Transcatheter versus minimally invasive surgical aortic valve replacement: A propensity score-matched analysis in low-risk patients

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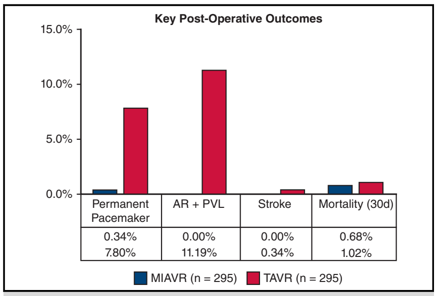
ABSTRACT

Objective: Minimally invasive aortic valve replacement (MIAVR) and transcatheter aortic valve replacement (TAVR) represent less-invasive alternatives to conventional surgical aortic valve replacement. In contrast to Society of Thoracic Surgeons (STS) Database data revealing <10% of all surgical aortic valve replacement procedures are performed via a minimally invasive approach, our center performs a high volume of MIAVR procedures. This propensity-score matched study aims to compare the outcomes of MIAVR versus TAVR in low-risk patients (STS Predicted Risk of Mortality <4%).

Methods: We identified 476 low-risk patients who underwent MIAVR via a right anterolateral minithoracotomy and 679 low-risk patients who underwent TAVR at our institution between 2017 and 2024. In a total of 1155 cases, propensity score analysis performed at a ratio of 1:1 yielded 295 matched pairs.

Results: The matched groups had similar baseline characteristics aside from a higher proportion of tricuspid valves in the TAVR group and greater rates of aortic regurgitation in the MIAVR group. The baseline STS scores were also higher in the TAVR group (1.84 vs 1.69; $P = .030$), although still below the low-risk threshold (STS-PROM <4.0). Postoperatively, patients in the MIAVR group experienced lower rates of permanent pacemaker implantation (0.4% vs 7.8%; $P < .001$), aortic regurgitation (0.3% vs 5.4%; $P < .001$), and paravalvular leak (0.0% vs 5.8%; $P < .001$). Patients undergoing MIAVR had longer hospital lengths of stay (6.23 vs 2.07; $P < .001$) and higher aortic valve mean gradients (7.29 vs 6.04 mm Hg; $P = .004$). There was no significant difference in early mortality or stroke rates between the 2 groups.

Conclusions: To our knowledge, this is the first propensity-score matched comparison of clinical outcomes in low-risk patients undergoing MIAVR versus TAVR, revealing that MIAVR could provide lower rates of permanent pacemaker implantation, paravalvular leak, and aortic regurgitation, without any increase in short-term mortality or stroke. Future prospective or randomized controlled trials are needed to validate these results. (JTCVS Open 2025;26:75-84)



Comparing key postoperative outcomes between low-risk patients undergoing MIAVR and TAVR.

CENTRAL MESSAGE

In low-risk patients, MIAVR was associated with lower rates of PPM and AI than TAVR, with comparable early mortality and stroke rates, highlighting its potential as a durable, underutilized alternative.

PERSPECTIVE

With shared decision making shaping AVR choices, patients increasingly favor less-invasive options. MIAVR demonstrated comparable early mortality and stroke rates to TAVR, suggesting it may confer many of the early benefits associated with TAVR while maintaining the proven long-term durability of SAVR. Integration of MIAVR into clinical practice could expand patient-centered treatment options.

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Abbreviations and Acronyms

AR	= aortic regurgitation
AS	= aortic stenosis
BEV	= balloon-expandable valve
LOS	= length of stay
MIAVR	= minimally invasive aortic valve replacement
PPM	= permanent pacemaker
PVL	= paravalvular leak
SAVR	= surgical aortic valve replacement
STS-PROM	= Society of Thoracic Surgeons Predicted Risk of Mortality
TAVR	= transcatheter aortic valve replacement

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Aortic stenosis (AS) is the most prevalent valvular disease in the developed world.[1] It affects approximately 12.4% of individuals older than age 75 years, with severe AS present in about 3.4% of this age group.[2] Historically, conventional surgical aortic valve replacement (SAVR) via a median sternotomy was the gold standard treatment for patients with symptomatic AS. However, the number of patients undergoing SAVR has steadily declined over the past 5 years as transcatheter aortic valve replacement (TAVR) continues to gain popularity.[3]

Although TAVR was initially marketed for those deemed intermediate[4] or high risk,[5] several groundbreaking clinical trials have expanded the indications to include low-risk patients.[6,7] These studies have demonstrated the early safety and efficacy of TAVR in lower-risk cohorts, yet concerns remain regarding long-term valve durability, paravalvular leak, and pacemaker implantation rates, particularly in younger, low-risk patients who may benefit from a more durable solution.[8,9]

Despite the rising predilection for minimally invasive transcatheter alternatives to conventional sternotomy, there has not been a reciprocal increase in the uptake of minimally invasive surgical aortic valve replacement (MIAVR) in recent years. Compared with conventional SAVR, MIAVR especially when performed through a right thoracotomy, has been associated with reduced transfusion incidence, intensive care stay, hospitalization, and renal failure.[10-13] Recent literature also suggests that MIAVR may be able to provide a mortality benefit compared with both conventional SAVR and TAVR.[14,15] However, <10% of SAVR procedures are performed minimally invasively, and the number of centers in the United States performing MIAVR has decreased from 2015 to 2022.[3]

This discrepancy underscores the need for a closer examination of MIAVR as a unique and underutilized option in the treatment landscape. MIAVR offers the potential to combine the benefits and long-term durability of a surgical prosthesis with the reduced invasiveness that makes TAVR appealing to patients. Furthermore, limited direct comparisons between MIAVR and TAVR, particularly in low-risk populations, highlight a significant knowledge gap. The present study aims to address this gap by directly comparing clinical outcomes of MIAVR and TAVR in low-risk patients.

