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Sub-Aortic Membrane: What Is Beyond Simple Membrane Resection Early and Mid-Term Results

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ABSTRACT

Background: Sub-aortic membrane (SAM) is a shelf-like fibrous structure beneath the aortic valve that is a common cause of left ventricular outflow tract obstruction (LVOTO). If untreated, it can lead to progressive aortic regurgitation (AR) and hemodynamic compromise. When indicated, surgical resection is the standard treatment, but recurrence rates and postoperative outcomes vary depending on surgical technique and patient characteristics.

Objective: To evaluate the early and mid-term outcomes of surgical resection for SAM, focusing on its impact on left ventricular outflow tract (LVOT) gradients, AR severity, and functional status.

Methods: This retrospective study included 16 patients with isolated SAM or SAM associated with mild to moderate AR, operated on at Beni Suef University Hospital between 2015 and 2021. Indications for surgery were a peak LVOT Doppler gradient ≥30 mmHg or more than mild AR. Surgical resection involved complete removal of the membrane, including its fibrous extensions, septal myomectomy with release of both fibrous trigons if needed. Patients were assessed intraoperatively, early postoperatively (within one month), and at mid-term follow-up (6 months to 4 years). Key outcomes included LVOT gradient reduction, AR progression, and functional status using The New York Heart Association (NYHA) classification.

Results: The mean preoperative LVOT gradient was 42.4 ± 9.9 mmHg, significantly reduced to 8.1 ± 4.5 mmHg intraoperatively and stabilized at 10.3 ± 5.2 mmHg at mid-term follow-up ($p < 0.001$). Moderate AR decreased from 25% preoperatively to 6.2% at mid-term ($p < 0.001$). NYHA Grade III cases improved from 31.3% preoperatively to 6.2% at mid-term follow-up ($p = 0.014$). One patient experienced postoperative AR progression due to cusp perforation, and another had persistent moderate AR due to dense fibrous adhesion. No recurrence of SAM was observed during follow-up.

Conclusions: A more extensive surgical approach to SAM resection can lead to prolonged relief of LVOTO, stabilizing or improving AR, and enhancing functional outcomes in early and mid-term follow-ups. These results highlight the importance of extensive and comprehensive surgical approach to reduce rate of recurrence and improve outcome. Long-term studies are needed to confirm the durability of these outcomes.

Keywords: Sub-aortic membrane, left ventricular outflow tract obstruction, aortic regurgitation, SAM resection, early and mid-term outcomes.

INTRODUCTION

Subaortic membrane (SAM) is a fibrous shelf-like structure that develops beneath the aortic valve, leading to left ventricular outflow tract obstruction (LVOTO) and, in many cases, progressive aortic regurgitation (AR). It is considered one of the most common causes of LVOTO, and while the exact etiology remains unclear, it is hypothesized that abnormal hemodynamic stress and turbulence in the subaortic region contribute to fibromuscular tissue proliferation [(1)]. If left untreated, SAM can lead to left ventricular hypertrophy, worsening AR, and increased risk of reoperation. Conventional surgical resection often relieves LVOTO, but high recurrence rates and persistent AR remain significant concerns, necessitating the exploration of more comprehensive surgical strategies [(2)].

Although simple membrane resection has been widely performed, studies have shown that fibrous extensions beyond the primary membrane, particularly those involving the mitral and aortic valves, may contribute to continued disease progression and recurrence. Additionally, incomplete resection of fibrous tissue and failure to address abnormal subaortic muscle hypertrophy may lead to residual obstruction. Given these challenges, a more extensive surgical approach incorporating complete membrane excision, septal myectomy, fibrous trigons release, and thorough removal of fibrous tissue from both the mitral and aortic valves may provide more durable results [(3)].

