

# Long-Term Outcome of Myectomy Associated With Secondary Mitral Valve Chordal Cutting in Obstructive Hypertrophic Cardiomyopathy



Paolo Ferrazzi, MD,<sup>a,b</sup> Paolo Spirito, MD,<sup>b</sup> Irene Binaco, MD,<sup>c</sup> Aleksei Zyrianov, MD,<sup>a,d</sup> Luca Boni, MD, PhD,<sup>e</sup> Daniele Poggio, MD,<sup>a</sup> Massimiliano Grillo, MD,<sup>a</sup> Margherita Chioffi, MD,<sup>a</sup> Antonio Sorropago, MD, PhD,<sup>a</sup> Valter Casati, MD,<sup>a</sup> Stefano Paleari, PhD,<sup>f,g</sup> Giuseppe Vaccari, MD<sup>a</sup>

## ABSTRACT

**BACKGROUND** The recent introduction of cardiac myosin inhibitors has modified the therapy of left ventricular outflow obstruction in patients with hypertrophic cardiomyopathy (HCM) and is raising uncertainties regarding the future role of surgery in the management of obstructive HCM. However, it is likely that a proportion of patients will continue to present with advanced, highly symptomatic HCM, despite medical therapy, and require surgical intervention. We previously reported the short-term results of cutting anterior mitral leaflet secondary chordae in combination with septal myectomy in patients with obstructive HCM. This operative approach has shown excellent results in several short-term studies from our and other centers. However, no data are currently available regarding the long-term outcome of this novel surgical procedure.

**OBJECTIVES** The study sought to investigate the long-term results of myectomy associated with chordal cutting.

**METHODS** Long-term results were assessed in 350 consecutive patients with obstructive HCM who underwent this operation at our center over a 5-year period. Median follow-up was 5.6 years (Q1-Q3: 4.2-6.3 years).

**RESULTS** Including 2 in-hospital deaths (surgical mortality 0.6%), 6-year overall survival after surgery was 96% and did not differ from that of the general Italian population matched for age and sex ( $P = 0.331$ ). Follow-up information was available in 344 (99%) patients. At the most recent evaluation, 271 (79%) patients were asymptomatic in NYHA functional class I, 65 (19%) were in NYHA functional class II, and 8 (2%) were in NYHA functional class III. During follow-up, there were 14 deaths, 6 of which were unrelated to HCM. At most recent echocardiographic evaluation,  $\geq 95\%$  of patients had no residual left ventricular outflow gradient, clinically significant mitral regurgitation, or impaired systolic function.

**CONCLUSIONS** Our results show that cutting thickened and/or retracted secondary chordae of the anterior mitral leaflet in association with septal myectomy has excellent long-term clinical and hemodynamic results in patients with obstructive HCM. These findings may further increase the number of myectomy referral centers and the availability of the surgical option for severely symptomatic HCM patients unresponsive to medical treatment. (JACC. 2026;■■■■) © 2026 by the American College of Cardiology Foundation.

From the <sup>a</sup>Centro per la Cardiomiopatia Ipertrofica e le Cardiopatie Valvolari, Policlinico di Monza, Monza, Italy; <sup>b</sup>International Heart School Foundation, Bergamo, Italy; <sup>c</sup>Cardiochirurgia, Ospedale Maggiore Policlinico, Milan, Italy; <sup>d</sup>Cardiochirurgia, Ospedale Santa Maria della Misericordia, Udine, Italy; <sup>e</sup>IRCCS Ospedale Policlinico San Martino, Genoa, Italy; <sup>f</sup>University of Bergamo, Dalmine, Italy; and the <sup>g</sup>ANTHEM Foundation, Dalmine, Italy.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the [Author Center](#).

Manuscript received January 8, 2026; revised manuscript received April 27, 2026, accepted April 30, 2026.

ISSN 0735-1097/\$36.00

<https://doi.org/10.1016/j.jacc.2026.04.049>

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**ABBREVIATIONS  
AND ACRONYMS****AF** = atrial fibrillation**CMR** = cardiac magnetic  
resonance**HCM** = hypertrophic  
cardiomyopathy**LV** = left ventricular

**T**ransaortic septal myectomy relieves left ventricular (LV) outflow gradient and heart failure symptoms, and extends survival in patients with hypertrophic cardiomyopathy (HCM).<sup>1-3</sup> For over 50 years this procedure, performed at experienced HCM centers, has represented the treatment of choice for patients with obstructive HCM who remain symptomatic despite guideline-directed therapy.<sup>4</sup> Recently, however, medical therapy of obstructive HCM has been substantially modified by the introduction of cardiac myosin inhibitors, a development that may ultimately change the selection criteria for surgical therapy and overall management of obstructive HCM, raising dilemmas in clinical decision making.<sup>5-8</sup>

In this developing context of disease management, HCM surgery has itself evolved.<sup>9-13</sup> In 2015, we introduced the procedure of cutting thickened and/or retracted secondary chordae of the anterior mitral leaflet in association with septal myectomy.<sup>14</sup> The rationale behind this innovative technique relies on severing selected abnormal chordae that exert a tethering effect on the anterior leaflet.<sup>14-16</sup> By eliminating anterior leaflet tethering, the procedure moves the mitral valve apparatus away from the septum, facilitating the abolition of the LV outflow gradient and allowing for a relatively shallow septal resection.<sup>14-16</sup> In short-term studies, this operative strategy has proved highly reliable in abolishing the outflow gradient, reducing or abolishing mitral valve regurgitation, and relieving heart failure symptoms in the great majority of patients.<sup>14-21</sup> This novel approach is also performed with relative ease by experienced surgeons, as evidenced by its increasing worldwide use.<sup>17-30</sup> However, no data are available regarding the long-term durability of the hemodynamic and clinical benefits of this procedure.

Despite the recent introduction of cardiac myosin inhibitors, it is likely that a subset of patients, particularly those presenting with advanced or highly symptomatic disease, will continue to require surgical intervention, underscoring the importance of understanding the long-term outcomes of contemporary myectomy strategies. In the present study, we report the first long-term results of chordal cutting performed with septal myectomy in a large and consecutive cohort of patients with obstructive HCM.