METHODS

This study was approved by the Trinity Health New York (Syracuse, NY) Institutional Review Board (study No. 19-1230-3; January 13, 2020). We queried the Society of Thoracic Surgeons (STS) database for patients at our center and identified 476 low-risk patients who underwent isolated MIAVR via a right anterolateral mini-thoracotomy between 2017 and 2024 (Table 1). Using the STS/American College of Cardiology Transcatheter Valve Therapy Registry we were also able to identify 679 low-risk patients who underwent TAVR at our institution between 2020 and 2024 (Table 1). In a total of 1155 cases, propensity score analysis performed at a ratio of 1:1 yielded 295 matched pairs (Figure 1).

Preoperative Planning

Patients with severe AS underwent evaluation through a standardized institutional algorithm to guide procedural planning and referral (Figure 2). The decision-making process incorporated initial referral to cardiac surgery or a dedicated valve clinic, where comprehensive risk stratification was performed. Key considerations included age, frailty, comorbidities (eg, chronic kidney disease, pulmonary disease, and prior chest radiation), and anatomical factors such as porcelain aorta or the need for concomitant procedures. Most patients were discussed by a multidisciplinary heart team, particularly in cases of elevated STS Predicted Risk of Mortality (PROM) score, complex anatomy, or unclear procedural benefit. Based on this assessment and patient preference, patients were triaged to the most appropriate intervention, as illustrated in Figure 2.

Surgical Approach

All SAVR procedures were performed minimally invasively through a small right anterolateral minithoracotomy via the second or third intercostal space, with or without rib division, depending on surgeon preference and patient body habitus (Video 1). The use of video assistance was also at the discretion of the operating surgeon. In most cases, cardiopulmonary bypass was achieved via femoral cannulation. Direct aortic arterial cannulation was performed if the patient had severe peripheral vascular disease. Cardioplegia strategy involved either Buckberg or del Nido cardioplegia solution delivered antegrade or retrograde at surgeon discretion. All replacement aortic valves (96.9% bioprosthetic) were implanted using fixed pledged sutures (2-0 Ti-Cron; Covidien) in a supra-annular position and secured with titanium knot fasteners (COR-Knot Device; LSI Solutions).

Transcatheter Approach

All procedures were performed in a hybrid operating room or catheterization laboratory under either monitored anesthesia care or general anesthesia, depending on patient comorbidities and procedural complexity. The majority

TABLE 1. Patient demographics and characteristics

Variable	Total cohort: MIAVR (n = 476)	Total cohort: TAVR (n = 679)	*P* value	Propensity-matched cohort: MIAVR (n = 295)	Propensity-matched cohort: TAVR (n = 295)	*P* value
Age (y)	66.00 (59.0-73.0)	76.33 (71.3-81.4)	**<.001**	71.00 (66.0-76.0)	72.07 (67.5-77.5)	.150
Male gender	298 (62.6)	457 (67.3)	.112	187 (63.4)	199 (67.5)	.341
BMI	30.08 (26.9-34.5)	29.4 (25.6-34.1)	.242	29.75 (26.8-34.0)	29.85 (25.5-34.7)	.790
STS-PROM	1.40 ± 0.8	2.2 ± 0.9	**<.001**	1.69 ± 0.8	1.84 ± 0.9	**.030**
Diabetes	135 (28.4)	256 (37.7)	**.001**	98 (33.2)	105 (35.6)	.603
Chronic lung disease	99 (20.8)	163 (24.0)	.226	68 (23.1)	63 (21.4)	.692
Peripheral vascular disease	17 (3.6)	96 (14.1)	**<.001**	17 (5.8)	26 (8.8)	.205
Valve morphology: Tricuspid	440 (92.4)	676 (99.6)	**<.001**	272 (92.2)	295 (100.0)	**<.001**
Aortic valve mean gradient (mm Hg)	43.88 ± 14.2	44.09 ± 10.9	.802	43.92 ± 14.5	45.0 ± 11.2	.333
Aortic regurgitation >trace	253 (53.2)	298 (42.6)	**.002**	165 (59.9)	133 (45.1)	**.008**
Mild	120 (25.2)	207 (30.5)		83 (28.1)	91 (30.8)	
Moderate	72 (15.1)	81 (11.2)		48 (16.7)	37 (12.5)	
Severe	61 (12.8)	10 (1.5)		34 (11.5)	5 (1.7)	

Data are presented as n (%), mean ± standard deviation, or median (quartile 1-quartile 3). Bold values indicates statistical significance. *MIAVR*, Minimally invasive aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *BMI*, body mass index; *STS-PROM*, Society of Thoracic Surgeons Predicted Risk of Mortality.

