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Precision Myectomy: Real-Time On-Pump Intracardiac Echocardiography for Resection in Patients with Thin Septa

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PII: S2666-2507(25)00464-X

DOI: https://doi.org/10.1016/j.xjtc.2025.09.037

Reference: XJTC 2129

To appear in: *JTCVS Techniques*

Received Date: 22 May 2025

Revised Date: 12 August 2025

Accepted Date: 4 September 2025

Please cite this article as: Phillips KG, Nampi RG, Sherrid MV, Massera D, Xia Y, Saric M, Grossi E, Colon P, Scheinerman JA, Swistel DG, Precision Myectomy: Real-Time On-Pump Intracardiac Echocardiography for Resection in Patients with Thin Septa, *JTCVS Techniques* (2025), doi: https://doi.org/10.1016/j.xjtc.2025.09.037.

JTCVS TECHNIQUES

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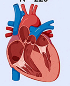
Precision Myectomy: Real-Time On-Pump Intracardiac Echocardiography for Resection in Patients with Thin Septa

METHOD

All adult patients with obstructive HCM with septa ≤2.0 cm who underwent extended myectomy between 07/2017-05/2024

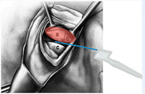
N = 220

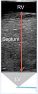


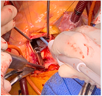
No-OPIE Guidance
n = 164

OPIE-Used
n = 56

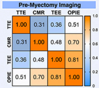
RESULTS

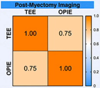






OPIE demonstrated strong concordance with both pre- and post-resection TEE, exceeding the concordance observed between any other pair of imaging modalities.





IMPLICATION

OPIE is a valuable adjunct for real-time assessment of septal thickness during myectomy, particularly in patients with HCM and thin septa which represent a growing proportion of patients being referred for septal myectomy

OPIE: On-pump Intracardiac Echocardiography; HCM: Hypertrophic Cardiomyopathy; SAM: Systolic Anterior Motion of the Mitral Valve

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Presentation: Abstract was presented as an oral presentation at the American Association of Thoracic Surgeons (AATS) 105th Annual Meeting, May 2-5th 2025, Seattle, WA

Disclosure Statement: The authors have no conflicts of interest to disclose.

Funding statement: The authors received no financial support for the research, authorship, or publication of this article.

IRB Approval: This study was approved by the IRB #i24-01262 on 11/21/2024

Informed Consent Statement: The need for informed consent was waived by the IRB

Article Word Count: 4,736/4,500

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Glossary Of Abbreviations

AVR	Aortic Valve Replacement
COPD	Chronic Obstructive Pulmonary Disease
CHB	Complete Heart Block
CMR	Cardiac Magnetic Resonance Imaging
HCM	Hypertrophic Cardiomyopathy
ICD	Implantable cardioverter-defibrillator
IVS	Interventricular septum
LV	Left Ventricle
LVOT	Left Ventricular Outflow Tract
MR	Mitral Regurgitation
MVR	Mitral Valve Replacement
NYHA	New York Heart Association
OPIE	On-Pump Intracardiac Echocardiography
PPM	Permanent Pacemaker
RBBB	Right Bundle Branch Block
ReLex	Residual Leaflet Excision
SAM	Systolic Anterior Motion
TEE	Transesophageal Echocardiogram
TTE	Transthoracic Echocardiogram
VSD	Ventricular Septal Defect

Central Picture Legend:(87/90 w/ spaces)

Intraoperative OPIE yields reproducible, concordant real-time septal thickness measures.

Central Message:(198/200 characters)

On-Pump Intracardiac Echocardiography is a valuable adjunct for real-time assessment of septal thickness during myectomy, particularly in patients with HCM and thin septa where precision is critical.

Perspective Statement:(340/405 characters)

Patients with normal or only mildly increased septal thickness represent a growing proportion of referrals for septal myectomy. On-Pump Intracardiac Echocardiography offers real-time assessment of septal thickness in the arrested heart and is particularly helpful to surgeons building experience with these technically demanding operations.

Structured Abstract:(239/250 words)

Objective: During septal myectomy once the heart is arrested and drained of blood on cardiopulmonary bypass, transesophageal echocardiography (TEE) can no longer assess septal thickness. In the present study we evaluated the effectiveness of on-pump intracardiac echocardiography (OPIE) for real-time intraoperative septal thickness assessment in patients with pre-operative thickness ≤2.0cm. Our hypothesis was that OPIE measurements would be conconcordant with the pre- and post-cardiopulmonary bypass TEE measurements that are at present the primary operative guides.

Methods: We retrospectively reviewed patients with hypertrophic cardiomyopathy and septal thickness ≤2.0 cm on transthoracic echocardiography (TTE) who underwent septal myectomy from 7/2017-7/2024. The OPIE probe was introduced into the left-ventricular chamber during cardioplegic arrest, with repeated measurements to assess the depth and adequacy of resection. Septal thickness was evaluated pre-myectomy using TTE, cardiac MRI (CMR), transesophageal echocardiography (TEE), and OPIE. Lin's concordance correlation coefficients and Bland-Altman analyses were used to evaluate agreement between modalities.

Results: A total of 220 patients were included with preoperative thickness ≤2.0, 56 of whom underwent myectomy with OPIE guidance. Pre-resection TEE and OPIE demonstrated the strongest agreement of all the imaging modalities (CCC=0.81, 95% CI 0.72, 0.88), with minimal bias (-0.73) and the narrowest limits of agreement [-3.76,+2.31]. OPIE-derived resection thickness estimates were tightly clustered. In the OPIE cohort, there was one ventricular septal defect (1.8%) and no 30-day mortality.

Conclusion: OPIE is a reliable tool for intraoperative assessment of septal thickness, particularly in patients with mild hypertrophy.

Keywords (3-5): septal myectomy, hypertrophic obstructive cardiomyopathy, intraoperative imaging, [on-pump intracardiac echocardiography (OPIE)], left ventricular outflow tract obstruction, echocardiography

Introduction

In patients with hypertrophic cardiomyopathy (HCM) who remain symptomatic despite pharmacologic therapy, septal myectomy is the gold-standard for alleviating left ventricular outflow tract (LVOT) obstruction.[1] In patients with thin septa and predominantly dynamic LVOT obstruction with systolic anterior motion (SAM) of the mitral valve, extent of resection needs to be as conservative as possible to minimize the risk of iatrogenic ventricular septal defects (VSD) and complete heart block (CHB). To reduce the risk of VSD while addressing SAM in patients with thin septa, some have advocated for mitral valve replacement (MVR), though this approach carries long-term concerns related to prosthetic durability and thromboembolic risk.[2] More recently, other specialized centers have advocated for more shallow and wider myectomy combined with adjunctive mitral techniques to address SAM.[3–5]

With improved imaging, particularly ability to detect dynamic SAM, we have observed a decrease in pre-operative septal thickness among patients referred for septal myectomy. Of imaging modalities for assessing septal thickness before cardiopulmonary bypass pre-cannulation TEE is relied upon most heavily by experienced surgeons. However, after cardiopulmonary bypass is begun TEE cannot be used because the heart is drained of blood and there are no longer blood-muscle ultrasonic interfaces to produce images that would permit on-line assessment of wall thickness. On-pump intracardiac echocardiography (OPIE) is the only tool that has been proposed to guide septal resection in the arrested heart. We previously reported resection using OPIE in a cohort of 10 consecutive myectomies.[6] In this study we explored the hypothesis that OPIE would be concordant with pre- and post-cardiopulmonary bypass TEE measurements in a large cohort and thus assist on-line with precision myectomy in patients with HCM undergoing myectomy with septal thickness ≤2.0 cm.

