Trends in Costs and Risk Factors of 30-Day Readmissions for Transcatheter Aortic Valve Implantation

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As transcatheter aortic valve implantation (TAVI) continues its rapid growth as a treatment approach for aortic stenosis, costs associated with TAVI, and its burden to healthcare systems will assume greater importance. Patients undergoing TAVI between January 2012 and November 2017 in the Nationwide Readmission Database were identified. Trends in cause-specific readmissions were assessed using Poisson regression. Thirty-day TAVI cost burden (cost of index TAVI hospitalization plus total 30-day readmissions cost) was adjusted to 2017 U.S. dollars and trended over year from 2012 to 2017. Overall, 47,255 TAVI were included and 30-day readmissions declined from 20% to 12% (p <0.0001). Most common causes of readmission (heart failure, infection/sepsis, gastrointestinal causes, and respiratory) declined as well, except arrhythmia/heart block which increased (1.0% to 1.4%, p <0.0001). Cost of TAVI hospitalization ($52,024 to $44,110, p <0.0001) and 30-day cost burden ($54,122 to $45,252, p <0.0001) declined. Whereas costs of an average readmission did not change ($9,734 to $10,068, p = 0.06), cost burden of readmissions (per every TAVI performed) declined ($4,061 to $1,883, p <0.0001), including reductions in each of the top 5 causes except arrhythmia/heart block ($171 to $263, p = 0.04). Index TAVI hospitalizations complicated by acute kidney injury, length of stay ≥5 days, low hospital procedural volume, and skilled nursing facility discharge were associated with increased odds of 30-day readmissions. In conclusion, the costs of index hospitalizations and 30-day cost burden for TAVI in the U.S. significantly declined from 2012 to 2017. However, readmissions due to arrhythmia/heart block and their associated costs increased. Continued strategies to prevent readmissions, especially those for conduction disturbances, are crucial in the efforts to optimize outcomes and costs with the ongoing expansion of TAVI. **(Am J Cardiol 2020;137:89−96)**

There has been a rapid dissemination of transcatheter aortic valve implantation (TAVI) since it was first approved in the United States (U.S.) in 2011. As the procedure continues to evolve and improve as a modality for treatment of patients with severe symptomatic aortic stenosis, resource utilization in performing TAVI has attained an important focus.[1] The Hospital Readmission Reduction program, established in 2012 by the Centers for Medicare and Medicaid Services, penalizes hospitals with higher than expected risk-standardized 30-day readmissions for medical conditions such as heart failure.[2] A previous study found that in 2013, readmissions accounted for 16% of the total cost (index and readmission) of TAVI.[3] Whereas recent data point to a decline in readmissions since TAVI was first approved,[4] it is unclear if readmissions after TAVI remain a costly proposition with regards to overall cost of TAVI to a healthcare system. Whereas overall readmissions may have declined, the readmissions stratified by cause have not yet been investigated. In this study, we investigate the most common causes of readmission after TAVI and assess the trends in the overall 30-day cost burden (index hospitalization plus all readmissions costs) of TAVI, stratified by cause. Furthermore, we attempt to study the potential risk factors for 30-day readmissions.

Methods

Hospitalizations for elective TAVI were identified using the Healthcare Cost and Utilization Project (HCUP) Nationwide Readmission Database (NRD). In 2017, the NRD included over 18 million discharges from 22 states and

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accounts for 60.0% of the total U.S. resident population and 58.2% of all U.S. hospitalizations.[5] It is an all-payer health care database in the United States that is nationally representative and contains verified patient linkage numbers which allows patients to be tracked across hospitals within a state, each year, allowing for all in-state hospital readmissions to be captured.

The International Classification of Disease, 9th revision, Clinical Modification (ICD-9-CM) and 10th revision, Clinical Modification (ICD-10-CM) diagnostic and procedural codes were used to identify eligible patients, co-morbidities, and cause of readmission and are reported in Supplemental Table 1.

Adults aged ≥50 years with aortic stenosis undergoing elective TAVI between January 2012 and November 2017 were eligible for inclusion. Patients discharged in December or who were not a resident of the state in which they were treated were excluded, as we were unable to complete 30-day follow-up, given how the NRD assigns patient linkage numbers. Patients diagnosed with congenital aortic disorders, rheumatic aortic stenosis, hypertrophic obstructive cardiomyopathy, who died during their index hospitalization, or who underwent additional vascular procedures such as coronary artery bypass grafting or surgical aortic valve replacement for complicated/failed TAVI were excluded. Additionally, only a patient's first TAVI within the year was included in the analyses.

The primary diagnosis of a patient's first readmission after TAVI was assessed and categorized (Supplemental Table 1). Poisson regression controlling for age and Charlson co-morbidity index (CCI) as well as likelihood ratio tests were used to assess yearly trends in 30-day overall and cause-specific readmissions.