of procedures were performed via a percutaneous transfemoral approach (94.4%) (Table 2). Alternative access routes, including transsubclavian or direct aortic access, were utilized primarily in patients with severe iliofemoral disease, excessive vascular tortuosity, or significant peripheral artery disease. Balloon-expandable valves (BEVs) comprised 95.6% of all TAVR implants, reflecting institutional preference for BEV devices in low-risk patients and those with

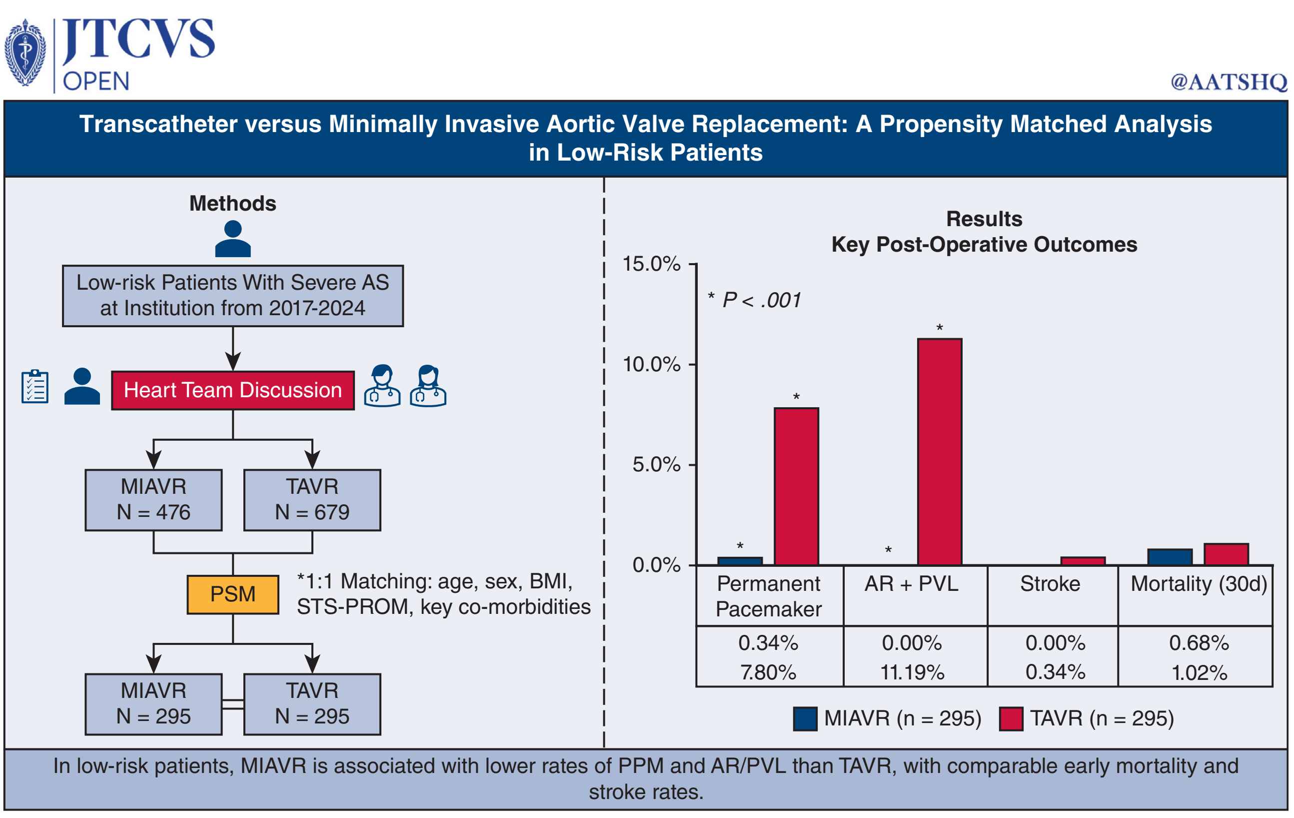


FIGURE 1. Graphical abstract. Summary of study design and key results. *AS*, Aortic stenosis; *MIAVR*, minimally invasive aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *PSM*, propensity score matching; *BMI*, body mass index; *STS-PROM*, Society of Thoracic Surgeons Predicted Risk of Mortality; *PPM*, permanent pacemaker; *AR*, aortic regurgitation; *PVL*, paravalvular leak.