Surgical techniques vary from just simple membrane resection to as far as membrane resection with septal myectomy and release of both fibrous trigons and peeling of both mitral and aortic valves from any fibrous membrane attached to them [(2)]. Consequently, the current study was conducted to evaluate the early and mid-term outcomes of an extensive surgical approach for SAM, focusing on reduction of left ventricular outflow tract (LVOT) gradient, improvement in AR severity, and functional recovery based on The New York Heart Association (NYHA) classification. By employing a more aggressive resection strategy, the study aimed to determine whether this approach enhances postoperative outcomes and decreases the likelihood of disease recurrence. Additionally, the study sought to compare its findings with previous research to determine how this technique performs relative to conventional SAM resection methods.

PATIENTS AND METHODS

This study utilized a retrospective design approved by the Human Research Ethical Committee at Beni Suef University Hospital. Conducted between 2015 and 2021, the study analyzed 16 patients who underwent surgical resection for discrete SAM. The primary goal was to evaluate the early and mid-term outcomes, focusing on LVOTO and associated AR.

Inclusion and Exclusion Criteria:

Patients were included if they had isolated SAM or SAM with mild to moderate AR. Those with significant associated cardiac abnormalities or those requiring aortic valve surgery were excluded. This ensured a homogeneous cohort for assessing the effectiveness of SAM resection without confounding variables.

Indications for Surgery and Follow-Up:

Surgery was indicated in cases of a peak LVOT Doppler gradient ≥30 mmHg (measured at a controlled resting heart rate of 60–70 beats per minute) and/or more than mild AR. Follow-up assessments of LVOT gradients and AR severity were conducted intraoperatively, early postoperatively (within one month), and mid-term (6 months to 4 years postoperatively). Early mortality was defined as death within 30 days of surgery or prior to hospital discharge. Recurrence of SAM was identified as a peak LVOT gradient exceeding 30 mmHg

postoperatively, and progression of AR was defined as any worsening compared to the preoperative state.

Surgical Procedure:

Surgery was performed under full cardiopulmonary bypass with moderate hypothermia (30–32°C). The left ventricle was vented via the superior pulmonary vein, and the heart was arrested using cold oxygenated blood/crystalloid cardioplegia. An oblique incision was made in the aorta, and the aortic valve leaflets were retracted to inspect the LVOT and surrounding structures, including the anterior mitral leaflet and fibrous trigons.

The membrane was held using a forceps then using a size 15 blade, an incision was made through the membrane only to its junction with the muscle. Using blunt dissection (a dissector or a tip of a small mosquito forceps) the membrane was peeled off the muscle from the entire circumference of the subaortic region. If there was fibrous extension on the anterior mitral leaflet, it was peeled from it down to the mitral chordea. If there was fibrous tissue extension obscuring left and right fibrous trigons, both trigons were mobilized and released. Then the aortic valve leaflets were peeled off from any fibrous tissue extensions, taking complete attention not to tear or perforate the aortic valve tissues. After complete removal of the Membrane and all its fibrous extension, septal myomectomy was performed. The extent of myectomy depended on septal wall thickness, usually 3 to 4 mm depth is enough to avoid compromising ventricular integrity. After washing out the left ventricle to remove any debris, the aortotomy was closed in two layers. After coming of cardiopulmonary bypass and patient's hemodynamics were stabilized, intraoperative transesophageal echocardiography (TEE) was used to assess LVOT gradient and valve integrity, ensuring no residual obstruction or any complication.

Outcome Measurement:

Key outcomes included reductions in LVOT gradient and AR severity, assessed at predefined intervals. Adverse events such as AR progression due to surgical challenges, including cusp perforation or residual fibrous tissue, were documented and managed accordingly.

Ethical Considerations: The patient data were anonymous. Data presentation was not by the patient's name but by diagnosis and patient confidentiality was protected. An informed consent was taken from all participants, it was in Arabic language and confirmed by date and time. Confidentiality was preserved by assigning a number to patients initials and only the investigator knew it. The study adhered to the Helsinki Declaration throughout its execution.

Statistical analysis: The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) software version 28.0, IBM Corp., Chicago, USA, 2021. Quantitative data tested for normality using Shapiro-Wilk test, then described as mean±SD (standard deviation) as well as minimum and maximum of the range, and then compared using RMANOVA test. Qualitative data described as number and percentage and then compared using Marginal homogeneity test. Dunnet's test was used as well as post hoc comparison for differences between follow ups from preoperative level. The level of significance was taken at p-value ≤ 0.050 was significant, otherwise was non-significant.