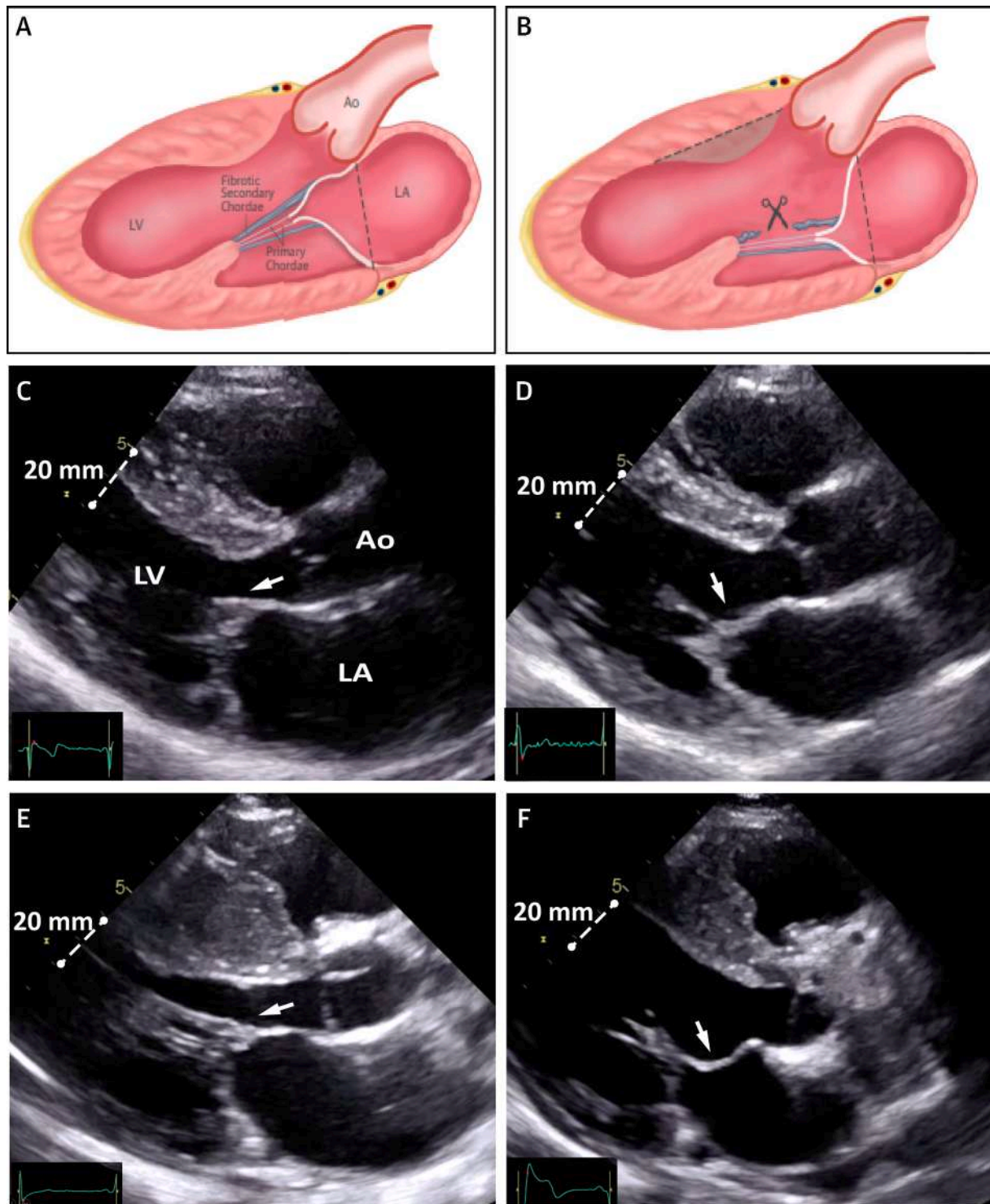
**METHODS**

**STUDY POPULATION.** Between June 2013 and December 2018, 373 consecutive patients with

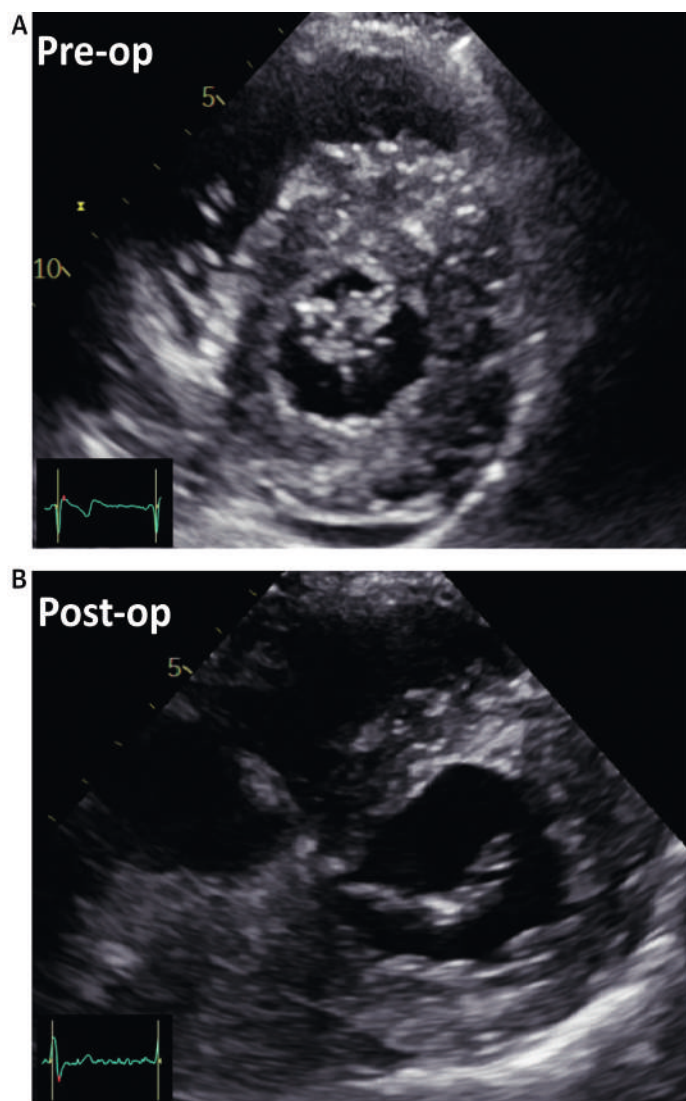
obstructive HCM underwent transaortic septal myectomy at the Policlinico di Monza, Italy. Each of the study patients had a LV outflow gradient  $\geq 50$  mm Hg at rest or with physiologic provocation and heart failure symptoms. Most of the patients were referred to us from HCM centers and individual cardiologists from all regions of Italy, while about 10% were referred from abroad. Most patients reflected the standard clinical features of candidates to surgical treatment of LV outflow obstruction referred to a specialized HCM center (ie, persisting heart failure symptoms and functional limitation despite maximal medical therapy). The period covered by the study (2013-2018) corresponds to the first years of activity of the HCM surgical center at the Policlinico di Monza. During this period, the operative procedure was principally performed by a single surgeon (P.F.). However, the 3 main procedural stages (papillary mobilization, septal myectomy, and chordal cutting) were systematically used for step-by-step training of other surgeons under the supervision of P.F.

