septal myectomy and its impact on cardiac function

Ommen et al. reviewed the experience of Mayo Clinic and studied the impact of surgical septal myectomy on long-term survival [29]. The 1-year, 5-year, and 10-year survival was 98, 96, and 83%, respectively, and they did not differ from those of the general population. They also stated that myectomy significantly improved all-cause mortality, obstructive cardiomyopathy-related mortality, and sudden cardiac death.

Woo et al. reviewed 338 patients who underwent septal myectomy at Toronto General Hospital and reported the excellent long-term survival with 1-year, 5-year, and 10-year survival of 98, 95, and 83%, respectively [30].

Deb et al. studied the impact of septal myectomy to left ventricular remodeling after surgery [31]. They found a significant decrease in the left ventricular mass index which occurred early after surgery and persisted beyond 2 years of follow-up.

Geske et al. reported that septal myectomy is associated with improvement in pulmonary hypertension, and it was most pronounced in patients with moderate or severe pulmonary hypertension [32].

In patients with hypertrophic cardiomyopathy, latent left ventricular outflow obstruction, which is defined as gradient <30 mmHg at rest and that increases to >50 mmHg with provocation, has been recognized important recently. Schaff et al. suggested that surgery should be offered to these patients [33].

2.7. Management of concomitant papillary muscle abnormalities

There is a subset of patients in whom the mitral valve and subvalvular apparatus such as papillary muscles and chordae play a significant role in creating the dynamic obstructive process [34–36]. Klues et al. reported that 66% of the patients with hypertrophic cardiomyopathy had a constellation of structural malformations, including increased leaflet area and elongation of the leaflets or anomalous papillary muscle insertion directly into anterior mitral leaflet, in mitral valve [34].

Minakata et al. reviewed 291 patients who underwent septal myectomy, and 56 (19.2%) had anomalous mitral subvalvular apparatus [37]. These anomalies were successfully treated with resection of anomalous chordae or relief of papillary muscle fusion, and no patients required mitral valve replacement.

Several reports described other surgical techniques to treat subvalvular abnormalities.

Redaelli et al. reported good outcomes of septal myectomy combined with papillary muscle repositioning for patients with abnormal papillary muscle morphology [38].

Ferrazzi et al. reported good outcomes of septal myectomy combined with a secondary chordal cutting for patients with thickened anomalous chordae [39].

2.8. Management of concomitant mitral regurgitation

Mitral valve leaflets play an important role in the pathophysiology of left ventricular outflow tract obstruction. Systolic anterior motion of the mitral apparatus narrows left ventricular outflow tract, and in many patients, leads to mitral regurgitation. There is a controversy how to treat concomitant mitral regurgitation at the time of septal myectomy. Ideally adequate septal myectomy can get rid of not only systolic anterior motion, but also mitral regurgitation. However, some groups have advocated that mitral valve replacement is necessary when mitral regurgitation is severe [40, 41].

Hong et al. reviewed the experience of septal myectomy operations at Mayo Clinic and concluded that mitral regurgitation related to systolic anterior motion of the mitral valve is relieved by septal myectomy alone in most cases, therefore, concomitant mitral operation is not necessary unless intrinsic mitral valve disease is present [42].

Balaram et al. suggested adding anterior mitral leaflet plication to septal myectomy when patients have long anterior leaflet (≥3 cm) and systolic anterior motion [43–45]. They call their method as "resection-plication-release" method (**Figure 5**). They have reported excellent outcomes using their technique.

