




ORIGINAL RESEARCH

Association of Transcatheter Mitral Valve Repair Availability With Outcomes of Mitral Valve Surgery

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BACKGROUND: Transcatheter mitral valve repair (TMVr) is currently offered at selected centers that meet certain operator and institutional requirements. We sought to explore the hypothesis that the availability of TMVr is associated with improved outcomes of MV surgery.

METHODS AND RESULTS: We used the Nationwide Readmissions Database to identify patients who underwent MV surgery at centers with or without TMVr capabilities between January 1 and December 31, 2017. The primary end point was in-hospital mortality. Secondary end points were postoperative complications, resource use, and 30-day readmissions. A total of 24 477 patients from 595 centers (446 TMVr, 149 non-TMVr) were included. There were modest but statistically significant differences in the prevalence of comorbidities between the groups. Patients at non-TMVr centers had higher unadjusted in-hospital mortality than those at TMVr centers (5.6% versus 3.6%, $P<0.001$). They also had higher rates of postoperative complications, longer hospitalizations, higher cost, and fewer home discharges but similar 30-day readmission rates. After propensity matching, mortality remained higher at non-TMVr centers (5.5% versus 4.0%, $P<0.001$). Rates of postoperative complications, prolonged hospitalizations, and nonhome discharges also remained higher. Postoperative mortality was consistently higher at non-TMVr centers in multiple risk-adjustment analyses incrementally accounting for differences in risk factors, surgical volume, availability of surgical repair, and excluding concomitant procedures. In the most comprehensive model, surgery at non-TMVr centers was associated with higher odds of death (odds ratio, 1.41; 95% CI, 1.14–1.73; $P=0.002$).

CONCLUSIONS: Mitral valve surgery at TMVr centers is associated with improved in-hospital outcomes compared with non-TMVr centers.

Key Words: mitral regurgitation ■ mitral valve surgery ■ transcatheter mitral valve repair

Innovations in transcatheter interventions have revolutionized the management of valvular heart diseases worldwide in the past decade.^{1–4} The introduction of transcatheter valve therapies in the United States was guided by strict operator and institutional requirements by professional societies and insurance payers to ensure quality and rational dispersion of new technologies.^{5–7} Hence, centers offering valve surgery evolved gradually into those that can provide only surgical interventions and those that are equipped with

both surgical and transcatheter options. This evolution has a potential impact on individual hospital perceived ranking, procedural volume, patient mix, and clinical outcomes.⁸ Jack et al studied this issue in the area of aortic stenosis and found that patients undergoing surgical aortic valve replacement at centers that offer transcatheter aortic valve replacement have lower adjusted in-hospital mortality compared with those receiving the procedure at non-transcatheter aortic valve replacement centers.⁵ Whether a similar phenomenon

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CLINICAL PERSPECTIVE

What Is New?

- Mitral valve surgery at mitral centers with transcatheter and surgical mitral valve treatment capabilities is associated with improved in-hospital outcomes compared with surgical only centers.

What Are the Clinical Implications?

- Management of complex mitral valve disease might be improved with the integration of surgical and transcatheter therapies at specialized centers of excellence.

Nonstandard Abbreviations and Acronyms

MV	mitral valve
NRD	Nationwide Readmissions Database
TMVr	transcatheter mitral valve repair

exists with regard to the surgical treatment of mitral regurgitation⁹ is unknown. We therefore sought to explore the association between the availability of transcatheter mitral valve repair (TMVr) and the outcomes of mitral valve (MV) surgery in a contemporary nationally representative database.

METHODS

Data Sharing Statement

Data obtained from the Nationwide Readmissions Database (NRD) could not be shared directly by the authors, but requests to access the NRD data set from qualified researchers trained in human subject confidentiality protocols may be sent to the Healthcare Cost and Utilization Project.

Data Source

We obtained data from the NRD between January 1 and December 31, 2017. The 2017 NRD collected discharge data from 28 geographically dispersed states, accounting for 60% of the total US resident population and 58.2% of all US hospitalizations.¹⁰ The NRD contains clinical and nonclinical variables with safeguards to protect the privacy of individual patients, physicians, and hospitals. These data include patient demographics, hospital characteristic, payment source, and diagnosis and procedure codes. The institutional review board exempted the study because it uses public deidentified data.