Of the 373 patients initially enrolled in the study, 23 were excluded from the investigation on the basis of the following criteria: 1) mitral valve replacement after preoperative diagnosis of intrinsic valve disease (ie, severely stenotic and calcified valve) ( $n = 5$ ); 2) mitral valve replacement after initial transaortic attempt to repair the valve ( $n = 16$ ); and 3) septal myectomy without associated secondary anterior mitral leaflet chordal cutting ( $n = 2$ ). The remaining 350 patients underwent secondary anterior leaflet chordal cutting in association with septal myectomy and were included in this retrospective-prospective study. NYHA functional class was assessed by cardiologists and cardiovascular surgeons (I.B., D.P., A.S., and G.V.). During follow-up, sequential data regarding LV outflow gradient, mitral valve regurgitation, and LV ejection fraction were obtained from echocardiograms recorded at the time of periodic clinical evaluations. This study complies with the Declaration of Helsinki and was approved by the Institutional Review Board at the Policlinico di Monza. Written informed consent was obtained from the study patients.

**PREOPERATIVE CARDIAC IMAGING.** Standard echocardiographic measurements were obtained before the myectomy operation, at the time of hospital discharge, and during follow-up.<sup>31</sup> Preoperative cardiac magnetic resonance (CMR) was performed in each of the study patients without prior implantation of cardiac devices incompatible with CMR. Tomographic CMR images were used, in combination with

**FIGURE 1** Effects of Secondary Chordal Cutting on the Mitral Valve

(A, B) Schematic representation. (A) Fibrotic secondary chordae of the anterior mitral leaflet cause leaflet tethering, displacing the mitral valve into the left ventricular (LV) outflow tract and reducing the outflow tract size. (B) Cutting selected fibrotic secondary chordae abolishes leaflet tethering, moving the mitral valve away from the septum and enlarging the outflow tract. (C, D) Preoperative and postoperative echocardiographic images, obtained in early systole, in a patient with obstructive hypertrophic cardiomyopathy and mild septal thickness and (E, F) in a patient with obstructive hypertrophic cardiomyopathy and marked septal thickness. Preoperatively, in both patients, anterior mitral leaflet tethering displaces the mitral valve toward the LV outflow tract (arrows). Postoperatively, cutting selected abnormal secondary chordae abolishes leaflet tethering and moves the mitral valve away from the outflow tract to a more normal posterior position in the ventricular cavity (arrows). Reprinted with permission from Ferrazzi et al.<sup>14</sup> Additional imaging is provided in [Videos 1 to 4](#). Ao = aorta; LA = left atrium.

**FIGURE 2** Effects of Secondary Chordal Cutting on LV Outflow Tract Size

Preoperative and postoperative echocardiographic images obtained in short-axis view at the onset of systole in a patient with obstructive hypertrophic cardiomyopathy. (A) Preoperatively, the mitral valve is displaced anteriorly, reducing the size of the left ventricular outflow tract. (B) Postoperatively, cutting selected fibrotic secondary chordae of the anterior mitral leaflet in association with a relatively shallow septal myectomy moves the mitral valve posteriorly to a more normal position and the outflow tract area is substantially enlarged. At bottom left, the electrocardiogram shows the phase of the cardiac cycle. Additional imaging is provided in [Video 1](#).

cardiac ultrasound, to obtain a meticulous preoperative reconstruction of the magnitude and distribution of septal hypertrophy, detailed information regarding the morphology of the mitral valve apparatus, and

presence and hemodynamic relevance of anomalous muscle bundles.<sup>14-16,32</sup> In patients with prior implantation of cardiac devices, preoperative reconstruction of the distribution of septal hypertrophy was obtained with computed chest tomography or contrast echocardiography.

**SURGICAL PROCEDURE.** Intraoperative transesophageal echocardiography was performed to visualize the ventricular septum and assess mitral valve morphology and associated mitral abnormalities.<sup>14-16</sup> The papillary muscles were mobilized with the technique originally described by Messmer<sup>33</sup> and were split in patients with particularly short anterior leaflet chordae. Septal muscular resection was performed as previously described.<sup>31</sup> In particular, the muscle from the anterior septum was excised in a single piece using scissors in order to leave a smooth surface on the remaining septum.<sup>14,31,32</sup> Great care was taken to ensure that the muscular resection went beyond the point of mitral-septal contact.<sup>31-34</sup> The extent of the myectomy (its thickness and length) was planned on the basis of our detailed preoperative assessment of the morphologic and functional cardiac abnormalities.<sup>31,32</sup> In the individual patient, a muscular excision of a depth corresponding to about 30% of the anterior septum maximal thickness was considered adequate because our previous and ongoing experience has shown that resection of secondary anterior leaflet chordae moves the mitral valve apparatus posteriorly to a more normal position in the inflow area, enlarging the outflow tract and making a deeper septal resection unnecessary ([Figures 1 and 2](#), [Videos 1 to 4](#)).<sup>16,32</sup>

In many patients, our preoperative assessment of ventricular morphology showed that septal hypertrophy also involved the distal portion of the posterior septum, reducing cavity size and favoring mid-ventricular obstruction.<sup>15,16,32</sup> In such patients, a second muscular excision was performed starting at 2.5 to 3 cm from the aortic annulus to avoid damaging the His bundle.<sup>15,16,32</sup> Purpose of this second muscular excision was to prevent contact between the anterior leaflet free margin and septum in this area and, in patients with important posterior septum hypertrophy, to increase mid-cavity dimension and prevent systolic mid-cavity occlusion.