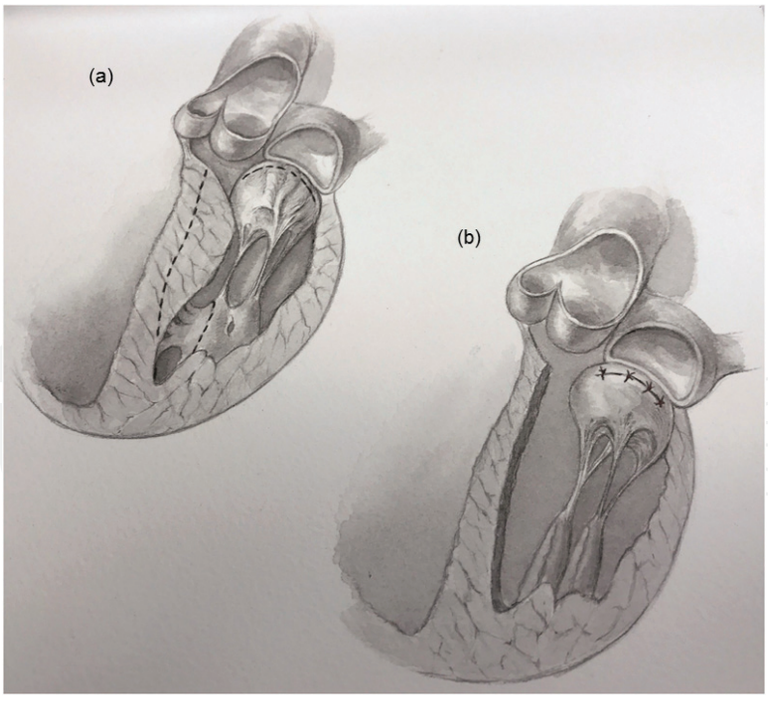

Figure 5. (a) The resection-plication-release method identifies areas of left ventricular outflow tract obstruction, including the hypertrophic septum, abnormal papillary muscle attachments, and an elongated anterior mitral valve leaflet. (b) Following the resection-plication-release procedure, the hypertrophic septum is resected, the abnormal papillary muscle attachments are released, and the elongated anterior mitral valve leaflet is plicated. Figure was cited from the study of Price et al. with their permission [49].

As the Society of Thoracic Surgeons database showed, concomitant mitral operations were performed in one-third of the cases in the United States. Operative mortality of concomitant septal myectomy and mitral operations was double compared with isolated septal myectomy (3.0% vs. 1.5%). However, postoperative grade 3–4 mitral regurgitation was found more frequently in isolated septal myectomy than combined septal myectomy and mitral operations (10.6% vs. 5.8%, $p < 0.0001$). Following risk adjustment, the odds ratio for composite mortality and morbidity was not significant for mitral valve replacement vs. repair at 1.43 [0.9–2.2] ($p = 0.0991$) [28].

2.9. Recurrent obstruction

The recurrent obstruction after surgical myectomy is reported to be rare.

Minakata et al. reviewed 610 septal myectomies at Mayo Clinic between 1975 and 2003, and 13 patients underwent redo septal myectomy [46]. The interval between initial myectomy and redo myectomy ranged from 13 months to 11 years. The mechanism for recurrent obstruction was limited myectomy at the initial operation in 11, septal hypertrophy at the midventricular level in 8, and anomalous papillary muscle in 3.

Cho et al. also reviewed the surgical series at Mayo Clinic and stated that inadequate length of septal excision was associated with residual and recurrent obstruction [47].

Smedira et al. reviewed 323 patients who underwent isolated septal myectomy at Cleveland Clinic, and there were 10 cardiomyopathy-related reoperations; 4 redo myectomy, and 6 mitral valve procedure [48].

3. Conclusions

Surgical septal myectomy provides a survival benefit to patients with drug-refractory hypertrophic cardiomyopathy. It also has a positive effect on patients' quality of life and cardiac function. According to the variation of pathology, appropriate surgical approach and technique should be applied. The recent study based on the national database showed surgical mortality doubles when concomitant mitral procedures are done at the time of septal myectomy. Careful decision making should be done in treating concomitant mitral regurgitation.

