Review

Transcatheter Mitral Valve Replacement for Treating Native Mitral Valve Disease:

Current Status

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Transcatheter mitral valve replacement is increasingly being used as a treatment for high-risk patients who have native mitral valve disease; however, no comprehensive studies on its effectiveness have been reported. We therefore searched the literature for reports on patients with native mitral valve disease who underwent transcatheter access treatment.

We found 40 reports, published from September 2013 through April 2017, that described the cases of 66 patients (mean age, 71 ± 12 yr; 30 women; 30 patients with mitral stenosis, 34 with mitral regurgitation, and 2 mixed) who underwent transcatheter mitral valve replacement. We documented their baseline clinical characteristics, comorbidities, diagnostic imaging results, procedural details, and postprocedural results.

Access was transapical in 41 patients and transseptal in 25. The 30-day survival rate was 82.5%. The technical success rate (83.3% overall) was slightly but not significantly better in patients who had mitral regurgitation than in those who had mitral stenosis. Transapical access procedures resulted in fewer valve-in-valve implantations than did transseptal access procedures (P=0.026).

These current results indicate that transcatheter mitral valve replacement is feasible in treating native mitral disease. The slightly higher technical success rate in patients who had mitral regurgitation suggests that a valve with a specific anchoring system is needed when treating mitral stenosis. Our findings indicate that transapical access is more reliable than transseptal access and that securely anchoring the valve is still challenging in transseptal access. ***(Tex Heart Inst J 2020;47(4):271-9)***

Key words: *Disease-free survival; heart valve prosthesis implantation/methods; mitral valve insufficiency/physiopathology; mitral valve stenosis/therapy; postoperative complications/etiology; recovery of function; retrospective studies; survival rate; transcatheter mitral valve replacement/methods; treatment outcome*

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Transcatheter aortic valve replacement (TAVR) has been a successful treatment for severe symptomatic aortic stenosis in older patients with comorbidities who are at high surgical risk.[1] Consequently, the use of transcatheter mitral valve replacement (TMVR) for treating native mitral regurgitation (MR) and mitral stenosis (MS) has increased. Mitral valve (MV) repair or replacement is the gold standard for treating mitral disease, but approximately half of patients are at high surgical risk.[2-4] Independent risk factors of 30-day postoperative death are New York Heart Association (NYHA) functional class IV status, diabetes mellitus, hypertension, renal insufficiency, rheumatic causes, and depressed left ventricular ejection fraction (<45%).[5] When surgery is risky, TMVR may be an option. Because comprehensive data on current clinical outcomes of TMVR are not available, we reviewed the medical literature and gathered information on the clinical, anatomic, and periprocedural characteristics of TMVR cases. We then compared clinical outcomes when MR or MS was treated by means of transapical (TA) access or transseptal (TS) access.

Patients and Methods

We systematically searched all English-language articles from January 2000 through April 2017 in PubMed and Web of Science that described TMVR, using the search terms *TMVI* OR *transcatheter mitral valve* OR *transcatheter mitral valve replacement* OR *transcatheter mitral valve implantation*. Articles were excluded if they were not in English, focused on animal experiments, lacked relevant information on TMVR, had

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TABLE I. Baseline Characteristics of the 66 Patients

