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Modified single-patch persus double-patch repair in complete atrioventricular septaldefect: a comparative study of surgical and long-term outcomes

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ABSTRACT

Aims: Complete atrioventricular septal defect (CAVSD) is a complex congenital cardiac anomaly, accounting for 3–4% of all congenital heart diseases and frequently associated with Trisomy 21. It involves a common atrioventricular valve (AVV) and large septal defects, often necessitating early surgical intervention to prevent irreversible pulmonary vascular disease. While the double-patch technique (DPT) has been widely used for decades, the modified single-patch technique (MSPT) has recently gained popularity due to its technical simplicity and reduced manipulation of the AVV. However, comparative data on the short- and long-term outcomes of these two approaches remain limited. This study aimed to compare the early and long-term clinical results of the MSPT and DPT, focusing on postoperative mortality and AVV regurgitation.

Methods: We conducted a retrospective review of 56 patients who underwent complete CAVSD repair between 2009 and 2023 at a single center. Thirty-seven patients (66%) were treated with MSPT, and 19 patients (34%) with DPT. Patient demographics, perioperative data, postoperative complications, mortality, and long-term outcomes were evaluated. The mean follow-up duration among 45 patients was 73.2±4.1 months.

Results: The MSPT group had a significantly younger median age (7.5 vs. 14 months; p=0.003) and smaller ventricular septal defect (VSD) diameters (8.2 mm vs. 13.8 mm; p<0.001) than the DPT group. Cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) times were significantly shorter in the MSPT group (p<0.001). Moderate-to-severe early postoperative left AVV (LAVV) regurgitation was more frequent in the DPT group (p=0.016), while postoperative drainage volume was significantly higher in the DPT group as well (p=0.019). Early postoperative mortality occurred in 2 patients (3.5%) overall, and the total mortality for the entire cohort was 11.1%, with no statistically significant difference observed between the MSPT and DPT Reoperation due to progressive LAVV regurgitation occurred in 3 patients (6.6%)—1 in the MSPT and 2 in the DPT group—again without statistical significance. No cases of left ventricular outflow tract obstruction were observed in either group.

Conclusion: Our findings suggest that MSPT, with its simplicity and favorable outcomes, may be an effective surgical technique for selected CAVSD patients, particularly those with smaller VSDs. Compared to DPT, it is associated with shorter operative times and a significantly lower rate of early moderate-to-severe LAVV regurgitation, while offering comparable long-term mortality and reoperation rates.

Keywords: Complete atrioventricular septal defect, congenital heart disease, modified single-patch technique, Trisomy 21

INTRODUCTION

Complete atrioventricular septal defect (CAVSD), first defined by Lillehei et al. in 1955[1-3], accounts for approximately 3-4% of all congenital heart defects, with an estimated incidence of 2-3 per 1000 live births.[3] CAVSD is most commonly associated with Trisomy 21, observed in 25–71% of cases, and exhibits a higher prevalence in females (female-to-male ratio: 1.3:1).[3-5]

Advancements in the understanding of congenital cardiac anatomy, refinement of surgical techniques, improved management of pulmonary hypertension, and technological progress have significantly reduced the historically high morbidity and mortality rates associated with CAVSD repair.[6-8] Today, with early diagnosis and intervention, the majority of patients can undergo surgical correction with favorable outcomes.[9]

Following the initial surgical repair by Lillehei, the evolution of CAVSD correction techniques began with the introduction of the double-patch technique (DPT) by Trusler in 1975.[3,10-11] More recently, the modified single-patch technique (MSPT),

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as described by Ben Wilcox from North Carolina in 1997 and Graham Nunn in from Sydney, Australia in 1999, has gained popularity due to its simplified approach often avoiding the need for a separate patch to close the ventricular septal defect (VSD) and reduced manipulation of the atrioventricular valve (AVV) apparatus.[8]

Despite these advances, comparative data on perioperative and long-term outcomes between these two approaches remain limited, particularly in diverse clinical settings. Additionally, several aspects of surgical management remain topics of ongoing debate, including the optimal timing of repair, whether to pursue a primary or staged surgical approach.

The present study aims to evaluate and compare the early and mid-term clinical outcomes of MSPT and DPT in patients undergoing CAVSD repair at our center. By examining parameters such as AVV function, morbidity, mortality, and reoperation rates, this study seeks to contribute to the evidence base guiding optimal surgical strategy selection in CAVSD repair.