Patients and Methods:

Patients:

This retrospective analysis included all patients with obstructive HCM and a septal thickness ≤2.0 cm, as determined by preoperative transthoracic echocardiography (TTE), who underwent surgical resection by a single surgeon (D.G.S.) at a high-volume, quaternary referral center (NYU Langone Health) between July 2017 to July 2024. All HCM patients referred for surgery had LVOT gradients >50 mmHg at rest or with provocation and had NYHA symptoms >II. The only exceptions were patients who were deemed to have syncope from obstruction albeit with milder limitation as recurrent syncope has potentially severe consequences. Of the 220 patients identified, 56 underwent extended septal myectomy with intraoperative assessment using the OPIE probe, who comprise the primary focus of this study. The remaining 164 patients underwent extended septal myectomy without OPIE guidance (Figure 1). The OPIE probe was not readily available for routine use during the early portion of the study period, when its application was predominantly investigational and limited to validation efforts. It was subsequently used with increasing frequency in cases of septal thickness ≤2.0 cm, based primarily on availability rather than specific clinical characteristics. Study was approved by institutional review board (#i24-01262) on 11/21/2024 and need for informed consent was waived.

Operative Techniques

Methods for performing extended septal myectomy have been described previously.[7–9] The extended myectomy increases the axial length of the resection to the base of the papillary muscles, widens the myectomy in the midventricle, and releases hypertrophied papillary muscles from their muscular connections to the anterior wall.

Patients were additionally considered for anterior mitral leaflet shortening if leaflet length was $\geq$30 mm, as described by our group.[5] The predominant leaflet shortening method used during this study period was residual leaflet excision (ReLex). On echocardiography the presence of a residual leaflet extending past the coaptation point of the mitral valve and protruding into left ventricular (LV) flow was identified. In the operating room it was confirmed by direct inspection; in all cases it was at A2, confirmed further by its attachment to the papillary muscles by redundant myxomatous curlicued chordae. Adequate chordal support on either side of the to-be-excised portion of A2 must be ensured. Also, one must ensure that there is at least 1 cm of coaptation distance between the remaining anterior and posterior leaflets. Factors that prevented ReLex in individual patients are a complex jumble of chordae tendineae at the leading edge and any abnormality there that could lead to prolapse.

The OPIE probe was introduced into the left ventricular chamber during the surgical resection on the arrested heart, with repeated measurements to assess the adequacy of the myectomy and septal integrity[6] (Figure1). Supplementary video S1 illustrates how the probe is used intraoperatively.

Septal thickness was evaluated pre-myectomy using TTE, cardiac magnetic resonance imaging (CMR), pre-bypass TEE, and pre-resection OPIE. The extent of resection was assessed through comparisons of pre- and post-bypass TEE, pre- and post-resection OPIE.

Study Objective and Outcomes:

The primary objective was to evaluate agreement and concordance between septal thickness measurements obtained using OPIE and those obtained through other imaging modalities. The incidence of ventricular septal defect (VSD) and need for permanent pacemaker

(PPM) placement were compared between patients who underwent resection with and without OPIE.

Statistical Analysis:

Statistical analyses were performed using IBM SPSS Statistics V29 (IBM, Armonk, NY) and GraphPad Prism V10 (Boston, MA). Categorical variables are expressed as frequency and percentage. Continuous variables are reported as mean ± standard deviation or median [25th, 75th percentile] as appropriate. Pre- and post-myectomy septal thickness and gradients were compared using the Wilcoxon matched-pairs signed rank test. Normally distributed variables were compared with the Student's *t* test, and non-normally distributed variables were compared with non-parametric testing (Mann-Whitney U). To assess agreement between measurement techniques, we used Bland–Altman analysis and Lin's Concordance Correlation Coefficient (CCC). Bland–Altman analysis was conducted for each pairwise comparison to quantify mean difference (bias) and limits of agreement. Lin's CCC was used to quantify overall agreement between methods; CCC estimates were calculated for each comparison along with corresponding 95% confidence. CCC values range from –1 to 1, with values closer to 1 indicating stronger agreement.

Results

Patient characteristics

Between June 2017 and July 2024, 220 patients with obstructive HCM and preoperative TTE measurements indicating septal thickness ≤2.0 cm underwent extended myectomy. Fifty-six patients (25.4%) underwent resection with intraoperative OPIE guidance. Of those undergoing resection with OPIE probe, the mean age (±SD) was 64.3 (±13.0) years, and 46.4% (26/56) were female (Table 1).

The majority of patients had New York Heart Association (NYHA) class III/IV symptoms (84%, 47/56), class II-III with presyncope (7%, 4/56) and syncope (9%, 5/56). One patient (1.8%) had previously undergone alcohol septal ablation. No differences were observed between those undergoing resection with and without the OPIE probe.

Preoperative Echocardiography

For patients who underwent myectomy with OPIE guidance, median left ventricular ejection fraction was 75% [70, 75], and median left ventricular mass index was 202 [158, 240] g/m^2 (Table 2). Moderate or severe mitral regurgitation (MR) was present in 54.4% (31/56), and mitral annular calcification (MAC) was identified in 13.7% (7/56). Provoked LVOT gradients were higher in patients undergoing resection with OPIE guidance (121[97,155] vs. 105[78,144], $p=0.02$).

Pre- and Post-Resection Septal Thickness Assessment

Figure 2 illustrates the distributions of septal thicknesses by imaging modality, with corresponding values provided by Table S1. Preoperatively, median septal thickness by TTE was 16 mm [15,18], with the thinnest measuring 9 mm. OPIE-derived resection thickness estimates were tightly clustered, indicating lower interquartile spread and suggesting consistency across patients. TEE estimates showed slightly wider distributions.

Bland-Altman and Lin's Correlation Coefficient (CCC) analyses were performed for nine pairwise comparisons (Table 3). Pre-resection TEE and OPIE demonstrated the strongest agreement (CCC=0.81, 95% CI 0.72, 0.88), with minimal bias (-0.73) and the narrowest limits of agreement [-3.76,+2.31]. This degree of concordance is considered good agreement. The Bland-Altman plot for this analysis is shown in Figure 3. Post-resection measurements between OPIE and TEE also showed moderate agreement (CCC = 0.75), with small bias (-1.14) and narrow limits of agreement [-3.94,+1.66]. Comparisons between OPIE and other modalities, such as CMR (CCC=0.70), also demonstrated higher concordance than all non-OPIE pairings.

Resection thickness estimates derived from the difference between paired pre- and post-resection measurements also showed concordance, with medians of 6 mm [5, 7] for OPIE and 5 mm [4, 7] for TEE (*CCC=0.75)*.

