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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Minimally invasive versus conventional mitral valve surgery: A propensity score matching analysis

Minimal invaziv ile konvansiyonel mitral kapak cerrahisinin karşılaştırılması: Eğilim skoru eşleştirme analizi

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ABSTRACT

Background: This study aimed to compare the outcomes of minimally invasive mitral valve surgery and conventional surgery in terms of mortality and postoperative complications.

Methods: A retrospective analysis was conducted on consecutive minimally invasive and conventional mitral valve surgeries performed between January 2019 and December 2022. Patients undergoing concomitant procedures were excluded from the study, and 293 patients (149 females, 144 males; mean age: 53.8±12.9 years; range, 18 to 82 years) were included in the study. Of these patients, 96 underwent minimally invasive surgery (MI group), and 197 underwent mitral valve surgery via conventional sternotomy (CS group). Propensity score matching was utilized to minimize the biases and confounding factors. After propensity score matching, 55 patients were included in each group.

Results: There was no statistically significant difference in terms of mortality between the propensity score-matched groups (p=0.315), and no statistically significant difference in postoperative complications was observed between the groups. However, it was found that postoperative new-onset atrial fibrillation was lower in the minimally invasive group (p=0.022).

Conclusion: This study demonstrates that minimally invasive mitral valve surgery is a safe alternative with similar mortality and postoperative complication rates compared to conventional surgery. Additionally, the study suggests an association between minimally invasive surgery and postoperative new onset atrial fibrillation.

Keywords: Minimally invasive, mitral valve surgery, mortality, sternotomy.

ÖZ

Amaç: Bu çalışmada minimal invaziv mitral kapak cerrahisi ve konvansiyonel cerrahi sonuçları, mortalite ve ameliyat sonrası komplikasyonlar açısından karşılaştırıldı.

Çalışma planı: Ocak 2019 ile Aralık 2022 tarihleri arasında gerçekleştirilen ardışık minimal invaziv ve konvansiyonel mitral kapak cerrahilerinin retrospektif bir analizi yapıldı. Eş zamanlı başka işlemler uygulanan hastalar çalışmadan çıkarıldı ve çalışmaya 293 hasta (149 kadın, 144 erkek; ort. yaş: 53.8±12.9 yıl; dağılım, 18-82 yıl) dahil edildi. Bu hastaların 96'sına minimal invazif cerrahi (MI grubu), 197'sine ise konvansiyonel sternotomi yoluyla mitral kapak ameliyatı (CS grubu) uygulandı. Yanlılığı ve yanıltıcı faktörleri en aza indirmek için eğilim skoru eşleştirme yöntemi kullanıldı. Eğilim skoru eşleştirme analizinden sonra her gruba 55 hasta alındı.

Bulgular: Eğilim skoru eşleşen gruplar arasında mortalite açısından istatistiksel olarak anlamlı bir fark yoktu (p=0.315) ve ameliyat sonrası komplikasyonlar açısından gruplar arasında istatistiksel olarak anlamlı bir fark görülmedi. Bununla birlikte, ameliyat sonrası yeni başlangıçlı atriyal fibrilasyonun minimal invaziv grubunda daha düşük olduğu bulundu (p=0.022).

Sonuç: Bu çalışma, minimal invaziv mitral kapak cerrahisinin konvansiyonel cerrahiye kıyasla benzer mortalite ve ameliyat sonrası komplikasyon oranlarına sahip güvenli bir alternatif olduğunu göstermektedir. Ayrıca çalışma, minimal invaziv cerrahi ile ameliyat sonrası yeni başlangıçlı atriyal fibrilasyonla arasında bir ilişkili olabileceğini göstermektedir.

Anahtar sözcükler: Minimal invaziv, mitral kapak cerrahisi, mortalite, sternotomi.