METHODS

Ethics

This retrospective, single-center study included 56 patients who underwent complete surgical repair for CAVSD between 2009 and 2023. Of these, 37 patients (66%) were operated on using MSPT, while 19 patients (34%) underwent repair with traditional DPT. The surgical technique was primarily selected based on the diameter of VSD, reflecting the surgeon's decision-making. The study protocol was approved by the Ethics Committee of Private Anadolu Medical Centre (Date: 19.03.2025, Decision No: ASM-EK-25/292); and the study was conducted in accordance with the Declaration of Helsinki. Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Preoperative Evaluation

All patients were evaluated with transthoracic echocardiography to determine Rastelli classification type, the degree of left and right AVV regurgitation (LAVVR, RAVVR), and VSD diameter. Additional cardiac anomalies, including patent ductus arteriosus (PDA), atrial septal defect (ASD), pulmonary stenosis, and others, were also documented.

Surgical Technique

All procedures were performed via standard median sternotomy under moderate hypothermia with ascending aortic and bicaval venous cannulation. Myocardial protection was achieved with antegrade blood cardioplegia. Mitral cleft closure was routinely performed in all patients. Additional LAVV or RAVV repair were performed as indicated based on intraoperative findings. No patient underwent correction using the conventional single-patch technique.

Data Collection and Outcomes

Patient demographics, perioperative variables (age, sex, weight, VSD diameter, cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) times, intubation duration, intensive care unit (ICU)/hospital length of stay, drainage volume, and blood product use were collected. Postoperative complications (including mortality, LAVVR/RAVVR, heart failure, infections, cerebrovascular events, and chylothorax) were analyzed.

Follow-Up

Long-term outcomes were assessed in 45 patients with available follow-up data, with a mean follow-up duration of 73.2±4.06 months (range: 22–128 months).

Statistical Analysis

The data analyses were performed using SPSS for Windows, version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean±standard deviation (SD) or median with range (minimum–maximum), depending on the normality of distribution. Categorical variables were expressed as frequencies and percentages. For comparison between two groups, the independent samples t-test was used for normally distributed continuous variables, while the Mann–Whitney U test was applied for non-normally distributed data. The Chi-square test was employed to analyze categorical variables. A p-value of <0.05 was considered statistically significant.

RESULTS

Patient Characteristic among MSPT and DPT Groups

The cohort consisted of 33 females (60%) and 23 males (40%), with a median age at the time of surgery of 9 months (range: 2–180 months). The mean body weight was 9.87±7.96 kg (range: 3.3–41 kg). A total of 56 patients underwent CAVSD repair, with 37 receiving the MSPT and 19 undergoing the DPT. The median age at the time of surgery was 7.5 months in the MSPT group and 14 months in the DPT group. Trisomy 21 was present in 70% of the MSPT group and 64% of the DPT group. Preoperative functional status, based on the New York Heart Association (NYHA) classification, showed that the majority of patients were in class I (28 in MSP, 17 in TPT).

Rastelli type A anatomy was the most common (81% in MSPT, 84% in DPT). The mean diameter of the VSD was 8.2 mm in the MSPT group and 13.78 mm in the DPT group. Moderate to severe LAVVR was observed in 20 MSPT and 17 DPT patients, while RAVVR was present in 18 and 15 patients, respectively. Demographic and baseline clinical and anatomic data of the patients among two groups are summarized in **Table 1**.

Additional cardiac anomalies were observed in both groups, with ASD combined with PDA being the most frequent in the MSPT group (n=15) and tetralogy of Fallot (TOF) in the DPT group (n=4). Other associated defects included pulmonary stenosis, double outlet right ventricle, partial anomalous pulmonary venous connection , and previously palliated cases with pulmonary banding or Blalock-Taussig shunt, as detailed in **Table 2**.