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References

[1] Maron BJ, Maron MS. Hypertrophic cardiomyopathy. Lancet. 2013;**381**:242-255. DOI: 10.1016/S0140-6736(12)60397-3

[2] Nishimura RA, Holmes DR Jr. Clinical practice. Hypertrophic obstructive cardiomyopathy. The New England Journal of Medicine. 2004;**350**:1320-1327. DOI: 10.1056/NEJMcp030779

[3] Maron BJ. Sudden death in hypertrophic cardiomyopathy. Journal of Cardiovascular Translational Research. 2009;**2**:368-380. DOI: 10.1007/s12265-009-9147-0

[4] Gersh BJ, Maron BJ, Bonow RO, Dearani JA, Fifer MA, Link MS, Naidu SS, Nishimura RA, Ommen SR, Rakowski H, Seidman CE, Towbin JA, Udelson JE, Yancy CW, American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons. 2011 ACCF/AHA guideline for the diagnosis and treatment of hypertrophic cardiomyopathy: A report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. Circulation. 2011;**124**: 783-831. DOI: 10.1161/CIR.0b013e318223e230

[5] Cleland WP. The surgical management of obstructive cardiomyopathy. Proceedings of the Royal Society of Medicine. 1964;**57**:446-448

[6] Morrow AG, Brockenbrough EC. Surgical treatment of idiopathic hypertrophic subaortic stenosis: Technic and hemodynamic results of subaortic ventriculomyotomy. Annals of Surgery. 1961;**154**:181-189

[7] Kirklin JW, Ellis FH Jr. Surgical relief of diffuse subvalvular aortic stenosis. Circulation. 1961;**24**:739-742

[8] Morrow AG, Reitz BA, Epstein SE, Henry WL, Conkle DM, Itscoitz SB, Redwood DR. Operative treatment in hypertrophic subaortic stenosis. Techniques, and the results of pre and postoperative assessments in 83 patients. Circulation. 1975;**52**:88-102

[9] Ashikhmina EA, Schaff HV, Ommen SR, Dearani JA, Nishimura RA, Abel MD. Intraoperative direct measurement of left ventricular outflow tract gradients to guide surgical myectomy for hypertrophic cardiomyopathy. The Journal of Thoracic and Cardiovascular Surgery. 2011;**142**:53-59. DOI: 10.1016/j.jtcvs.2010.08.011

[10] Nguyen A, Schaff HV, Nishimura RA, Dearani JA, Geske JB, Lahr BD, Ommen SR. Does septal thickness influence outcome of myectomy for hypertrophic obstructive cardiomyopathy? European Journal of Cardio-Thoracic Surgery. 2018;**53**:582-589. DOI: 10.1093/ejcts/ezx398

[11] Brown ML, Schaff HV, Dearani JA, Li Z, Nishimura RA, Ommen SR. Relationship between left ventricular mass, wall thickness, and survival after subaortic septal myectomy for hypertrophic obstructive cardiomyopathy. The Journal of Thoracic and Cardiovascular Surgery. 2011;**141**:439-443. DOI: 10.1016/j.jtcvs.2010.04.046

[12] Eriksson MJ, Sonnenberg B, Woo A, Rakowski P, Parker TG, Wigle ED, Rakowski H. Long-term outcome in patients with apical hypertrophic cardiomyopathy. Journal of the American College of Cardiology. 2002;**39**:638-645

[13] Schaff HV, Brown ML, Dearani JA, Abel MD, Ommen SR, Sorajja P, Tajik AJ, Nishimura RA. Apical myectomy: A new surgical technique for management of severely symptomatic patients with apical hypertrophic cardiomyopathy. The Journal of Thoracic and Cardiovascular Surgery. 2010;**139**:634-640. DOI: 10.1016/j.jtcvs.2009.07.079

[14] Said SM, Schaff HV, Abel MD, Dearani JA. Transapical approach for apical myectomy and relief of midventricular obstruction in hypertrophic cardiomyopathy. Journal of Cardiac Surgery. 2012;**27**:443-448. DOI: 10.1111/j.1540-8191.2012.01475.x