Reference	Pt. No.	Age (yr), Sex	NYHA Class	Native Mitral Disease	Comorbidities	MAC	Access
Sinning JM, et al.[7] (2013)	1	75, F	IV	MS	SAVR	Yes	TA
Hasan R, et al.[8] (2013) and Mahadevan VS, et al.[9] (2015)	2	70, F	NS	MS	CABG; SAVR	Yes	TA
Ribeiro HB, et al.[10] (2014)	3	55, F	III	MS	TAVR	Yes	TA
Himbert D, et al.[11] (2014)	4	72, F	IV	MS	SAVR; tricuspid annuloplasty	Yes	TS
	5	74, F	IV	MS	COPD; cirrhosis; breast cancer	Yes	TS
	6	66, F	IV	MR	SAVR; morbid obesity; CKD	Yes	TS
	7	45, M	III	MR	CAD; SAVR; CABG	Yes	TS
Guerrero M, et al.[12] (2014)	8	75, M	NS	MS	CABG; AS; PAH	Yes	TS
Fassa AA, et al.[13] (2014)	9	72, F	NS	MS	SAVR; tricuspid annuloplasty	Yes	TS
Sondergaard L, et al.[14] (2014)	10	88, F	III	MR	CABG; CKD	No	TA
Lutter G, et al.[15] (2014)	11	57, M	NS	MR	HT; rheumatic heart disease	No	TA
	12	55, F	NS	MR	Rheumatic heart disease	No	TA
Cheung A, et al.[16] (2014)	13	73, NS	IV	MR	CAD; HT; DM; CKD; COPD	No	TA
	14	61, NS	III	MR	CAD; AF; HT; COPD; chronic liver disease	No	TA
Bapat V, et al.[17] (2014)	15	NS, M	NS	MR	—	No	TA
	16	NS, F	NS	MR	CKD; CAD; aneurysm	No	TA
	17	NS, NS	NS	MR	CABG; COPD	No	TA
	18	NS, M	NS	MR	CABG	No	TA
	19	NS, NS	NS	MR	CAD	No	TA
Witkowski A, et al.[18] (2015)	20	39, M	III	MS	AS	Yes	TA
Nielsen NE, et al.[19] (2015)	21	70, M	III	MS	CABG; TAVR; AS; HT; CAD	Yes	TS
Akujuo AC, et al.[20] (2015)	22	68, F	NS	MS	AS	Yes	TA
Bedzra E, et al.[21] (2016)	23	71, M	IV	Mixed	CABG; SAVR; radiotherapy; sequelae; mediastinal tumor	Yes	TA
Lim ZY, et al.[22] (2015)	24	62, M	III	MR	TAVR; Alport syndrome	Yes	TA
Abdul-Jawad Altisent O, et al.[23] (2015)	25	66, M	III	MR	Ischemic cardiomyopathy	No	TA
Abdul-Jawad Altisent O, et al.[24] (2015)	26	67, M	III	MR	CABG; AF; CAD	No	TA
	27	65, F	IV	MR	CABG; CAD	No	TA
	28	81, M	III	MR	CABG; AF; CAD; peripheral artery disease	No	TA
Sondergaard L, et al.[25] (2015)	29	89, F	IV	MR	CABG; HT; dyslipidemia	No	TA
	30	78, M	III	MR	HT; dyslipidemia; DM; COPD	No	TA
	31	80, F	IV	MR	CABG; HT; dyslipidemia	No	TA
Sondergaard L, et al.[26] (2015)	32	86, M	NS	MR	NS	No	TS
Weich H, et al.[27] (2016)	33	91, F	NS	MS	AS	Yes	TA
Ahn HC, et al.[28] (2016)	34	71, M	IV	MS	CABG; TAVR; HT; AF; stroke; CAD; percutaneous valvulotomy	Yes	TS
	35	89, F	III	MS	AS; PAH	Yes	TS

Continued

TABLE I. Baseline Characteristics of the 66 Patients (continued)