Perioperative and Postoperative Outcomes

The mean CPB time was 98±31 minutes (range: 34–175 minutes), while the ACC time was 70.1±25 minutes (range: 89–140 minutes). The mean postoperative drainage volume was 427±409 ml (range: 10–2200 ml), and the average volume of blood product transfused was 597.4±444.3 ml (range: 0–2750 ml). Postoperative moderate and severe LAVVR was

Table 1. Baseline demographic, clinical and anatomical characteristics of the subjects

Demographic data	MSPT	DPT
Median age (months)	7.5	14
Sex	19 M, 18 F	14 M, 5 F
Weight (kg)	9.26±8.74	11.2±6.59
Trisomy 21	26 (70%)	11 (64%)
NYHA Class I Class II Class III	 8 7 2	 17 2 -
Rastelli		
Type A	30	16
Type B	5	2
Type C	2	1
Mean VSD diameter (mm)	8.2	13.78
Moderate to severe LAVVR	20	17
Moderate to severe RAVVR	18	15

MSPT: Modified single-patch technique, DPT: Double-patch technique, NYHA: New York Heart Association, VSD: Ventricular septal defect, LAVVR: Left atrioventricular valve regurgitation, RAVVR: Right atrioventricular valve regurgitation

Table 2. Additional congenital anomalies of the subjects

Additional anomalies	MSPT	DPT
ASD+PDA	15	3
PDA	8	2
Pulmonary stenosis	4	3
Operation pulmonary banding	2	4
TOF	1	4
DORV+PS	-	3
ASD	1	1
Operated BT shunt	-	2
RV hypoplasia	1	1
PAPVC+mesocardia+LPSVC	-	1
Mesocardia	1	-
Multiple VSD	-	1
LPSVC+PDA	1	-

MSPT: Modified single-patch technique, DPT: Double-patch technique, ASD: Atrial septal defect, TOF: Tetralogy of Fallot, DORV: Double outlet right ventricle, PS: Pulmonary stenosis, BT: Blalock taussig, RV: Right ventricle, PAPVC: Partial abnormal pulmonary venous connection, LPSVC: Left persistent superior vena cava, PDA: Patent ductus arteriosus

observed in 15 and 1 patients, respectively. Moderate RAVVR was seen in 10 patients, with no cases of severe regurgitation. A small residual VSD causing minimal shunt was detected in one patient.

The mean intubation time was 75.1±108.5 hours (range: 4–456 hours), with an average ICU stay of 7.8±7.5 days and hospital stay of 17.1±15.6 days (range: 4–90 days) (**Table 3**).

Among rhythm-related complications, 7 patients developed arrhythmias: 4 (7.1%) experienced complete AV block requiring permanent pacemaker implantation, two developed junctional ectopic tachycardia, and one had right bundle branch block.

Additional postoperative complications included pericardial tamponade (n=2), chylothorax (n=4), Dressler's syndrome

Table 3. Surgical data

	MSPT	TPT
CPB time (min)	93.97±23.65	125.31±27.29
ACC (min)	60.62±22.17	88.63±23.53
Intubation time (h)	78.02±117.76	69.36±93.88
Length of ICU stay (day)	7.59±7.64	8.26±7.47
Length of hospital stay (day)	15.91±2.71	19.52±3.27
Drainage amount (ml)	334.16±320.31	603.15±511.72
Blood product (ml)	505.54±286	776.31±631.43
AV block	2	2
JET	2	-
RBBB	1	-
Pacemaker implantation	2	2

MSPT: Modified single-patch technique, CPB: Cardio-pulmonary bypass, ACC: Aortic cross-clamp, ICU; Intensive care unit, AV: Atrioventricular, JET: Junction ectopic tachycardia, RBBB: Right bundle branch block

requiring pericardial drainage (n=1), and renal failure necessitating peritoneal dialysis (n=8). Infectious complications were also noted, including pneumonia requiring prolonged antibiotic therapy (n=12), urinary tract infection (n=2), and one case each of sepsis and seizure. Inhaled nitric oxide therapy was administered in four patients due to elevated pulmonary pressures.

Comparative Outcomes Between Surgical Techniques

Patients undergoing DPT were significantly older than those undergoing MSPT (median: 14 vs. 7.5 months; p=0.003). The female-to-male ratio was significantly higher in the MSPT group (p=0.023). VSD diameter was also significantly larger in the DPT group compared to the MSPT group (13.8 mm vs. 8.2 mm; Mann-Whitney U test, p<0.001) (**Figure 1**).