Intra-Operative Course

Mitral repair including ReLex was significantly more common in those undergoing extended myectomy with OPIE than without (repair: 87.5% vs. 67.7%, $p=0.005$; ReLex 57.1% vs. 38.4%, $p=0.02$), and MVR was less frequently performed (3.6% vs. 16.5%, $p=0.01$; Table 4). No MVR was performed for SAM. MVR was only performed in patients with severe intrinsic mitral disease, predominantly with severe central MR secondary to posterior leaflet calcification and MAC. Concurrent operations were more prevalent in patients who underwent myectomy without OPIE, with concurrent coronary revascularization in 11.0% vs. 1.8% ($p=0.05$). Aortic valve replacement was numerically more common 11.6% vs. 7.1% ($p=0.45$).

VSD occurred in one patient in each cohort. Both patients had septal thickness ≤1.6cm. Persistent SAM or elevated gradients requiring re-arresting the heart and additional resection or repair were similar in the non-OPIE and OPIE groups (3.0% vs. 1.8%, $p=0.52$).

Post-Operative Course

Among patients undergoing myectomy without concurrent valve replacement, CHB requiring PPM placement were similar between OPIE group and non-OPIE group (3.9% vs. 10.4%, $p=0.24$, Table S3). To account for the known impact of preoperative RBBB on conduction outcomes, we performed a sensitivity analysis excluding these patients. In this subgroup, PPM rates were 0.0% in the OPIE group and trended lower than in the non-OPIE group, 8.2% (p=0.06).

There were no instances of delayed VSD. Peak gradients on pre-discharge TTE were clinically low in both groups but significantly lower in those with OPIE guidance (5 [5,11.5] vs. 9.5 [5,15], $p<0.01$) (Figure S1). Notably, median intensive care unit length of stay was <24 hours in both cohorts and the median post-operative stay was 5 days for both cohorts. There were two 30-day mortalities in the overall study population (0.9% overall), and both occurred within cohort without OPIE guidance.

Resting gradients at follow-up were similarly low between groups, measured at a median of 17 months in OPIE group and 18.5 months in non-OPIE group (OPIE: 0 [0, 5] vs. non-OPIE: 0 [0, 7], p=0.30). Median follow-up duration was 3 years in OPIE group and 2.6 years in non-OPIE group, during which the majority of patients experienced significant improvement in NYHA class (83.6% vs. 79.5%, p=0.56; Figure S1).

Discussion

Exploring our hypothesis, in this study we have shown that of all the preop imaging modalities, that with the tightest concordance with the pre-canulation TEE is the OPIE thickness measured by the surgeon with this novel hand-held device. Moreover, the concordance of the post-canulation OPIE with the post-canulation TEE was higher than any other concordance. The concordance of OPIE with pre-op TTE, pre-op TEE and pre-op CMR were poor. The concordance of pre-op TTE, pre-op CMR, and pre-canulation TEE with each other were poor as well. We conclude that the OPIE has good concordance with OR TEE images and can be relied on for guidance about the depth of surgical resection.

It is clear from large national databases, that there is substantial room for improvement in outcomes of surgical myectomy. Failed myectomy often results from either inadequate or too aggressive septal resection. Away from few highly specialized centers of excellence, there is ample evidence of failed myectomies performed in the general cardiology community. Hospital mortalities of 5.9% are reported from Medicare data, and a rate of 4% was reported from the National Readmission Database from 2010 to 2019.[10,11] Besides the depth of the resection it is particularly important in the extended myectomy to extend the muscular resection axially to the level of the papillary muscles.[7,8] One impetus for researching OPIE was to provide an aid to the surgeon tailoring the resection. Most crucially, wall thickness after the initial myectomy resection cannot be assessed. At this point, for the surgeon, it may not be clear whether further resection is indicated or whether it might be prudent to stop. Hence, the utility of OPIE for assessing the exact septal thickness under the probe.

Even in a cohort limited to septal thickness ≤2.0 cm, the patients undergoing OPIE-guided resection likely represent those with the most technically complex anatomy—characterized by dynamic LVOT obstruction driven primarily by SAM rather than only by septal hypertrophy, as reflected by the significantly higher provoked gradients pre-myectomy in the OPIE cohort and the higher rate of leaflet shortening. These patients often required precise septal resection and complex mitral valve repair. In select patients with elongated anterior mitral leaflets, adjunctive techniques have been incorporated to further alleviate SAM and optimize valve competence.[5,9,12,13] [12] Over the past decade, our group has shifted to ReLex (from anterior leaflet plication) with associated papillary muscle modifications when indicated. ReLex is associated excellent survival with sustained reductions in MR, resting and provoked LVOT gradients, and left atrial volume at a median of 2.5 year follow-up.[5] These techniques address not only leaflet redundancy but also abnormal secondary chordal attachments, which contribute to the anterior displacement of the mitral valve and augmentation of drag forces that precipitate SAM[15–17], reinforcing evolving understanding that mitral apparatus abnormalities are central to the pathophysiology of obstruction in HCM.[18]

In contrast, patients in the non-OPIE group more frequently exhibited MAC, often necessitating MVR. MAC contributes to anterior displacement of the mitral valve, impaired leaflet mobility, and mitral stenosis.[19,20] In such cases, MVR may be preferable to repair, particularly when posterior leaflet mobility is severely restricted or MR arises primarily from calcification rather than SAM.[20] In our previously reported experience in oldest patients with HCM, MAC was present in nearly half, with a substantial proportion requiring MVR, and higher MAC offset distances were associated with increased risk of LVOT obstruction.[20]

Despite greater anatomic complexity in the OPIE cohort – as indicated by higher preoperative provoked gradients and more frequent adjunctive mitral valve repair – the rate of re-clamping for persistent SAM was similar. There was a trend toward lower rate of PPM for post-op heart block in patients with pre-existing RBBB, 0% in the OPIE cohort vs. 8.2 % in the non-OPIE group.

This study has several limitations. Its retrospective design introduces potential confounding and selection bias. Additionally, incomplete paired septal thickness measurements in some OPIE patients limited their inclusion in concordance analyses. The OPIE probe is excellent at imaging the basal septum. However, we have found that it is less effective in imaging the mid and apical septum because of inadequate visualization of the right ventricular endocardium perhaps due to heavy trabeculations there. In our experience, VSDs that manifest immediately after myectomy can occur for 2 reasons. First, the myectomy resection can be carried too deeply. The OPIE probe protects against this misadventure. The second though may occur even with an optimally judged myectomy in a patient with a thin septum. On quite rare occasion the septal muscle is soft and compliant and tears through even with optimally judged resection. This complication, though rare, may not be prevented even with an OPIE-optimally-judged resection depth.

Conclusion

Intraoperative OPIE assessment provides an accurate method for real-time measurement of septal thickness during myectomy, demonstrating strong concordance with pre- and post-myectomy TEE. While not all patients may require OPIE-guided resection, it is likely to be particularly valuable in patients with dynamic LVOT obstruction and thin septa, where the margin for error is narrow. We believe that OPIE may prove useful in 2 situations: first, when even an experienced surgeon is uncertain about the adequacy of the depth and length of resection, especially in patients with septal thickness ≤2.0cm; second, to aid the inexperienced surgeon in such judgements. If our findings about the utility of OPIE are confirmed by others, we believe OPIE may have its greatest utility helping nascent HCM surgeons achieve good and reproducible results.

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Figure Legends (double spaced, separate pages)

Graphical Abstract: Real-time intraoperative OPIE assessment provides reproducible measurement of septal thickness.