Study Population

We identified all adult (>18 years of age) hospitalizations with *International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM)* procedure codes for MV surgery between January 1, and December 31, 2017 (Table S1). We excluded hospitalizations with *ICD-10-CM* diagnosis code for endocarditis, mitral stenosis, or *ICD-10-CM* procedure code for concomitant cardiac surgery except coronary artery bypass grafting (CABG) or maze procedure. Concomitant CABG and/or maze were included in the initial analysis because these are commonly performed with MV surgery. Patients were then divided into those who had MV surgery at TMVr centers versus at surgical only centers (non-TMVr centers) (Figure 1). Centers were classified as TMVr centers if they performed ≥ 5 TMVr in the calendar year 2017. The cutoff was selected to avoid including nonoperational or very low-volume TMVr programs as suggested by Butala et al. For the calculation of 30-day readmission rates, we excluded patients who died during the index visit, those who left against medical advice, and those who had surgery in December owing to lack of 30-day follow-up data. For patients who had multiple readmissions within 30 days, only the first readmission was included.

Outcomes Measured

The *primary outcome* was in-hospital mortality. *Secondary outcomes* were in-hospital complications (stroke, acute kidney injury, tamponade, prolonged mechanical ventilation, tracheostomy, gastrostomy, blood transfusion, urinary tract infection, pneumonia, and pacemaker placement), and resource use parameters (length of stay, cost, discharge disposition, and 30-day readmission). To estimate the cost of hospitalization, the NRD data were merged with cost-to-charge ratios available from the Healthcare Cost and Utilization Project. We estimated the cost of each stay by multiplying the total hospital charge with cost-to-charge ratios.

Statistical Analysis

Descriptive statistics were presented as frequencies with percentages for categorical variables. Mean, SD, median, and interquartile ranges were reported for continuous measures. Baseline characteristics were compared between the 2 groups using a Pearson chi-square test for categorical variables and an independent-samples *t* test or Wilcoxon rank sum for continuous variables. To account for confounding factors and reduce the effect of selection bias, multivariable logistic regression derived propensity scores were matched 1:1 using nearest neighbor matching

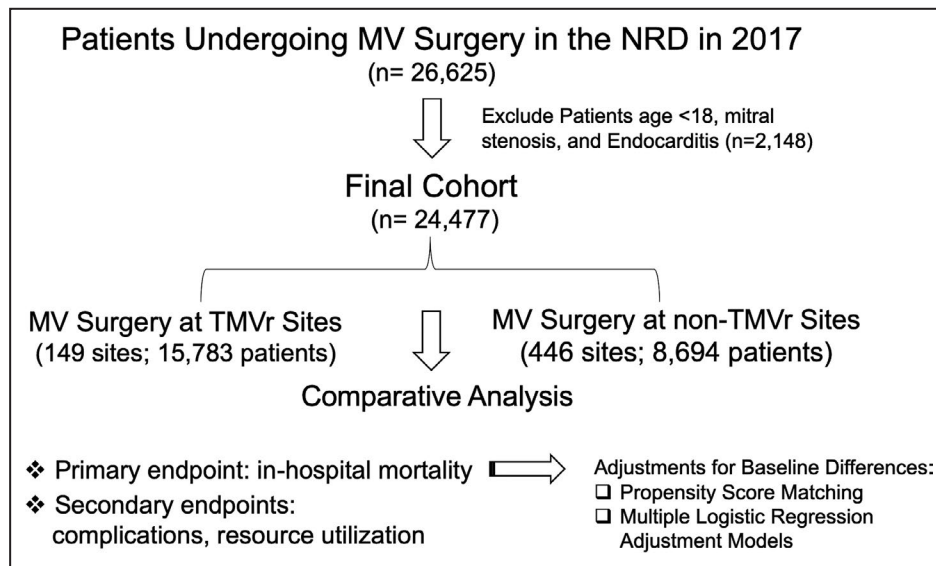


Figure 1. Study flow chart.

MV indicates mitral valve; NRD, Nationwide Readmissions Database; and TMVr, transcatheter mitral valve repair.

(caliper 0.01 without replacement) to attain comparable groups of patients undergoing MV surgery at TMVr versus non-TMVr centers. Variables included in the model included the baseline characteristics listed in Table 1. Matched categorical variables were presented as frequencies with percentages and compared using McNemar's test. Matched continuous variables were presented as means±SDs and compared using a paired-samples *t* test.