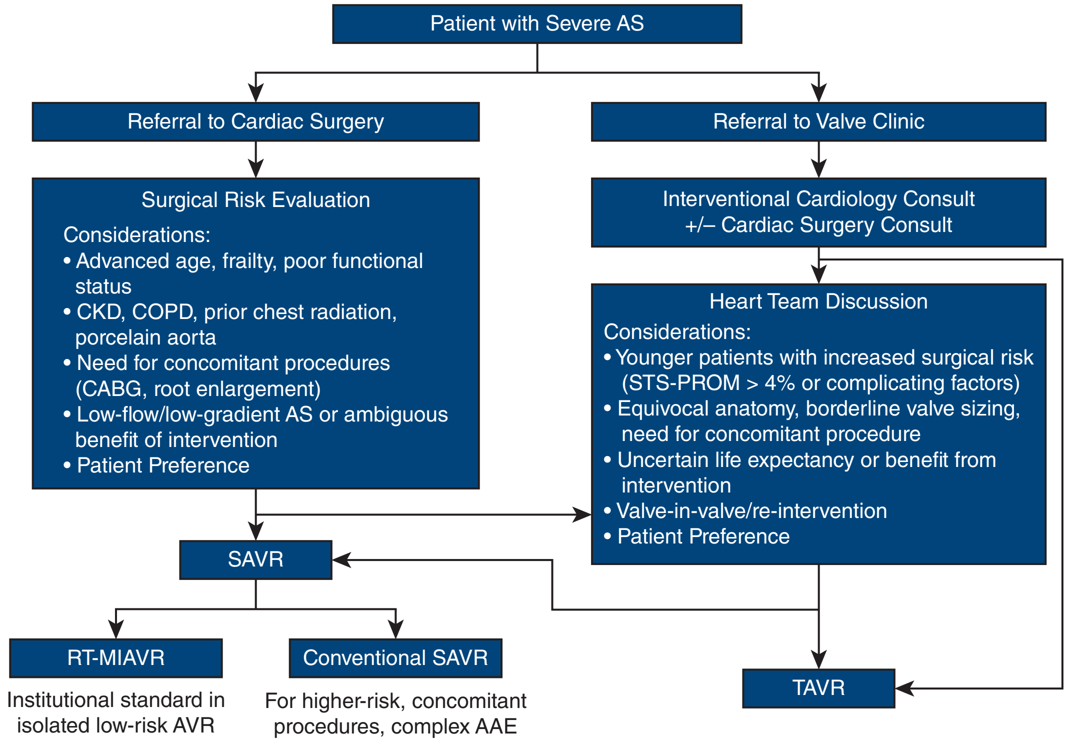


FIGURE 2. Institutional Preoperative planning and referral pattern. *AS*, Aortic stenosis; *CKD*, chronic kidney disease; *COPD*, chronic obstructive pulmonary disease; *STS-PROM*, Society of Thoracic Surgeons Predicted Risk of Mortality; *SAVR*, surgical aortic valve replacement; *RT-MIAVR*, right thoracotomy minimally invasive aortic valve replacement; *AVR*, aortic valve replacement; *AAE*, aortic annular enlargement; *TAVR*, transcatheter aortic valve replacement.

favorable annular anatomy (Table 2). Self-expanding valves were used selectively in patients with small aortic annuli or extensive annular and left ventricular outflow tract calcification to minimize the risk of annular rupture and patient-prosthesis mismatch. Valve deployment was guided by fluoroscopy and transesophageal echocardiography to ensure optimal positioning, valve function, and the absence of significant paravalvular leak (PVL). Deployment was aimed at ensuring no more than 20% of the device was below the annulus and the noncoronary isolation technique was utilized to optimize positioning, with the caveat that there are always individual patient factors that are considered. Following valve implantation, patients were monitored for conduction abnormalities with continuous telemetry. Permanent pacemaker implantation (PPM) was performed only in cases of persistent high-degree atrioventricular block or other conduction disturbances unresponsive to conservative management.

Matching Procedure

Nearest neighbor matching was performed using the MatchIt package in R (R Foundation for Statistical Computing) to balance preoperative characteristics between the 2 treatment groups. This approach was selected to minimize differences in propensity scores, which were estimated using a logistic regression model incorporating age, sex, body mass index, STS-PROM score, and key comorbidities such as chronic lung disease, diabetes, and peripheral artery disease. A caliper of 0.2 was applied to restrict the maximum allowable difference in propensity scores between matched pairs, enhancing the quality of the match and reducing potential bias. Target standard mean difference was <0.10 and was achieved for most variables (Figure 3). As a result, 295 well-matched pairs were identified, ensuring comparable baseline characteristics between patients undergoing AVR in both treatment groups.

Statistical Analysis

Following propensity score matching, we compared the baseline characteristics and surgical outcomes between the groups. Categorical variables were analyzed using χ^2 tests to assess the independence between groups. Continuous variables were tested for normality using visual inspections and the Shapiro-Wilk test. Based on these assessments, Student *t* tests were applied to normally distributed continuous variables, whereas the Wilcoxon rank-sum test was used for those not meeting normality assumptions. This tailored approach to data analysis ensured the application of the most appropriate statistical methods, enhancing the robustness of our findings. All statistical analyses were performed using SPSS software (SPSS Inc) and R.

RESULTS

Prematch Cohort

Prematch patient characteristics from the 2 groups demonstrated the TAVR group having greater age (76.33 vs 66.00 years; $P < .001$), STS-PROM scores (2.20 vs 1.40; $P < .001$), rates of diabetes (37.7% vs 28.4%; $P = .001$), peripheral vascular disease (14.1% vs 3.6%; $P < .001$) and proportion of tricuspid valve morphology (99.6% vs 92.4%; $P < .001$). Rates of aortic regurgitation (AR) were greater in the MIAVR group (53.2% vs 42.6%; $P = .002$) (Table 1).