Figure 1: On-pump intraoperative echocardiography (OPIE) probe. Opie probe, with diameter just larger than the thickness of two small coins, the blue portion of the probe is thin enough to be inserted transaortically into the LVOT and placed against the basilar interventricular septums. *Images reproduced with permission from FujiFilm.*

Figure 2: Distribution of Septal Thickness. Violin plots show septal thickness measured (A) pre-myectomy (TTE, CMR, OPIE, TEE), (B) post-myectomy (OPIE, TEE).

Solid line: Median; Dashed lines: IQR; Statistical significance of Lin's concordance correlation indicated as: $^{*}p < 5.0E\text{-}02$, $^{**}p < 1.0E\text{-}02$, $^{***}p < 1.0E\text{-}03$. ns, not significant ($p \geq 5.0E\text{-}02$).

Figure 3: Cross-Modality Concordance of Septal Thickness. Bland-Altman plots show TEE–OPIE agreement pre- (A) and post-myectomy (B). Lin's concordance coefficients indicate strongest pre- (C) and post-myectomy (D) agreement between OPIE and TEE.

OPIE:On-Pump Intracardiac Echocardiography; TEE:Transesophageal Echocardiography; TTE:Transthoracic Echocardiography; CMR:Cardiac Magnetic Resonance Imaging

Figure S1: Figure S1: Pre- and Post-Myectomy Gradients, Mitral Regurgitation, and NYHA Symptoms in patients in whom OPIE was used. (A) Peak LVOT gradients at a median echocardiographic follow-up of 17 months. Box-and-whisker plots show the median (black horizontal line), interquartile range (box), and whiskers extending to the most extreme data points within 1.5 × the interquartile range (Tukey method). NYHA (B) and MR (C) are also shown.

Table 1. Baseline Characteristics.

Variables	**Myectomy with OPIE probe (n = 56)**	**Myectomy without OPIE probe (n= 164)**	***P*-value**
Age, years	64.3 ± 13.0 *(n=56)*	66.9 ± 12.8 *(n=164)*	0.13
Female	46.4% *(n=26/56)*	60.4% *(n=99/164)*	0.09
Former or current tobacco use	44.6% *(n=25/56)*	45.7% *(n=75/164)*	1.00
Diabetes	23.2% *(n=13/56)*	18.9% *(n=31/164)*	0.56
Hypertension	66.1% *(n=37/56)*	70.1% *(n=115/164)*	0.62
COPD	14.3% *(n=8/56)*	9.1% *(n=15/164)*	0.31
Atrial Fibrillation	21.4% *(n=12/56)*	29.3% *(n=48/164)*	0.30
Cerebrovascular Disease	10.7% *(n=6/56)*	7.9% *(n=13/164)*	0.58
Chronic Kidney Disease	16.1% *(n=9/56)*	22.0% *(n=36/164)*	0.44
Liver Disease	1.8% *(n=1/56)*	2.4% *(n=4/164)*	1.00
Previous Cardiac Surgery	0.0% *(n=0/56)*	2.4% *(n=4/164)*	0.57
Syncope	8.9% *(n=5/56)*	9.1% *(n=15/164)*	1.00
NYHA Class III/IV	83.9% *(n=47/56)*	71.7% *(n=119/164)*	0.11
Prior Alcohol Septal Ablation	1.8% *(n=1/56)*	3.0% *(n=5/164)*	1.00
Pre-Operative ICD	10.7% *(n=6/56)*	15.9% *(n=26/164)*	0.39
Pre-Operative PPM	3.6% *(n=2/56)*	7.9% *(n=13/164)*	0.37

OPIE:On-Pump Intracardiac Echocardiography; COPD:Chronic Obstructive Pulmonary Disease; NYHA:New York Heart Association functional class; ICD:Implantable Cardioverter-Defibrillator; PPM:Permanent Pacemaker.

Table 2. Preoperative Echocardiographic Parameters.

Variables	Myectomy with OPIE (n = 56)	Myectomy without OPIE (n = 164)	*P*- value
Ejection fraction (%)	75 [70, 75] *(n=56)*	72 [65, 75] *(n=164)*	0.57
Septal thickness (mm)	16 [15, 18] *(n=56)*	17 [15, 19] *(n=164)*	0.22
Resting LVOT gradient (mmHg)	55 [30, 81] *(n=56)*	50 [27, 88] *(n=164)*	0.96
Maximum provoked gradient (mmHg)	121 [97, 155] (*n = 56*)	105 [78, 144] *(n=141)*	**0.02**
Left atrial diameter (cm)	4.1[3.7, 4.8] *(n=35)*	4.2 [3.7, 4.7] *(n=110)*	0.52
Left ventricular Mass Index (g/m^2)	202 [158, 240] *(n=42)*	199.5 [164, 249] *(n=112)*	0.89
Moderate or severe mitral regurgitation	54.4% *(31/56)*	49.6% *(70/141)*	0.53
Mitral annular calcification	13.7% *(7/56)*	32.4% *(46/142)*	**0.01**

LVOT:Left Ventricular Outflow Tract; SAM:Systolic Anterior Motion.

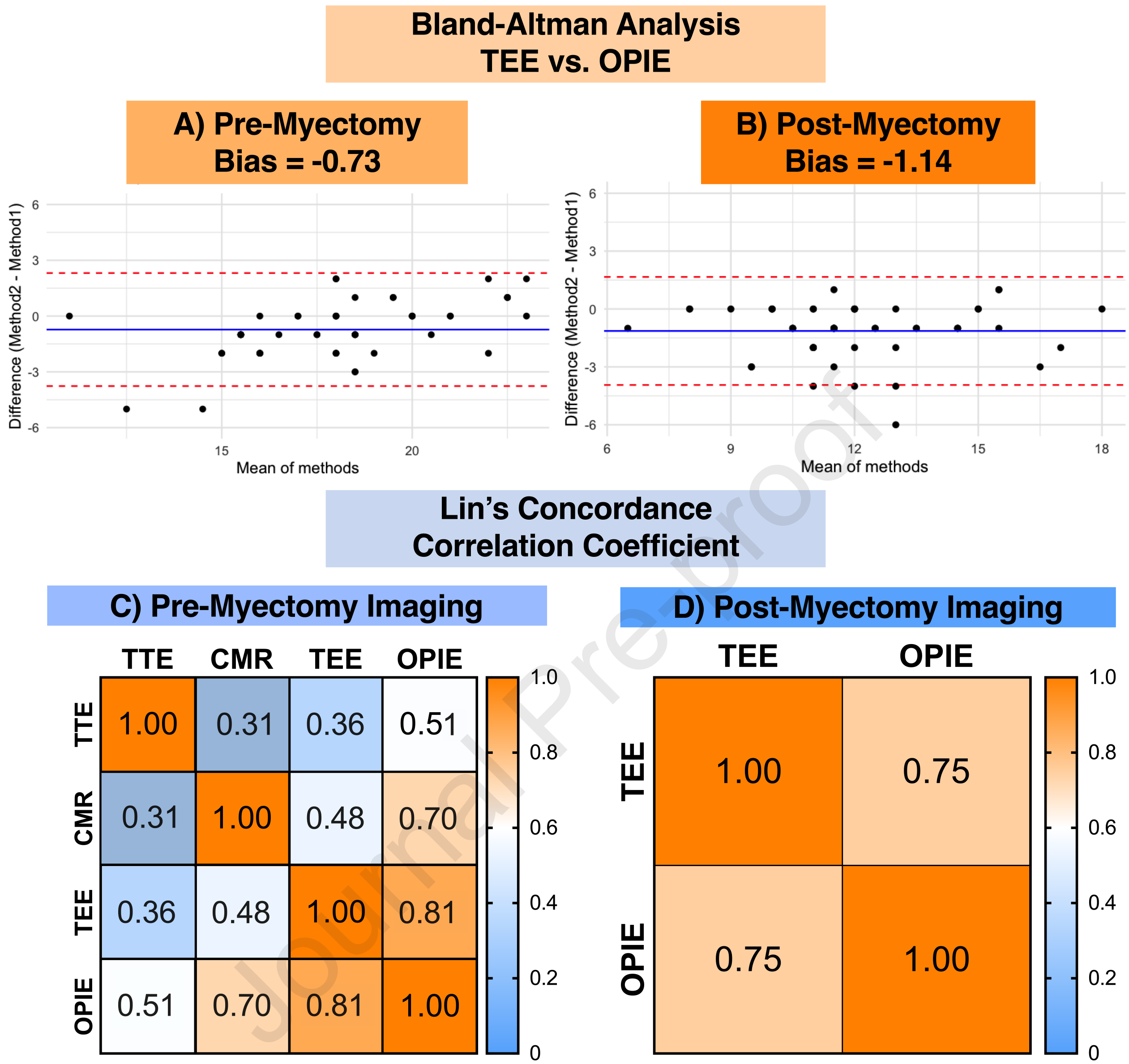
Table 3. Bias, Limits of Agreement, and Lin's Concordance Correlation Coefficients for Imaging Modalities.