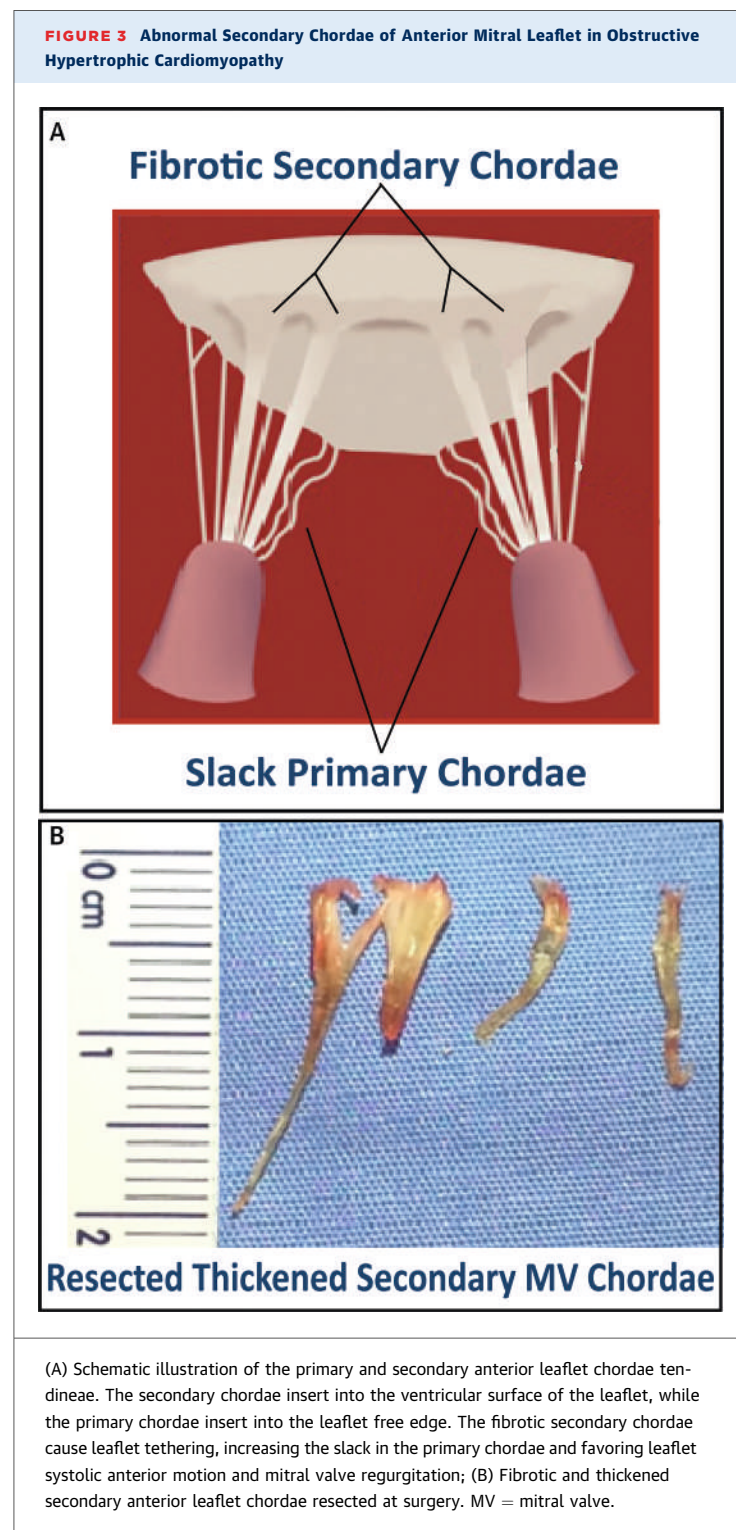
After papillary muscle mobilization and septal myectomy, the ventricular surface of the anterior leaflet was examined to select which secondary chordae required resection, the secondary chordae being those not inserted into the free margin of the

leaflet (**Figure 3**).<sup>14-16</sup> Thickened and/or retracted anterior mitral leaflet secondary chordae were resected at their distal origin and at the level of the leaflet body and then removed (**Figure 4**, **Video 5**).<sup>14-16</sup> In patients with particularly elongated anterior or posterior leaflets, the excessive and slack tissue at the leaflet margin, which floated in the outflow tract, was plicated.<sup>14-16,32</sup> Muscle bundles judged to reduce mid-cavity dimension and/or papillary muscle mobility were routinely dissected from the contiguous ventricular wall or resected.<sup>14-16,31,32</sup>

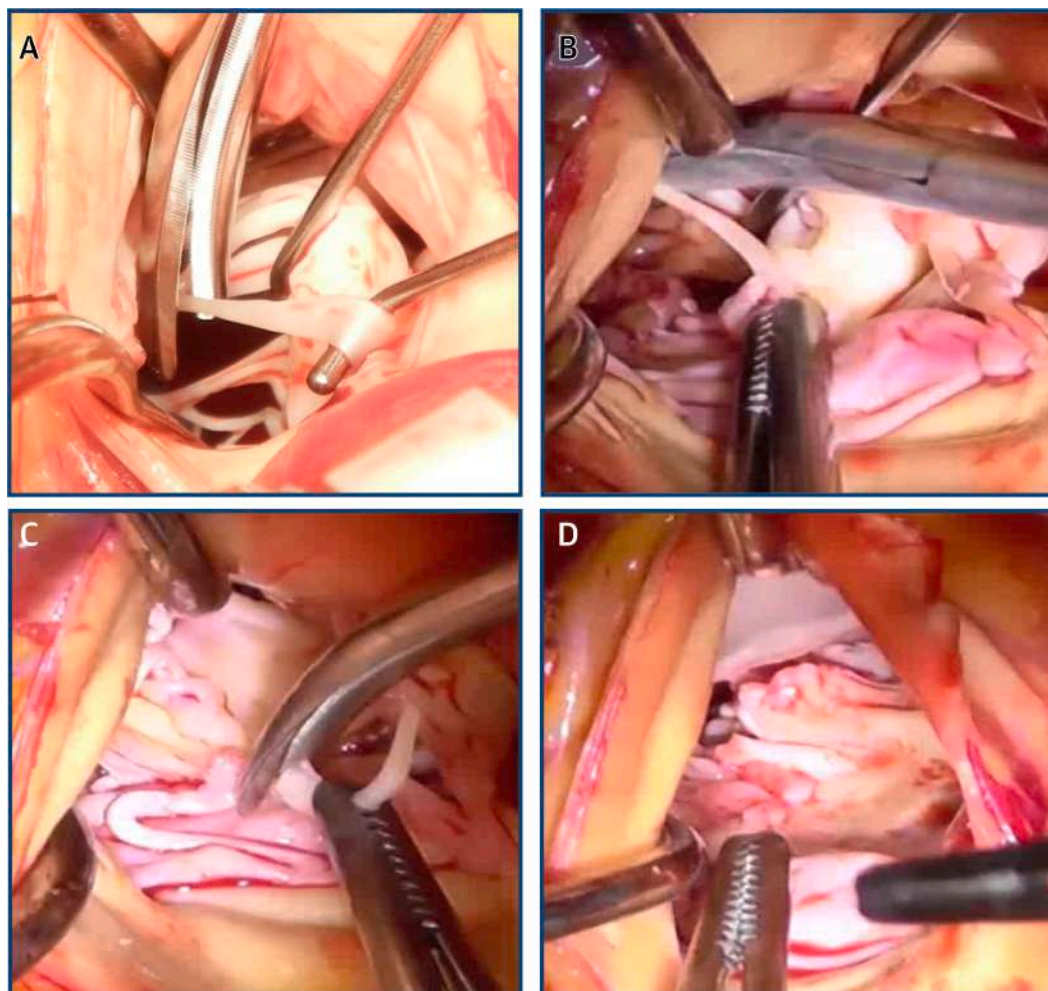
**STATISTICAL ANALYSIS.** The distribution of the study patients according to their demographic and clinical characteristics was summarized as frequency and percentage. Continuous variables were described as mean  $\pm$  SD, median, and range of variation. The median duration of follow-up time was calculated for the entire study cohort according to the reverse Kaplan-Meier method. The actual proportion of the study patients still alive after septal myectomy at each evaluated time point was calculated using the Kaplan-Meier product limit method. The expected survival was calculated according to the Ederer II method matching, by age, sex, and calendar period, each study patient with the general Italian population life tables obtained from the Italian National Institute of Statistics. The distributions of observed and expected survival times were then compared by means of the Pearson's chi-square test. The change in the distribution of the clinical characteristics evaluated before surgery and at most recent evaluation was analyzed according to McNemar's or Bowker's symmetry tests for binomial and multinomial variables, respectively. The Wilcoxon signed rank test for paired data was used for continuous parameters. Survival curves were estimated with the Kaplan-Meier product limit method and compared with the log-rank test. In case of discrete variables, differences between independent samples were assessed with the chi-square test for heterogeneity. No adjustment for multiplicity was performed. All 2-sided *P* values  $\leq 0.05$  were considered significant. Data were analyzed by L.B., using the statistical software SAS 9.4 (SAS Institute).