Additionally, multivariable risk adjustments using generalized estimating equation to account for clustering of observation within hospitals were used to assess the impact of certain confounding factors on the primary end point: Model (1) adjusted for demographic and clinical characteristics; Model (2) adjusted for demographic, clinical, and surgical volume; Model (3) adjusted for demographic, clinical characteristics, surgical volume, and surgical repair; and Model (4) adjusted for demographic, clinical characteristics, surgical volume, percentage of surgical repair, and excluding concomitant CABG or maze procedures. Hospital volume was represented in Model 2 and Model 3 as a continuous variable. Because of the nonlinearity of the volume-mortality relationship, a restricted cubic spline was applied. This approach allows for accurate assessment of volume-outcome relationship by accounting for the commonly documented nonlinearity in this relationship.^{11,12} Type I error <0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 24 (IBM Corporation, Armonk, NY) and R, version 3.3.1

RESULTS

A total of 24 477 patients who underwent MV surgery at 595 centers were included. Among those, 15 783 patients (64.5%) underwent surgery at TMVr centers (n=446 centers), and 8694 patients (35.5%) underwent surgery at non-TMVr centers (n=149 centers). Patients who underwent MV surgery at TMVr centers were older (68±13 versus 66±11, *P*<0.001), were more likely to be insured by Medicare (63.4% versus 59.5%, *P*<0.001), and were less likely to be in the lowest quartile of median household income (19.9% versus 27.5%, *P*<0.001). There were modest but statistically significant differences in the prevalence of key comorbidities between the 2 groups (Table 1). Overall, patients undergoing surgery at TMVr centers had a slightly lower Elixhauser comorbidity index score (2.23±1.38 versus 2.38±1.45, *P*<0.001). There were also differences in the performance of concomitant CABG and maze procedures between the 2 groups, with concomitant surgery being less commonly performed at TMVr centers. The rates of MV repair was higher at TMVr centers (49.7% versus 41.6%, *P*<0.001).

Patients who underwent MV surgery at non-TMVr centers had significantly higher in-hospital mortality than those who underwent surgery at TMVr centers (5.6% versus 3.6%, *P*<0.001). They also had higher rates of postoperative complications including stroke, acute kidney injury, prolonged ventilation, pneumonia, blood transfusion, and permanent pacemaker implantation. In addition, their hospitalizations were longer, they accrued higher cost, and they were less likely to

Table 1. Baseline Characteristics of the Study Cohort

Baseline Characteristics	TMVr Centers (n=15 783)	Non-TMVr Centers (n=8694)	P Value
Demographics			
Age, y (mean±SD)	68±13	66±11	<0.001
Female sex (%)	46.2%	45.4%	0.23
Medicare insurance	63.4%	59.5%	<0.001
Lowest median household income	19.9%	27.5%	<0.001
Clinical risk factors			
Diabetes mellitus	38.6%	37.6%	0.13
Hypertension	26.8%	30.2%	<0.001
Coronary artery disease	49.0%	51.3%	0.001
Prior stroke	7.6%	6.8%	0.03
Vascular disease	8.1%	7.1%	0.005
Carotid artery disease	2.6%	3.1%	0.02
Chronic kidney disease	17.6%	15.4%	<0.001
Chronic lung disease	17.6%	20.6%	<0.001
Prior sternotomy	10.7%	8.1%	<0.001
Prior pacemaker	5.9%	4.2%	<0.001
Anemia	17.8%	20.5%	<0.001
Smoking	8.1%	12.4%	<0.001
Atrial fibrillation	63.3%	62.3%	0.13
Conduction disorder	6.4%	5.6%	0.02
Liver disease	2.0%	2.1%	0.33
Elixhauser comorbidity index	2.23±1.38	2.38±1.45	<0.001
Operative characteristics			
Weekend admission	6.3%	7.3%	0.002
Percentage of any MV repair	49.7%	41.6%	<0.001
Percentage of MV leaflet repair only	10.3%	9.1%	0.02
Concomitant coronary bypass	15.0%	26.4%	<0.001
Concomitant maze procedure	20.3%	27.6%	<0.001
Robotic approach	2.3%	0.7%	<0.001

MV indicates mitral valve; and TMVr, transcatheter mitral valve repair.

be discharged to home discharge (versus to a nursing facility) (Table 2). The 30-day readmission rates were, however, similar between the 2 groups (15.1% versus 15.6%, $P=0.35$).