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Mitral valve surgery, in the era of transcatheter advancements, offers a pivotal intervention for patients with mitral regurgitation and stenosis. Advances in surgical technology and techniques have led to the improvement of minimally invasive mitral valve surgery (MIMVS), which has become a preferred surgical approach for many patients. Since Carpentier et al.'s[1] description of video-assisted MIMVS, various techniques have emerged, such as lower hemisternotomy, direct vision right minithoracotomy, endoscopic right minithoracotomy, and robotic-assisted right minithoracotomy.

Several studies have supported numerous advantages of MIMVS compared to traditional approaches, including improved cosmetic outcomes, decreased postoperative pain levels, faster recovery time, and reduced necessity for blood product transfusions in comparison to mitral valve surgery performed via sternotomy.[2-4] Despite the potential advantages of MIMVS, the existing body of evidence, including randomized controlled trials and meta-analyses, has not yielded a significant difference in mortality between minimally invasive and conventional surgical approaches.[5-7] This study sought to evaluate the clinical outcomes of MIMVS and contribute valuable insights to the ongoing debate surrounding a controversial issue.

PATIENTS AND METHODS

In the retrospective study, a total of 1,343 patients who underwent mitral valve surgery in our hospital between January 2019 and December 2022 were initially included. Patients who underwent concomitant procedures (tricuspid valve, coronary surgery, aortic valve, hypertrophic obstructive cardiomyopathy surgery, or aortic surgery), those with endocarditis, redo surgery, and those requiring emergency procedures were excluded. After excluding 1,050 patients, a final sample of 293 patients (149 females, 144 males; mean age: 53.8±12.9 years; range, 18 to 82 years) was analyzed, comprising 96 who underwent minimally invasive surgery (MI group) and 197 who underwent mitral valve surgery via conventional sternotomy (CS group). To address potential confounding factors and biases, propensity score matching was performed using variables such as age, chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), and whether patients underwent mitral valve repair or replacement. The matching process created two equal groups, where each group comprised 55 patients. A flowchart illustrating the patient selection and utilization of propensity score matching is shown in Figure 1.

The retrospective analysis involved evaluating the patient data before, during, and after the surgery. The primary endpoint of the study was operative mortality, whereas secondary endpoints included length of intensive care unit (ICU) stay, length of stay in the hospital, and postoperative atrial fibrillation.

Statistical analysis

Statistical analysis was conducted using R version 4.0.3 (R Foundation for Statistical Computing, Wien, Austria). Categorical data were presented as several patients and ratios, and their comparison was carried out using the chi-square test. In cases where the assumptions for the chi-square test were not met, Fisher exact test was employed. Continuous data distribution was assessed using the Kolmogorov-Smirnov test. Continuous variables that exhibited a normal distribution were presented as mean ± standard deviation (SD) and compared using Student's t-test. Nonnormally distributed continuous variables were compared using the Mann-Whitney U test and presented as median (first quartile-third quartile).

Propensity score matching was employed to minimize potential confounding factors and biases. Patients were matched using a 1:1 nearest neighbor algorithm with calipers of 0.25 standard deviations. A significance level of $p<0.05$ was adopted to indicate statistical significance, with a 95% confidence interval.

RESULTS

Before propensity score matching

Patients in the MI group were younger than those in the CS group (47.43±13.66 *vs*. 56.90±11.27 years, p<0.001). In the MI group, 60 (62.5%) patients were male, while in the CS group, 84 (42%) patients were male, with a statistically significant difference between the groups (p<0.001). Of the 96 patients who underwent the minimally invasive approach, 15 (15.6%) underwent an endoscopic right minithoracotomy, and 81 (84.4%) had a robotic right minithoracotomy. A comprehensive overview of the preoperative characteristics is presented in Table 1. In the MI group, there were fewer patients with COPD compared to the CS group (10 [10.4%] *vs*. 49 [24.9%], p=0.004). Diabetes mellitus was significantly lower in the MI group compared to the CS group (6 [6.3%] *vs*. 48 [24.4%], p<0.001). Regarding preoperative cerebrovascular events, the CS group had a higher prevalence compared to the MI group (22 [11.2%] *vs*. 3 [3.1%], p=0.02).