## RESULTS

**BASELINE CHARACTERISTICS AND PERIOPERATIVE OUTCOME.** At the time of the operation, the 350 study patients were 15 to 81 years of age (median 55 years of age); 199 (57%) were male. The preoperative mean peak LV outflow gradient at rest was  $69 \pm 37$  mm Hg. Mean septal thickness was  $22 \pm 5$  mm. Mitral valve regurgitation was absent or mild in 112



(32%) patients, moderate in 138 (39%), moderate to severe in 59 (17%), and severe in 41 (12%) patients. A history of atrial fibrillation (AF) was present in 77 (22%) patients. Before surgery, HCM patients referred

**FIGURE 4** Transaortic Intraoperative Resection of Anterior Leaflet Abnormal Secondary Chordae

(A) A thickened and retracted secondary chord is selected with a nerve hook, and scissors (on the left) are positioned to cut this structure. A second hook separates primary chordae from the abnormal secondary chordae. (B) On the top, a secondary chord is resected at its insertion in the papillary muscle. (C) Resection of the proximal portion of a secondary thickened chordae from the ventricular side of the anterior mitral leaflet. (D) Ventricular surface of the mitral leaflet free from the resected fibrotic secondary chordae. At the tip of the forceps, the stumps of two resected chordae are visible. Additional imaging regarding the resection of secondary chordae is provided in [Video 5](#).

to our center were treated with the standard pharmacologic therapy for this disease, including beta-blockers or nondihydropyridine calcium-channel blockers, with or without associated disopyramide depending on the patient clinical history. Most patients with signs or symptoms of congestion were also on low-dose diuretics. Clinical characteristics of the study population at baseline are reported in [Table 1](#).

Of the 350 study patients, none had iatrogenic septal defect at the time of myectomy; 1 patient died of pulmonary embolism 13 days after surgery and 1 died of sepsis 60 days after surgery (in-hospital mortality 0.6%). At the time of surgery, these 2 patients were 75 and 74 years of age, respectively. In the remaining 348 study patients, mean peak LV outflow gradient at hospital discharge was  $4 \pm 8$  mm Hg, and a residual resting outflow

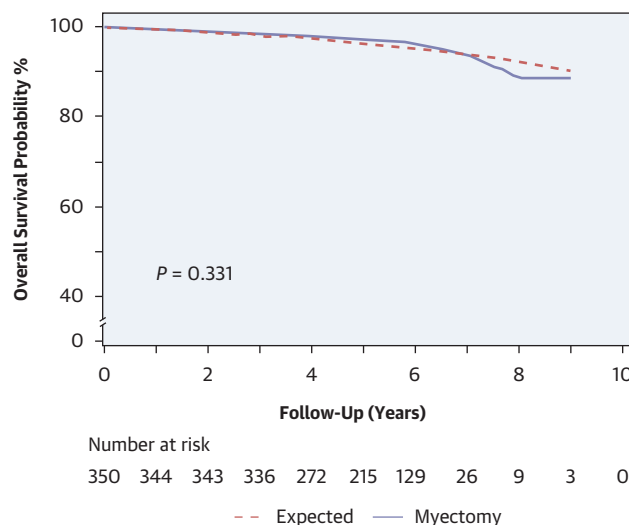
**TABLE 1** Baseline Demographic and Clinical Characteristics in the Study Patients

| Preoperative Variable                      | All Patients (N = 350) |
|--------------------------------------------|------------------------|
| Age, y                                     |                        |
| Median (range)                             | 55 (15-81)             |
| Mean $\pm$ SD                              | 53 $\pm$ 15            |
| Male                                       | 199 (57)               |
| NYHA functional class                      |                        |
| I                                          | —                      |
| II                                         | 76 (22)                |
| III                                        | 239 (68)               |
| IV                                         | 35 (10)                |
| Atrial fibrillation                        | 77 (22)                |
| Ejection fraction, %                       |                        |
| Median (range)                             | 66 (38-81)             |
| Mean $\pm$ SD                              | 65 $\pm$ 7             |
| Maximal septal thickness, mm               |                        |
| Median (range)                             | 21 (12-42)             |
| Mean $\pm$ SD                              | 22 $\pm$ 5             |
| Maximal LV outflow gradient at rest, mm Hg |                        |
| Median (range)                             | 70 (10-264)            |
| Mean $\pm$ SD                              | 69 $\pm$ 37            |
| Mitral valve regurgitation grade           |                        |
| None or mild                               | 112 (32)               |
| Moderate                                   | 138 (39)               |
| Moderate to severe                         | 59 (17)                |
| Severe                                     | 41 (12)                |
| Pacemaker                                  | 15 (4)                 |
| ICD                                        | 49 (14)                |

Values are n (%), unless otherwise indicated. ICD = implantable cardioverter-defibrillator; LV = left ventricular.

gradient  $\geq 30$  mm Hg was present in 6 (2%) patients. Moderate-to-severe mitral valve regurgitation was present in 1 (0.3%) patient and severe mitral regurgitation in none. Mean thickness of the excised septal muscle, quantified at echocardiography as maximal preoperative minus maximal postoperative septal thickness, was  $7 \pm 4$  mm, corresponding to a 29% proportional average decrease in maximal septal thickness. In the perioperative period, a permanent pacemaker was implanted for advanced atrioventricular block in 13 (3.7%) patients.