We examined temporal trends in costs of index TAVI hospitalizations, all subsequent 30-day readmissions, total 30-day cost burden (index hospitalization plus all 30-day readmissions costs, where applicable), and cause-specific readmissions costs. Total hospital charges (amount hospital billed, which does not include professional fees or non-covered charges) were converted to costs (actual expenses incurred) using HCUP Cost-to-Charge ratios. All costs were adjusted for inflation to 2017 U.S. Dollars and scaled to thousands of dollars. Temporal changes in costs were analyzed using general linear regression adjusting for age and CCI. Changes in estimate (CIE) were reported and represent the modeled yearly change in thousands of 2017 U.S. dollars.

Finally, multivariable logistic regression adjusting for age, sex, CCI, primary insurance type, median household income in the patient's ZIP code, hospital teaching status, and hospital size were used to assess the effect of inpatient complications, length of stay (LOS, categorized as <5 days and ≥5 days), discharge disposition, and TAVI hospital volume on 30-day cardiovascular (CV) and non-CV readmissions. Both age and CCI were modeled as restricted quadratic splines, to allow for the most flexibility. Hospital volumes were calculated by counting all TAVI procedures performed within a year, irrespective of inclusion/exclusion criteria. Yearly TAVI hospital volumes were then categorized as low (<100 TAVI procedures per year) or high (≥100 TAVI procedures per year); classification was done on a yearly basis and hospitals could be reclassified from year to year depending on yearly TAVI volume. Index hospitalization complications of interest included permanent pacemaker placement, acute kidney injury, transient ischemic attack (TIA)/stroke, acute myocardial infarction, cardiogenic shock, blood transfusion, and vascular complications, Supplemental Table 1. All analyses were performed using SAS 9.4 (SAS Inc., Cary, NC).

Results

Overall, 47,255 patients undergoing TAVI were included and 14% of patients (n = 6,471) were readmitted within 30-days. Of all the readmissions, 33% (n = 2,211) were classified as CV. Between 2012 and 2017, the demographics of patients undergoing TAVI remained relatively stable, Table 1. However, patients undergoing TAVI seemed to have less co-morbidities over time, including significant decreases in prevalence of diabetes mellitus ($p < 0.0001$), hypertension ($p < 0.0001$), chronic obstructive pulmonary disease ($p < 0.0001$), and atrial fibrillation ($p < 0.0001$).

Between January 2012 and November 2017, 30-day readmissions after TAVI significantly declined from 20% to 12% ($p < 0.0001$). When stratified by cause of readmission, both CV (7% to 4%, $p < 0.0001$) and non-CV (11% to 5%, $p < 0.0001$) readmissions declined. The 5 most common causes of readmissions after TAVI were heart failure (18% of readmissions), infection/sepsis (12%), arrhythmia/heart block (10%), gastrointestinal causes (10%), and respiratory causes (6%), Supplemental Table 2. Over the study period, readmissions for heart failure (4.6% to 1.8%, $p < 0.0001$), infection/sepsis (3.6% to 1.0%, $p < 0.0001$), gastrointestinal causes (1.9% to 1.2%, $p < 0.0001$), and respiratory causes (1.6% to 0.4%, $p < 0.0001$) all declined. Readmissions for arrhythmia/heart block increased over time (1.0% to 1.4%, $p < 0.0001$), (Figure 1).

Median hospital costs for index TAVI hospitalizations over the course of the study were $46,632 (IQR $37,022, $58,968). Median readmissions costs including all subsequent 30-day readmissions were $10,028 (IQR $5,493, $19,119) and represented a median of 20% of a readmitted patient's total 30-day cost burden (IQR 11%, 39%). Between 2012 and 2017, median index TAVI hospitalization costs decreased from $52,024 to $44,110 (adjusted CIE −2.40, 95% CI −2.55, −2.25). The cost of an average readmission did not meaningfully change over time ($9,734 to $10,068, adjusted CIE −0.38, 95% CI −0.79, 0.02), although the cost burden of readmissions (per TAVI performed, regardless of readmission status) significantly declined ($4,061 to $1,883, adjusted CIE −0.34, 95% CI −0.41, −0.27), (Figure 2). Overall, 30-day cost burden of TAVI (TAVI hospitalization plus all readmissions within 30 days, if applicable) decreased from $54,122 in 2012 to $45,252 in 2017 (adjusted CIE −2.76, 95% CI −2.93, −2.58).