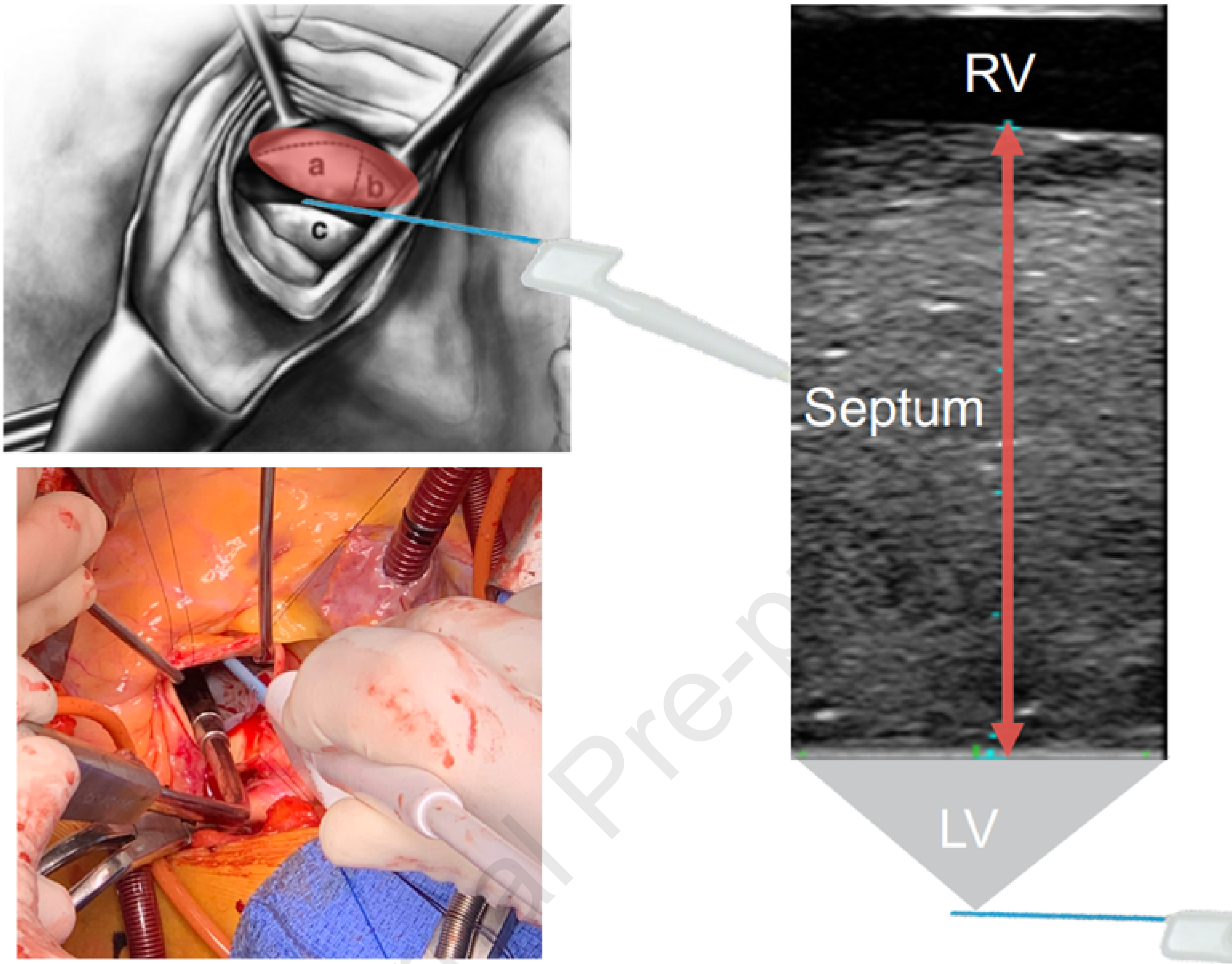
Comparison	Bias	SD	Limits of Agreement	Concordance Correlation Coefficient
Pre-Myectomy				
TTE vs. OPIE	1.35	2.57	-3.68, +6.39	0.51 [0.31, 0.66]
TEE vs. OPIE	-0.73	1.55	-3.76, +2.31	0.81 [0.72, 0.88]
CMR vs. OPIE	-0.24	2.69	-5.5, +5.03	0.7 [0.48, 0.83]
TTE vs. TEE	2.11	2.33	-2.46, +6.69	0.36 [0.23, 0.47]
TTE vs. CMR	2.67	3.93	-5.03, +10.38	0.31 [0.17, 0.44]
TEE vs. CMR	-0.08	3.47	-6.87, +6.72	0.48 [0.30, 0.63]
Post-Myectomy				
TEE vs. OPIE	-1.14	1.43	-3.94, +1.66	0.75 [0.61, 0.84]