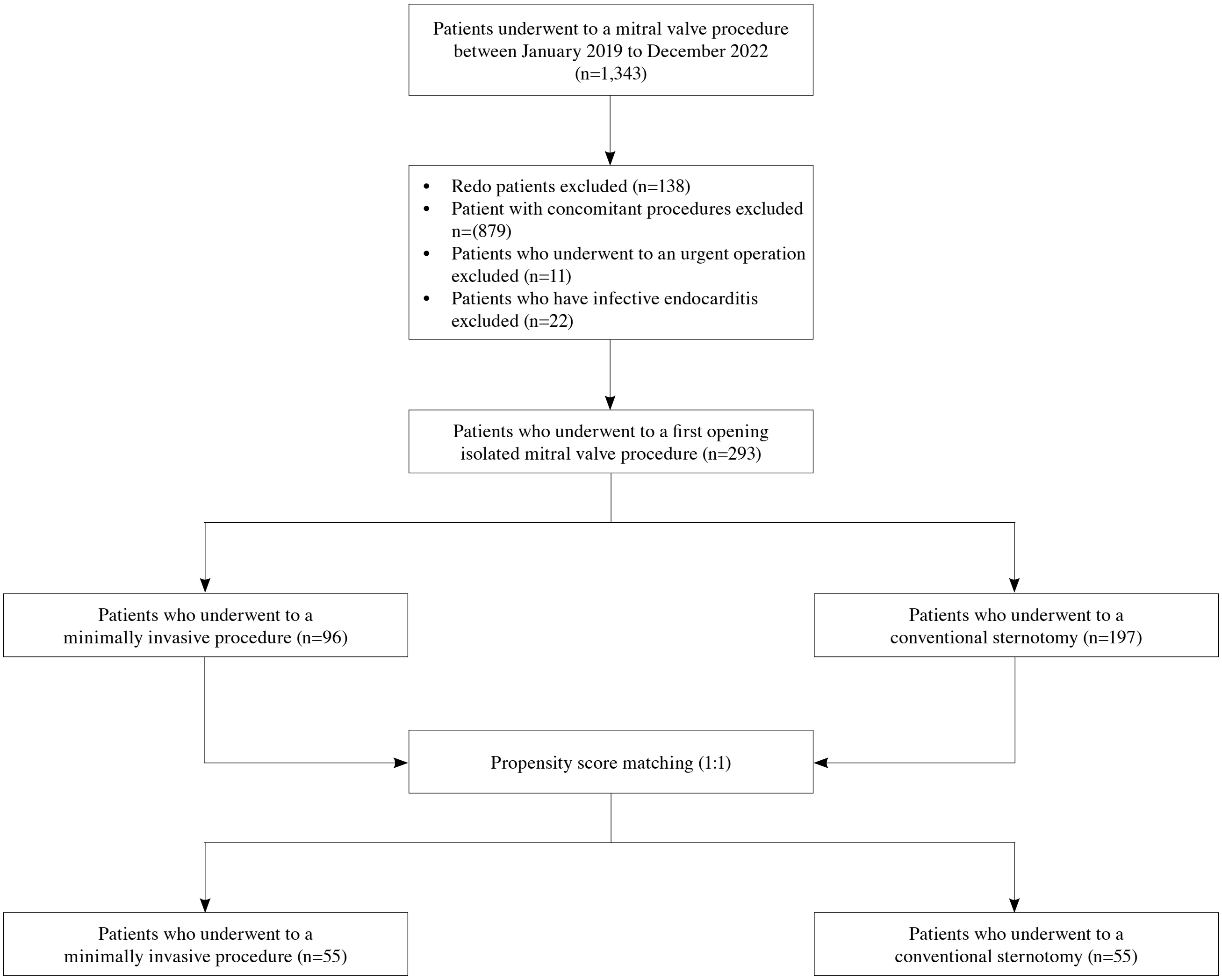

Figure 1. Flow diagram of the study.