Aggregate total healthcare dollars spent on each of the top 5 causes of readmission increased from 2012 to 2017, consistent with the rapid expansion of TAVI. Readmission cost burden (per TAVI performed, regardless of readmission status) only increased for arrhythmia/heart block ($171 to $263, adjusted CIE 0.02, 95% CI 0.01, 0.04). These costs

Table 1
Baseline characteristics of patients undergoing elective TAVI for aortic stenosis, stratified by year

Variable	20121,350 (3%)	20132,804 (6%)	20144,241 (9%)	20157,563 (16%)	201613,073 (28%)	201716,236 (34%)
Age, mean (SD)	82 (7.8)	82 (7.7)	81 (7.7)	81 (7.6)	81 (7.6)	80 (7.7)
Men	715 (53%)	1480 (53%)	2396 (57%)	4068 (54%)	7098 (54%)	9956 (55%)
Charlson score, mean (SD)	2.6 (1.7)	2.6 (1.7)	2.7 (1.7)	2.6 (1.7)	2.6 (1.8)	2.6 (1.8)
Atrial fibrillation	589 (44%)	1269 (45%)	1900 (45%)	3127 (41%)	5073 (39%)	6969 (38%)
Diabetes	437 (32%)	939 (33%)	1475 (35%)	2675 (35%)	3617 (28%)	4001 (22%)
Chronic kidney disease	476 (35%)	933 (33%)	1497 (35%)	2582 (34%)	4366 (33%)	5811 (32%)
Hypertension	638 (47%)	1416 (51%)	2054 (48%)	4025 (53%)	6665 (51%)	4362 (24%)
Coronary artery disease	863 (64%)	1899 (68%)	2884 (68%)	5119 (68%)	8820 (67%)	12198 (67%)
Heart failure	928 (69%)	1933 (69%)	3034 (72%)	5255 (69%)	9012 (69%)	12659 (69%)
Chronic obstructive pulmonary disease	471 (35%)	944 (34%)	1350 (32%)	2351 (31%)	3757 (29%)	5018 (28%)
Primary insurance						
Medicaid/Medicare	1244 (92%)	2585 (92%)	3935 (93%)	7035 (93%)	12176 (93%)	16815 (92%)
Private	82 (6%)	164 (6%)	233 (6%)	388 (5%)	641 (5%)	1065 (6%)
Other/self-pay	24 (2%)	51 (2%)	69 (2%)	126 (2%)	232 (2%)	321 (2%)
Teaching hospital	1176 (87%)	2404 (86%)	3820 (90%)	6789 (90%)	11389 (87%)	15927 (87%)
Household income						
Low	247 (18%)	493 (18%)	687 (16%)	1408 (19%)	2488 (19%)	3260 (18%)
Medium	263 (20%)	645 (23%)	1078 (26%)	1264 (24%)	3099 (24%)	4852 (27%)
High	356 (27%)	758 (25%)	1073(26%)	2137 (29%)	3565 (28%)	4950 (27%)
Highest	467 (35%)	874 (32%)	1349 (32%)	2150 (29%)	3774 (29%)	4951 (27%)
Hospital size						
Small	99 (7%)	132 (5%)	240 (6%)	384 (5%)	543 (4%)	803 (4%)
Medium	158 (12%)	429 (15%)	607 (14%)	1411 (19%)	2451 (19%)	3877 (21%)
Large	1093 (81%)	2243 (80%)	3394 (80%)	5768 (76%)	10079 (77%)	13544 (74%)

Abbreviations: TAVI = transcatheter aortic valve implantation; SD = standard deviation.

for heart failure ($490 to $194, adjusted CIE −0.07, 95% CI −0.09, −0.05), infection/sepsis ($537 to $161, adjusted CIE −0.09, 95% CI −0.11, −0.07), gastrointestinal causes ($475 to $143, adjusted CIE −0.03, 95% CI −0.04, −0.01), and respiratory causes ($360 to $44, adjusted CIE −0.08, 95% CI −0.12, −0.05) all declined, (Figure 3).

After adjusting for patient's clinical characteristics, CCI, hospital characteristics, and other potential predictors, several potential risk factors for CV and non-CV readmission were identified (Figure 4). Hospital LOS ≥5 days was the largest predictor associated with both CV and non-CV readmissions (CV: OR 1.65, 95% CI 1.48, 1.83; non-CV: OR 1.79, 95% CI 1.63, 1.97). Acute kidney injury during the index hospitalization (CV: OR 1.58, 95% CI 1.39, 1.81; non-CV: OR 1.31, 95% CI 1.16, 1.47), discharge to skilled nursing facility (CV: OR 1.14, 95% CI 1.01, 1.28; non-CV: OR 1.42, 95% CI 1.29, 1.57), and undergoing TAVI at a low volume (<100 TAVI/year) center (CV: OR 1.11, 95% CI 1.00, 1.23; non-CV: OR 1.25, 95% CI 1.14, 1.37) were also associated with both types of readmission. Vascular complications (OR 1.49, 95% CI 1.25, 1.77) and requiring a blood transfusion (OR 1.23, 95% CI 1.07, 1.40) were only associated with non-CV readmissions. Interestingly, placement of a permanent pacemaker, transient ischemic attack/stroke, acute myocardial infarction, and cardiogenic shock were not associated with 30-day readmission.