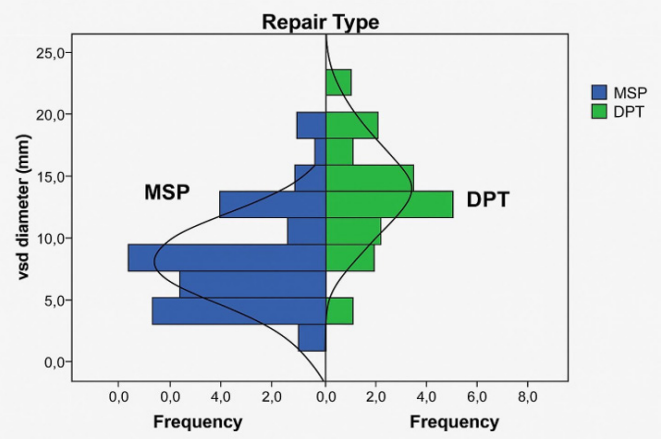

Figure 1. Comparison of VSD diameter between MSPT and DPT
VSD: Ventricular septal defect, MSPT: Modified single-patch technique, DPT: Double-patch technique

While the need for LAVV repair did not differ significantly between groups, RAVV repair was more frequently performed in the MSPT group (p=0.043). CPB and ACC times were significantly longer in the DPT group (CPB: 125.3±27.3 min vs. 83.4±23.8 min; ACC: 88.6±23.5 min vs. 60.1±22.3 min; t-test, both p<0.001) (**Figure 2, 3**). Postoperative moderate-to-severe LAVVR was significantly more common in the DPT group (Chi-square test, p=0.016), and postoperative

drainage volume was also higher (603 ml vs. 334 ml; p=0.019). No statistically significant differences were found in other parameters. Early comparative postoperative outcomes were summarized in **Table 4**.

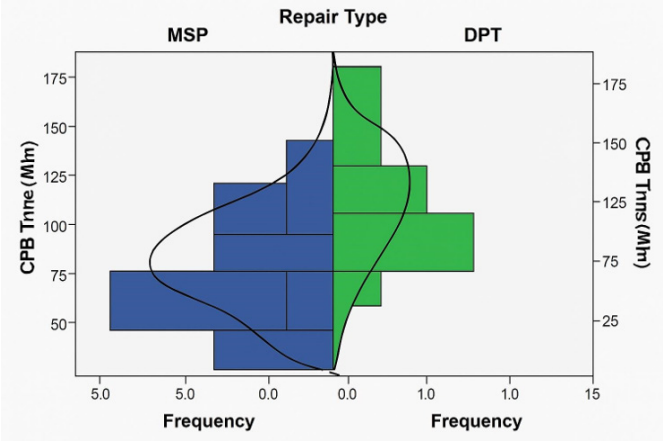

Figure 2. Comparison of CPB time between MSPT and DPT groups
CPB: Cardiopulmonary bypass, MSPT: Modified single-patch technique, DPT: Double-patch technique

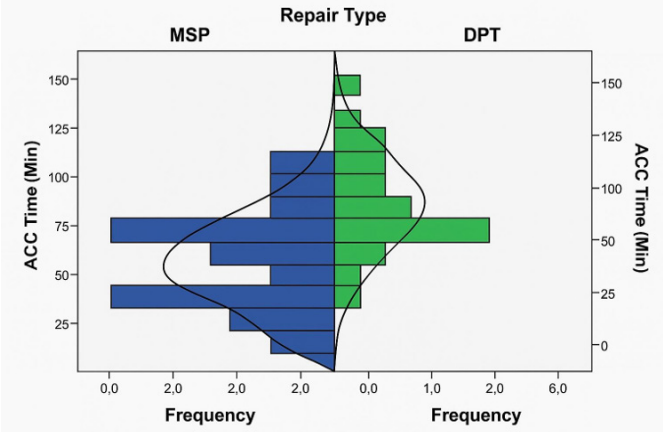

Figure 3. Comparison of aortic cross-clamp time between MSPT and DPT groups
MSPT: Modified single-patch technique, DPT: Double-patch technique, ACC: Aortic cross-clamp

Table 4. Early postoperative morbidity following CAVSD repair in MSPT and DPT groups

	MSPT	DPT
Pneumonia	7	5
UTI	2	-
Sepsis	-	1
Epileptic attack	-	1
Tamponade	1	1
Chylothorax	1	3
Advanced left AV valve regurgitation	1	-
Reintubation	5	3
Peritoneal dialysis catheter	2	6
Pericardial tube	1	-
NO inhalation	2	2

