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# Temporal Trends and Outcomes in Utilization of Transcatheter and Surgical Aortic Valve Therapies in Aortic Valve Stenosis Patients with Heart Failure

**Running title**: TAVR and SAVR in Patients with Heart Failure

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**ABSTRACT:**

*Introductions & Aims:* Heart failure (HF) is a common comorbidity in patients undergoing surgical aortic valve replacement (SAVR) and transcatheter aortic valve replacement (TAVR). We sought to access the temporal trends and outcomes of TAVR or SAVR in HF patients.

*Method:* The NIS database from 2011-2014 was queried for patients that underwent TAVR or SAVR and were subsequently diagnosed with HF. Temporal trends in the utilization of TAVR or SAVR in HF patients were analyzed.

*Results:* Among 27,982 patients who were diagnosed with HF of whom 17,681 (63.2%) had heart failure with reduced ejection fraction (HFrEF) while 10,301 (36.8%) had heart failure with preserved ejection fraction (HFpEF), 9,049 (32.3%) underwent TAVR and 16,933 (76.7%) underwent SAVR. Patients with HFrEF and HFpEF had higher utilization of TAVR compared to SAVR over the course of the study period (p trend < 0.001). TAVR was associated with lower mortality [2.8% in 2012 and 1.8% in 2014 (p 0.013)] compared with SAVR. Similarly, multiple logistic regression showed a statistically significant lower in-hospital mortality in the TAVR group compared to SAVR (aOR 0.634; CI 0.504, 0.798, P < 0.001).

*Conclusion:* For patients with severe aortic valve stenosis and heart failure who undergo aortic valve intervention, TAVR is associated with less odds of in-hospital mortality compared with SAVR.

**What's Known:**

- Transcatheter aortic valve replacement (TAVR) or surgical aortic valve replacement (SAVR) are frequently done for asymptomatic or severe symptomatic aortic stenosis (AS)
- Efficacy of TAVR or SAVR, and its general complications are well reported

**What's New:**

- Research focus of TAVR or SAVR outcomes in subset of patients with heart failure (HF) either HF with either preserved ejection fraction (HFpEF) or reduced ejection fraction (HFrEF) have been scarcely discussed in literature
- With the rising prevalence of HFpEF and HFrEF in severe AS, the patients can have worse complications posing to high post-surgical morbidity, and mortality, hence this study done to enlighten this focus.
- The comparison of TAVR with SAVR showed lower mortality in TAVR as compared to SAVR in heart failure patients.

## INTRODUCTION:

Aortic stenosis (AS) is the most common valvular heart disease in developed countries [1]. The prevalence of AS ranges from 3 to 23% [2-4]. Transcatheter aortic valve replacement (TAVR) is considered an alternative to surgical aortic valve replacement (SAVR) in patients with severe symptomatic aortic stenosis and high surgical or intermediate risk with STS or EuroSCORE II score ≥ 4% or those who are frail [5,6]. Recent studies showed favorable outcomes of TAVR for low risk patients with comparable rates of mortality, stroke and vascular complications [7-10].

Patients with heart failure (HF), advanced age, hypertension and diabetes who develop aortic stenosis often have higher STS risk and EuroSCORE scores compared with patient who do not have these comorbidities; at which TAVR is considered more suitable than SAVR due to high surgical mortality and morbidity [9]. Limited clinical data suggested no difference in mortality and stroke between TAVR and SAVR in patients with left ventricular (LV) dysfunction [11,12]. Indeed, reports from the Transcatheter Valve Therapy (TVT) registry showed that LV dysfunction is present in approximately 25% of TAVR cases[13] and reduced LV ejection fraction (EF) was associated with higher rates of mortality and recurrent HF in TAVR patients compared with patients with preserved LV ejection fraction [14]. However, there is limited data available on the temporal trends of utilization of TAVR or SAVR and outcomes in patients with severe aortic stenosis and heart failure with reduced ejection fraction (HFrEF) or heart failure with preserved ejection fraction (HFpEF). Therefore, we sought to evaluate the temporal trends and in-hospital outcomes among HFrEF and HFpEF patients undergoing TAVR versus SAVR.