The prematch comparison yielded several differences in postoperative outcomes. As expected, total hospital length of stay (LOS) was higher in the MIAVR group (5.91 vs 2.03 days; $P < .001$) as well as the number of operative approaches converted (1.5% vs 0.0%; $P = .005$). Mean left ventricular ejection fraction was higher in the MIAVR group (59.36 vs 57.54; $P < .001$) although aortic valve mean gradients were also increased in the MIAVR group (7.64 vs 5.92 mm Hg; $P < .001$). In the TAVR group, rates of PPM (8.7% vs 0.4%; $P < .001$), AR (6.9% vs 0.2%; $P < .001$), and PVL (5.9% vs 0.0%; $P < .001$) were all significantly higher than those seen in MIAVR (Table 3).

Propensity Score-matched Cohort

In the propensity score-matched cohort, we observed a higher proportion of tricuspid valves (100% vs 92.2% tricuspid; $P < .001$) in the TAVR group and higher rates of preoperative AR in the MIAVR group (59.9% vs 45.1%; $P < .001$). Despite propensity score matching, mean STS-PROM scores remained slightly higher in the TAVR group (1.84 vs 1.69; $P = .030$), although still well below the low-risk threshold (STS-PROM score <4.0) (Table 1). All other baseline patient characteristics were similar between matched groups.

Postoperatively, patients in the MIAVR group experienced lower rates of PPM (0.4% vs 7.8%; $P < .001$), AR (0.3% vs 5.4%; $P < .001$), and PVL (0.0% vs 5.8%; $P < .001$) than the TAVR group (Table 3). Patients undergoing MIAVR did have longer hospital LOS (6.23 vs 2.07 days; $P < .001$), higher aortic valve mean gradients (7.29 vs 6.04 mm Hg; $P = .004$) and had a greater mean left ventricular ejection fraction (59.87 vs 57.67; $P = .003$) (Table 3). There was no significant difference in early mortality (<30 days) or stroke rates between the 2 groups (Table 3).

DISCUSSION

The results of this propensity score-matched analysis comparing MIAVR and TAVR in low-risk patients highlight important clinical differences between these 2 treatment strategies. MIAVR was associated with significantly lower rates of PPM, PVL, and AR compared with TAVR (Table 3). These findings are consistent with previous studies comparing surgical and transcatheter approaches to AVR, irrespective of risk stratification and degree of surgical invasiveness.[4,5,7,16-18] The long-term significance of these findings is increasingly recognized, particularly in younger low-risk patients with greater life expectancy. PPM after TAVR has been associated with higher long-term mortality, increased risk of heart failure hospitalization, and reduced left ventricular function.[19-21] Similarly, PVL and AR—especially moderate or greater—have been shown to independently predict late mortality after TAVR.[5,22] Even mild PVL has been associated with worse long-term outcomes in low-risk patients at extended follow-up points.[23,24] Although outcomes in this study were excellent overall, it is important to acknowledge that differences in conduction disturbances and valve seating may have long-term consequences.

Patients undergoing MIAVR also demonstrated higher postoperative left ventricular ejection fraction and mean aortic valve gradients compared with those undergoing TAVR (Table 3). Although these differences reached

TABLE 2. Procedure-specific variables

Variable	n*	Result
MIAVR		
Valve size (mm)	473	24.01 (2.0)
19		3 (0.6)
21		75 (15.8)
23		158 (33.2)
25		167 (35.1)
27		57 (12.0)
29		13 (2.73)
Unknown		3 (0.6)
Valve type	476	
Bioprosthetic		461 (96.9)
Perimount Magna Ease†		366 (76.9)
Resilia†		43 (9.0)
Avalus‡		17 (3.6)
Mosaic Ultra‡		17 (3.6)
Other FDA-approved device		18 (3.8)
Mechanical		15 (3.2)
Abbott§		11 (2.3)
St Jude§		4 (0.9)
Annular enlargement	475	21 (4.4)
Cardiopulmonary bypass time	475	97.14 ± 31.7
Aortic crossclamp time	475	68.04 ± 18.2
TAVR		
Valve size	634	25.97 ± 2.5
20		11 (1.6)
23		175 (25.7)
26		270 (39.8)
29		171 (25.2)
34		7 (1.0)
Unknown		45 (6.6)
Valve type	634	
BEV		606 (95.6)
Sapien 3 Ultra†		383 (60.4)
Sapien 3†		143 (22.6)
Sapien 3 Ultra Resilia†		80 (12.6)
SEV		28 (4.4)
Evolut Pro Plus‡		20 (3.15)
Evolut FX‡		8 (1.26)
Valve sheath access	640	
Femoral		604 (94.4)
Subclavian		19 (3.0)
Transaortic		17 (2.7)

Values are presented as mean ± standard deviation or n (%). *MIAVR*, Minimally invasive aortic valve replacement; *FDA*, Food and Drug Administration; *TAVR*, transcatheter aortic valve replacement; *BEV*, balloon-expandable valve; *SEV*, self-expandable valve. *Number of observations with available data. †Edwards Lifesciences. ‡Medtronic. §Abbott.