Discussion

In this analysis of TAVI in the U.S. from 2012 to 2017, one in seven TAVI patients were readmitted within 30-days, with heart failure, infection/sepsis, and arrhythmia/heart block the 3 most common causes. Index TAVI hospitalization costs as well as overall 30-day cost burden have declined during this period, whereas the cost of each readmission has remained largely stable. Although both the overall and cause-specific incidences and costs of readmissions have declined, readmissions for arrhythmia/heart block and their associated costs have increased. Finally, in a multivariable model, acute kidney injury during index TAVI hospitalization, longer index LOS, skilled nursing facility discharge, and lower hospital TAVI volumes were associated with an increased risk of CV and non-CV readmission.

Previous retrospective cohort studies of patients hospitalized for TAVI between January and November 2013 in NRD initially raised concerns about the high incidence of readmissions and their financial implications.[3,6,7] A more recent study found TAVI index hospitalization costs exceeded that of surgical aortic valve replacement but have become more competitive, though they did not examine readmission cost burden.[8] Our data suggest that average TAVI hospitalization costs have declined by approximately $8,000 (from median of ~$52,000 to ~$44,000) from 2012 to 2017. Even though an average TAVI readmission continues to cost the same, 30-day readmission cost burden per each TAVI performed has in fact halved (from mean $4,000 to $1,890) largely due to a reduction in the number of readmissions. These declines in costs were significant even after adjusting for baseline co-morbidities. This indicates that increasing operator experiences and technological advances have not only made TAVI safer, but also less expensive and thereby cause lesser financial burden to healthcare systems.

There are likely multiple factors that account for the decline in readmissions after TAVI. Kolte et al attributed