## METHODS:

### *Study population:*

The National Inpatient Sample (NIS) is a publicly available and identified database of hospital discharges in the United States, containing data from approximately 8 million hospital stays that were selected using a complex probability sampling design. It is the weighting scheme recommended by the Agency for Healthcare Research and Quality which is intended to represent all discharges from nonfederal hospitals[15]. Each record includes one primary diagnosis and up to 24 secondary diagnosis codes between 2009 and 2013, and 29 secondary diagnosis codes in 2014. We obtained NIS data from 2011 to 2014 and used the International Classification of Disease, Ninth Edition, Clinical Modification (ICD-9-CM) codes to identify patients 18-years of age or older, who were diagnosed with chronic systolic and chronic diastolic heart failure using the ICD-9 codes 428.22 and 428.32, respectively. Patients with combined systolic and diastolic heart failure were excluded due to potential selection bias. ICD-9 was used to select patients who underwent TAVR (codes 35.05 and 35.06), and SAVR (codes 35.21 and 35.22), retrospectively.

*Patient and Hospital Characteristics:*

Baseline patient-level characteristics included demographics (age, sex, race, primary expected payer, median household income for patient's zip code), urgency of the procedure (elective vs non-elective), all of the Elixhauser comorbidities - except congestive heart failure and valvular disease -, such as smoking, hyperlipidemia, coronary artery disease (CAD), prior percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG), history of stroke/transient ischemic attack (TIA), atrial fibrillation, and carotid artery disease. Hospital-level characteristics were census region, bed size, and teaching status. Using the Clinical Classification Software codes provided by the Healthcare Cost and Utilization Project and the Elixhauser Comorbidity Index comorbidities were appointed via ICD-9 codes, we created a list of ICD-9-CM codes and Clinical Classification Software codes to identify comorbidities (supplemental table 1).

*Outcome measures:*

The primary outcome of interest was in-hospital mortality of SAVR or TAVR across heart failure including HFrEF and HFpEF. The secondary outcomes include major vascular complications (vessel puncture/injury, major bleeding i.e. retroperitoneal hematoma), cardiac complications (hemopericardium, cardiac tamponade), respiratory complications (iatrogenic acute pneumothorax, postoperative pulmonary edema, respiratory failure, prolonged mechanical ventilation >96 hours, tracheostomy), postprocedural stroke and acute kidney injury (AKI). Length of stay (LOS) was included in the secondary outcomes. ICD-9-CM diagnosis codes were used to identify in-hospital outcomes (supplemental table 1).

*Statistical analysis:*

Continuous variables were expressed as weighted mean values ± standard deviation (normal distribution) or median with interquartile range (non-normal distribution), while categorical variables were expressed as percentages. Independent t-tests were used for the comparison of continuous variables measurements, while chi-square test for categorical variables. Weighted values of patient level observations were generated to produce a nationally representative estimate of the entire US population of hospitalized patients. Multiple logistic regression analyses were used to evaluate the odds of in-hospital mortality and complications for the patients that underwent TAVR and SAVR. The regression models were adjusted for demographics (age, race and gender), patients' insurance, socioeconomic status, hospital characteristics, procedure urgency (elective vs. non-elective) and all comorbidities listed in table 1. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) were used to report the results of regression models. Linear regression models were used to assess the LOS. Log transformation of LOS was done to adjust for positively skewed data.

To further explore the validity of our findings, we stratified patients by heart failure subtype defined as heart failure with reduced ejection fraction and heart failure with preserved ejection fraction. We also performed propensity score-matching analysis between TAVR and SAVR groups. All patients in both groups were matched for baseline characteristics, hospital characteristics, patients' socioeconomic status, insurance and urgency of the procedure in 1:3 propensity score matching analysis, using the nearest neighbor method. For the trend analysis, Cochrane-Armitage test was used to determine the presence of a linear trend between SAVR and TAVR utilization over the studied calendar years. P-value of less than 0.05 was considered statistically significant. SPSS version 25 software (IBM Corp, Armonk, NY) was used for all statistical analyses.