To adjust for differences in baseline patients risk profile and hospital characteristics, propensity score matching (PSM) as well as several risk adjustment models were applied:

In the PSM analysis, baseline characteristics were well matched between the 2 groups post matching (Figure S1). In this analysis, in-hospital mortality after MV surgery remained significantly higher in non-TMVr centers (5.5% versus 4.0%, $P<0.001$). The incidence of postoperative complications and nonhome discharges remained higher in the non-TMVr group. Although length of stay was longer in the non-TMVr group, the total cost of the hospitalization was no longer different (Table 2).

In the risk adjusted analyses, in-hospital mortality remained higher among patients at non-TMVr centers in all models (Table 3). In Model 1 adjusting for demographics, and clinical risk factors, the odds ratio (OR) of in-hospital mortality after MV surgery at non-TMVr centers was 1.54 (95% CI, 1.35–1.76; $P<0.001$). In Model 2, which also adjusted for hospital surgical volume, the OR was 1.37 (95% CI, 1.18–1.58; $P<0.001$). In Model 3 adjusting to variable in Model 2 in addition to the MV surgery program characteristics (availability and percentage of MV repair), the OR was 1.40 (95% CI, 1.21–1.61; $P<0.001$). In the most comprehensive model (Model 4) adjusting for demographics, risk factors, surgical volume/characteristics, and excluded concomitant bypass and maze procedures, in-hospital mortality remained higher at non-TMVr centers (OR, 1.41; 95% CI, 1.14–1.73; $P=0.002$).

Table 2. Unmatched and Matched Outcomes of Mitral Valve Surgery at TMVr and Non-TMVr Centers

Clinical Outcomes	Unmatched Outcomes			Matched Outcomes		
	TMVr Centers (n=15 783)	NonTMVr Centers (n=8694)	P Value	TMVr Centers (n=8504)	NonTMVr Centers (n=8504)	P Value
In-hospital mortality	3.6%	5.6%	<0.001	4.0%	5.5%	<0.001
Clinical stroke	2.0%	2.8%	<0.001	2.1%	2.8%	0.004
Acute kidney injury	22.3%	26.7%	<0.001	23.0%	26.7%	<0.001
Cardiac tamponade	1.0%	1.2%	0.05	0.9%	1.2%	0.05
Prolonged ventilation	9.7%	14.0%	<0.001	10.9%	13.9%	<0.001
Tracheostomy	2.0%	2.6%	0.003	2.4%	2.5%	0.65
Gastrostomy	0.9%	1.5%	<0.001	1.0%	1.5%	0.007
Cardiogenic shock	8.8%	9.8%	0.01	9.6%	9.6%	0.96
Urinary tract infection	6.0%	6.4%	0.21	6.2%	6.3%	0.77
Pneumonia	5.8%	8.7%	<0.001	6.6%	8.6%	<0.001
Blood transfusion	21.2%	25.4%	<0.001	22.1%	25.4%	<0.001
Pacemaker implantation	10.0%	12.5%	<0.001	10.4%	12.5%	<0.001
Discharge disposition						
Home	41.9%	32.1%	<0.001	40.3%	32.0%	<0.001
Home health care	40.0%	43.1%		41.3%	43.2%	
Other short-term hospitals	0.4%	0.9%		0.5%	0.9%	
Skilled nursing facility	17.6%	23.7%		17.8%	23.8%	
Length of stay (median, 25th/75th percentile)	7 (4–12)	9 (6–15)	<0.001	7 (5–13)	9 (6–15)	<0.001
Total cost (median, 25th/75th percentile)	\$50 723 (36 375–74 024)	\$53 847 (38 124–78 015)	0.006	\$51 534 (36 851–75 913)	\$53 657 (38 058–77 797)	0.82
30-d readmission	15.1%	15.6%	0.35	14.9%	16.1%	0.10

TMVr indicates transcatheter mitral valve repair.

DISCUSSION

The main findings of this study are (1) one in four centers performing MV surgery does not have TMVr

Table 3. Association Between Availability of Transcatheter Mitral Valve Repair and In-Hospital Mortality of Mitral Valve Surgery

In-Hospital Mortality	Odds Ratio	95% CI		P Value
Unadjusted	1.57	1.39	1.78	<0.001
Risk-Adjusted Model 1	1.54	1.35	1.76	<0.001
Risk-Adjusted Model 2	1.37	1.18	1.58	<0.001
Risk-Adjusted Model 3	1.40	1.21	1.61	<0.001
Risk-Adjusted Model 4	1.41	1.14	1.73	0.002

Model 1 adjusted for demographics and clinical risk factors*. Model 2 adjusted for demographics, clinical risk factors, and hospital volume†. Model 3 adjusted for demographics, clinical risk factors, hospital volume, and surgical repair. Model 4 adjusted for demographics, clinical risk factors, hospital volume, surgical repair, and excluded concomitant surgeries.