Patients in the MI group had lesser rheumatic mitral valve pathology compared to those in the CS group (30 [31.3%] *vs*. 107 [54.6%], p<0.001), and mitral stenosis patients were more likely to be in the CS group than in the MI group (78 [39.6%] *vs*. 22 [22.9%], p=0.005). A previous myocardial infarct was more common in the CS group compared to the MI group (13 [6.6%] *vs*. 1 [1%], p=0.03). Patients in the CS group also had lower ejection fraction than those in the MI group (54.11±10.06 *vs*. 59.98±4.99, p<0.001). Preoperative atrial fibrillation frequencies were similar between groups.

The operating time, cardiopulmonary bypass time, and cross-clamp time were significantly longer in the MI group than in the CS group (281.0±44.68 *vs*. 220.50±51.96, p<0.001; 149.94±43.06 *vs*. 104.83±33.87, p<0.001; 95.01±25.01 *vs*. 69.79±22.53, p<0.001, respectively). Mitral valve repair was performed in 38 (39.6%) patients in the MI group, while valve repair was performed in only 22 (11.2%) patients in the CS group (p<0.001). Left atriotomy was the surgical approach for mitral valve exposure in 91 (94.8%) and 57 (28.9%) patients in the MI and CS groups, respectively (p<0.001). In the MI group, Custodiol was the most preferred cardioplegic solution during surgery and was used in 70 (72.9%) patients, whereas in the CS group, warm blood cardioplegia was the predominant choice and was preferred in 153 (77.7%) patients (p<0.001, Table 2).

The incidence of postoperative mediastinitis, postoperative renal failure, cerebrovascular events, permanent pacemaker insertion, reexploration for

Table 1. Preoperative and operative characteristics of the patients

	Before PSM										After PSM						
	All (n=293)			MI group (n=96)			CS group (n=197)				MI group (n=55)			CS group (n=55)			
Variables	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			53.80±12.88			47.43±13.66			56.90±11.27	<0.001*			49.93±12.44			49.58±11.84	0.882
Sex																	
Male	144	49.1		60	62.5		84	42.6		0.001*	30	54.5		21	38.2		0.085
Body surface area (m^2)			1.85±0.17			1.84±0.16			1.85±0.17	0.479			1.84±0.17			1.87± 0.15	0.354
Hypertension	71	24.2		10	10.4		61	31.0		<0.001*	6	10.9		9	16.4		0.405
Diabetes mellitus	54	18.4		6	6.3		48	24.4		<0.001*	6	10.9		5	9.1		0.751
Chronic obstructive pulmonary disease smoking habit	59	20.1		10	10.4		49	24.9		0.004*	6	10.9		7	12.7		0.768
Active smoker	52	17.7		17	17.7		35	17.8		0.966	11	20.0		10	18.2		0.957
Ex-smoker	79	27.0		25	26.0		54	27.4			12	21.8		13	23.6		
Non-smoker	162	55.3		54	56.3		108	54.8			32	58.2		32	58.2		
Preoperative renal failure	24	8.2		4	4.2		20	10.2		0.079	2	3.6		5	9.1		0.241
Preoperative cerebrovascular event	25	8.5		3	3.1		22	11.2		0.021*	2	3.6		7	12.7		0.082
Ejection fraction (%)			56.03±9.15			59.98±4.99			54.11±10.06	<0.001*			59.22±5.13			56.71±9.37	0.085
Rheumatic mitral valve	137	46.9		30	31.3		107	54.6		<0.001*	30	54.5		21	38.2		0.085
Mitral valve stenosis	100	34.1		22	22.9		78	39.6		0.005*	19	34.5		26	47.3		0.175
Mitral valve insufficiency	252	86.0		86	89.6		166	84.3		0.218	47	85.5		43	78.2		0.323
Left atrial size (mm)			49.30±8.10			49.13±8.27			49.38±8.04	0.800			50.78±8.15			48.82±7.61	0.195
Left ventricle size (mm)			53.33±6.53			54.19±6.65			52.91±6.45	0.118			53.31±6 .69			51.51±6.23	0.147
Preoperative atrial fibrillation	73	24.9		20	20.8		53	26.9		0.260	19	34.5		11	20.0		0.087
Previous percutaneous coronary intervention	14	4.8		1	1.0		13	6.6		0.036*	0	0.0		3	5.5		0.079

PSM: Propensity score matching; MI: Minimally invasive; CS: Conventional sternotomy; SD: Standard deviation.