**RESULTS:**

*Baseline characteristics:*

A total of 27,973 patients were identified with the diagnosis of heart failure from 2011 to 2014. Out of 27,973 patients, 18,899 (67.5%) underwent SAVR and 9,074 (32.4%) underwent TAVR. Baseline characteristics for both groups are summarized in table 1. Compared to patients who underwent SAVR (mean age 70.40 ± 12.1 years), patients who underwent TAVR were older (mean age 81.71 ± 7.6 years), more likely to be women and less likely to be African American (p <0.001 for all). The prevalence of diabetes, dyslipidemia, hypertension, prior stroke/transient ischemic attack (TIA), percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery (CABG), renal failure, peripheral vascular disease, and deficiency anemia were higher among patients who underwent TAVR. Coagulopathy, fluid and electrolyte disturbances, and drug abuse were more prevalent in SAVR patients (p ≤ 0.002 for all). Patients who underwent TAVR were less likely to have private insurance, and less likely to have median household income in the lowest quartile, compared with patients who underwent SAVR (p < 0.001). Elective admissions were more frequent in patients who underwent TAVR (p < 0.001).

Using the Cochrane-Armitage method, we found a statistically significant linear uptrend in the utilization of TAVR in heart failure patients from 154 (4.0%) to 4,765 (46.7%) cases between the years 2011 and 2014; whereas the linear trend for the utilization of SAVR was down trending from 3,723 (96.0%) to 5,450 (53.4%) cases between 2011 and 2014 (P-Trend < 0.001, for all) (figure 1 and 2). Furthermore, both HFrEF and HFpEF patients had an uptrend in the utilization of TAVR and downtrend in the utilization of SAVR during the studied years (P-Trend < 0.001 for all). As for mortality, HF patients who underwent either TAVR or SAVR had a downtrend in mortality rate between the years 2011 and 2014 (P-Trend < 0.001 for all).

*In-Hospital Outcomes*

In-hospital mortality was significantly lower in patients who underwent TAVR compared to the ones underwent SAVR (1.8% vs 3.0%, p < 0.001). After adjusting for patients' demographics, procedure urgency, comorbidities, insurance and socioeconomic status using multivariate regression mode, TAVR patients remained at lower risk of in-hospital mortality (adjusted OR: 0.63 [95% CI: 0.50-0.79]) (Table 2). Risk-adjusted linear regression for LOS demonstrated a statistically significant shorter LOS in the TAVR group (median LOS= 5 days; Interquartile range [IQR] (3-7)) compared to those with SAVR (median LOS= 8 days; [IQR] (6-12)) ($p < 0.001$).

Patients who underwent TAVR had lower incidence of bleeding requiring transfusion (11.6% vs 22.5%, $p < 0.001$), cardiac complications (16.3% vs 19.9%, $p = 0.010$), respiratory complications (11.8% vs 22.4%, $p < 0.001$), and AKI (13.1% vs 21.0%, $p < 0.001$) but had higher incidence of vascular complications (3.5% vs 2.0%, $P < 0.001$) and permanent pacemaker implantation (10.0% vs 6.2%, $P < 0.001$) (figure 3). After multivariable adjustment, the odds of bleeding requiring transfusion (adjusted OR: 0.47 [95% CI: 0.43 – 0.52]), cardiac complications (adjusted OR: 0.89 [95% CI: 0.82 – 0.97]), respiratory complications (adjusted OR: 0.47 [95% CI: 0.43 – 0.52]), and AKI (adjusted OR: 0.54 [95% CI: 0.49 – 0.59]) remained significantly lower in the TAVR group; whereas post-procedural stroke showed no difference between the TAVR and SAVR groups (adjusted OR: 0.97 [95% CI: 0.66 – 1.42]). The TAVR group continued to have higher vascular complication and permanent pacemaker rates after multivariable adjustment (adjusted OR: 1.96 [95% CI: 1.60 – 2.38] and 1.67 [95% CI: 1.48 – 1.88], respectively) (Table 2).