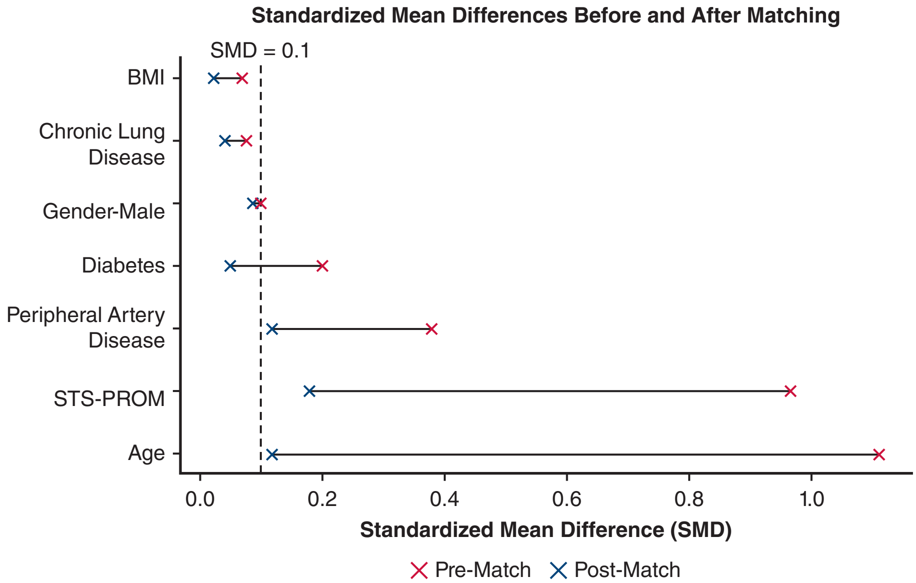


FIGURE 3. Standard mean difference before and after matching. *SMD*, Standardized mean difference; *BMI*, body mass index; *STS-PROM*, Society of Thoracic Surgeons Predicted Risk of Mortality.

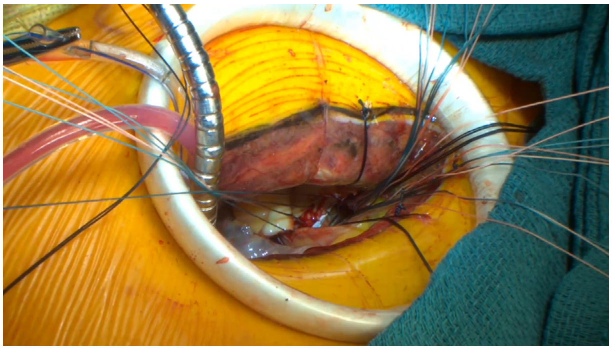
statistical significance, both values remained within normal physiologic ranges, suggesting that the observed differences are unlikely to be clinically meaningful. Instead, these findings reinforce the notion that both approaches provide excellent postprocedural hemodynamic performance, with effective restoration of left ventricle function and valve hemodynamics. As expected, MIAVR patients also experienced a significantly longer postoperative hospital stay compared with patients undergoing TAVR.

The early postoperative period constitutes the highest-risk interval for SAVR, a phase during which TAVR has consistently demonstrated superior outcomes across all risk

TABLE 3. Postoperative outcomes

	Total cohort			Propensity-score matched cohort		
	Procedure			Procedure		
	MIAVR (n = 476)	TAVR (n = 679)	*P* value	MIAVR (n = 295)	TAVR (n = 295)	*P* value
Total hospital LOS (d)	5.91 ± 3.7	2.03 ± 3.0	**<.001**	6.23 ± 4.3	2.07 ± 3.0	**<.001**
Operative approach converted	7 (1.5)	0 (0)	**.005**	5 (1.7)	0 (0)	.072
Annular rupture	0 (0)	0 (0)	1.000	0 (0)	0 (0)	1.000
Major bleeding*	27 (5.7)	40 (5.9)	**.876**	12 (4.1)	19 (6.4)	.196
Pacemaker required	2 (0.4)	59 (8.7)	**<.001**	1 (0.4)	23 (7.8)	**<.001**
Stroke	1 (0.2)	3 (0.4)	.880	0 (0.0)	1 (0.3)	1.000
Mean LVEF	59.36 ± 8.3	57.64 ± 9.0	**<.001**	59.87 ± 8.6	57.67 ± 9.4	**.003**
Aortic valve mean gradient (mm Hg)	7.64 ± 3.9	5.92 ± 4.6	**<.001**	7.29 ± 4.1	6.038 ± 3.3	**.004**
Aortic regurgitation >trace	1 (0.2)	47 (6.9)	**<.001**	1 (0.3)	16 (5.4)	**<.001**
Mild	1 (0.2)	45 (6.6)		1 (0.3)	14 (4.7)	
Moderate	0 (0.0)	2 (0.3)		0 (0.0)	2 (0.7)	
Severe	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Paravalvular leak >trace	0 (0.0)	40 (5.9)	**<.001**	0 (0.0)	17 (5.8)	**<.001**
Mild	0 (0.0)	38 (5.6)		0 (0.0)	15 (5.1)	
Moderate	0 (0.0)	2 (0.3)		0 (0.0)	2 (0.7)	
30-d Mortality	2 (0.4)	3 (0.4)	1.000	2 (0.7)	3 (1.0)	1.000

Values are presented as n (%), mean ± standard deviation, or median (quartile 1-quartile 3). Bold values indicates statistical significance. *MIAVR*, Minimally invasive aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *LOS*, length of stay; *LVEF*, left-ventricular ejection fraction. *Valve Academic Research Consortium-3.