Table 2. Operative characteristics of the patients

	Before PSM										After PSM						
	All (n=293)			MI group (n=96)			CS group (n=197)				MI group (n=55)			CS group (n=55)			
Variables	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*	n	%	Mean±SD	n	%	Mean±SD	*p*
Operating time (min)			240.40±57.34			220.50±51.96			220.50±51.96	<0.001*			285.62±47.10			212.91±40.96	<0.001*
Cardiopulmonary bypass time (min)			119.81±42.77			149.94±43.06			104.83±33.87	<0.001*			156.72±46.31			100.42±24.05	<0.001*
Aortic clamping time (min)			78.16±26.19			95.01±25.01			69.79±22.53	<0.001*			96.57±26.84			68.26±17.55	<0.001*
Mitral valve repair	60	20.5		38	39.6		22	11.2		<0.001*	7	12.7		7	12.7		1.000
Access to mitral valve										<0.001*							<0.001*
Transseptal	145	49.4		5	5.2		140	71.1			5	9.1		43	78.2		
Left atrium	148	50.6		91	94.8		57	28.9			50	90.9		12	21.8		
Type of cardioplegia										<0.001*							<0.001*
Del Nido	63	21.5		21	21.9		42	21.3			6	10.9		14	25.5		
Custodiol	72	24.5		70	72.9		2	1.0			47	85.5		1	1.8		
Blood cardioplegia	158	53.0		5	5.2		153	77.7			2	3.6		40	72.7		

PSM: Propensity score matching; MI: Minimally invasive; CS: Conventional sternotomy; SD: Standard deviation.

Table 3. Postoperative characteristics of the patients

	Before PSM													After PSM								
	All (n=293)				MI group (n=96)				CS group (n=197)					MI group (n=55)				CS group (n=55)				
	n	%	Median	IQR	n	%	Median	IQR	n	%	Median	IQR	*p*	n	%	Median	IQR	n	%	Median	IQR	*p*
Operative mortality	8	2.7			0	0			8	4.1			0.045*	0	0			1	1.8			0.315
New onset atrial fibrillation	46	15.7			9	9.4			37	18.8			0.038*	3	5.5			11	20			0.022*
Mediastinitis	2	0.7			0	0			2	1.0			0.322	0	0			0	0			NA
Permanent pacemaker insertion	4	1.4			2	2.1			2	1.0			0.463	0	0			2	1.8			0.154
Re-exploration for bleeding	21	7.2			9	9.4			12	6.1			0.306	6	10.9			4	7.3			0.507
Postoperative stroke	6	2.0			0	0			6	3.0			0.084	0	0			1	1.8			0.315
Postoperative renal failure	5	1.7			1	1.0			4	2.0			0.540	0	0			1	1.8			0.315
Low cardiac output syndrome	20	6.8			3	3.1			17	8.6			0.080	1	1.8			3	5.5			0.308
Readmission to ICU	15	5.1			2	2.1			13	6.6			0.100	2	3.6			3	5.5			0.647
Length of ICU stay (days)			1	1-2			1	1-2			2	1-2	0.079			2	1-2			1	1-2	0.167
Length of hospital stay (days)			7	5-10			6	5-7			7	6-10	<0.001*			6	5-8			7	5-8	0.153

PSM: Propensity score matching; MI: Minimally invasive; CS: Conventional sternotomy; IQR: Inter-quartile range; ICU: Intensive care unit; NA: Non-applicable.

bleeding, low cardiac output syndrome, and ICU readmission were similar between the groups. Postoperative new-onset atrial fibrillation occurred significantly less frequently in the MI group than in the CS group, which indicates a positive outcome associated with the minimally invasive approach (p=0.04, Table 3).