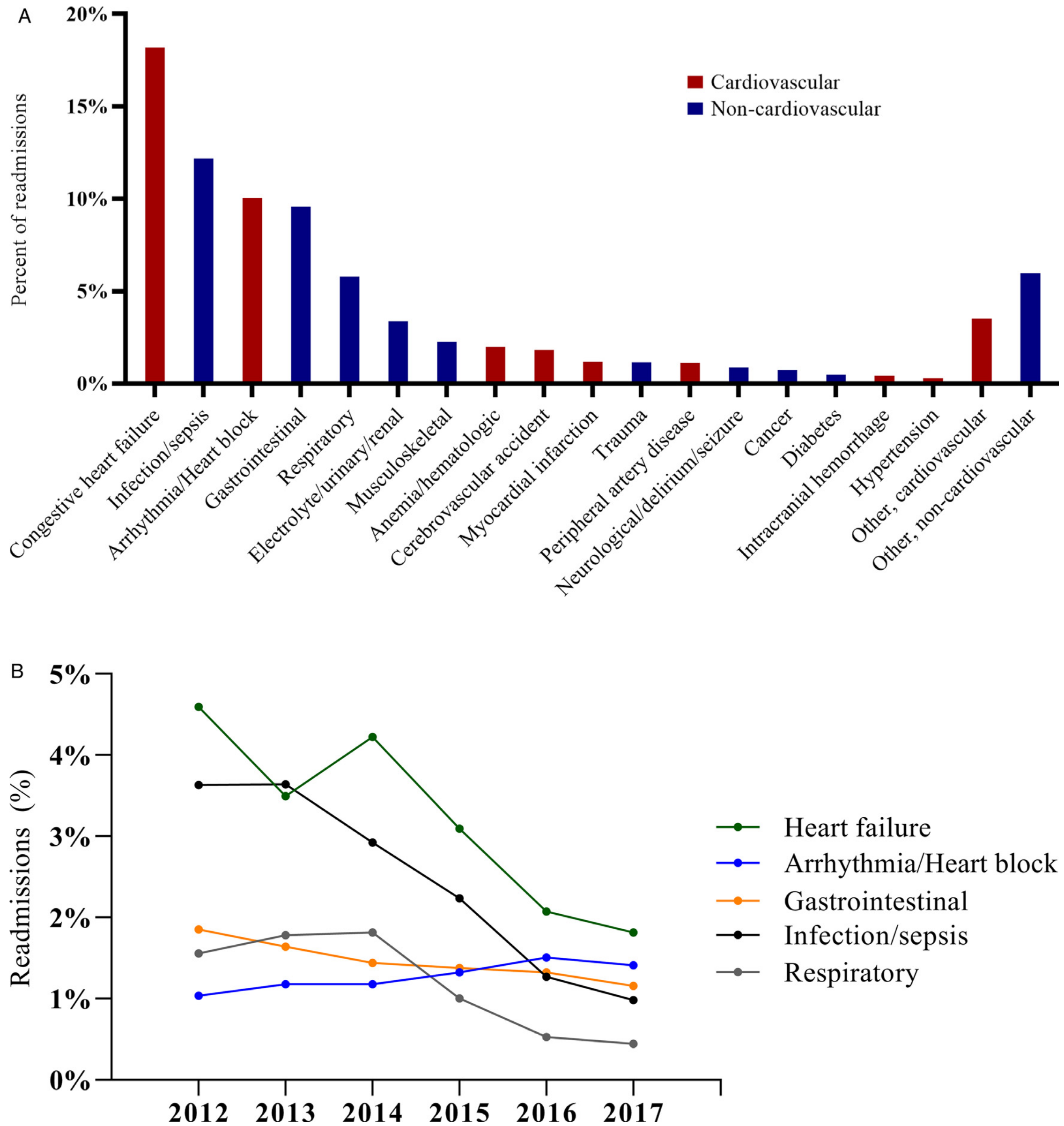

Figure 1. (A) Causes of 30-day readmissions after TAVI. Primary causes of readmission were captured using ICD-9-CM and ICD-10-CM codes for a patient's first readmission after TAVI. Histogram depicts the most common causes of readmission from 2012 to 2017 by percentage of readmissions. Readmissions were further categorized into cardiovascular and noncardiovascular. Heart failure, infection/sepsis, arrhythmia/heart block, gastrointestinal causes, and respiratory causes were the 5 most common causes of readmission after TAVI from 2012 to 2017. (B) Trends of most common causes of readmission after TAVI, from 2012 to 2017. Yearly incidence of the 5 most common causes of readmission after TAVI were assessed from 2012 to 2017. Four of the top 5 causes of readmission (heart failure, infection/sepsis, gastrointestinal causes, and respiratory causes) decreased over time, whereas arrhythmia/heart block increased.

the higher incidences of readmissions after TAVI to baseline co-morbidities, TAVI access site, and postprocedural complications.[3] Previous studies have focused on chronic, co-morbid conditions to modestly predict readmissions.[9,10] In this study, we found longer index LOS, discharge to a nursing home, acute kidney injury, postprocedural blood transfusion, low hospital TAVI volume, and vascular complications after TAVI as independent risk factors associated with readmissions. In recent studies published by our group and others, there has been a reduction in the incidence of these inpatient complications and improved outcomes after hospital discharge.[1,11−14] Presumably, these are attributed to improvements in patient selection as well as technological and procedural improvements with TAVI. Other contributing factors for improved outcomes after TAVI include the expanding use of conscious sedation (as opposed to general anesthesia in early years), a trend toward restricting the use of circulatory support, and the use of cardiac catheterization lab rather than an operating room as a setting for TAVI. All these factors have proven to play a role in improving outcomes and lowering readmission after other procedures.[15,16]

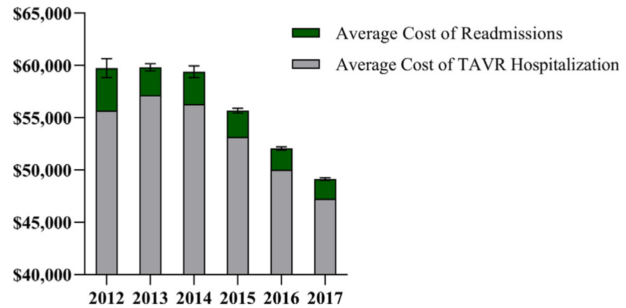

Figure 2. Index hospitalization costs, readmissions costs, and 30-day cost burden in patients undergoing TAVI from 2012 to 2017. TAVI index hospitalization costs and readmissions costs for all readmissions within 30 days were adjusted to 2017 U.S. dollars. Average TAVI hospitalization costs, readmissions-associated costs (per TAVI performed, regardless of readmission status), and therefore 30-day cost burden were calculated by year from 2012 to 2017. Error bars represent 95% confidence intervals for mean estimates. Both the costs of index TAVI hospitalization and the costs associated with readmissions decreased from 2012 to 2017, leading to a reduction in the overall 30-day TAVI cost burden.