**OVERALL SURVIVAL AFTER MYECTOMY.** The median duration of follow-up for the study population was 5.6 years (Q1-Q3: 4.2-6.3 years). The observed survival in the 350 study patients and their expected survival, derived from a general Italian population after matching the 2 cohorts for age, sex, and

**FIGURE 5** Overall Survival after Surgery

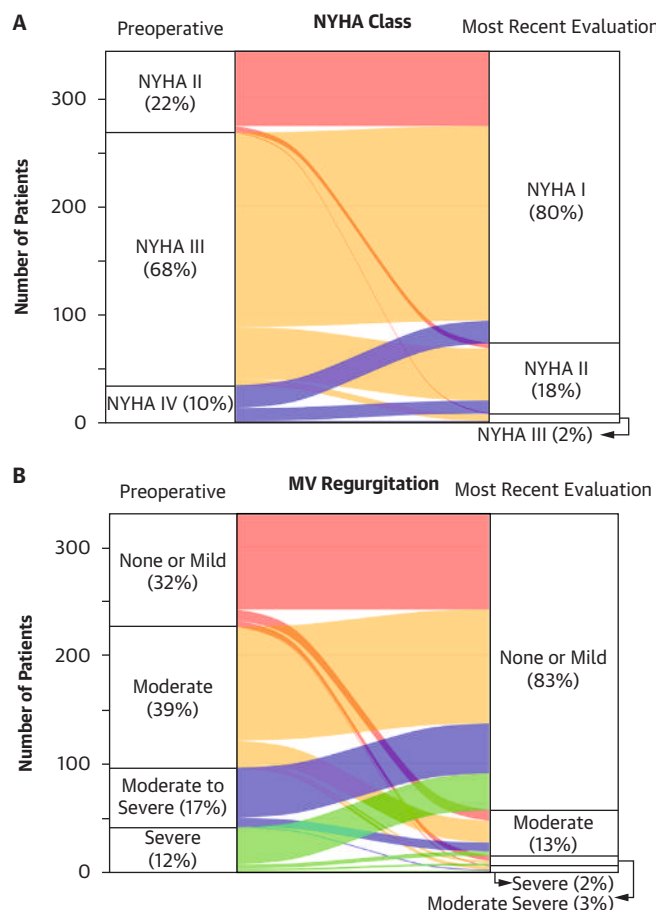
In the 350 study patients, overall survival free from all-cause mortality after septal myectomy, associated with cutting thickened and/or retracted anterior mitral leaflet secondary chordae, was 95% at 6 years and did not differ from that of a general Italian population matched for age, sex, and calendar. The number of patients at risk refers to the study patients.

calendar period, are shown in **Figure 5**. The 1-, 3-, and 6-year observed overall survival probability after myectomy was 98.6%, 97.7%, and 94.9%, respectively, and did not differ from the expected survival probability, which was 99.4%, 98.1%, and 95.6% (Pearson's chi-square test,  $P = 0.331$ ).

Of the 348 study patients discharged from the hospital after myectomy, 14 (4%) died during follow-up, including 7 (2%) who died of HCM-related causes (4 of heart failure, 2 of stroke, and 1 of pulmonary embolism), 6 (1.7%) who died of causes not related to HCM (3 of cancer, 2 of COVID-19 and 1 of pneumonia), and 1 (0.3%) in whom the causes of death could not be determined. One (0.3%) patient survived an out-of-hospital resuscitated cardiac arrest.

#### LONG-TERM CLINICAL COURSE AFTER MYECTOMY.

Long-term follow-up clinical information was available in 344 (99%) of the 348 study patients discharged from the hospital after myectomy. The information was obtained at clinical evaluation in 139 (40.4%) and by telephone in 205 (59.6%). Of the 4 patients without clinical information during follow-up, 1 was lost to follow-up. The 3 remaining patients (as reported previously) had died during

**FIGURE 6 NYHA Functional Class and MV Regurgitation Before Surgery and at Most Recent Evaluation**

Transition figure. (A) NYHA functional class in 344 study patients. (B) Mitral valve (MV) regurgitation in 330 study patients.

follow-up of stroke, pulmonary embolism, and an unexplained cause, respectively, and their clinical condition before the event could not be reconstructed.

At most recent evaluation, 271 (79%) of the 344 study patients with long-term follow-up information were in NYHA functional class I, 65 (19%) were in NYHA functional class II, and 8 (2%) were in NYHA functional class III (Figure 6A). A total of 12 (3%) patients underwent a second HCM-related surgical operation during follow-up, including mitral valve replacement (n = 6), aortic and mitral valve replacement (n = 4), repair of LV pseudoaneurysm (n = 1), and heart transplantation (n = 1). Of the 75 study patients with preoperative history of AF, 38 (51%) did not have recurrent or permanent AF at most recent

follow-up. When the 75 patients with preoperative history of AF were compared with the 269 patients without preoperative history of AF, 37 (49%) and 26 (10%) had recurrent or permanent AF, respectively, at most recent follow-up ( $P < 0.001$ ). After surgery, most of the study patients were discharged on beta-blockers, and a minority on nondihydropyridine calcium-channel blockers. Additional cardiovascular medications were added when indicated. None of the study patients were discharged on disopyramide. At most recent evaluation, most of the study patients were on beta-blockers or nondihydropyridine calcium-channel blockers, while a minority with episodes of AF or congestive symptoms were on antiarrhythmic medications or low-dose diuretics, respectively. None of the study patients were on disopyramide or cardiac myosin inhibitors.

Sequential postoperative echocardiographic data recorded at the time of periodic clinical evaluations during follow-up were available in 330 (94%) of the 344 study patients. At most recent clinical evaluation, a residual significant resting gradient ( $\geq 30$  mm Hg) was present in 10 (3%) patients (range 30–79 mm Hg, median 36 mm Hg). Mitral valve regurgitation was mild or absent in 273 (83%) patients, moderate in 42 (13%), moderate to severe in 9 (3%), and severe in 6 (2%) patients (Figure 6B). LV ejection fraction was  $\geq 55\%$  in 304 (92%) and was  $< 50\%$  in 6 (2%) patients (range 34%–48%, median 46%). Mean maximal LV outflow gradient and LV ejection fraction documented at serial follow-up evaluations are shown in Figures 7A and 7B. Clinical characteristics of the study population at most recent evaluation are reported in Table 2.

#### IMPACT OF PREOPERATIVE AGE AND FUNCTIONAL CLASS ON OVERALL SURVIVAL AND LONG-TERM CLINICAL COURSE AFTER MYECTOMY.

When the possible impact of preoperative age and NYHA functional class on overall survival after myectomy was assessed in the 350 study patients, none of the 58 patients  $< 40$  years of age at the time of surgery died, 4 (3%) of the 161 patients between 40 and 59 years of age died, and 12 (9%) of the 131 patients  $\geq 60$  years of age died (log-rank test,  $P = 0.006$ ) (Figure 8A). None of the 76 patients in NYHA functional class II before surgery and 16 (6%) of the 274 patients in NYHA functional class III or IV died (log-rank test,  $P = 0.030$ ) (Figure 8B).

With regard to the possible impact of these 2 clinical features (ie, preoperative age and NYHA functional class) on long-term clinical course in the 344 study patients with long-term follow-up, at most recent evaluation 53 (91%) of the 58 patients  $< 40$

years of age preoperatively were in NYHA functional class I compared with 133 (83%) of the 161 patients 40 to 59 years of age and 85 (68%) of the 125 patients  $\geq 60$  years of age before surgery ( $P = 0.002$ ). Of the 76 patients in NYHA functional II preoperatively, 70 (92%) were in NYHA functional class I at most recent evaluation compared with 201 (75%) of the 268 patients in NYHA functional class III or IV preoperatively (test of symmetry,  $P < 0.001$ ).

