Transcatheter Mitral Valve Replacement for Treating Native Mitral Valve Disease: Current Status

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]

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%).3 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
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     |
| Jain R, et al.\(^{32}\) 2016    | 40      | 77, F                     | NS, MS               | CABG, SAVR, PAH | Yes | TA     |
| Eagle MF, et al.\(^{33}\) 2016  | 41      | 80, F                     | NS, MS               | CABG, PAH     | Yes | TA     |
| Guerrero M, et al.\(^{29}\) 2016 | 42      | 85, F                     | Previous cardiac surgery | Yes | TS     |
| Capretti G, et al.\(^{30}\) 2016 | 43      | NS, MS                    | Previous cardiac surgery | Yes | TS     |
| Nguyen A, et al.\(^{31}\) 2016  | 44      | NS, NS                    | Previous cardiac surgery | Yes | TS     |
| Jain R, et al.\(^{32}\) 2016    | 45      | NS, NS                    | Mixed                | Previous cardiac surgery | Yes | TS     |
| Hulman M, et al.\(^{34}\) 2016  | 46      | NS, NS                    | MR                   | Previous cardiac surgery | Yes | TS     |
| Eleid MF, et al.\(^{35}\) 2016  | 47      | NS, NS                    | NS                   | NS            | Yes | TA     |
| Deharo P, et al.\(^{36}\) 2016  | 48      | 76, F                     | NS                   | NS            | Yes | TS     |
| van Gils L, et al.\(^{37}\) 2016| 49      | 73, M                     | NS                   | CABG          | No  | TA     |
| Romeo F, et al.\(^{38}\) 2016   | 50      | 72, M                     | III/IV, MR           | CABG, CAD     | No  | TA     |
| Ren B, et al.\(^{39}\) 2016     | 51      | 75, F                     | III/IV, MS           | COPD; latent tuberculosis; thrombocytopenia | Yes | TA     |
| Dvir D, et al.\(^{40}\) 2016    | 52      | 39, M                     | NS                   | Dilated cardiomyopathy | No  | TA     |
| Quarto C, et al.\(^{41}\) 2016  | 53      | 68, F                     | IV, MR               | CABG          | No  | TA     |
| Bashir M, et al.\(^{42}\) 2016  | 54      | 75, M                     | IV, MR               | CABG, CKD     | No  | TA     |
| Guerrero M, et al.\(^{43}\) 2016| 55      | 87, M                     | III, MR              | NS            | No  | TA     |
| Bauernschmitt R, et al.\(^{44}\)2016 | 56      | 67, F                     | NS                   | AF; COPD; PAH; CKD; bleeding; bladder tumor | Yes | TA     |
| Ussia GP, et al.\(^{45}\) 2016  | 57      | 72, M                     | III/IV, MR           | CABG, HT; dyslipidemia; CAD; COPD | No  | TA     |
| Bashir M, et al.\(^{42}\) 2016  | 58      | 78, M                     | III/IV, MR           | Nonischemic cardiomyopathy; CAD; PAH    | No  | TA     |
| Guerrero M, et al.\(^{43}\) 2016| 59      | 72, M                     | III, MR              | CABG, CAD; COPD; PAH; AF; coagulopathy | No  | TS     |
| Otton JM and Muller DW\(^{46}\) 2016 | 60      | 73, M                     | III, MR              | CABG, CAD; AF | No  | TS     |

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. 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 χ² 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). 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
### 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. (2014) | 8 | RF; pulmonary edema; metabolic abnormalities leading to pulseless electrical cardiac arrest | CPR | 10 d | Died of noncardiac causes |
| Cheung A, et al. (2014) | 13 | Congestive HF; chronic RF | Not reported | 69 d | Died of congestive HF and chronic RF |
| Bapat V, et al. (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. (2015) | 27 | Gastrointestinal bleeding | Warfarin and aspirin discontinued; clopidogrel started | 3 mo | Lived |
| Sondergaard L, et al. (2015) | 31 | Hospital-acquired pneumonia | Not reported | 9 d | Died of hospital-acquired pneumonia |
| Sondergaard L, et al. (2015) | 32 | SIRS | Not reported | 3 d | Died of SIRS |
| Weich H, et al. (2016) | 33 | LVOT obstruction | CPR | 12 hr | Died of LVOT obstruction |
| Ahn HC, et al. (2016) | 34 | HF | Not reported | 9 mo | Died of HF |
| Guerrero M, et al. (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. (2016) | 37 | Restrictive motion and thickening of valve leaflet | Aspirin and long-term anticoagulant therapy | 6 mo | Lived |
| Nguyen A, et al. (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. (2016) | 47 | Persistent HF | Not reported | 1 mo | Lived |
| Hulman M, et al. (2016) | 48 | Prosthesis migration toward LA; severe MR | Transcatheter redeployment of prosthesis | 5 mo | Lived |
| Deharo P, et al. (2016) | 51 | LVOT obstruction; severe hypotension | Bailout septal alcohol ablation; permanent pacemaker | 6 mo | Lived |
| Quarto C, et al. (2016) | 56 | Ventricular dyssynchrony | Permanent pacemaker | 6 mo | Lived |
| | 57 | 2nd-degree AV block | Permanent pacemaker | 7 mo | Lived |
| Guerrero M, et al. (2017) | 60 | Transient ischemic attack; HF | Not reported | 3 mo | Died; cause not reported |
| Ussia GP, et al. (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 (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. Nevertheless, TMVR is a feasible option in high-risk patients who have native MV disease.

Puri and colleagues 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 noncalsific 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. 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 paravalvular 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. 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. 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.

**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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