Reference	Pt. No.	Age (yr), Sex	NYHA Class	Native Mitral Disease	Comorbidities	MAC	Access
Guerrero M, et al.[29] (2016)	36	90, F	III	MS	COPD; AS; HT	Yes	TS
Capretti G, et al.[30] (2016)	37	46, M	NS	MS	Liver cirrhosis	Yes	TS
Nguyen A, et al.[31] (2016)	38	69, M	NS	MS	Ischemic cardiomyopathy	Yes	TS
	39	84, F	NS	MS	NS	Yes	TS
Jain R, et al.[32] (2016)	40	77, F	NS	MS	CABG; SAVR; PAH	Yes	TA
	41	77, F	NS	MS	CABG; PAH	Yes	TA
Eleid MF, et al.[33] (2016)	42	80, F	NS	MS	Previous cardiac surgery	Yes	TS
	43	85, F	NS	MS	Previous cardiac surgery	Yes	TS
	44	NS, NS	NS	MS	Previous cardiac surgery	Yes	TS
	45	NS, NS	NS	Mixed	Previous cardiac surgery	Yes	TS
	46	NS, NS	NS	MS	Previous cardiac surgery	Yes	TS
	47	NS, NS	NS	MR	Previous cardiac surgery	Yes	TS
Hulman M, et al.[34] (2016)	48	39, F	II/III	MS	AS; rheumatic heart disease	Yes	TA
	49	69, M	III	MR	AS; SAVR; tricuspid valve repair	Yes	TA
Elkharbotly A, et al.[35] (2016)	50	68, F	III/IV	MS	CABG; AS; AF; COPD; CAD; PAH; pulmonary embolism; CKD	Yes	TA
Deharo P, et al.[36] (2016)	51	76, F	NS	MS	NS	Yes	TS
van Gils L, et al.[37] (2016)	52	73, M	NS	MR	SAVR	No	TA
Romeo F, et al.[38] (2016)	53	72, M	III/IV	MR	CABG; CAD	No	TA
Ren B, et al.[39] (2016)	54	75, F	III/IV	MS	COPD; latent tuberculosis; thrombocytopenia	Yes	TA
Dvir D, et al.[40] (2016)	55	39, M	NS	MR	Dilated cardiomyopathy	No	TA
Quarto C, et al.[41] (2016)	56	68, F	IV	MR	CABG	No	TA
	57	75, M	IV	MR	CABG; CKD	No	TA
	58	87, M	III	MR	NS	No	TA
Bashir M, et al.[42] (2017)	59	87, F	III	MS	AS; CKD; PAH; COPD; AF	Yes	TS
Guerrero M, et al.[43] (2017)	60	59, F	III	MS	COPD; morbid obesity; systemic lupus erythematosus; CKD	Yes	TS
Bauernschmitt R, et al.[44] (2017)	61	67, F	NS	MS	AF; COPD; PAH; CKD; bleeding; bladder tumor	Yes	TA
Ussia GP, et al.[45] (2017)	62	72, M	III/IV	MR	CABG; HT; dyslipidemia; CAD; COPD	No	TA
	63	78, M	III/IV	MR	Nonischemic cardiomyopathy; CAD; PAH	No	TA
	64	72, M	III	MR	CABG; CAD; COPD; PAH; AF; coagulopathy	No	TS
	65	73, M	III	MR	CABG; CAD; AF	No	TS
Otton JM and Muller DW[46] (2017)	66	76, M	NS	MR	CABG; HT; DM; hyperlipidemia; COPD; CKD	No	TA

AF = atrial fibrillation; AS = aortic stenosis; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; F = female; HT = hypertension; M = male; MAC = mitral annular calcification; MR = mitral regurgitation; MS = mitral stenosis; NS = not specified; NYHA = New York Heart Association; PAH = pulmonary artery hypertension; Pt = patient; SAVR = surgical aortic valve replacement; TA = transapical; TAVR = transcatheter aortic valve replacement; TS = transseptal

inadequate details on postoperative outcomes, involved valve-in-valve or valve-in-ring mitral implantation, or involved a thoracotomy approach (except conversion to thoracotomy intraoperatively).

Statistical Analysis

We collected data on baseline clinical characteristics, relevant comorbidities, diagnostic imaging results, procedural details, and postprocedural outcomes. Technical success was defined in accordance with Mitral Valve Academic Research Consortium criteria: no procedural death; successful access, delivery, and retrieval of the device delivery system; successful deployment and correct positioning of the first intended device; and no emergency surgery or reintervention related to the device or access procedure.[6] Continuous variables were described as mean ± SD; differences between them were analyzed by using *t* tests. Categorical variables were described as number and percentage, and the χ^2 test was used to evaluate differences. Mean gradients were derived from <80% of the reports, and NYHA class from <50%; other variables were from >80%. Survival curves were estimated by using the Kaplan-Meier method. All data were analyzed with use of SPSS 23.0 for Windows (SPSS, an IBM company). *P* values <0.05 were considered statistically significant.