CAVSD: Complete atrioventricular septal defect, MSPT: Modified single-patch technique, DPT: Double-patch technique, UTI: Urinary tract infection, AV: Atrioventricular

Mortality and Long-Term Outcomes

Early hospital mortality occurred in 2 patients (3.5%). One patient with Trisomy 21 and both LAVV and RAVV repair (MSPT) died from aspiration pneumonia shortly after discharge. The second, with multiple muscular VSDs and prior pulmonary banding, underwent DPT repair and required pacemaker implantation; the patient died of respiratory failure in the ICU.

Of the total 5 patients who died during the study period, 2 deaths occurred in the early postoperative phase, while 3 deaths were recorded during long-term follow-up (mean: 73.2±4.06 months), resulting in an overall mortality rate of 11.1%. Among the late deaths, three patients had undergone DPT and two had undergone MSPT. Two deaths were from non-cardiac causes, and the remaining three were cardiac-related—including one sudden death in a pacemaker-dependent patient and one due to LAVV insufficiency following reoperation.

Freedom from reoperation was 95.6% at 5 years and 93.4% at 10 years. Three patients (6.6%) underwent reoperation for LAVV insufficiency—one in the MSPT group and two in the DPT group. There was no statistically significant difference in long-term outcomes between the surgical techniques.

DISCUSSION

In this retrospective cohort study, our findings demonstrated that both approaches were safe, with low early mortality and good long-term survival. However, MSPT was associated with shorter CPB and ACC times, less postoperative drainage, and lower rates of moderate-to-severe LAVVR, suggesting procedural advantages in selected patients, especially with regard to VSD sizes. VSD diameter was significantly smaller in the MSPT group, reflecting its suitability for simpler anatomies. Despite these differences, long-term outcomes were comparable.

Since the Rastelli classification, CAVSD has been recognized as a congenital anomaly with a well-characterized anatomy that can be surgically corrected with high success rates, owing to advancements in technology and surgical techniques. The presence of associated cardiac anomalies does not appear to significantly affect outcomes, which are generally marked by low morbidity and mortality. Atz et al.[12] reported no significant difference in residual lesions or valve regurgitation between the MSPT and DPTs in patients with trisomy 21. In a separate study, Xie et al.[13] recommended performing surgical correction between 3 and 6 months of age, based on a cohort in which 92% of patients were treated with the DPT and only 2.2% with MSPT. Importantly, they found that the presence of Trisomy 21 was not associated with an increased risk of reoperation. In contrast, Tumanyan et al.[14] compared outcomes between 214 patients with isolated CAVSD and 163 patients with concomitant Trisomy 21, using the DPT in 75.4% and MSPT in 24.6% of cases. While they found no significant difference in outcomes based on surgical technique, they noted that the additional morbidity associated with Trisomy 21 affected both recovery time and life expectancy. In our cohort, additional cardiac anomalies

and Trisomy 21 were frequently observed, with the latter present in approximately 65% of patients. However, neither Trisomy 21 nor other associated anomalies were associated with increased morbidity or mortality, and no statistically significant differences were observed in clinical outcomes.

Timely surgical intervention is critical to prevent irreversible pulmonary vascular disease, as the left-to-right shunt in CAVSD can rapidly elevate pulmonary pressures. While the optimal surgical window is generally between 3–6 months of age[15], our series had a slightly delayed median operative age (7.5 months in MSPT vs. 14 months in DPT), largely due to late referrals from abroad or underserved regions. Nonetheless, pulmonary hypertension was not a major concern in our cohort, and only a small number of patients required postoperative inhaled NO therapy.

In recent years, the MSP technique has gained widespread acceptance as an alternative to the conventional DPT. In our study, 66% of cases were repaired with MSP, consistent with contemporary trends. Compared to DPT, MSPT was associated with significantly shorter CPB ACC times and a smaller VSD diameter—findings consistent with other reports.[16-18] Although shorter CPB/ACC times did not translate into shorter ICU or hospital stays, the MSPT group experienced significantly less postoperative drainage, with no difference in transfusion requirements, supporting a more conservative transfusion protocol.