RESULTS

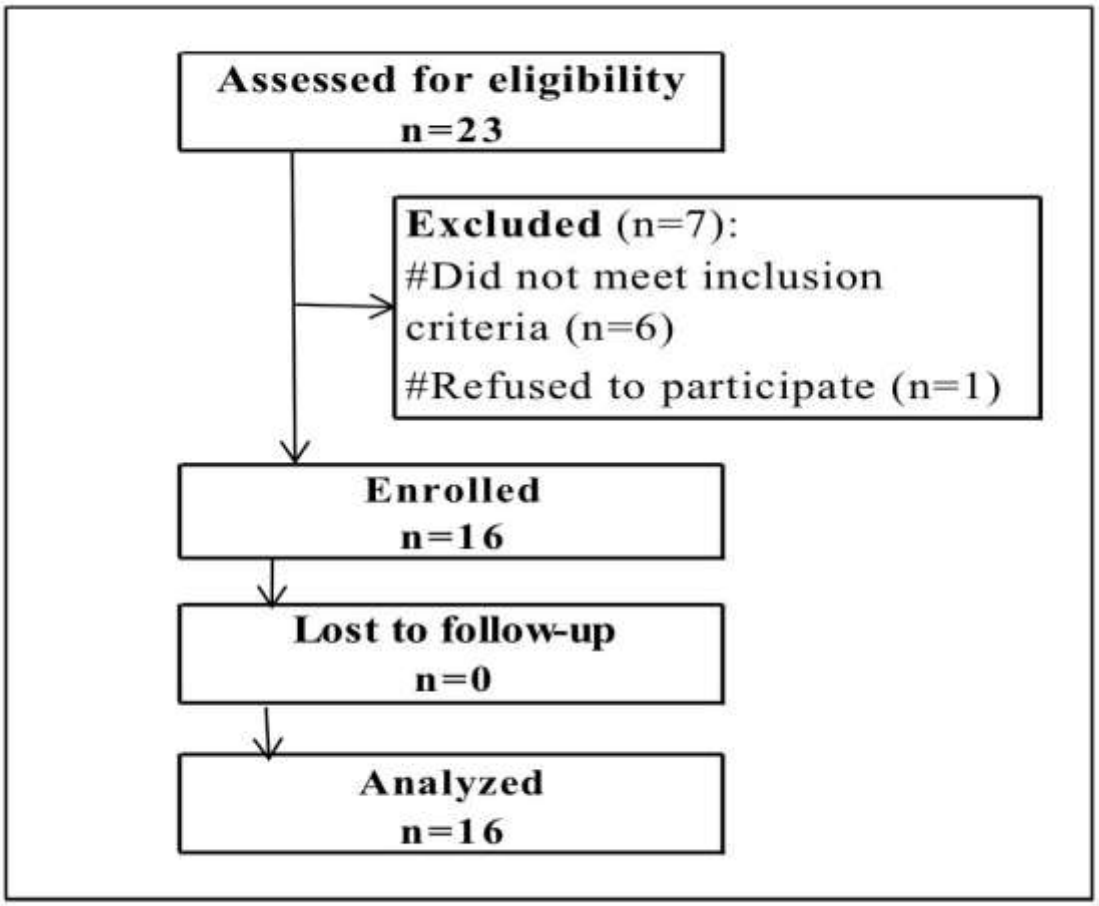

Figure (1): Study flow diagram (CONSORT)

Table (1): Demographic and clinical characteristics of the study cases

Characteristics		Mean±SD	Range
Age (years)		27.7±9.1	16.0–43.0
		n	**%**
Sex	**Male**	11	68.8%
	Female	5	31.3%

Total=16.

Table (1) showed that: Mean±SD of age (years) was 27.7±9.1. Males and females were 68.8% and 31.3% respectively.