A total of eight (2.7%) patients in the entire isolated mitral valve surgery cohort experienced operative mortality. Notably, all eight patients belonged to the CS group, while no mortality occurred in the MI group (p=0.04). All eight patients underwent a replacement rather than a repair procedure. The causes of mortality varied among patients: one patient suffered a cerebral hemorrhage and died on the fifth postoperative day, three patients had a preoperative ejection fraction <35% and died as a result of postoperative low cardiac output syndrome, two patients with preoperative renal failure died due to renal and dialysis-related complications, one patient died due to mediastinitis and sepsis after two months of hospitalization, and one patient experienced unexpected ventricular fibrillation and died on the second postoperative day.

After propensity score matching

To mitigate potential bias and confounding factors, propensity score matching was performed in our study. The propensity score was calculated based on several key variables, including age, comorbidities (COPD and DM), and surgical technique (repair/replacement). These variables were chosen because they are believed to affect the choice of surgical approach and could potentially impact the outcomes.

After the propensity score matching, two groups with an equal number of patients were created for comparison. The matching results demonstrated that age, sex, hypertension, DM, COPD, ejection fraction, previous myocardial infarction, mitral valve pathology, mitral stenosis, and previous percutaneous coronary intervention were not statistically significant between the matched groups.

In the matched groups, the MI group exhibited significantly longer operating times (285.62±47.10 *vs*. 212.91±40.96, p<0.001), cardiopulmonary bypass time (156.72±46.31 *vs*. 100.42±24.05, p<0.001), and aortic cross-clamp time (96.57±26.84 *vs*. 68.26±17.55, p<0.001) compared to the CS group (Table 2). In the MI group, left atriotomy was the preferred route to access the left atrium, whereas in the CS group, transseptal access was more commonly performed (p<0.001). Additionally, surgeons preferred the Custodiol solution for cardioplegia in minimally invasive procedures, while blood cardioplegia was the favored choice for patients who underwent conventional sternotomy (p<0.001).

Before propensity score matching, operative mortality was statistically significant in the CS group. However, following propensity score matching, the analysis found no significant difference between the two groups in terms of mortality (Table 3). Furthermore, when analyzing postoperative complications including mediastinitis, postoperative renal failure, cerebrovascular events, permanent pacemaker insertion, re-exploration for bleeding, and low cardiac output syndrome, no significant differences were observed between the matched groups.

DISCUSSION

The field of MIMVS has witnessed significant advancements in recent decades, revolutionizing the treatment approach of the mitral valve. Patients are increasingly demanding procedures that offer lesser invasiveness, faster recovery times, improved cosmetic outcomes, and decreased postoperative pain. Moreover, surgeons have an increased willingness to adopt and refine minimally invasive techniques driven by the benefits they offer to patients. According to the Society of Thoracic Surgeons data from 2011 to 2016, approximately 23% of isolated mitral valve surgeries were performed using less invasive techniques.[8] According to a large multi-institutional cohort conducted in Italy, mitral valve procedures using a minimally invasive approach increased significantly from 27.5% in 2011 to 71.7% in 2017.[9] The 2020 German Heart Surgery Report, which analyzed the data of 78 German heart surgery departments, revealed that 55.2% of isolated mitral valve procedures were performed via a minimally invasive approach in Germany.[10]

In this study, patients who underwent MIMVS were younger than those who underwent sternotomy. This finding aligns with the notion that minimally invasive approaches are preferred by younger patients. Several factors contribute to this preference. First, younger individuals often prioritize cosmetic outcomes and faster recovery times, which are commonly associated with minimally invasive techniques. Furthermore, younger patients may have higher expectations for their quality of life postoperatively. Minimally invasive mitral valve surgery offers the potential for a quicker return to normalcy.[11] Moreover, consistent with our findings, younger individuals generally have fewer comorbidities and a lower risk profile, making them suitable candidates for minimally invasive procedures.