Results

We found 40 reports, published from September 2013 through April 2017, with case descriptions of patients who had native-valve MR or MS and underwent TMVR (Table I).[7-46] The 66 patients' mean age was 71 ± 12 years; 75% of those whose sex was specified were women (41 of 55); and 100% were in NYHA functional class III or IV. Mitral stenosis was predominant in 30 patients and MR in 34, and 2 patients had mixed native mitral disease. Forty-one procedures involved TA access, and 25 involved TS access. Twenty-nine patients with predominant MR were given one of the following transcatheter MV platforms: Edwards-CardiAQ (Edwards Lifesciences Corporation), Tendyne (Abbott Cardiovascular), Neovasc Tiara (Neovasc Inc.), or Edwards Fortis (Edwards Lifesciences). The 30 patients with predominant MS were given Sapien, Sapien XT, or Sapien 3 balloon-expandable transcatheter aortic valves (Edwards Lifesciences).

The median follow-up time was 2 months, and the longest was 20 months (Fig. 1). The overall mean survival time was 13.07 months (95% CI, 10.24–15.89 mo). The mean survival time for MR patients was 9.8 months (95% CI, 7.5–12.09 mo); and for MS patients, 13.17 months (95% CI, 9.34–17.01 mo). Median survival could not be calculated because of the limitation of reported follow-up time. For all patients, the technical success rate was 83.3% (55 of 66 cases), and the 30-day survival rate was 82.5% (47 of 57) (Table II).

Complications and Deaths

Six patients needed a second valve: 4 intraoperatively for severe regurgitation, paravalvular leak, or initial valve displacement; and 2 postoperatively after prosthesis migration. Of these 6, 5 underwent successful valve-in-valve implantation, and the remaining patient underwent urgent open surgical repair (Table III).

In the 23 patients who had postoperative complications, the most frequent was migration of the prosthetic MV. In 5 patients, this happened from 4 days to 8 months later, and one of these patients died. The remaining patients survived after open surgery, valve redeployment, or implantation of a second valve (Table IV).

Deaths. Two patients died intraoperatively, one of apical perforation from the delivery system's nose cone with consequent cardiac tamponade, and the other of cardiogenic shock. Of the 16 patients who died postoperatively (time range, 12 hr–9 mo), 8 died of cardiac causes. A patient who had no complications died of fractured cervical vertebrae; this death was not documented in Table III or IV.

Mitral Pathologic Conditions and Access Routes

The causes and pathophysiology of MS and MR differed. All 30 patients who had predominant MS had mitral annular calcification (MAC) visible on echocardiograms (100%), compared with 5 patients who had predominant MR (14.7%) (*P* <0.001). The mean mitral

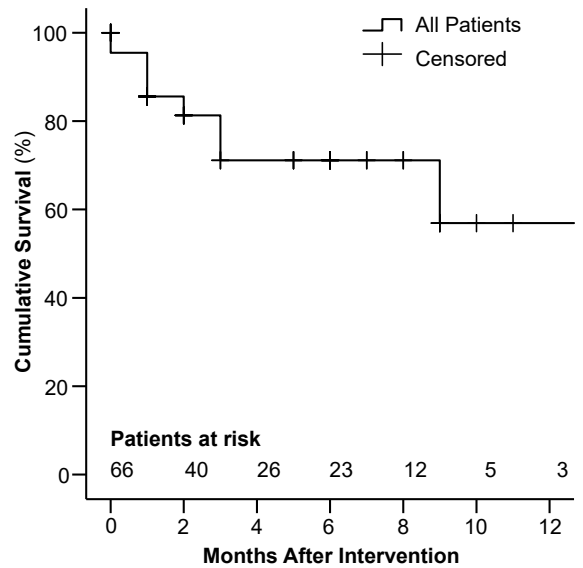

Fig. 1 *Graph shows Kaplan-Meier estimates of the cumulative survival of the 66 patients after transcatheter mitral intervention (median follow-up time, 2 mo).*