Whereas it is very encouraging to see that there has been a rapid evolution in the procedural aspects and outcomes associated with TAVI, the growth in readmissions for arrhythmia or heart block is alarming. Conduction abnormalities following TAVI have been well described since the inception of the procedure. Risk factors for heart block following TAVI include the use of self-expanding valves, distribution of calcification in the aortic-valvular complex, pre-existing right bundle branch block, percent oversizing of the valve, and ventricular implantation depth, among others.[17-19] Rodés-Cabau et al recently put forth an algorithm strategy for management of conduction disturbances post-TAVI, utilizing pre-existing right bundle branch block as a predictor of poor outcomes.[19] Interestingly, our study found that placement of a permanent pacemaker during the index TAVI hospitalization was not a risk factor for nor protective of readmission. However, the development of heart block or other arrhythmias following discharge appears to be a significant contributor to the risk of readmissions and appears to be a growing cause of readmission after TAVI with increasing costs over time. It is possible that with the push to reduce hospital LOS following TAVI, we are discharging some patients too soon before they manifest the conduction abnormalities that can present days after TAVI. Better prediction models are needed to identify those patients who may require additional inpatient telemetry monitoring, benefit

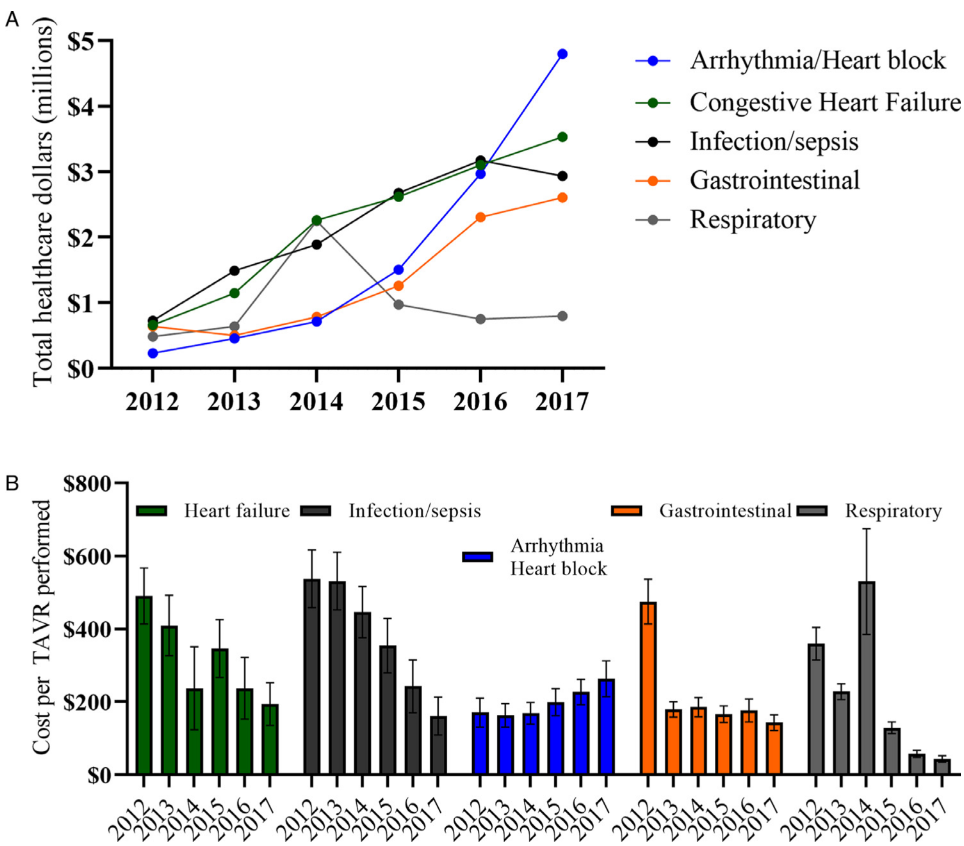

Figure 3. (A) Trends in total healthcare dollars attributable to common causes of readmission after TAVI. After primary cause of readmission was identified via ICD-9-CM and ICD-10-CM codes, total healthcare dollars attributable to each of the top 5 causes of readmissions after TAVI were adjusted to millions of 2017 U.S. dollars and calculated by year. Increases in healthcare dollars due to each of the top 5 causes is consistent with the rapid expansion of TAVI, despite a known reduction in proportion of patients needing readmission. The disproportionate increase in healthcare dollars attributable to arrhythmia/heart block readmissions is consistent with increasing incidence and/or costs of readmissions for conduction abnormalities. (B) Cost burden of common causes of readmission after TAVI, from 2012 to 2017. Cost burden of each of the top 5 causes of readmission (per TAVI performed, irrespective of readmission status) was scaled to 2017 U.S. dollars and calculated by year. Error bars represent 95% confidence intervals of mean estimates. Costs associated with each of the top 5 causes of readmission significantly declined over the period except arrhthmia/heart block, which significantly increased.