Importantly, early postoperative moderate-to-severe LAVVR was significantly less frequent in the MSPT group compared to the DPT group. This difference may be attributed to several technical advantages inherent to the MSPT. First, MSPT avoids the use of a separate patch for VSD closure, thereby reducing potential distortion or traction on the atrioventricular (AV) valve tissue. Second, by not dividing the common AV valve, the risk of leaflet tethering or malalignment is minimized, preserving the native valve architecture and function. These benefits have been consistently emphasized in prior reports, most notably by Graham Nunn, who reported no significant postoperative LAVVR in his MSPT cohort.[8] In our study, although moderate LAVVR was observed in 15 patients and severe in one patient overall, the incidence was significantly lower in the MSPT group. Furthermore, no cases of left ventricular outflow tract obstruction (LVOTO) were identified in either group during the early or late follow-up, further suggesting that neither technique adversely impacted ventricular outflow dynamics when carefully executed.

Although overall long-term mortality and reoperation rates did not differ significantly between the two techniques in our cohort, LAVVR remained the most common indication for reintervention, aligning with findings from multiple previous studies.[19-21] The pathophysiology of LAVVR progression over time is multifactorial and may be influenced by factors such as annular dilatation, suboptimal initial repair, leaflet prolapse, and valve tissue dysplasia. Some authors have suggested that delayed surgical timing may exacerbate annular stretching due to prolonged volume overload, thereby increasing the risk of residual or recurrent AV valve regurgitation.[22,23] Interestingly, despite the relatively late median age at operation in our series (7.5 months in MSPT and 14 months in DPT), the MSP group demonstrated a significantly lower incidence of LAVVR, suggesting that this technique may offer a protective effect even when repair is not performed during the ideal window of 3–6 months.

The technical simplicity and tissue-preserving nature of the MSP technique offer notable advantages. By avoiding a separate VSD patch, it reduces the risk of injury to conduction tissue and AV valve structures, contributing to shorter CPB and ACC times. Although long-term reoperation rates did not significantly differ between MSPT and DPT, the overall reoperation rate for AV valve dysfunction was low (6.6%), consistent with literature suggesting improved valve preservation with MSPT.[24,25]

The potential superiority of the MSPT technique over the double-patch (DPT) approach has been the subject of continuous discussion. Although a single meta-analysis and recent propensity score-matched studies found no discernible differences in mortality or reoperation rates between the two methods, these analyses primarily matched cohorts based on the size of VSD without taking VSD depth into consideration. Notably, new studies indicate that when MSPT is used, VSD depth may be crucial in the development of late LAVVR.[26,27] VSD diameter and surgical technique selection were closely correlated in our study, indicating the importance of this anatomical factor in procedural decision-making. Notably, however, in a recent review by Backer et al.[26], it is recommended to apply DPT for VSDs deeper than 15mm, a threshold later refined to 11 mm based on longer-term follow-up and larger patient cohorts. This supports the rationale for selecting MSPT in patients with shallower VSDs, aligning with our findings of favorable outcomes in those with smaller defects. Importantly, no cases of LVOTO were observed in either group, further underscoring the hemodynamic safety of both techniques when appropriately selected.

Limitations

This study has several limitations. First, its retrospective and single-center design may limit the generalizability of the findings. Surgical technique selection was based on individual surgeon preference, based on the diameter of VSD rather than randomization, potentially introducing selection bias. Second, the relatively small sample size, particularly in the DPT group, may reduce the statistical power to detect differences in less common outcomes such as late mortality or need for reoperation. Additionally, echocardiographic assessments of AV valve function were not standardized across all time points or operators, which may have introduced variability in grading regurgitation severity. Finally, although follow-up was sufficient to evaluate mid-term outcomes, longer-term surveillance is needed to assess durability of valve function and late reinterventions.

CONCLUSION

MSPT was associated with significantly shorter CPB and ACC times and lower rates of early moderate-to-severe LAVV regurgitation. Although long-term mortality and reoperation rates were comparable between the two groups, the reduced

incidence of AV valve dysfunction and the simplicity of the MSPT suggest it may offer surgical and clinical advantages in appropriately selected patients with small VDSs.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study protocol was approved by the Ethics Committee of Private Anadolu Medical Centre (Date: 19.03.2025, Decision No: ASM-EK-25/292).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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