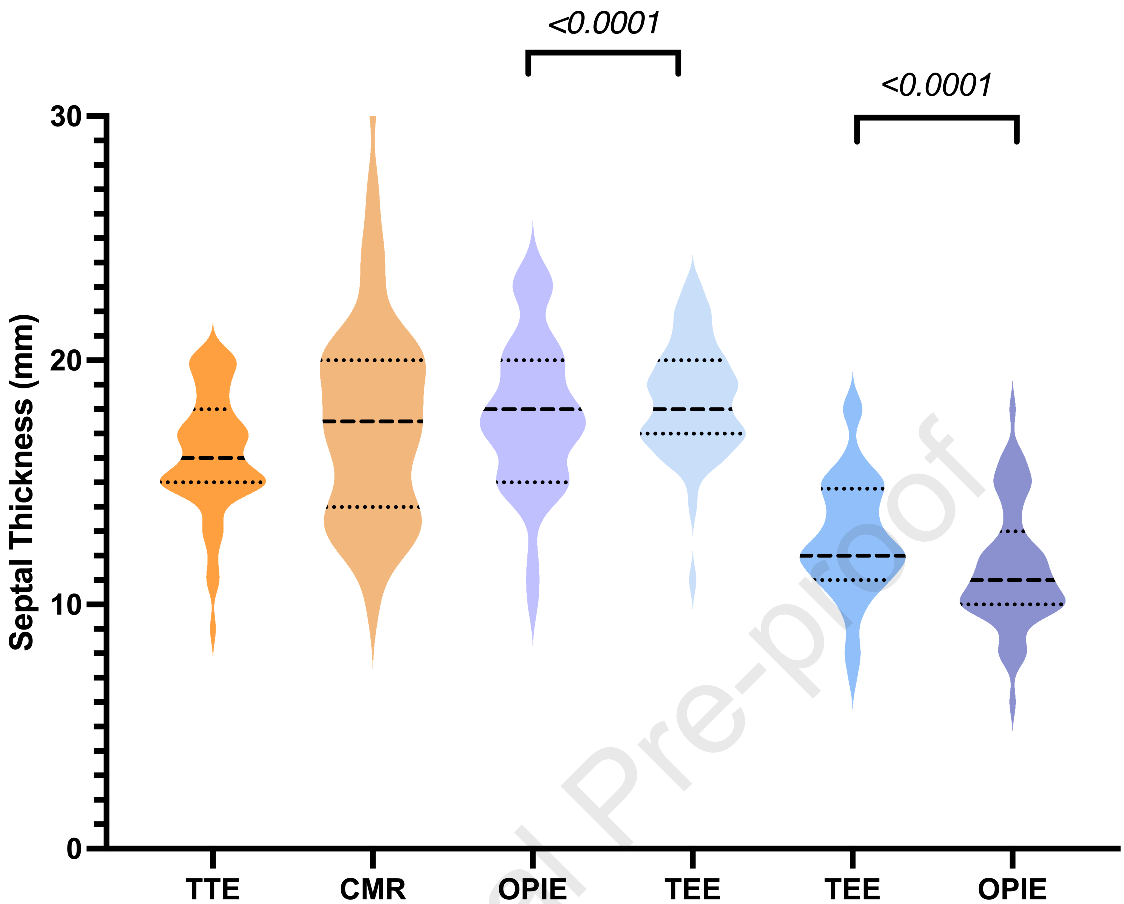
Bias is the mean difference between the two methods (method 2-method 1), a positive bias means method 2 tends to give higher values, negative means lower. SD is the standard deviation of the bias, with higher SD indicating less consistent bias. Limits of Agreement reflect the 95% confidence intervals of the bias. Lin's Concordance Correlation Coefficient and it's 95% confidence intervals are also shown.

Table 4. Intra-operative Details.

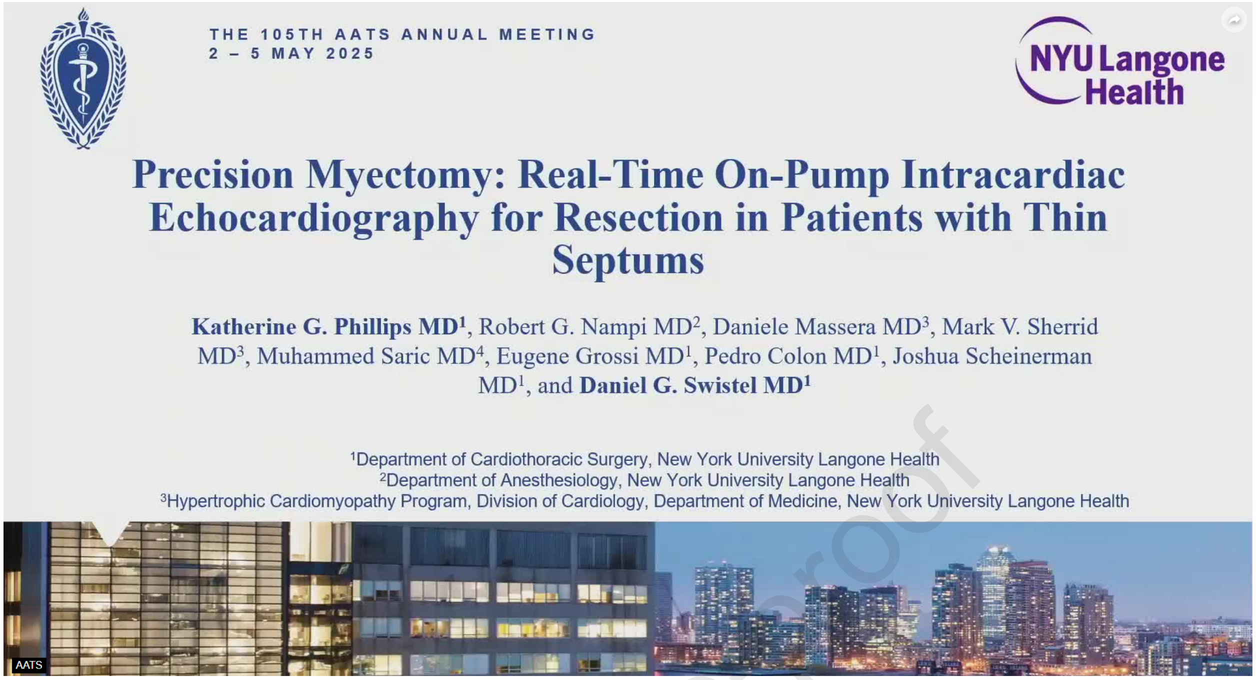
Variables	**Myectomy with OPIE (n = 56)**	**Myectomy without OPIE (n = 164)**	***P value***
Cardiopulmonary Bypass Time, mins	84 [75, 97] *(n=56)*	91 [72, 117] *(n=164)*	0.31
Crossclamp Time, mins	61.5 [54, 71] *(n=56)*	70 [52, 93] *(n=164)*	0.20
Mitral Repair (including papillary muscle/chordal release)	87.5% *(49/56)*	67.7% *(111/164)*	**0.005**
ReLex performed	57.1% *(32/56)*	38.4% *(63/164)*	**0.02**
Mitral Valve Replacement	3.6% *(2/56)*	16.5% *(27/164)*	**0.01**
Left Ventricular Aneurysm Resection	0.0% *(0/0)*	4.3% *(7/164)*	0.20
Concurrent coronary revascularization	1.8% *(1/56)*	11.0% *(18/164)*	**0.05**
Concurrent Aortic Valve Replacement	7.1% *(4/56)*	11.6% *(19/164)*	0.45
Intraoperative Complications			
VSD	1.8% *(1/56)*	0.6% *(1/164)*	0.45
Re-Clamp for SAM	1.8% *(1/56)*	3.0% *(5/164)*	0.52
Peak Intra-Operative lactate	1.7 [1.3, 2.2] *(n=56)*	1.9 [1.3, 2.3] *(n=159)*	0.36