*Clinical risk factors included in Model 1 (hypertension, diabetes mellitus, coronary disease, prior stroke, vascular disease, carotid stenosis, chronic renal disease, chronic lung disease, prior sternotomy, prior pacemaker, anemia, smoking, atrial fibrillation, conduction disorder, liver disease, and Elixhauser comorbidity index).

†Hospital volume was represented in the model as a continuous variable. Because of the nonlinearity of the volume-mortality relationship, a restricted cubic spline was used. This model was adjusted for the same covariates as the main model.

capabilities and perform ≈35% of MV surgeries in a nationally representative sample; (2) MV surgery at centers with TMVr programs is characterized with higher rates of MV repair but lower rates than concomitant surgery compared with centers without non-TMVr programs; and (3) MV surgery performed at centers with TMVr programs is associated with better short-term outcomes compared with MV surgery performed at centers without TMVr programs (Figure 2).

The EVEREST II (Endovascular Valve Edge-to-Edge Repair) Study compared TMVr to MV surgery in patients with severe degenerative mitral regurgitation who are at high risk for surgery.¹³ In EVEREST II, TMVr was associated with similar clinical improvements as MV surgery, which led to its approval by the Food and Drug Administration in 2013.¹³ Since then, the efficacy of TMVr has been confirmed in real-world registries and in a landmark clinical trial of patients with severe functional mitral regurgitation.^{14–16} These data established the central role of TMVr in the management of high-risk patients with severe mitral regurgitation, leading to >100 000 procedures worldwide to date.¹⁷ The impact of the integration of TMVr into clinical practice on surgical volume, case mix, and clinical outcomes has been a topic of interest in light of the increasing adoption of

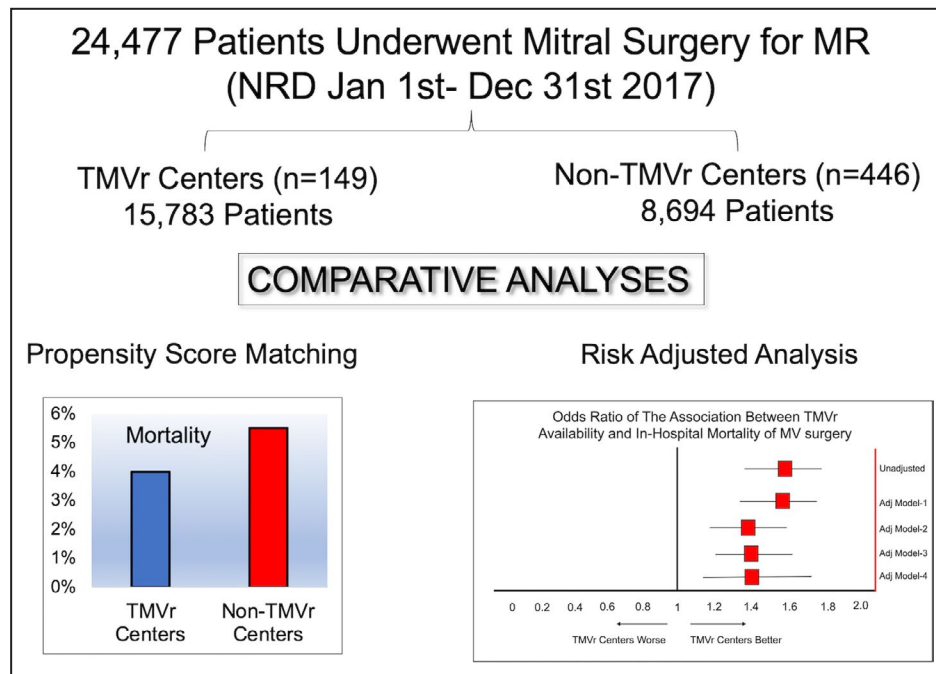


Figure 2. Outcomes of mitral valve surgery at TMVr vs non-TMVr centers.

This figure illustrates the higher postoperative in-hospital mortality (primary end point) at non-TMVr centers after propensity score matching and multiple risk-adjustment analyses. MR indicates mitral regurgitation; MV, mitral valve; NRD, Nationwide Readmissions Database; and TMVr, transcatheter mitral valve repair.