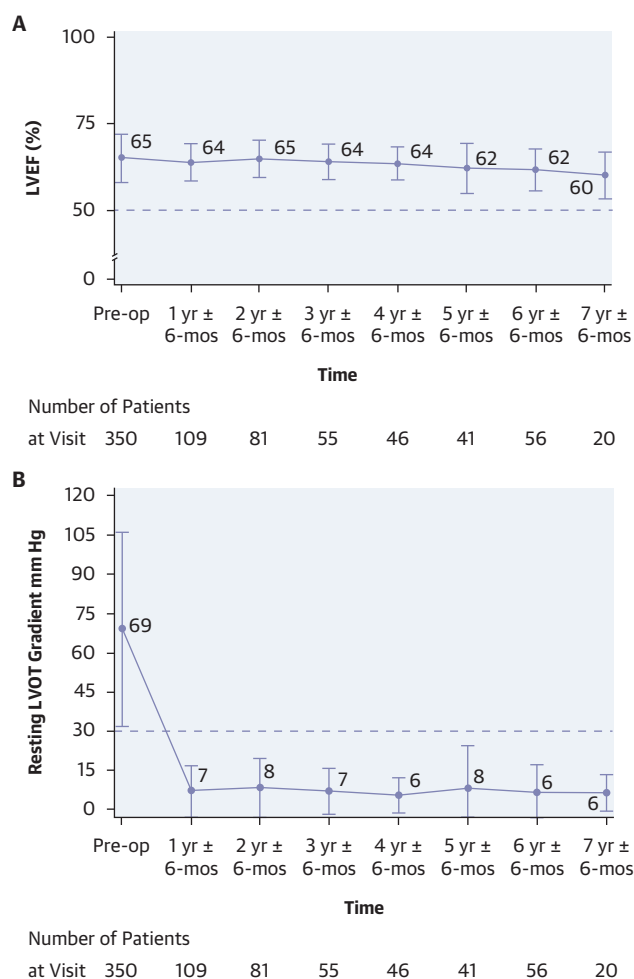
## DISCUSSION

The present investigation reports for the first time the long-term results of cutting thickened and/or retracted secondary chordae of the anterior mitral leaflet, in association with transaortic septal myectomy and papillary muscle mobilization, in a large consecutive cohort of symptomatic patients with obstructive HCM. Overall survival free from all-cause mortality after myectomy was excellent (95% at 6 years) and did not differ from that of the general Italian population. At long-term follow-up, the great majority of the study patients were free from heart failure symptoms in NYHA functional class I, about 20% were in NYHA functional class II, and 2% in NYHA functional class III. Serial echocardiographic data during follow-up showed that  $\geq 95\%$  of our study patients had no residual LV outflow gradient, clinically significant mitral regurgitation, or impaired systolic function.

Our findings arrive at a crucial time in the long history of septal myectomy, an operation that has contributed substantially to reduce mortality in HCM.<sup>1-3,13,35</sup> In recent short-term trials, cardiac myosin inhibitors mavacamten and aficamten reduced LV outflow gradient and alleviated heart failure symptoms in about 70% of symptomatic patients with obstructive HCM, raising questions regarding the future of surgery as a treatment for outflow obstruction.<sup>5-8</sup> Therefore, in this rapidly evolving clinical context, the aim of the present investigation has been expanded from reporting the long-term results of our novel myectomy procedure to a more general discussion of the future role of surgery in HCM.

We would like to emphasize that the marked improvement in quality of life and enhanced survival after myectomy reported in our study is also consistent with much of the contemporary experience at high-volume myectomy centers,<sup>1-3,9,10,13</sup> an experience that includes low in-hospital mortality (0.5%) in cohorts comprising largely patients in NYHA

**FIGURE 7 Long-Term Hemodynamic Results of Surgery**



(A) Left ventricular ejection fraction (LVEF) and (B) resting left ventricular outflow gradient assessed preoperatively and at periodic evaluations in 330 (94%) of the 344 study patients with follow-up clinical information. LVOT = left ventricular outflow tract.

functional class III or IV.<sup>1-3,9,10,13</sup> Therefore, our results do not necessarily imply superiority of our surgical approach over other myectomy strategies. Beyond these consistently favorable results of the myectomy operation, support for continuing access to the surgical option is justified for a number of reasons. First, in the randomized trials on cardiac myosin inhibitors, about 30% of symptomatic patients treated with these medications failed to respond to short-term treatment, and the long-term durability and potential side effects of this new class of drugs remain unresolved.<sup>5-8</sup> In addition, in

**TABLE 2** Clinical Characteristics Before Surgery and at Most Recent Evaluation in Patients With Clinical Information During Follow-Up

|                                               | Before Surgery | Most Recent Evaluation | P Value             |
|-----------------------------------------------|----------------|------------------------|---------------------|
| NYHA functional class                         |                |                        | <0.001 <sup>a</sup> |
| I                                             | —              | 271 (79)               |                     |
| II                                            | 76 (22)        | 65 (19)                |                     |
| III                                           | 234 (68)       | 8 (2)                  |                     |
| IV                                            | 34 (10)        | —                      |                     |
| Echocardiographic data                        |                |                        |                     |
| Maximal LV outflow gradient at rest, mm Hg    | 69 ± 35        | 6 ± 10                 | <0.001 <sup>b</sup> |
| Maximal LV outflow gradient at rest ≥30 mm Hg |                |                        | <0.001 <sup>c</sup> |
| No                                            | 49 (15)        | 320 (97)               |                     |
| Yes                                           | 281 (85)       | 10 (3)                 |                     |
| Maximal septal thickness, mm                  | 22 ± 5         | 16 ± 3                 | <0.001 <sup>b</sup> |
| LV ejection fraction, %                       | 65 ± 7         | 63 ± 6                 | <0.001 <sup>b</sup> |
| Mitral valve regurgitation grade              |                |                        | <0.001 <sup>b</sup> |
| None or mild                                  | 104 (32)       | 273 (83)               |                     |
| Moderate                                      | 130 (39)       | 42 (13)                |                     |
| Moderate to severe                            | 55 (17)        | 9 (3)                  |                     |
| Severe                                        | 41 (12)        | 6 (2)                  |                     |

Values are n (%) or mean ± SD. NYHA functional class and echocardiographic data were available in 344 (98%) and 330 (94%), respectively, of the 350 study patients. <sup>a</sup>Test of symmetry. <sup>b</sup>Wilcoxon signed rank test for paired data. <sup>c</sup>McNemar's test.

LV = left ventricular.

an important proportion of HCM patients, the mechanisms responsible for LV outflow obstruction are not confined to a hypertrophied and hypercontractile ventricle but include congenital and/or acquired abnormalities of papillary muscles and mitral valve that may be amenable only to surgical correction.<sup>9-12,36-38</sup> Therefore, independently of how successful cardiac myosin inhibitors will be in the future, the experience with myectomy supports a continuing role for surgery in the management of obstructive HCM.