TABLE II. Results of Treatment Based on Type of Mitral Disease

Variable	All Patients (N=66)	MR (n=34)*	MS (n=30)*	*P* Value
Technical success	55 (83.3)	31 (91.2)	22 (73.3)	0.059
30-day survival**	47/57 (82.5)	24/29 (82.8)	21/26 (80.8)	0.999
Moderate-to-severe MR	7 (10.6)	3 (8.8)	4 (13.3)	0.697
Mitral gradient (mmHg)	4 ± 1.5	3.2 ± 1.3	4.3 ± 1.6	0.026
Postoperative complications	23 (34.8)	12 (35.3)	11 (36.7)	0.777
LVOTO	2 (3)	0	2 (6.7)	0.216
Stroke or TIA	1 (1.5)	0	1 (3.3)	0.469
Acute kidney injury	2 (3)	1 (2.9)	1 (3.3)	0.999
Bleeding	2 (3)	2 (5.7)	0	0.494
Permanent pacemaker insertion	3 (4.5)	2 (5.7)	1 (3.3)	0.999
Prosthesis migration	5 (7.6)	1 (2.9)	4 (13.3)	0.177
Needed valve-in-valve implantation	6 (9.1)	1 (2.9)	5 (16.7)	0.09
Needed open surgery	2 (3)	1 (2.9)	1 (3.3)	0.999
NYHA functional class I or II**	29/31 (93.5)	17/18 (94.4)	12/13 (92.3)	0.999

LVOTO = left ventricular outflow tract obstruction; MR = mitral regurgitation; MS = mitral stenosis; NYHA = New York Heart Association; TIA = transient ischemic attack

*Two patients with mixed mitral disease were not included in this analysis.
** Data are from patients whose records contained the applicable data.

Data are presented as number and percentage or as mean ± SD. $P<0.05$ was considered statistically significant.

TABLE III. Results in Patients Who Had Intraoperative Complications

Reference	Pt. No.	Complications	Treatment	Follow-Up Time	Outcome
Ribeiro HB, et al.[10] (2014)	3	Prosthesis migration to LA; severe PVL; high pulmonary pressures	Valve-in-valve implant	3 mo	Lived
Himbert D, et al.[11] (2014)	5	Prosthesis migration to LA	Valve-in-valve implant	6 mo	Lived
	6	Severe MR	Balloon dilation	7 mo	Lived
Guerrero M, et al.[29] (2014)	36	Mild PVL; substantial LVOTO; hypotension; intermittent AV block	Pericardiocentesis; fluid resuscitation; percutaneous alcohol septal ablation; implanted pacemaker	4 d	Died of 3rd-degree AV block and ventricular tachycardia
Capretti G, et al.[30] (2016)	37	Prosthesis migration to LA	Valve-in-valve implant	6 mo	Lived
Eleid MF, et al.[33] (2016)	42	Apical perforation from delivery system	CP resuscitation	None	Died of apical perforation
	47	Severe MR	Valve-in-valve implant, converted to urgent open surgery	>1 mo	Lived
van Gils L, et al.[37] (2016)	52	Cardiogenic shock	Extracorporeal CP support	None	Died of cardiogenic shock
Bauernschmitt R, et al.[44] (2017)	61	Prosthesis migration to LA	Percutaneous rescue	21 d	Died of multiorgan failure
Ussia GP, et al.[45] (2017)	63	Major bleeding	Blood transfusions	14 mo	Lived
	65	Nonsustained ventricular tachycardia without hemodynamic change	Not reported	11 mo	Lived

AV = atrioventricular; CP = cardiopulmonary; LA = left atrium; LVOTO = left ventricular outflow tract obstruction; MR = mitral regurgitation; Pt = patient; PVL = paravalvular leak