Bland-Altman Analysis
TEE vs. OPIE
A) Pre-Myectomy
Bias = -0.73
B) Post-Myectomy
Bias = -1.14
Difference (Method2 - Method1)
Mean of methods
Lin's Concordance
Correlation Coefficient
C) Pre-Myectomy Imaging
TTE CMR TEE OPIE
TTE 1.00 0.31 0.36 0.51
CMR 0.31 1.00 0.48 0.70
TEE 0.36 0.48 1.00 0.81
OPIE 0.51 0.70 0.81 1.00
D) Post-Myectomy Imaging
TEE OPIE
TEE 1.00 0.75
OPIE 0.75 1.00


a
b
c
RV
Septum
LV



<0.0001
<0.0001
Septal Thickness (mm)
30
20
10
0
TTE
CMR
OPIE
TEE
TEE
OPIE


THE 105TH AATS ANNUAL MEETING
2 – 5 MAY 2025
NYU Langone Health
Precision Myectomy: Real-Time On-Pump Intracardiac Echocardiography for Resection in Patients with Thin Septums
Katherine G. Phillips MD[1], Robert G. Nampi MD[2], Daniele Massera MD[3], Mark V. Sherrid MD[3], Muhammed Saric MD[4], Eugene Grossi MD[1], Pedro Colon MD[1], Joshua Scheinerman MD[1], and Daniel G. Swistel MD[1]
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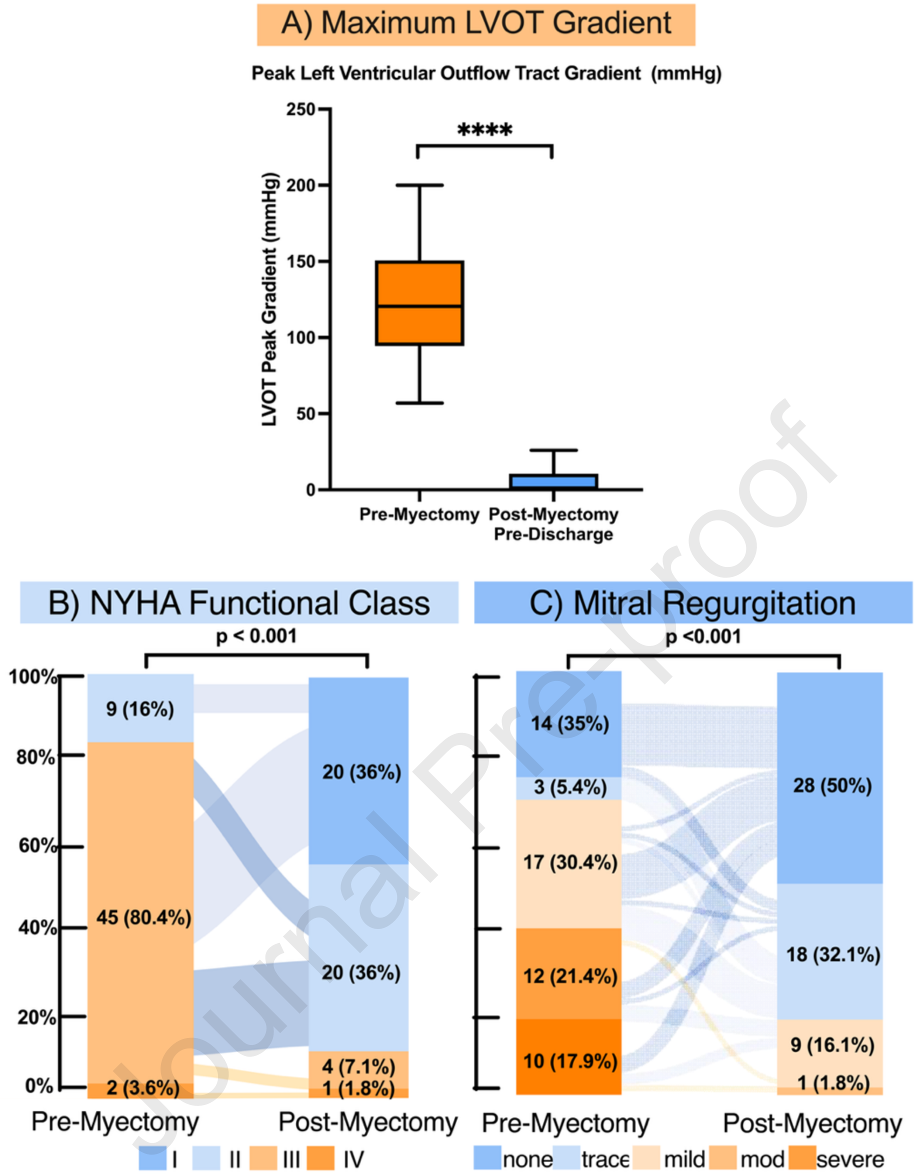
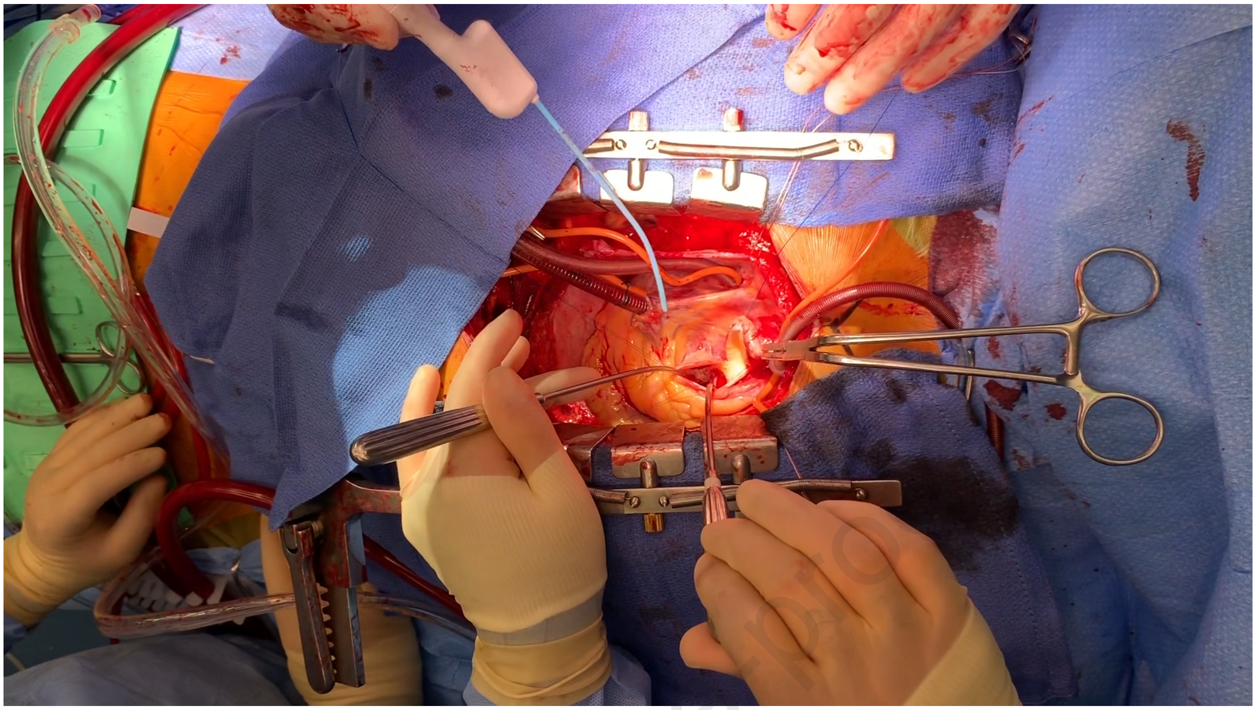
AATS