In the subgroup analysis, TAVR patients had lower in-hospital mortality, bleeding requiring transfusion, respiratory complications and AKI in both HFrEF and HFpEF patients ($P \leq 0.037$ for all); whereas vascular complications and permanent pacemaker implantation remained higher in the TAVR patients with HFrEF and HFpEF patients ($P \leq 0.004$ for all). Furthermore, after removing patients diagnosed with infective endocarditis, HF patients undergoing TAVR had lower odds of in-hospital mortality (OR 0.58, [95%, CI: 0.47 – 0.72] $P < 0.001$) and cardiac complications while having higher odds of permanent pacemaker implantation and vascular complications compared with those who underwent SAVR.

*Propensity-score matching and in-hospital outcomes:*

Table 3 demonstrates baseline characteristics of the propensity score matched groups. Patients who underwent TAVR had lower in-hospital mortality, bleeding requiring transfusion, respiratory complications and AKI %) ($P < 0.001$) (Table 4). There were no differences in the rates of post-procedural stroke and cardiac complications between the TAVR and SAVR groups (0.8% vs 1.0%), (16.8% vs 19.0%), respectively, (P ≥ 0.139 for both). Vascular complications and permanent pacemaker implantation remained higher in the TAVR group compared with the SAVR group (3.7% vs 2.0%) and (10.4% vs 6.7%), respectively, (P ≤ 0.008 for both). Histogram of standardized differences of covariates between TAVR and SAVR groups before and after matching are shown in supplementary figure 1.

**DISCUSSION:**

Using a large nationally representative data between 2011 and 2014, we found that heart failure patients who underwent TAVR had lower in-hospital mortality, bleeding requiring transfusion, cardiac complications and respiratory complications compared with those who underwent SAVR regardless of the type of heart failure. Furthermore, TAVR patients had lower length of stay compared to those who underwent SAVR.

Interestingly, despite the higher percentage of different comorbidities in patients underwent TAVR compared to SAVR group, such as: renal failure (37% vs 24%), hypertension (81% vs 74%), dyslipidemia (69% vs 60%), coronary artery disease (70% vs 60%), history of PCI (22% vs 9%) and CABG (23% vs 7%), prior strokes (14% vs 9%), and coexisting chronic pulmonary disease (34% vs 25%); outcomes such as mortality (1.8% vs. 3.0%) and the length of stay post procedure (5 days vs. 8 days), were more favorable for TAVR than for SAVR in patients with HF.

Patients with heart failure (HF) and advanced age have higher STS and EuroSCORE, TAVR can be preferable in these subsets of patients but long-term age-related outcomes of patients undergoing TAVR vs. SAVR is not well known. A review by Alsara et al. included 8 studies (5 observational, 3 clinical trials), comparing TAVR with SAVR in age >80, the author mentioned that elderly individuals who underwent TAVI experienced better in-hospital recovery and similar short and mid-term mortality compared to those who underwent SAVR. However, they required closer monitoring for higher vascular complications that can require a higher length of stay [16]. In our preliminary analysis, patients who underwent TAVR were on mediocre older than

SAVR patients by ten years (81.7 vs. 70.4) and had a higher prevalence of female sex (48% vs. 40%) (Table-1). These differences in the risk profile of the two cohorts, particularly that the TAVR cohort was more likely to be elderly and female may contribute to the higher vascular complications associated with TAVR compared to SAVR (3.5% vs. 2%); as a consequence of the age-related deficient vascular elasticity and narrower vasculature in females [17-19]. Such observations could also be further supported by the higher incidences of vasculopathies among TAVR patients compared to the SAVR group reflected by higher percentages of PCI, CABG, PVD, and CAD records. Nevertheless, the absolute risk of vascular complication was only 1.5% higher in the TAVR group compared to SAVR.