VIDEO 1. Minimally invasive aortic valve replacement (MIAVR) performed via a right anterior thoracotomy, as routinely performed at our institution. The video demonstrates standard steps, including thoracotomy exposure, aortic crossclamping, native valve excision, annular decalcification, and implantation of a bioprosthetic valve using interrupted sutures. This approach reflects the institutional technique used for MIAVR in low-risk patients included in the study cohort. Video available at: https://www.jtcvs.org/article/S2666-2736(25)00152-4/fulltext.

profiles.[4,5,7,17,25-28] In this current study, no differences were observed in early mortality or stroke rates (Table 3), supporting the notion that MIAVR may deliver many of the early safety benefits attributed to TAVR while preserving the long-term durability profile of surgical bioprostheses.

Initially introduced for patients with AS deemed inoperable, the indications for TAVR have expanded rapidly during the past 10 years supported by several pivotal randomized trials.[4,5,16,17,27,28] The optimal treatment strategy for low-risk patients with AS remains an area of ongoing debate. In 2023, the highly anticipated 5-year results of the Placement of Aortic Transcatheter Valves 3 (PARTNER-3) trial demonstrated no significant differences between TAVR and SAVR in key outcomes, including a composite end point of death, stroke, or rehospitalization.[7] However, critics argue that these findings are premature, emphasizing that aortic valve disease management is lifelong and that concerns persist regarding higher rates of mild or greater paravalvular regurgitation in TAVR (20% vs 3%), which has been associated with increased long-term mortality rates.[23,29,30] Additionally, they argue that using rehospitalization in the composite end point may skew results in favor of TAVR, downplaying the fact that mortality numerically favored surgery (hazard ratio [HR], 1.23; 95% CI, 0.79 to 1.97).[29]

The current guidelines reflect this uncertainty surrounding long-term outcomes in younger patients undergoing TAVR, recommending SAVR for those younger than age 65 years with severe symptomatic AS, provided they are not at prohibitive surgical risk. However, a recent study derived from the California statewide registry found that between 2013 and 2021, TAVR rates in patients aged 60 years and younger increased from 7.2% to 45.7% and was associated with significantly worse 5-year survival when compared to SAVR in a propensity-score matched analysis.[26] Similarly, a national Medicare analysis by Mehaffey and colleagues[25] found that among low-risk patients younger than age 75 years, TAVR was associated with significantly worse 3-year survival, stroke, and valve reintervention rates compared with SAVR, despite lower in-hospital morbidity.

The deviation from consensus guidelines in real-world clinical practice has been largely fueled by the increasing emphasis of shared decision making as a quality metric, which has empowered patients to take a more active role in their treatment choices.[31] Given the choice, many patients naturally gravitate toward less-invasive options to avoid the risks and recovery associated with heart surgery involving a median sternotomy. Although TAVR offers compelling short-term benefits—faster recovery, reduced perioperative morbidity, and earlier discharge—emerging long-term data suggest that it may not provide equivalent durability or optimal outcomes compared with SAVR, especially in younger patients.[25,26,32,33] Structural valve deterioration, PVL, PPM requirements, and the need for future valve interventions remain concerns because TAVR is increasingly used in younger, lower-risk individuals.

MIAVR via right thoracotomy presents a potential best of both worlds approach, offering a less-invasive alternative to a full sternotomy while preserving the durability and outcomes of conventional surgical valve replacement. A recent network meta-analysis comparing MIAVR, TAVR, and SAVR found that in pairwise comparison of high-quality randomized controlled trials and propensity score-matched data, TAVR showed superior mortality to conventional SAVR until 37.5 months, beyond which there was no significant difference, much like the results observed in high-profile randomized controlled trials.[7,14] MIAVR on the other hand demonstrated significantly lower mortality than both TAVR (HR, 0.70; 95% CI, 0.59-0.82) and conventional SAVR (HR, 0.69; 95% CI, 0.59-0.80).[14] Although these data are encouraging and support the potential for MIAVR to provide improved outcomes, it is important to note that the direct comparison of MIAVR and TAVR relied on propensity score-matched studies, highlighting the need for further validation.[14]

Another recent meta-analysis of 12 observational studies directly comparing MIAVR and TAVR found that patients undergoing MIAVR had lower rates of both 30-day (relative risk, 0.63; 95% CI, 0.42-0.96; $P = .03$) and midterm mortality at 4 years of follow-up (HR, 0.76; 95% CI, 0.67-0.87; $P < .001$).[15] Notably, in both meta-analyses, MIAVR was broadly defined to include right thoracotomy, ministernotomy, and sutureless aortic valves.[14,15] However, prior literature suggests that a sternal-sparing, right thoracotomy approach may provide superior outcomes compared with other MIAVR approaches, potentially reducing operative time, hospital LOS, postoperative pain, and morbidity, while improving both early and long-term survival.[34,35]

Therefore, it is possible these meta-analyses are underestimating the benefits of MIAVR performed through a right thoracotomy due to the inclusion of other approaches.

An additional limitation of these meta-analyses is the lack of stratification by patient risk profile because neither analysis performed a subgroup evaluation for low-risk patients and only 1 study included in the meta-analyses compared MIAVR and TAVR in low-risk patients. Furthermore, in that single low-risk propensity score-matching study, the MIAVR cohort was defined as those receiving stentless valves and >50% of the procedures were performed via median sternotomy, making it questionable for inclusion in the MIAVR meta-analyses at all. The lack of direct comparisons between MIAVR via right thoracotomy and TAVR in low-risk populations represents a significant knowledge gap in the management of severe AS. Addressing this gap is critical as it involves the most controversial area of TAVR expansion and the patient group where MIAVR has the greatest potential to demonstrate superior outcomes.