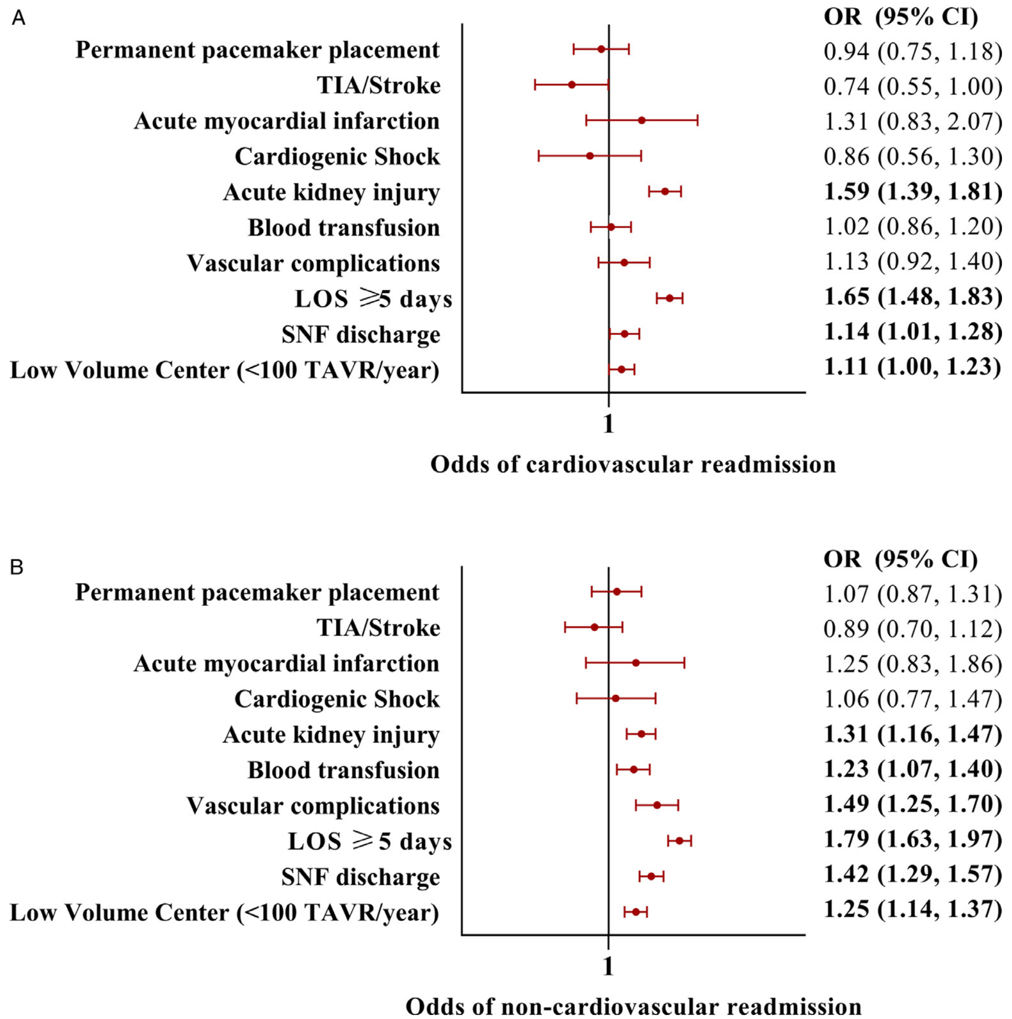

Figure 4. (A) Adjusted odds of 30-day cardiovascular readmission after TAVI. A multivariable logistic regression model adjusting for age, sex, Charlson co-morbidity index, primary insurance type, median household income in the patient's ZIP code, hospital teaching status, and hospital size was generated to assess the impact of baseline characteristics and complications of interest on risk of cardiovascular readmissions. Odds ratios (OR) are shown with 95% confidence intervals (CI). Acute kidney injury during the index TAVI hospitalization, length of stay (LOS) of greater than or equal to 5 days, skilled nursing facility (SNF) discharge, and undergoing TAVI at a low-volume center (defined as <100 TAVI per year) increased odds of cardiovascular readmission after TAVI. (B) Adjusted odds of 30-day noncardiovascular readmission after TAVI. A multivariable logistic regression model adjusting for age, sex, Charlson co-morbidity index, primary insurance type, median household income in the patient's ZIP code, hospital teaching status, and hospital size was generated to assess the impact of baseline characteristics and complications of interest on risk of noncardiovascular readmissions. ORs are shown with 95% CI. Acute kidney injury during the index TAVI hospitalization, blood transfusion, vascular complications, LOS of greater than or equal to 5 days, SNF discharge, and undergoing TAVI at a low-volume center (defined as <100 TAVI per year) increased odds of cardiovascular readmission after TAVI. Abbreviations: TIA = transient ischemic attack; LOS = length of stay; SNF = skilled nursing facility; OR = Odds ratio; 95% CI = 95% confidence interval.

from live ambulatory rhythm monitoring, or should have permanent pacemaker implantation before discharge after TAVI.