Available data suggested TAVR mortality ranges between 1.1 to 4.2% [8,20,21]. Contrary to our findings, Brennan and colleagues found from a retrospective data analysis obtained from a national surgical database linked to Medicare, that TAVR and SAVR resulted in similar mortality and stroke rates in patients with intermediate and high-risk [12]. We think such incongruity observations from our analysis due to a few factors in Brennan and colleagues' study. First, the data comparison between SAVR and TAVR was collected in different time-frames as SAVR data was obtained from July 2011, to December 2013, while TAVR data from January 2014, to September 2015; which may be meaningful as surgical and interventional techniques had advanced between 2011 and 2015. Second, ventricular remodeling and aortic insufficiency degree were not reported, which may jeopardize the sample standardization. Third, the statistics of stroke outcomes, which is a primary point of interest, had wide confidence intervals in each subgroup which challenge the conclusion accuracy. In our analysis, we identified patients with HF and addressed the outcomes accordingly in SAVR and TAVR patients, making the variation in sample characteristics less likely to confound the results. Even in studies showing a non-inferiority of TAVR approach based on the mortality outcome, TAVR with such a conclusion would present a preferred method giving the less invasive intervention, lower length of stay, and less overall complications [22,23].

On the other hand, the need for permanent pacemaker (PP) implant due to significant bradyarrhythmia has been reported in many data registry post TAVR over SAVR, supporting our analysis findings. One of the most common predictors identified by the need for PP post-TAVR is the history of right bundle branch block (RBBB) [24,25]. Other factors include left ventricular end-diastolic dimension and annulus location and calcification, besides the depth of implantation technique, oversizing, and balloon-valvuloplasty [26]. The implant of PP after TAVR raises concerns of prolonging the hospitalization and intensive care unit stay, however, in our analysis the total length of stay remained shorter in TAVR patients than SAVR with a lower mortality rate [27]. Aside from medical factors, patients' socioeconomic status appears to play a minor role in our analysis outcome.

*Limitations:*

Our study has several limitations. This study is a retrospective observational study, which poses a possible selection bias and unmeasured confounding factors. Furthermore, the National Inpatient Sample is an administrative database which could be subject to inaccurate coding and underreporting of comorbid diagnoses. Furthermore, echocardiogram quantitative data regarding ejection fraction were not available. In addition, quality of life and long-term outcome would aid further in guidance for therapy choice. Furthermore, the type of anesthesia used for the TAVR procedure was not available. This is important as with early experience, TAVR was undertaken under general anesthesia, while in recent years, TAVR now undertaken with moderate sedation which might contribute to more favorable outcomes associated with TAVR. Despite these limitations, we used a large publicly available database to address the limited data around outcomes in HF patients after aortic valve replacement with TAVR compared to SAVR. Larger scale prospective studies on the older population are needed to validate our findings and to perform long-term survival analysis.

**Conclusion:**

For high surgical risk patients with severe aortic valve stenosis and heart failure, the utilization of TAVR has been increasing and associated with better in-hospital outcomes compared with SAVR