Table (2): LVOT PG (mmHg) among the study cases

Time	Mean±SD	Range	p-value
Preoperative	42.4±9.9	30.0–65.0	**<0.001**
Intraoperative	8.1±4.5*	2.0–16.0	
Early	11.8±5.5*	3.0–26.0	
Mid-term	10.3±5.2*	4.0–22.0	

Total=16. RMANOVA. *Significantly different from preoperative based on post hoc Dunnet test.

Table (2) and **figure (2)** showed that: LVOT PG (mmHg) decreased from preoperative level (42.4±9.9) to be 8.1±4.5 intraoperatively, then increased at early

postoperative follow-up to be 11.8±5.5 and finally re-decreased to be 10.3±5.2 at mid-term follow up, the reduction from preoperative level was statistically significant (p<0.001).

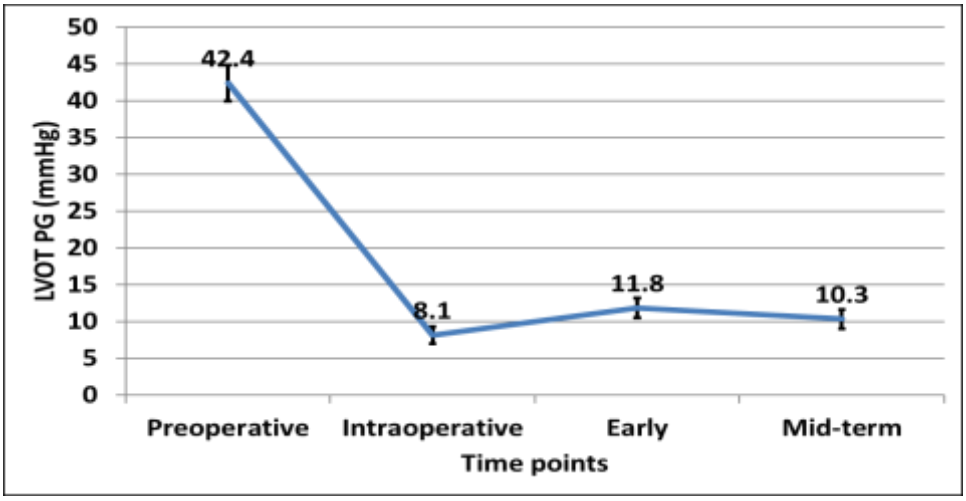

Figure (2): LVOT PG (mmHg) among the study cases

Table (3): AR degree among the study cases

AR degree	Pre-operative	Intra-operative	Early	Mid-term	p-value
Trivial	2 (12.5%)	8 (50.0%)	8 (50.0%)	10 (62.5%)	**<0.001**
Mild	10 (62.5%)	7 (43.8%)	6 (37.5%)	5 (31.3%)	
Moderate	4 (25.0%)	1 (6.2%)*	2 (12.5%)*	1 (6.2%)*	

Total=16. Marginal homogeneity test. *Significantly different from preoperative based on post hoc Dunnet test.

Table (3) and **figure (3)** showed that: moderate degree AR decreased from preoperative level (25.0%) to be (6.3%) intraoperatively, then increased at early postoperative follow-up to be (12.5%) and finally re-decreased to be (6.2%) at mid-term follow up, the reduction from preoperative level was statistically significant (p<0.001).