The present investigation is focused on the long-term results of septal myectomy combined with the resection of thickened and/or retracted anterior mitral leaflet secondary chordae. The rationale for this operative approach relies on abolishing the negative effects exerted by these abnormal chordae on the intricate interplay between mitral valve apparatus and outflow obstruction.<sup>14,16</sup> Retracted chordae cause leaflet tethering and tenting, displacing the mitral apparatus into the LV outflow tract and promoting slack in the primary chordae with consequent leaflet systolic anterior motion and valve regurgitation.<sup>14,16</sup> Severing selected abnormal secondary chordae mitigates leaflet tethering and tenting, moving the mitral apparatus away from the

septum to a more physiologic position, enlarging the outflow tract, reducing or abolishing mitral valve regurgitation, and allowing for a relatively shallow septal resection.<sup>14,16</sup> In our experience with this operative strategy, a muscular excision of a depth of about 30% of preoperative septal thickness and a length extending beyond the point of mitral-septal contact is sufficient to abolish the LV outflow gradient in most patients.<sup>14-16,32</sup> Because secondary mitral valve chordae are known to maintain ventricular geometry and contribute to systolic wall thickening,<sup>39,40</sup> the question lingered as to whether cutting selected chordae could favor progression to systolic dysfunction. In the present long-term investigation, LV ejection fraction at most recent evaluation was preserved (>55%) in >90% of the study patients and impaired (<50%) in only 2%, showing that cutting retracted chordae in obstructive HCM is not associated with long-term deterioration of systolic function.

In addition, our data offer support for selecting some HCM patients for surgery earlier in the clinical course of their disease. None of our young patients (<40 years of age) and none of the patients in NYHA functional class II preoperatively experienced perioperative deaths, and there were no HCM-related deaths during follow-up, with 90% free from heart failure symptoms (in NYHA functional class I) at most recent evaluation. These findings and the results of previous investigations suggest that in order to prevent progressive clinical deterioration and improve long-term outcome, septal myectomy performed at experienced HCM surgical centers should not be delayed in selected patients with obstructive HCM.<sup>4,41,42</sup> Therefore, we believe that individual symptomatic patients with obstructive HCM should have the freedom to choose between early surgery and treatment with cardiac myosin inhibitors, after having been fully informed with regard to these two therapeutic options.

**STUDY LIMITATIONS.** This is a single-center investigation, and our long-term findings reflect the operative experience of a single surgeon. Therefore, although excellent short-term results have been reported by several other centers using the same surgical strategy, the results of the present study need to be confirmed by additional long-term investigations at other institutions.

## CONCLUSIONS

In the present study, we report for the first time the long-term outcome of cutting thickened and/or

retracted anterior mitral leaflet secondary chordae in association with a relatively shallow septal myectomy, an operative approach we introduced a decade ago. Several centers have adopted this operative strategy and reported excellent short-term hemodynamic and clinical results.<sup>17-30</sup> Our present long-term data confirm the durability of these beneficial effects. Overall survival after myectomy did not differ from that of the general population. At most recent evaluation, the great majority of study patients were free from heart failure symptoms in NYHA functional class I, and almost all had no residual LV outflow gradient, clinically significant mitral valve regurgitation, or impaired systolic function.

At this critical time in the evolution of the management of obstructive HCM, the discussion of our innovative myectomy approach also offers us the opportunity to defend and promote the unique role of surgery in the treatment of symptomatic patients with the obstructive form of the disease. We believe that the future management of obstructive HCM should allow for both the surgical and medical therapeutic options to thrive in the best interest of all patients.

**DATA AVAILABILITY** To minimize the possibility of unintentionally sharing information that can be used to reidentify private information, a subset of the data generated for this study are available at Harvard Dataverse and can be accessed at <https://doi.org/10.7910/DVN/FJLHYF> in completely anonymized format.

## FUNDING SUPPORT AND AUTHOR DISCLOSURES

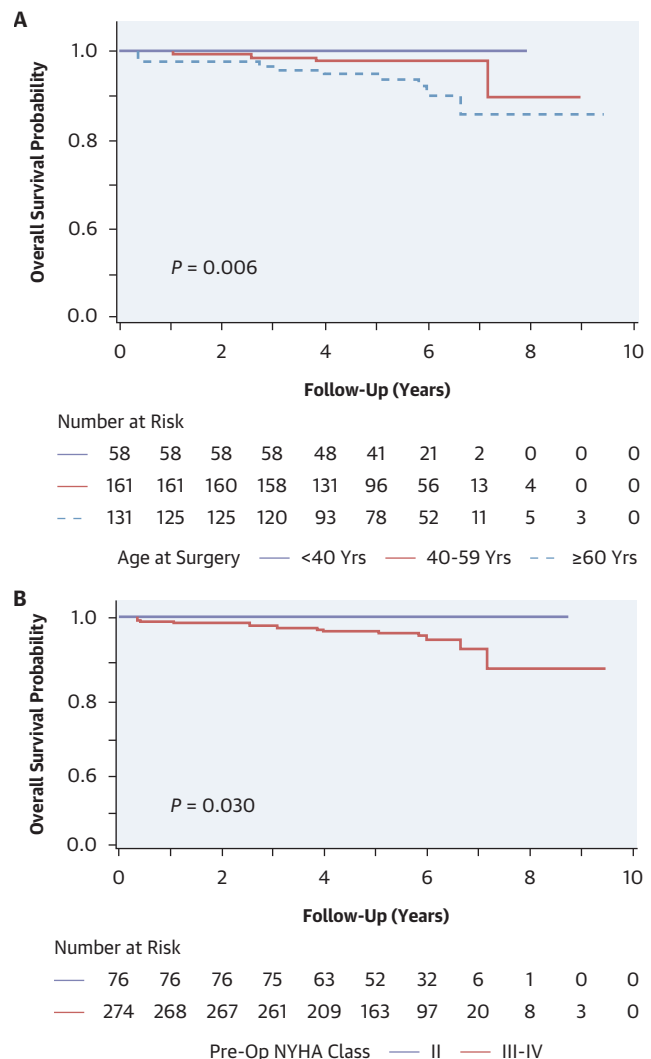
The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

**ADDRESS FOR CORRESPONDENCE:** Dr Paolo Ferrazzi, International Heart School ANTHEM Foundation, Viale Marconi 9, 24044, Dalmine, Bergamo, Italy. E-mail: [paoloferrazzi@gmail.com](mailto:paoloferrazzi@gmail.com).

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**FIGURE 8** Impact of Preoperative Age and Functional Class on Overall Survival After Surgery



In the 350 study patients, overall survival free from all-cause mortality after surgery differed significantly in relation to (A) preoperative age and (B) NYHA functional class.

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**KEY WORDS** hypertrophic cardiomyopathy, obstructive hypertrophic cardiomyopathy, secondary mitral valve chordal cutting, septal myectomy

**APPENDIX** For supplemental videos, please see the online version of this paper.