To minimize bias that could affect the outcomes of our study, propensity score matching was employed. With the propensity score-matched groups, we assessed the impact of the surgical approach on the outcomes more confidently ensuring a more rigorous and reliable data analysis. After the propensity score matching, our findings showed that operation, cardiopulmonary bypass, and cross-clamp times were higher in MIMVS than in the conventional approach. Several studies reported findings consistent with ours, as limited access and restricted field of view may require meticulous maneuvers to achieve optimal surgical outcomes. Furthermore, the use of endoscopic instruments and robotic-assisted systems requires more time for setup and manipulation during the procedure. Mkalaluh et al.,[12] in a retrospective propensity-score-matched analysis, demonstrated that minimally invasive surgery has prolonged operation, cardiopulmonary bypass, and aortic cross-clamp times compared to the conventional approach. These findings were consistent with those of two published reports.[13,14]

The occurrence of postoperative atrial fibrillation in patients undergoing MIMVS remains controversial with conflicting evidence in the literature. While a majority of studies have reported no significant difference in postoperative atrial fibrillation rates between minimally invasive and conventional approach groups, some studies have found results indicating positive outcomes in favor of the minimally invasive group. For instance, a study by Gammie et al.,[15] utilizing the data of 28,143 patients from the Society of Thoracic Surgeons Adult Cardiac Surgical Database between 2004 and 2008, showed that less invasive mitral valve procedures are associated with a lower incidence of postoperative atrial fibrillation. In our study, a similar trend was observed with a lower occurrence of postoperative new-onset atrial fibrillation in the minimally invasive group.

Several studies have reported a shorter hospital and ICU stay in patients undergoing MIMVS compared to the conventional approach.[4,16,17] These findings suggest potential benefits of the minimally invasive approach, including shorter recovery times and reduced hospital costs. However, despite the unmatched findings indicating a difference in the length of hospital stays between the two groups in this study, our propensity score matching analysis did not reveal a statistically significant difference between the matched groups.

In our study, the in-hospital mortality rate among patients who underwent MIMVS was 0%, a finding consistent with that of previous studies that reported low mortality rates ranging from 0 to 3%, with several studies even reporting mortality rates <1%.[18-20] When comparing mortality outcomes between minimally invasive and conventional sternotomy techniques, several studies have consistently shown no statistically significant difference.[21,22] This aligns with the results of our propensity score-matched analysis, where no significant difference was observed in terms of mortality between the matched groups.

When interpreting the results, it is important to consider several limitations. First, minimally invasive procedures were performed by multiple surgeons, each with varying experience levels in this technique. While some surgeons were highly experienced, others were still in the early stages of their learning curve. Additionally, the study involved the use of two different techniques for minimally invasive surgery, including robotic and endoscopic approaches, which may introduce variability as a potential limitation. Second, although propensity score matching was used to minimize confounding factors, it has its own limitations. The matching process relies on available variables and may not account for unmeasured or unknown confounders that could potentially affect the outcomes. Lastly, this study focused on early outcomes and did not investigate long-term clinical outcomes. Understanding the long-term durability and efficacy of MIMVS is essential for evaluating its overall benefits. Future research should consider conducting follow-up studies to assess long-term outcomes.

In conclusion, our study supports the notion that MIMVS is a reliable and safe alternative to sternotomy with comparable outcomes in terms of mortality and postoperative complications. While some limitations exist, overall findings highlight the potential benefits of minimally invasive approaches.

Ethics Committee Approval: The study protocol was approved by the SBÜ Mehmet Akif Ersoy Chest Heart and Vascular Surgery Training and Research Hospital Clinical Research Ethics Committee (date: 18.05.2023, no: 2023.04-50). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Concept/idea generation: E.Y., B.O., Ü.A.; Research design: Z.M.D., M.G., M.B.; Control/supervision: Ü.A., B.O.; Data collection: E.K., E.Y., Z.M.D.; Data analysis: M.G., M.B., Ü.A.; Manuscript writing: E.Y., E.K.; Manuscript review: Ü.A., B.O.; References: Z.M.D., M.G., M.B.; Materials: E.Y., Z.M.D.; Literature deview: E.Y., Ü.A., B.O.

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