TMVr.¹⁷ However, data assessing this issue have been limited. Downs et al showed that the addition of TMVr into an established high-volume MV surgical program resulted in an increase in MV referrals, without an adverse effect on the outcomes of MV surgery.¹⁸ These promising findings, however, remained specific to a single high-volume MV surgical center, and its generalizability to MV centers in the United States remains unknown.¹⁸

The dissemination of TMVr across the United States after approval of the MitraClip device was limited to selected centers that meet certain qualification criteria: (1) a surgical program with ≥ 2 hospital-based surgeons experienced in valvular surgery who perform ≥ 25 MV operations for severe mitral regurgitation per year of which at least 10 must be MV repairs; and (2) an interventional cardiology program that performs ≥ 1000 catheterizations annually, including ≥ 400 percutaneous coronary interventions, with acceptable outcomes compared with national standard benchmarks.¹⁹ This led to many MV surgical centers not having local access to TMVr. The number of non-TMVr centers that perform MV surgery in contemporary practice, and the outcomes of MV surgery at these centers compared with those with access to TMVr have not been previously studied.

Our analysis documents a strong association between the availability of TMVr and improved outcomes

of MV surgery. A plausible explanation of this association is that the addition of TMVr to the armamentarium of MV centers leads to maturation of the “MV Heart Team” and better triaging and treatment selection in high-risk patients. Additionally, lower rates of MV repair were noted in centers without TMVr, further suggesting a lesser degree of MV surgical expertise in this group. Although in theory non-TMVr center can refer patients to TMVr-capable centers if not deemed suitable for surgery, this may be hindered by the lack of an MV Heart Team with familiarity with TMVr, its indication, and its limitations. Referral also may be limited by payer authorization and patient and physician preferences. The strong association between TMVr availability and surgical outcomes documented in our study may, however, be related to the differences in patients’ risk profile, surgical capabilities, practice patterns, and experience between TMVr and non-TMVr centers.^{20,21} Hence, to account for those differences, we performed additional confirmatory analyses, and those deserve some elaboration.

We first performed a PSM analysis to adjust for demographics and baseline clinical characteristic between the 2 groups. This analysis showed a persistent strong association between MV surgery at TMVr centers and improved outcomes across primary and secondary end points. Second, we performed multistep risk adjustments to verify the robustness of

this association with regard to the primary end point. In Model 1 adjusting for demographics and baseline characteristic, MV surgery at non-TMVr centers was associated with 54% higher odds of in-hospital mortality. This association was modestly attenuated but remained significant in subsequent models adjusting incrementally for additional key factors: surgical volume, availability of surgical repair, and excluding concomitant CABG/maze (37%, 40%, and 41%, respectively). This confirms that the relationship between the availability of TMVr and improved outcomes of MV surgery is independent of the differences in patients' risk profiles, characteristics of the MV surgery, and surgical experience between TMVr and non-TMVr centers. Although the large sample size allows for very high statistical power to detect small differences in outcomes between the 2 groups (power of 99.6% for the primary end point in the PSM cohort), an absolute difference in mortality of 1.5% (4.0% versus 5.5%) remains significant by most clinical standards (number needed to treat=67).

These findings may have important practical implications. The expanding indications for MitraClip, and the future approval of other novel transcatheter MV repair and replacement technologies (currently in clinical trials), may lead to further distinction of TMVr centers as "comprehensive centers" that offer the full gamut of MV therapies. This may be associated with further increase in MV referrals and concentrated experience at TMVr centers at the cost of declining volume and experience in non-TMVr centers. Those centers may face increasing pressure to expand their portfolio but also increasingly stricter requirements to establish a new transcatheter MV program.^{22,23} Collaborative efforts by professional societies and other stakeholders will be needed to assess the future impact of the evolution of transcatheter MV therapies on surgical centers and to define the balance between restricting new technology to maintain quality versus and liberalizing access to "upgrade" existing programs into comprehensive centers.