A) Maximum LVOT Gradient
Peak Left Ventricular Outflow Tract Gradient (mmHg)
LVOT Peak Gradient (mmHg)
250
200
150
100
50
0
****
Pre-Myectomy
Post-Myectomy Pre-Discharge
B) NYHA Functional Class
p < 0.001
100%
80%
60%
40%
20%
0%
9 (16%)
45 (80.4%)
2 (3.6%)
20 (36%)
20 (36%)
4 (7.1%)
1 (1.8%)
Pre-Myectomy
Post-Myectomy
I
II
III
IV
C) Mitral Regurgitation
p <0.001
14 (35%)
3 (5.4%)
17 (30.4%)
12 (21.4%)
10 (17.9%)
28 (50%)
18 (32.1%)
9 (16.1%)
1 (1.8%)
Pre-Myectomy
Post-Myectomy
none
trace
mild
mod
severe



Supplementary Appendix

Contents

Figures

Video

Tables

Figure S1: Pre- and Post-Myectomy Gradients, Mitral Regurgitation, and NYHA Symptoms in patients in whom OPIE was used. A) Peak LVOT gradients at a median echocardiographic follow-up of 17 months. Change in NYHA functional status (B) and MR (C) are also shown.

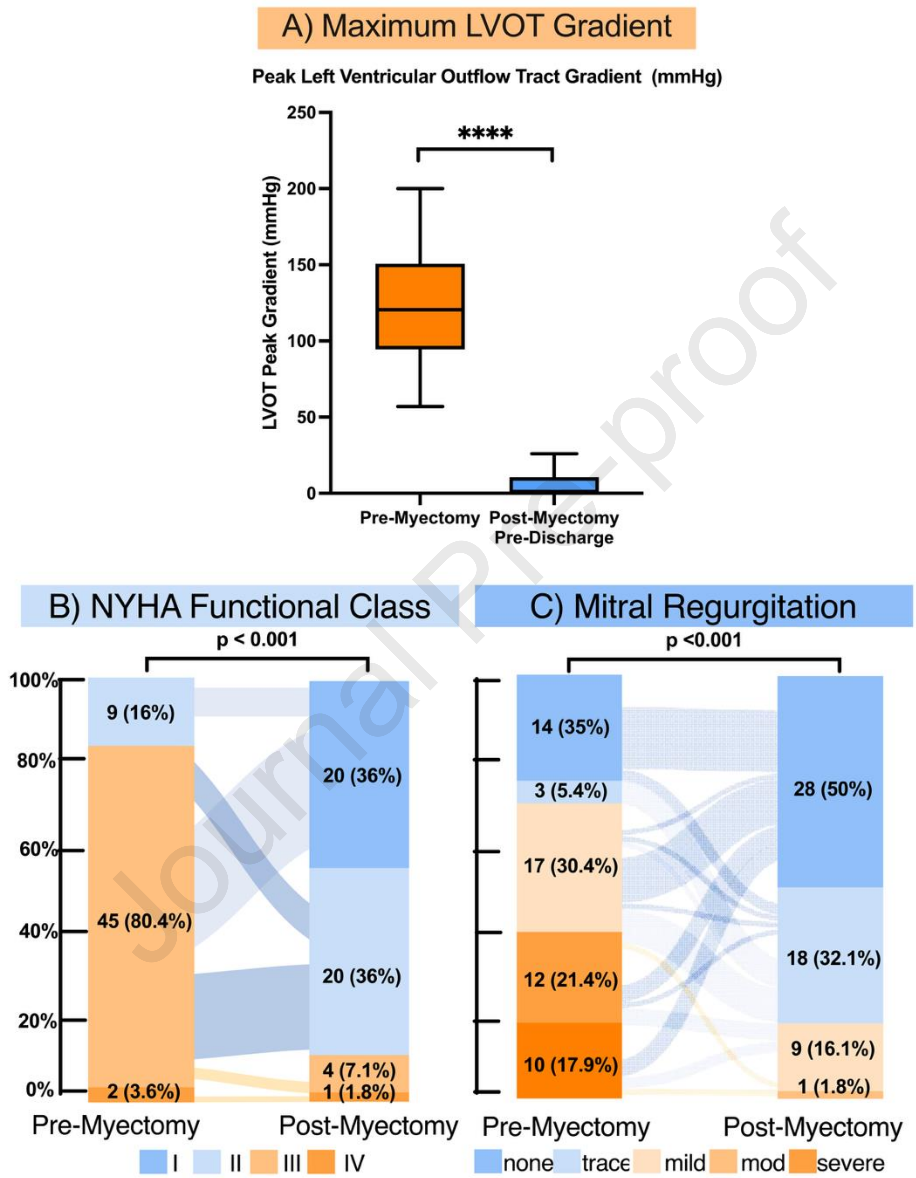


Table S1. Septal Thickness by Imaging Modality in Patients Undergoing Myectomy with OPIE Guidance. Septal thickness was assessed pre- and post-resection using multiple modalities. Postoperative values reflect measurements following resection but prior to discharge. Pathologic specimen thickness is reported only in cases were a single, well-oriented sample was available.

Modality	Pre-Resection Thickness (mm)	Post-Resection Thickness (mm)	*P value*
TTE	16 [15, 18] *(n=56)*		
CMR	17.5 [14, 20] *(n=40)*		
Intraoperative TEE	18 [17, 20] *(n=56)*	11 [10, 13] *(n=52)*	**<0.01**
OPIE	18 [15, 20] *(n=50)*	11 [10, 13] *(n=50)*	**<0.01**
Pathologic Specimen Thickness		8 [6, 11] *(n=43)*	
Extent of Resection OPIE		6 [5, 7] *(n=50)*	
Extent of Resection TEE		6 [4, 7] *(N=52)*	

Values are median [interquartile range].

TTE = transthoracic echocardiography; TEE = transesophageal echocardiography; CMR = cardiac magnetic resonance imaging; OPIE = on pump intracardiac echocardiography

Supplementary Table 2. Post-Operative Rhythm Occurrences. Any post-operative EKG prior to discharge with the following rhythm is included, even when resolved prior to discharge or was present pre-operatively.

Variables	**Myectomy with OPIE (n = 56)**	**Myectomy without OPIE (n = 164)**	***P value***
New Onset POAF	27.3% *(12/44)*	25.0% *(29/116)*	0.84
First Degree Heart Block	32.1% *(18/56)*	29.9% *(49/164)*	0.74
Right Bundle Branch Block	14.3% *(8/56)*	15.9% *(26/164)*	1.00
Left Bundle Branch Block	78.6% *(44/56)*	74.4% *(122/164)*	0.59
Complete Heart Block	12.5% (7/56)	14.0% *(23/164)*	1.00

Values are mean ± SD, median [25th percentile, 75th percentile], or n(%).

POAF = post-operative atrial fibrillation; OPIE: On-Pump Intracardiac Echocardiography