TABLE IV. Results in Patients Who Had Postoperative Complications

Reference	Pt. No.	Complications	Treatment	Follow-Up Time	Outcome
Guerrero M, et al.[12] (2014)	8	RF; pulmonary edema; metabolic abnormalities leading to pulseless electrical cardiac arrest	CPR	10 d	Died of noncardiac causes
Cheung A, et al.[16] (2014)	13	Congestive HF; chronic RF	Not reported	69 d	Died of congestive HF and chronic RF
Bapat V, et al.[17] (2014)	15	Persistent HF	Aggressive treatment	67 d	Died of persistent HF
	16	Prosthesis migration toward LA; severe MR; acute RF	Aggressive treatment	4 d	Died of severe MR and acute RF
	18	Reduced mobility of 2 valve leaflets; cardiac decompensation; SIRS	Antibiotics; additional heparin	15 d	Died of cardiac decompensation and SIRS
Abdul-Jawad Altisent O, et al.[24] (2015)	27	Gastrointestinal bleeding	Warfarin and aspirin discontinued; clopidogrel started	3 mo	Lived
Sondergaard L, et al.[2] (2015)	31	Hospital-acquired pneumonia	Not reported	9 d	Died of hospital-acquired pneumonia
Sondergaard L, et al.[26] (2015)	32	SIRS	Not reported	3 d	Died of SIRS
Weich H, et al.[27] (2016)	33	LVOT obstruction	CPR	12 hr	Died of LVOT obstruction
Ahn HC, et al.[28] (2016)	34	HF	Not reported	9 mo	Died of HF
Guerrero M, et al.[29] (2016)	36	Hypotension; large residual intra-atrial shunt; 3rd-degree AV block; ventricular tachycardia	Transcutaneous pacing; CPR	4 d	Died of 3rd-degree AV block and ventricular tachycardia
Capretti G, et al.[30] (2016)	37	Restrictive motion and thickening of valve leaflet	Aspirin and long-term anticoagulant therapy	6 mo	Lived
Nguyen A, et al.[31] (2016)	38	Refractory HF; prosthesis migration toward LA; severe PVL	Valve-in-valve implant	5 mo	Lived
	39	Prosthesis migration toward LA; severe PVL	Valve-in-valve implant	9 mo	Lived
Eleid MF, et al.[33] (2016)	47	Persistent HF	Not reported	1 mo	Lived
Hulman M, et al.[34] (2016)	48	Prosthesis migration toward LA; severe MR	Transcatheter redeployment of prosthesis	5 mo	Lived
Deharo P, et al.[36] (2016)	51	LVOT obstruction; severe hypotension	Bailout septal alcohol ablation; permanent pacemaker	6 mo	Lived
Quarto C, et al.[41] (2016)	56	Ventricular dyssynchrony	Permanent pacemaker	6 mo	Lived
	57	2nd-degree AV block	Permanent pacemaker	7 mo	Lived
Guerrero M, et al.[43] (2017)	60	Transient ischemic attack; HF	Not reported	3 mo	Died; cause not reported
Ussia GP, et al.[45] (2017)	62	Prosthesis migration toward LVOT	Open heart surgery	9 mo	Died of malignant bladder tumor
	64	Atrial fibrillation with rapid ventricular response; systemic fungemia	Antiarrhythmic and antifungal therapy	35 d	Died of unrelated pulmonary infection and septicemia
Otton JM and Muller DW[46] (2017)	66	Thrombus formation; severe intestinal bleeding	Vitamin K antagonist therapy	3 mo	Died of severe intestinal bleeding

AV = atrioventricular; CPR = cardiopulmonary resuscitation; HF = heart failure; LA = left atrium; LVOT = left ventricular outflow tract; MR = mitral regurgitation; PVL = paravalvular leak; RF = renal failure; SIRS = systemic inflammatory response syndrome

transvalvular gradient was significantly lower in the patients with MR (3.2 ± 1.3) than in those with MS (4.3 ± 1.6) (*P*=0.026). The results were otherwise similar between groups (Table II).

Fewer patients who had TA procedures (1 [2.4%]) needed valve-in-valve implantation than did those who had TS procedures (5 [20%]) (*P*=0.026). Otherwise, the results in regard to approach were similar (Table V).

Discussion

The technical success rate of TMVR was 83.3% overall, the 30-day survival rate was 82.5%, and 23 patients had postoperative complications, chiefly valve migration. To date, the results of TMVR have not been as successful as those of MV surgery.[47] Nevertheless, TMVR is a feasible option in high-risk patients who have native MV disease.