Our study has limitations. First, we were unable to account for some clinical covariates, such as illness severity and patient frailty, which likely are associated with both risk of readmission and some of our potential risk factors, such as inpatient complications. There is also potential for coding errors and differences in coding practices across the hospitals included in the database, although we would not expect these differences to differ across study years or inpatient outcomes. The competing risk of mortality during the follow-up period was not able to be accounted for. In addition, residual measured and unmeasured confounding may have influenced some of the findings.

Conclusions

In conclusion, the costs of index hospitalizations for TAVI in the U.S. significantly declined from 2012 to 2017. In addition, the costs associated with readmissions for TAVI declined during that time due to a reduction in the proportion of TAVI patients needing readmission, whereas the costs of the readmissions themselves have remained largely stable. Readmissions due to arrhythmia or heart block and the costs associated with these readmissions increased over the same period.

Author Statement

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Conflict of Interest

Dr. Deepak L. Bhatt discloses the following relationships - Advisory Board: Cardax, Elsevier Practice Update Cardiology, Medscape Cardiology, Regado Biosciences; Board of Directors: Boston VA Research Institute, Society of Cardiovascular Patient Care, TobeSoft; Chair: American Heart Association Quality Oversight Committee; Data Monitoring Committees: Baim Institute for Clinical Research (formerly Harvard Clinical Research Institute, for the PORTICO trial, funded by St. Jude Medical, now Abbott), Cleveland Clinic, Duke Clinical Research Institute, Mayo Clinic, Mount Sinai School of Medicine (for the ENVISAGE trial, funded by Daiichi Sankyo), Population Health Research Institute; Honoraria: American College of Cardiology (Senior Associate Editor, Clinical Trials and News, ACC.org; Vice-Chair, ACC Accreditation Committee), Baim Institute for Clinical Research (formerly Harvard Clinical Research Institute; RE-DUAL PCI clinical trial steering committee funded by Boehringer Ingelheim), Belvoir Publications (Editor in Chief, Harvard Heart Letter), Duke Clinical Research Institute (clinical trial steering committees), HMP Global (Editor in Chief, Journal of Invasive Cardiology), Journal of the American College of Cardiology (Guest Editor; Associate Editor), Population Health Research Institute (for the COMPASS operations committee, publications committee, steering committee, and USA national co-leader, funded by Bayer), Slack Publications (Chief Medical Editor, Cardiology Today's Intervention), Society of Cardiovascular Patient Care (Secretary/Treasurer), WebMD (CME steering committees); Other: Clinical Cardiology (Deputy Editor), NCDR-ACTION Registry Steering Committee (Chair), VA CART Research and Publications Committee (Chair); Research Funding: Abbott, Amarin, Amgen, AstraZeneca, Bayer, Boehringer Ingelheim, Bristol-Myers Squibb, Chiesi, Eisai, Ethicon, Forest Laboratories, Idorsia, Ironwood, Ischemix, Lilly, Medtronic, PhaseBio, Pfizer, Regeneron, Roche, Sanofi Aventis, Synaptic, The Medicines Company; Royalties: Elsevier (Editor, Cardiovascular Intervention: A Companion to Braunwald's Heart Disease); Site Co-Investigator: Biotronik, Boston Scientific, St. Jude Medical (now Abbott), Svelte; Trustee: American College of Cardiology; Unfunded Research: FlowCo, Merck, Novo Nordisk, PLx Pharma, Takeda. Dr. Qamar has received research grants to his institution from Daiichi-Sankyo, NIH, and AHA and fees for CME programs from Medscape, Pfizer, ACC, SCAI and NATF. Dr. Strassle has received salary support from researchEZ LLC and Dr. Arora's spouse has proprietary role in researchEZ LLC. Dr. Fonarow reports consulting for Abbott, Edwards, and Medtronic and serving as an Associate Section Editor of JAMA Cardiology. Dr. Cavender receives non-salary research support from Amgen, AstraZeneca, Chiesi, CSL Behring, GlaxoSmithKline, and Novartis. He receives salary research support from Novo-Nordisk. He receives consulting fees from Amgen, AstraZeneca, Boehringer-Inhelheim, Boston Scientific, Edwards Lifesciences, and Merck. Dr. Vavalle is supported by a research grant from CSI Inc. He is a principal investigator for Abbott Medical Device Company (PORTICO and POST MI VSD studies) and Boston Scientific (ACURATE trial, member of an advisory board). He receives consulting fees from Edwards Lifesciences (proctor) and has an Honoraria from ZOLL Medical Corporation. The remaining authors have nothing to disclose.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2020.09.041.

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