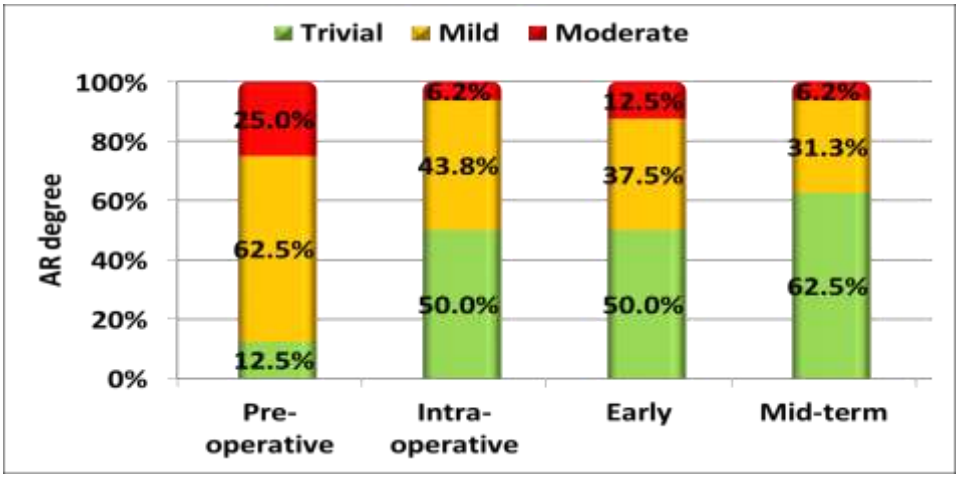

Figure (3): AR degree among the study cases

Table (4): NYHA grade among the study cases

NYHA grade	Pre-operative	Early	Mid-term	p-value
I	4 (25.0%)	7 (43.8%)	8 (50.0%)	**0.014**
II	7 (43.8%)	7 (43.8%)	7 (43.8%)	
III	5 (31.2%)	2 (12.4%)*	1 (6.2%)*	

Total=16. Marginal homogeneity test. *Significantly different from preoperative based on post hoc Dunnet test.

Table (4) and **figure (4)** showed that: NYHA grade III decreased from preoperative level (31.3%) to be (12.5%) at early postoperative follow-up and finally more decreased to be (6.2%) at mid-term follow up, the reduction from preoperative level was statistically significant (p=0.014).

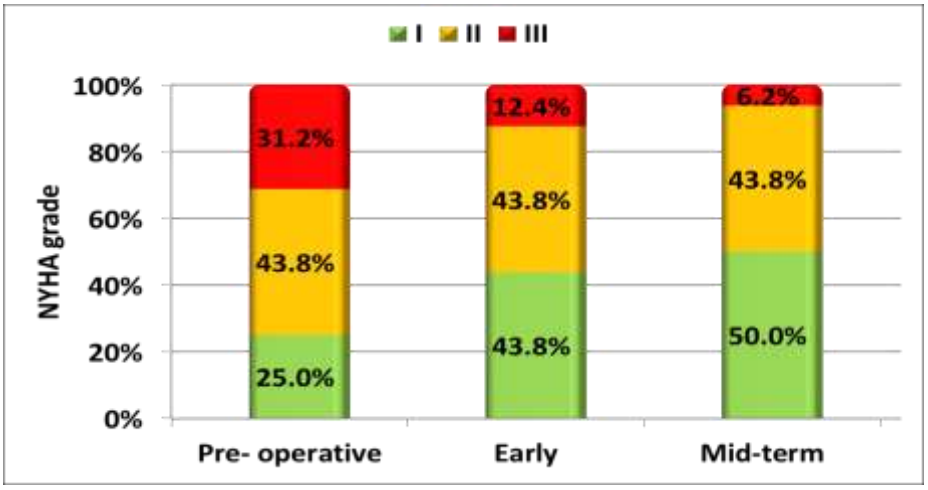

Figure (4): NYHA grade among the study cases

Adverse outcome

A patient with moderate AR at baseline maintained this status due to dense fibrous adhesion that could not be fully excised. Another patient experienced AR progression from mild preoperatively to moderate AR postoperatively due to cusp perforation which was repaired. No further intervention was needed for both patients.

DISCUSSION

Surgery for discrete SAM is associated with a relatively high incidence of late problems which often require further surgical intervention. The two most significant late problems are AR and recurrence of LVOTO. Attempts to reduce the incidence of late complications are hampered by our lack of understanding of the cause of the sub-aortic obstruction [(2)].

Since various surgical approaches for management of subaortic stenosis represents major conflict and often associated with complications of the recurrence rate and aortic regurgitation [(4)]. Surgical approach should address all fibrous extensions beyond the membrane and if there was fibrous tissue extension obscuring left and right fibrous trigons then mobilization and release of both Left and right fibrous trigons angles is essential to restore the normal mobility of the subaortic curtain thus decreasing LVOT gradient [(5)].