[15] Kunkala MR, Schaff HV, Nishimura RA, Abel MD, Sorajja P, Dearani JA, Ommen SR. Transapical approach to myectomy for midventricular obstruction in hypertrophic cardiomyopathy. The Annals of Thoracic Surgery. 2013;**96**:564-570. DOI: 10.1016/j.athoracsur.2013.04.073

[16] Hang D, Schaff HV, Ommen SR, Dearani JA, Nishimura RA. Combined transaortic and transapical approach to septal myectomy in patients with complex hypertrophic cardiomyopathy. Journal of Thoracic and Cardiovascular Surgery. 2017. DOI: 10.1016/j.jtcvs.2017.10.054

[17] Lillehei CW, Levy MJ. Transatrial exposure for correction of subaortic stenosis. Journal of the American Medical Association. 1963;**186**:8-13

[18] Gutermann H, Pettinari M, Van Kerrebroeck C, Vander Laenen M, Engelen K, Fret T, Dion RA. Myectomy and mitral repair through the left atrium in hypertrophic obstructive cardiomyopathy: The preferred approach for contemporary surgical candidates? The Journal of Thoracic and Cardiovascular Surgery. 2014;**147**:1833-1836. DOI: 10.1016/j.jtcvs.2013.07.024

[19] Matsuda H, Nomura F, Kadoba K, Taniguchi K, Imagawa H, Kagisaki K, Sano T. Transatrial and transmitral approach for left ventricular myectomy and mitral valve plication for diffuse-type hypertrophic obstructive cardiomyopathy: A novel approach. The Journal of Thoracic and Cardiovascular Surgery. 1996;**112**:195-196

[20] Casselman F, Vanermen H. Idiopathic hypertrophic subaortic stenosis can be treated endoscopically. The Journal of Thoracic and Cardiovascular Surgery. 2002;**124**:1248-1249

[21] Bayburt S, Senay S, Gullu AU, Kocyigit M, Karakus G, Batur MK, Alhan C. Robotic septal myectomy and mitral valve repair for idiopathic hypertrophic subaortic stenosis with systolic anterior motion. Innovations (Phila). 2016;**11**:146-149. DOI: 10.1097/IMI.0000000000000249

[22] Khalpey Z, Korovin L, Chitwood WR Jr, Poston R. Robot-assisted septal myectomy for hypertrophic cardiomyopathy with left ventricular outflow tract obstruction. The Journal of Thoracic and Cardiovascular Surgery. 2014;**147**:1708-1709. DOI: 10.1016/j.jtcvs.2013.12.017

[23] Kim HR, Yoo JS, Lee JW. Minimally invasive trans-mitral septal myectomy to treat hypertrophic obstructive cardiomyopathy. Korean Journal of Thoracic and Cardiovascular Surgery. 2015;**48**:419-421. DOI: 10.5090/kjtcs.2015.48.6.419

[24] Maron BJ, Dearani JA, Ommen SR, Maron MS, Schaff HV, Nishimura RA, Ralph-Edwards A, Rakowski H, Sherrid MV, Swistel DG, Balaram S, Rastegar H, Rowin EJ, Smedira NG, Lytle BW, Desai MY, Lever HM. Low operative mortality achieved with surgical septal myectomy: Role of dedicated hypertrophic cardiomyopathy centers in the management of dynamic subaortic obstruction. Journal of the American College of Cardiology. 2015;**66**: 1307-1308. DOI: 10.1016/j.jacc.2015.06.1333

[25] Maron BJ, Dearani JA, Maron MS, Ommen SR, Rastegar H, Nishimura RA, Swistel DG, Sherrid MV, Ralph-Edwards A, Rakowski H, Smedira NG, Rowin EJ, Desai MY, Lever HM, Spirito P, Ferrazzi P, Schaff HV. Why we need more septal myectomy surgeons: An emerging recognition. The Journal of Thoracic and Cardiovascular Surgery. 2017;**154**: 1681-1685. DOI: 10.1016/j.jtcvs.2016.12.038