Although our study demonstrates favorable outcomes for MIAVR via right thoracotomy, several limitations must be considered. A key limitation is that both surgeons in this study have more than 20 years of experience in minimally invasive cardiac surgery, including extensive expertise in MIAVR. Similarly, the expertise of the interventional cardiologists at our institution, who rank among the top in New York State in terms of TAVR volume and outcomes, represents another factor that may influence the study's findings. The added technical complexity and steep learning curve associated with minimally invasive cardiac surgery may limit the generalizability of this study to lower-volume centers or less-experienced surgeons. Studies have shown that operative times, complication rates, and overall outcomes improve significantly as surgeons progress along the minimally invasive cardiac surgery learning curve, with some estimates suggesting that 50 to 100 cases may be required to achieve proficiency.[36,37] Consequently, centers without established MIAVR expertise may experience longer crossclamp times, increased perioperative complications, and a higher conversion rate to full sternotomy, potentially diminishing the advantages observed in our study.[37] Similarly, the predominant use of BEVs in our TAVR cohort, reflecting institutional preference and operator experience, may limit the generalizability of our findings to centers with different device selection practices.

Compared with surgical approaches, a key limitation of TAVR is the inability to perform aortic annular enlargement, a technique often necessary to accommodate appropriately sized prostheses in patients with small aortic annuli. This limitation has important implications for the lifetime management of AS, particularly in younger, low-risk patients who may require future valve interventions. Performing aortic annular enlargement at the time of SAVR has gained increasing attention in structural cardiac surgery because it can also facilitate the placement of a larger prosthesis in the event of a future valve-in-valve TAVR.[38]

Traditionally performed via median sternotomy, aortic annular enlargement has more recently been adapted to minimally invasive techniques, including right thoracotomy approaches.[39] In our study, 4.4% of MIAVR patients underwent annular enlargement (Table 2), demonstrating the feasibility of this technique in a minimally invasive setting. Although this proportion may appear modest, it is notable that most of these cases occurred in the later years of the study period, with more than 50% occurring during the past 2 years in response to the increasing national emphasis. Annular enlargement at our institution was also historically performed through sternotomy and thus excluded from this cohort. Similarly, the need for aortic annular enlargement adds to the overall surgical risk, and some patients undergoing MIAVR with aortic annular enlargement may have had STS-PROM scores exceeding 4.0%, rendering them ineligible for inclusion in this low-risk analysis.

As with any observational study comparing treatment options, patient selection bias is an inherent limitation. To mitigate this bias, we used propensity score matching to balance preoperative risk factors and baseline characteristics, ensuring that comparisons between MIAVR and TAVR patients were as equitable as possible. Propensity score matching is a widely accepted method for addressing confounding in nonrandomized studies, but it cannot fully eliminate unmeasured confounders such as frailty, anatomical suitability, or surgeon/institutional preferences, which may have influenced treatment selection. It is also important to acknowledge that randomized controlled trials comparing TAVR and SAVR are not immune to selection bias and often include highly selected patient populations.[40] In the PARTNER-3 trial, for example, low-risk patients randomized to TAVR versus SAVR were carefully screened for favorable anatomy, often excluding those with complex root morphology, bicuspid aortic valves, or small annuli, which may not fully represent real-world practice. This reinforces the need for broader, real-world studies to guide clinical decision making.

Finally, our study, like most observational studies comparing surgical and transcatheter approaches, lacks adequate long-term follow-up. Thus, limiting our ability to definitively assess valve longevity, reintervention rates, and long-term mortality. Although surgical bioprostheses have historically demonstrated superior durability compared with early-generation TAVR valves, it remains unclear whether current-generation TAVR prostheses will match or exceed surgical durability in low-risk patients. Ultimately, the excellent outcomes observed in both groups underscore the strength of a well-integrated heart team approach, where collaborative expertise in patient selection, perioperative management, and procedural proficiency optimizes results and ensures the highest standard of care.

Although MIAVR is the standard approach for low-risk isolated SAVR at our institution, it remains underutilized nationally. This disparity highlights a critical opportunity for the cardiac surgical community to expand MIAVR adoption through enhanced training and increased exposure, bridging the gap between conventional SAVR and TAVR. Future prospective and randomized controlled trials are warranted to validate these findings and further delineate the optimal treatment strategy for low-risk patients.

CONCLUSIONS

To our knowledge, this study is the first propensity score-matched comparison of clinical outcomes in low-risk patients undergoing MIAVR versus TAVR. Both groups demonstrated excellent short-term outcomes; however, the lower rates of PPM, PVL, and AR observed in the MIAVR cohort may offer long-term advantages. Similarly, the comparable early mortality and stroke profiles suggest that MIAVR may confer the benefits of reduced invasiveness traditionally only seen in TAVR.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/post-cardiotomy-ecmo-support-i-9821.

Conflict of Interest Statement

Dr Lutz is a consultant for Medtronic. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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