Consequently, this study was conducted and aimed to evaluate the early and mid-term outcomes of an extensive surgical approach for SAM, incorporating complete membrane excision, septal myectomy, fibrous trigons release, and meticulous peeling of the mitral and aortic valves from any fibrous membrane attachments. By employing a more aggressive surgical technique, we aimed to achieve prolonged relief of LVOTO and significant reduction in AR, thereby improving functional outcomes and reducing recurrence rates.

During this study, 23 patients were assessed for eligibility and 16 patients were included in the study. Of all eligible patients, 6 patients were excluded from the study based on the inclusion criteria and one patient refused to participate in of the study. Ultimately, the analysis was based on the data of 16 patients diagnosed with sub-aortic membrane,

specifically cases with isolated SAM or SAM associated with mild to moderate aortic regurgitation.

Regarding Demographic and Clinical Characteristics, our study included **16 patients** with a mean age of **27.7±9.1 years** (range **16–43 years**), with a male predominance (**68.8% male, 31.3% female**). This is somewhat comparable to **Parry et al. [6]**, where the study cohort consisted of **37 patients aged 0.5–35 years**, with a **median age of 7.5 years**, indicating a younger study population. Similarly, **Waqar et al. [4]** included **51 patients** with a **mean age of 16.29 years**, which is notably younger than our cohort. **Cao et al. [2]** studied **65 patients** over a **10-year period**, with a **median age of 6 years**, further emphasizing that many studies on subaortic membrane (SAM) focus on pediatric populations. In contrast, **Talwar et al. [7]** had a larger cohort of **146 patients**, with a **median age of 9 years**, while **van der Linde et al. [8]** analyzed **313 adult patients** who had previously undergone surgery for discrete subaortic stenosis, making it the largest and most long-term study available. **Talwar et al. [9]** included **45 patients** aged **2–23 years**, again highlighting a much younger cohort compared to our study. But the older mean age of our study could be explained, as we only focused on young adult and adult and no children was included in our study.

Our study employed an **extensive surgical approach**, including **complete membrane excision**, **septal myectomy, release of fibrous trigons, and complete removal of fibrous tissue from the mitral and aortic valves** to ensure **prolonged relief of LVOTO and reduction in associated AR**. This approach was designed to minimize the risk of **recurrence** and address the **progressive nature of subaortic stenosis**.

In comparison, **Parry et al. [6]** emphasized an **aggressive surgical approach** and demonstrated that this method **significantly reduced AR progression and recurrent LVOTO**. Their study found that **no patients required reoperation for recurrent obstruction**, reinforcing the importance of thorough **subaortic membrane resection and leaflet release**. Our study findings align with **Parry et al. [6]** in suggesting that **more aggressive techniques lead to better mid-term outcomes**.

Waqar et al. [4] performed **isolated resection of the subaortic membrane through the aorta**, with additional **aortic valve replacement in cases of severe AR**. While their results showed a **significant reduction in LVOT gradient (from 94.7 mmHg to 20.7 mmHg, p<0.001)**, they did not utilize a **more extensive approach, such as fibrous trigon release or myectomy**, which may have implications for long-term recurrence. Our study differs in that it incorporated **additional procedures to prevent recurrence**, potentially explaining our sustained mid-term results.

Cao et al. [2] compared **simple lesion resection versus complex lesion repair**, demonstrating that **patients with complex lesions had higher recurrence rates and required longer bypass and aortic cross-clamp times**. Their findings highlight the **importance of tailored surgical strategies**, which our study supports by showing that **more extensive approaches can yield better outcomes in selected cases**.