[26] Kotkar KD, Said SM, Dearani JA, Schaff HV. Hypertrophic obstructive cardiomyopathy: The Mayo Clinic experience. Annals of Cardiothoracic Surgery. 2017;**6**:329-336. DOI: 10.21037/acs.2017.07.03

[27] Parry DJ, Raskin RE, Poynter JA, Ribero IB, Bajona P, Rakowski H, Woo A, Ralph-Edwards A. Short and medium term outcomes of surgery for patients with hypertrophic obstructive cardiomyopathy. The Annals of Thoracic Surgery. 2015;**99**:1213-1219. DOI: 10.1016/j.athoracsur.2014.11.020

[28] Wei LM, Rankin JS, Alkhouli M, Thibault DP, Yerokun B, Ad N, Schaff HV, Smedira NG, Takayama H, Murashita T, McCarthy P, Vemulapalli S, Thourani V, Ailawadi G, Jacobs J, Badhwar V. Contemporary surgical management of hypertrophic cardiomyopathy in the United States. Presenting at the Society of Thoracic Surgeons 54th Annual Meeting.

[29] Ommen SR, Maron BJ, Olivotto I, Maron MS, Cecchi F, Betocchi S, Gersh BJ, Ackerman MJ, McCully RB, Dearani JA, Schaff HV, Danielson GK, Tajik AJ, Nishimura RA. Long-term effects of surgical septal myectomy on survival in patients with obstructive hypertrophic cardiomyopathy. Journal of the American College of Cardiology. 2005;**46**:470-476

[30] Woo A, Williams WG, Choi R, Wigle ED, Rozenblyum E, Fedwick K, Siu S, Ralph-Edwards A, Rakowski H. Clinical and echocardiographic determinants of long-term survival after surgical myectomy in obstructive hypertrophic cardiomyopathy. Circulation. 2005;**111**:2033-2041

[31] Deb SJ, Schaff HV, Dearani JA, Nishimura RA, Ommen SR. Septal myectomy results in regression of left ventricular hypertrophy in patients with hypertrophic obstructive cardiomyopathy. The Annals of Thoracic Surgery. 2004;**78**:2118-2122

[32] Geske JB, Konecny T, Ommen SR, Nishimura RA, Sorajja P, Schaff HV, Ackerman MJ, Gersh BJ. Surgical myectomy improves pulmonary hypertension in obstructive hypertrophic cardiomyopathy. European Heart Journal. 2014;**35**:2032-2039. DOI: 10.1093/eurheartj/eht537

[33] Schaff HV, Dearani JA, Ommen SR, Sorajja P, Nishimura RA. Expanding the indications for septal myectomy in patients with hypertrophic cardiomyopathy: Results of operation

in patients with latent obstruction. The Journal of Thoracic and Cardiovascular Surgery. 2012;**143**:303-309. DOI: 10.1016/j.jtcvs.2011.10.059

[34] Klues HG, Maron BJ, Dollar AL, Roberts WC. Diversity of structural mitral valve alterations in hypertrophic cardiomyopathy. Circulation. 1992;**85**:1651-1660

[35] Klues HG, Proschan MA, Dollar AL, Spirito P, Roberts WC, Maron BJ. Echocardiographic assessment of mitral valve size in obstructive hypertrophic cardiomyopathy. Anatomic validation from mitral valve specimen. Circulation. 1993;**88**:548-555

[36] Klues HG, Roberts WC, Maron BJ. Morphological determinants of echocardiographic patterns of mitral valve systolic anterior motion in obstructive hypertrophic cardiomyopathy. Circulation. 1993;**87**:1570-1579

[37] Minakata K, Dearani JA, Nishimura RA, Maron BJ, Danielson GK. Extended septal myectomy for hypertrophic obstructive cardiomyopathy with anomalous mitral papillary muscles or chordae. The Journal of Thoracic and Cardiovascular Surgery. 2004;**127**:481-489