Puri and colleagues[48] summarized the clinical, anatomic, periprocedural, and postprocedural characteristics of 11 patients with severely calcified MVs but discussed neither the role of TMVR in patients with varying types of MV disease nor novel devices specifically designed for treating noncalcific MR. Conversely, we compared the role of TMVR in patients with MR and MS, documenting the different causes, pathophysiology, and valve types. Severe MS was caused by MAC, a condition that can enable stable anchoring of balloon-expandable transcatheter aortic valves.[49] In patients who do not have MAC, an anchoring system is needed. Accordingly, the patients with MS and the 5 with MR and MAC were given balloon-expandable transcatheter aortic valves, and transcatheter MV platforms were used in the patients who had MR but not MAC. Better technical success was achieved in patients with MR. Reasons for technical failure were incorrect valve positioning, valve migration, major bleeding, and apical perforation. Incorrect positioning and early migration caused valve embolism, left ventricular outflow tract obstruction, or perivalvular leakage. The 30-day survival rates of patients with MR (82.8%) and MS (80.8%) were similar, as were the results for the other outcome variables evaluated. Valve type and different baseline characteristics had no significant impact on outcome.

Transapical TMVR access is achieved through a minithoracotomy and has a shorter path. The direct access to the MV and the shorter distance between the introducer tip and the MV enable better control of the prosthesis during deployment. Transseptal access is much less invasive; however, stent anchorage occurs in a more complex geometric environment.[50] Among transcatheter MV platforms, only the Edwards-CardiAQ valve has been implanted through both access routes; the others have been implanted only through TA access.[45] Fewer patients treated by means of TA access needed a second valve implantation (*P*=0.026), possibly because TS access involves a longer path and anchoring is more difficult. Transcatheter mitral valve-in-valve

TABLE V. Results Based on Approach

Variable	All Patients (N=66)	TA Access (n=41)	TS Access (n=25)	*P* Value
Technical success	55 (83.3)	37 (90.2)	18 (72)	0.112
30-day survival*	47/57 (82.5)	28/34 (82.4)	19/23 (82.6)	0.999
Moderate-to-severe MR	7 (10.6)	3 (7.3)	4 (16)	0.412
Mean gradient (mmHg)	4 ± 1.5	3.5 ± 1.5	4.1 ± 1.5	0.172
Postoperative complications	23 (34.8)	12 (29.3)	11 (44)	0.223
LVOTO	2 (3)	1 (2.4)	1 (4)	0.999
Stroke or TIA	1 (1.5)	0	1 (4)	0.379
Acute kidney injury	2 (3)	1 (2.4)	1 (4)	0.999
Bleeding	2 (3)	2 (4.9)	0	0.522
Permanent pacemaker	3 (4.5)	2 (4.9)	1 (4)	0.999
Valve migration	5 (7.6)	3 (7.3)	2 (8)	0.999
Needed valve-in-valve implant	6 (9.1)	1 (2.4)	5 (20)	0.026
Needed open surgery	2 (3)	1 (2.4)	1 (4)	0.999
NYHA class I or II*	29/31 (93.5)	19/19 (100)	10/12 (83.3)	0.142

LVOTO = left ventricular outflow tract obstruction; MR = mitral regurgitation; NYHA = New York Heart Association; TA = transapical; TIA = transient ischemic attack; TS = transseptal

*Data are from patients whose records contained the applicable data.

Data are presented as number and percentage or as mean ± SD. $P < 0.05$ was considered statistically significant.

implantation, performed when mitral bioprostheses degenerate, was successful in 5 of 6 patients; the 6th was converted to open surgery because of valve embolism. Technical success was slightly better in patients who underwent TA access, and postoperative complications were more frequent in patients who underwent TS access.

Study Limitations

Because data consistency and completeness inevitably varied across reports, our main challenge was publication bias. Bias also resulted from the small number of cases, different standards in different centers, and different valves used. In addition, case reports and series mixed different valve types, pathologic conditions, and approaches. Cases were too few for subgroup analysis. Nevertheless, this review enabled objective conclusions about TMVR in treating native MV disease.

Conclusion

In high-risk patients who have MR and MS, TMVR is generally feasible. Less technical success in patients with MS implies that valves with specific anchoring systems are needed. The TA approach resulted in slightly better technical success and fewer postoperative complications. Comparatively more patients treated by means of TS access underwent a second valve implantation. Accurate valve fixation in TS access remains a challenge.

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