**Figure legends:**

Figure 1. Trends of SAVR and TAVR mortality in heart failure patients

Figure 2. Trends of SAVR and TAVR utilization in heart failure patients

**References:**


1. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases: a population-based study. *Lancet.* 2006;368(9540):1005-1011.
2. Osnabrugge RL, Mylotte D, Head SJ, et al. Aortic stenosis in the elderly: disease prevalence and number of candidates for transcatheter aortic valve replacement: a meta-analysis and modeling study. *J Am Coll Cardiol.* 2013;62(11):1002-1012.
3. Stewart BF, Siscovick D, Lind BK, et al. Clinical factors associated with calcific aortic valve disease. Cardiovascular Health Study. *J Am Coll Cardiol.* 1997;29(3):630-634.
4. Vaes B, Rezzoug N, Pasquet A, et al. The prevalence of cardiac dysfunction and the correlation with poor functioning among the very elderly. *Int J Cardiol.* 2012;155(1):134-143.
5. Baumgartner H, Falk V, Bax JJ, et al. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. *Eur Heart J.* 2017;38(36):2739-2791.
6. Nishimura RA, Otto CM, Bonow RO, et al. 2017 AHA/ACC Focused Update of the 2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol.* 2017;70(2):252-289.
7. Mack MJ, Leon MB, Smith CR, et al. 5-year outcomes of transcatheter aortic valve replacement or surgical aortic valve replacement for high surgical risk patients with aortic stenosis (PARTNER 1): a randomised controlled trial. *Lancet.* 2015;385(9986):2477-2484.
8. Leon MB, Smith CR, Mack MJ, et al. Transcatheter or Surgical Aortic-Valve Replacement in Intermediate-Risk Patients. *N Engl J Med.* 2016;374(17):1609-1620.
9. Mack MJ, Leon MB, Thourani VH, et al. Transcatheter Aortic-Valve Replacement with a Balloon-Expandable Valve in Low-Risk Patients. 2019.
10. Popma JJ, Deeb GM, Yakubov SJ, et al. Transcatheter Aortic-Valve Replacement with a Self-Expanding Valve in Low-Risk Patients. 2019.

11. Onorati F, D'Errigo P, Grossi C, et al. Effect of severe left ventricular systolic dysfunction on hospital outcome after transcatheter aortic valve implantation or surgical aortic valve replacement: results from a propensity-matched population of the Italian OBSERVANT multicenter study. *J Thorac Cardiovasc Surg.* 2014;147(2):568-575.
12. Brennan JM, Thomas L, Cohen DJ, et al. Transcatheter Versus Surgical Aortic Valve Replacement: Propensity-Matched Comparison. *J Am Coll Cardiol.* 2017;70(4):439-450.
13. Carroll JD, Vemulapalli S, Dai D, et al. Procedural Experience for Transcatheter Aortic Valve Replacement and Relation to Outcomes: The STS/ACC TVT Registry. *J Am Coll Cardiol.* 2017;70(1):29-41.
14. Baron SJ, Arnold SV, Herrmann HC, et al. Impact of Ejection Fraction and Aortic Valve Gradient on Outcomes of Transcatheter Aortic Valve Replacement. *J Am Coll Cardiol.* 2016;67(20):2349-2358.
15. Behan M, Dixon G, Haworth P, et al. PCI in octogenarians—our centre 'real world'experience. 2009;38(4):469-473.
16. **Alsara O, Alsarah A, Laird-Fick H. Advanced age and the clinical outcomes of transcatheter aortic valve implantation. J Geriatr Cardiol. 2014 Jun; 11(2): 163–170. doi: 10.3969/j.issn.1671-5411.2014.02.004.**
17. Evans JM, Wang S, Greb C, et al. Body Size Predicts Cardiac and Vascular Resistance Effects on Men's and Women's Blood Pressure. *Front Physiol.* 2017;8:561.
18. Van Mieghem NM, Tchetche D, Chieffo A, et al. Incidence, predictors, and implications of access site complications with transfemoral transcatheter aortic valve implantation. *Am J Cardiol.* 2012;110(9):1361-1367.
19. Miller VM, Duckles SP. Vascular actions of estrogens: functional implications. *Pharmacol Rev.* 2008;60(2):210-241.
20. Holmes DR, Jr., Brennan JM, Rumsfeld JS, et al. Clinical outcomes at 1 year following transcatheter aortic valve replacement. *JAMA.* 2015;313(10):1019-1028.
21. Smith CR, Leon MB, Mack MJ, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med.* 2011;364(23):2187-2198.