[38] Redaelli M, Poloni CL, Bichi S, Esposito G. Modified surgical approach to symptomatic hypertrophic cardiomyopathy with abnormal papillary muscle morphology: Septal myectomy plus papillary muscle repositioning. The Journal of Thoracic and Cardiovascular Surgery. 2014;**147**:1709-1711. DOI: 10.1016/j.jtcvs.2013.10.085

[39] Ferrazzi P, Spirito P, Iacovoni A, Calabrese A, Migliorati K, Simon C, Pentiricci S, Poggio D, Grillo M, Amigoni P, Iascone M, Mortara A, Maron BJ, Senni M, Bruzzi P. Transaortic chordal cutting: Mitral valve repair for obstructive hypertrophic cardiomyopathy with mild septal hypertrophy. Journal of the American College of Cardiology. 2015;**66**:1687-1696. DOI: 10.1016/j.jacc.2015.07.069

[40] Cooley DA, Leachman RD, Hallman GL, Gerami S, Hall RJ. Idiopathic hypertrophic subaortic stenosis. Surgical treatment including mitral valve replacement. Archives of Surgery. 1971;**103**:606-609

[41] Furukawa K, Hayase T, Yano M. Mitral valve replacement and septal myectomy for hypertrophic obstructive cardiomyopathy. General Thoracic and Cardiovascular Surgery. 2014;**62**:181-183. DOI: 10.1007/s11748-013-0245-1

[42] Hong JH, Schaff HV, Nishimura RA, Abel MD, Dearani JA, Li Z, Ommen SR. Mitral regurgitation in patients with hypertrophic obstructive cardiomyopathy: Implications for concomitant valve procedures. Journal of the American College of Cardiology. 2016;**68**: 1497-1504. DOI: 10.1016/j.jacc.2016.07.735

[43] Balaram SK, Ross RE, Sherrid MV, Schwartz GS, Hillel Z, Winson G, Swistel DG. Role of mitral valve plication in the surgical management of hypertrophic cardiomyopathy. The Annals of Thoracic Surgery. 2012;**94**:1990-1997. DOI: 10.1016/j.athoracsur.2012.06.008

[44] Balaram SK, Sherrid MV, Derose JJ Jr, Hillel Z, Winson G, Swistel DG. Beyond extended myectomy for hypertrophic cardiomyopathy: The resection-plication-release (RPR) repair. The Annals of Thoracic Surgery 2005;**80**:217-223

[45] Swistel DG, Balaram SK. Surgical myectomy for hypertrophic cardiomyopathy in the 21st century, the evolution of the "RPR" repair: Resection, plication, and release. Progress in Cardiovascular Diseases. 2012;**54**:498-502. DOI: 10.1016/j.pcad.2012.03.001

[46] Minakata K, Dearani JA, Schaff HV, O'Leary PW, Ommen SR, Danielson GK. Mechanisms for recurrent left ventricular outflow tract obstruction after septal myectomy for obstructive hypertrophic cardiomyopathy. The Annals of Thoracic Surgery. 2005;**80**:851-856

[47] Cho YH, Quintana E, Schaff HV, Nishimura RA, Dearani JA, Abel MD, Ommen SR. Residual and recurrent gradients after septal myectomy for hypertrophic cardiomyopathy-mechanisms of obstruction and outcomes of reoperation. The Journal of Thoracic and Cardiovascular Surgery. 2014;**148**:909-915. DOI: 10.1016/j.jtcvs.2014.05.028

[48] Smedira NG, Lytle BW, Lever HM, Rajeswaran J, Krishnaswamy G, Kaple RK, Dolney DO, Blackstone EH. Current effectiveness and risks of isolated septal myectomy for hypertrophic obstructive cardiomyopathy. The Annals of Thoracic Surgery. 2008;**85**:127-133

[49] Price J, Clarke N, Turer A, Quintana E, Mestres C, Huffman L, Peltz M, Wait M, Ring WS, Jessen M, Bajona P. Hypertrophic obstructive cardiomyopathy: Review of surgical treatment. Asian Cardiovascular & Thoracic Annals. 2017;**25**:594-607. DOI: 10.1177/0218492317733111