Talwar et al. [7] advocated for **complete membrane excision with additional septal myectomy**, which significantly reduced recurrence rates and resulted in **96.9% freedom from reoperation at 25 years**. This approach closely mirrors our methodology, reinforcing that **adding myectomy to SAM resection can provide long-term benefits**. **Van der Linde et al. [8]**, however, reported that **additional myectomy did not reduce the risk of reoperation**, although it increased the risk of **complete heart block requiring pacemaker implantation**. This finding suggests that while myectomy is beneficial, **it should be performed cautiously to avoid conduction disturbances**.

Finally, **Talwar et al. [9]** demonstrated that **routine septal myectomy was associated with a lower recurrence rate**, further supporting our decision to incorporate **septal myectomy into our surgical approach**. Our study's findings align with **Talwar et al. [7, 9]** in showing that **a more aggressive surgical technique can improve mid-term outcomes and reduce recurrence**.

Regarding Changes in LVOT Pressure Gradient (PG), Our study demonstrated a significant reduction in LVOT PG from a **preoperative mean of 42.4±9.9 mmHg** to **8.1±4.5 mmHg intraoperatively**. This reduction was sustained at early postoperative follow-up (**11.8±5.5 mmHg**) and remained stable at mid-term follow-up (**10.3±5.2 mmHg**, $p<0.001$). These results align with **Parry et al. [6]** who reported a preoperative gradient of **66.9±30.4 mmHg**, which reduced to **15.1±12.2 mmHg postoperatively** and remained at **14.8±12.8 mmHg at mid-term follow-up**. Similarly, **Waqar et al. [4]** reported a substantial reduction in LVOT PG from 94.7 mmHg to 20.7 mmHg postoperatively ($p<0.001$), confirming that surgical intervention provides significant relief.

Other studies, such as **Cao et al. [2]** found that the LVOT PG in simple cases reduced from 75±24.5 mmHg preoperatively to 8.7 mmHg postoperatively, while complex cases showed a reduction from 86.7±32.1 mmHg to 18.3 mmHg. **Talwar et al. [7]** also noted a dramatic decrease from 83.4±26.2 mmHg to 15.1±6.2 mmHg postoperatively. These findings reinforce the effectiveness of surgical resection in relieving LVOT obstruction. **Van der Linde et al. [8]** reported a similar pattern, with LVOT PG decreasing from 75.7±28.0 mmHg preoperatively to 15.1±14.1 mmHg postoperatively, although they noted a slow increase over time (1.31 mmHg per year), emphasizing the need for long-term monitoring.

Compared to these studies, our results showed a lower initial LVOT PG but a more stable reduction at mid-term follow-up, suggesting that our surgical approach may lead to more sustained relief.

Regarding Aortic Regurgitation Severity, our study found that moderate AR decreased from 25.0% preoperatively to 6.2% intraoperatively, slightly increased to 12.5% early postoperatively, but then further reduced to 6.2% at mid-term follow-up ($p<0.001$). The proportion of patients with trivial AR increased from 12.5% preoperatively to 62.5% mid-term, suggesting that our surgical technique helped in reducing AR and prevent its progression.

These findings are comparable to **Parry et al. [6],** where mild/moderate AR improved postoperatively (**p=0.019**) and remained stable at mid-term follow-up. **Waqar et al.[4]** reported that three patients developed mild-to-moderate AR postoperatively, but none required surgical intervention, indicating that most cases remained stable. **Cao et al. [2]** found that 51.5% of patients had AR, and among them, those with simple lesions showed better postoperative outcomes than complex cases.

Talwar et al. [7] showed an overall improvement in AR, with 92.6% freedom from significant AR at 15 years, and 82.1% at 25 years, indicating that surgical excision of SAM can have long-term benefits in preventing AR progression. However, **van der Linde et al. [8]** observed that while mild AR was present in 68% of patients postoperatively, it did not significantly progress over time.

In comparison, our study showed a lower initial incidence of AR, but the trend of early stabilization and mid-term reduction aligns with previous findings. Our results suggest that our more extensive approach, including fibrous membrane peeling, may contribute to prolonged AR improvement.