Limitations

First, the NRD database is an administrative database. Data in NRD are collected primarily for billing purposes and hence are subject to under- or overcoding. However, coding for major procedures, key complications, and vital status is less prone to coding errors as these are directly related to reimbursement. Second, granular data on the echocardiographic and laboratory data are not available in the NRD. Third, the superior outcomes of MV surgery at TMVr centers could be merely a reflection of selection bias. Sicker patients might be offered MitraClip, which reduces the mortality of MV surgery at TMVr centers, an option that is not available at non-TMVr centers. However, only modest differences in the patient's risk profile between the 2

study cohorts were noted at baseline and those were adjusted for both in the PSM and in all of the risk adjustment models. Fourth, surgical experience has a known relationship with outcomes. Because non-TMVr centers were lower volume centers, the higher operative mortality could have been explained by their lower volume. Nonetheless, our risk adjustment models (2–4) accounted for surgical volume and showed a persistent higher mortality at non-TMVr centers. Fifth, MV included a mixture of MV repair and MV replacement operations. This may have led to an increased operative mortality at centers that do not have MV repair capabilities. However, this was accounted for in our risk adjustment models (3–4) with no change in the primary end point. Sixth, the inclusion of concomitant CABG/maze may have introduced an additional selection bias. However, the odds of mortality at non-TMVr centers remained significantly higher after excluding concomitant procedures in Model 4. Despite the application of rigorous PSM and risk-adjustment models, unmeasured confounders could have still affected the results given the retrospective observational nature of the study. Finally, the study spanned procedures performed in 2017. TMVr has evolved considerably since, and hence, the findings of this study should be interpreted in that context.

CONCLUSIONS

Mitral valve surgery performed at TMVr centers is associated with improved in-hospital outcomes compared with surgery performed at non-TMVr centers. This association remained consistent in confirmatory PSM and several risk adjustment analyses. The impact of the anticipated future expansion of transcatheter MV techniques and volumes on non-TMVr MV surgical centers need to be studied.

ARTICLE INFORMATION

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None.

Disclosures

None.

Supplementary Material

Table S1
Figure S1

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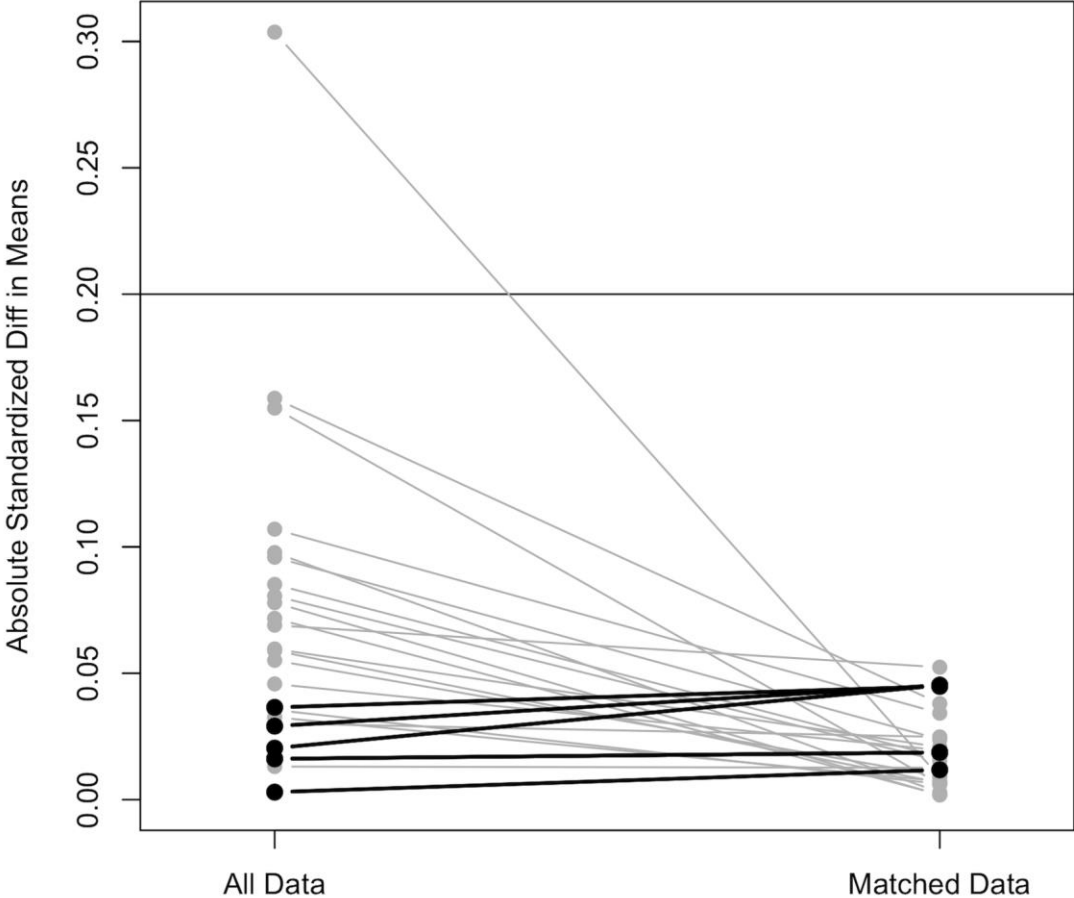
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SUPPLEMENTAL MATERIAL