Regarding NYHA Functional Classification, the functional status of patients, assessed using NYHA classification, improved significantly after surgery. Preoperatively, 31.3% of our patients were classified as NYHA III. After surgery, this decreased to 12.5% at early follow-up and further to 6.2% at mid-term follow-up (p=0.014). The proportion of patients in NYHA I increased from 25.0% preoperatively to 50.0% at mid-term, reflecting an overall improvement in functional status.

Parry et al. (6) did not explicitly report NYHA classification but found that early postoperative AR status predicted long-term functional outcomes. **Waqar et al. (4)** reported that all patients were under pediatric cardiology follow-up for functional assessment, and none had severe functional decline postoperatively. **Cao et al. (2)** found that patients with simple lesions had better NYHA improvement compared to complex cases, reinforcing the importance of lesion type in surgical outcomes.

Talwar et al. (7) demonstrated significant long-term NYHA improvement, with Kaplan-Meier survival at 25 years reaching 93% and 96.9% freedom from reoperation, indicating that a well-executed surgical intervention can lead to lasting functional benefits. Similarly, **Talwar et al. (9)** reported that 41 out of 45 patients were in NYHA I at follow-up, showing sustained improvement in physical capacity.

Clinical Implications

The clinical implications of our study suggest that a more extensive surgical approach to subaortic membrane resection, including complete membrane excision, septal myectomy, fibrous trigons release, and thorough removal of fibrous tissue from the mitral and aortic valves, should be considered in routine practice for patients with significant LVOTO and associated AR. This approach has been shown to provide sustained reduction in LVOT pressure gradient, significant improvement in AR, and enhanced functional status (NYHA classification), ultimately improving patient outcomes. The findings reinforce the need for early intervention in symptomatic patients to prevent disease progression and reduce the likelihood of reoperation. Additionally, incorporating intraoperative transesophageal echocardiography (TEE) for real-time assessment of LVOT gradient and AR severity can help optimize surgical precision. Given the evidence supporting lower recurrence rates and improved mid-term outcomes, cardiothoracic surgeons should adopt a more aggressive surgical strategy in selected cases, ensuring comprehensive removal of fibrous tissue to enhance long-term durability and minimize the need for repeat interventions.

Strength Points

Our study has several notable strengths. First, it employed a comprehensive and extensive surgical approach to subaortic membrane resection, leading to sustained relief of LVOTO and a significant reduction in AR at mid-term follow-up. Second, the study demonstrated statistically significant improvements in LVOT pressure gradient, AR severity, and NYHA functional classification, reinforcing the effectiveness of our approach. Finally, the low complication rate in our study highlights the safety of this surgical strategy when performed with meticulous technique.

Limitations

Despite its strengths, our study has certain limitations. The sample size was relatively small (n=16), which may limit the generalizability of the findings. A larger cohort with longer follow-up durations is needed to confirm whether the observed benefits persist over time. Additionally, while we reported mid-term outcomes, long-term follow-up data beyond several years were not available, making it difficult to assess whether AR progression or LVOT gradient recurrence occurs in the distant future. Another limitation is the lack of a direct

control group undergoing conventional subaortic membrane resection without additional interventions, which would have provided a clearer comparison of surgical outcomes**.**

CONCLUSION

Our study confirms that a more extensive surgical approach to subaortic membrane resection leads to significant and sustained improvements in LVOT gradient, AR, and functional capacity (NYHA classification). The results suggest that addressing fibrous extensions beyond the membrane, including trigon release, septal myectomy and peeling of the mitral and aortic valves from any fibrous membrane attachments may contribute to better long-term relief from LVOT obstruction and AR reduction. The findings also align with previous research, further supporting the idea that a more aggressive surgical strategy can reduce recurrence rates and improve mid-term outcomes. However, long-term follow-up studies are needed to determine if these benefits persist over decades.

Based on our findings, we recommend that cardiothoracic surgeons consider a more extensive approach when performing subaortic membrane resection, especially in patients with severe LVOT obstruction or moderate AR. Future studies should focus on larger patient cohorts with extended follow-up periods to evaluate the long-term durability of this surgical approach.

Conflict of interest: None.

Financial disclosures: None.

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