Table S1. International Classification of Diseases, 10th Revision, Clinical Modification Codes Used in the Study

<p>Mitral Valve Repair</p>	<p>* Annuloplasty: 02UG07Z Supplement Mitral Valve with Autologous Tissue Substitute, Open Approach 02UG08Z Supplement Mitral Valve with Zooplastic Tissue, Open Approach 02UG0JZ Supplement Mitral Valve with Synthetic Substitute, Open Approach 02UG0KZ Supplement Mitral Valve with Nonautologous Tissue Substitute, Open Approach * Other Repair: 027G04Z Dilation of Mitral Valve with Drug-eluting Intraluminal Device, Open Approach 027G0DZ Dilation of Mitral Valve with Intraluminal Device, Open Approach 027G0ZZ Dilation of Mitral Valve, Open Approach 02NG0ZZ Release Mitral Valve, Open Approach 02QG0ZZ Repair Mitral Valve, Open Approach 02VG0ZZ Restriction of Mitral Valve, Open Approach 028D0ZZ Division of Papillary Muscle, Open Approach 02QD0ZZ Repair Papillary Muscle, Open Approach 02890ZZ Division of Chordae Tendineae, Open Approach 02Q90ZZ Repair Chordae Tendineae, Open Approach 02QG0ZZ Repair Mitral Valve, Open Approach</p>
<p>Mitral Valve Replacement</p>	<p>* Tissue valve replacement: 02RG07Z Replacement of Mitral Valve with Autologous Tissue Substitute, Open Approach 02RG08Z Replacement of Mitral Valve with Zooplastic Tissue, Open Approach 02RG0KZ Replacement of Mitral Valve with Nonautologous Tissue Substitute, Open Approach * Mechanical valve replacement: 02RG0JZ Replacement of Mitral Valve with Synthetic Substitute, Open Approach</p>
<p>Coronary Artery Bypass Grafting</p>	<p>02130KW, 02130Z3, 02130Z8, 02130Z9, 02130ZC, 02130ZF, 02130K8, 02130K9, 02130KC, 02130KF, 02130A9, 02130AC, 02130AF, 02130AW 02130J3, 02130J8 02130J9, 02130JC 02130JF, 02130JW 02130K3, 02120Z8, 02120Z9, 02120ZC, 02120ZF, 0213093, 0213098, 0213099, 021309C, 021309F, 021309W, 02130A3, 02130A8, 02120AW, 02120J3, 02120J8, 02120J9, 02120JC, 02120JF, 02120JW, 02120K3, 02120K8 02120K9, 02120KC 02120KF, 02120KW, 02120Z3, 02110Z9, 02110ZC, 02110ZF 0212093, 0212098, 0212099, 021209C, 021209F, 021209W, 02120A3, 02120A8, 02120A9, 02120AC 02120AF, 02110J3, 02110J8, 02110J9, 02110JC, 02110JF, 02110JW, 02110K3, 02110K8, 02110K9, 02110KC, 02110KF, 02110KW, 02110Z3, 02110Z8, 02100ZC 02100ZF 0211093 0211098, 0211099, 021109C, 021109F, 021109W, 02110A3, 02110A8, 02110A9, 02110AC, 02110AF, 02110AW, 02100J3, 02100K9, 02100KC, 02100KF, 02100KW, 02100Z3, 02100Z8, 02100Z9, 0210093, 0210099, 021009C, 021009F, 021009W, 02100A3, 02100A8, 02100A9, 02100AC, 02100AF, 02100AW</p>
<p>MAZE Procedure</p>	<p>02570ZZ Destruction of Left Atrium, Open Approach 02B70ZZ Excision of Left Atrium, Open Approach 02574ZZ Destruction of Left Atrium, Percutaneous Endoscopic 02B74ZZ Excision of Left Atrium, Percutaneous Endoscopic Approach</p>

Figure S1. Standardized Differences in Baseline Characteristics Between the 2 Groups Before and After PSM.



PSM; propensity score matching