22. Alfadhli J, Jeraq M, Singh V, Martinez C. Updates on transcatheter aortic valve replacement: Techniques, complications, outcome, and prognosis. *J Saudi Heart Assoc.* 2018;30(4):340-348.
23. Grigorios T, Stefanos D, Athanasios M, et al. Transcatheter versus surgical aortic valve replacement in severe, symptomatic aortic stenosis. *J Geriatr Cardiol.* 2018;15(1):76-85.
24. Munoz-Garcia AJ, Hernandez-Garcia JM, Jimenez-Navarro MF, et al. Factors predicting and having an impact on the need for a permanent pacemaker after CoreValve prosthesis implantation using the new Accutrak delivery catheter system. *JACC Cardiovasc Interv.* 2012;5(5):533-539.
25. Nazif TM, Dizon JM, Hahn RT, et al. Predictors and clinical outcomes of permanent pacemaker implantation after transcatheter aortic valve replacement: the PARTNER (Placement of AoRtic TraNscathetER Valves) trial and registry. *JACC Cardiovasc Interv.* 2015;8(1 Pt A):60-69.
26. Guetta V, Goldenberg G, Segev A, et al. Predictors and course of high-degree atrioventricular block after transcatheter aortic valve implantation using the CoreValve Revalving System. *Am J Cardiol.* 2011;108(11):1600-1605.
27. Terre JA, George I, Smith CR. Pros and cons of transcatheter aortic valve implantation (TAVI). *Ann Cardiothorac Surg.* 2017;6(5):444-452.

Figures 1:

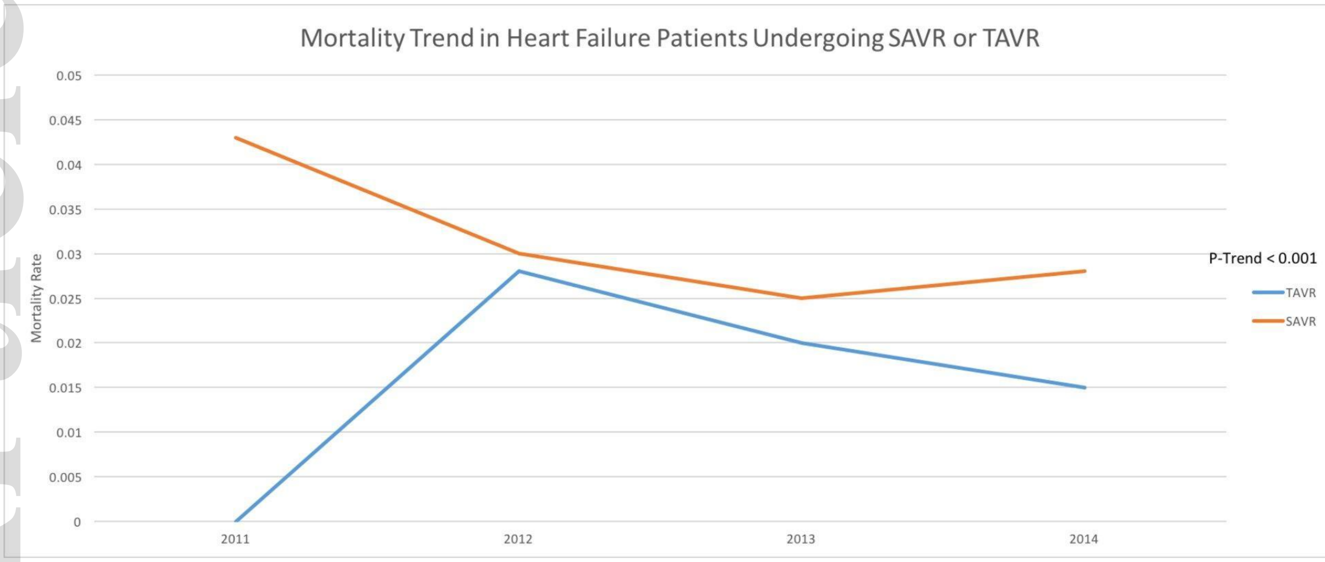
Mortality Trend in Heart Failure Patients Undergoing SAVR or TAVR
Mortality Rate
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2011
2012
2013
2014
P-Trend < 0.001
TAVR
SAVR

Figure 2:

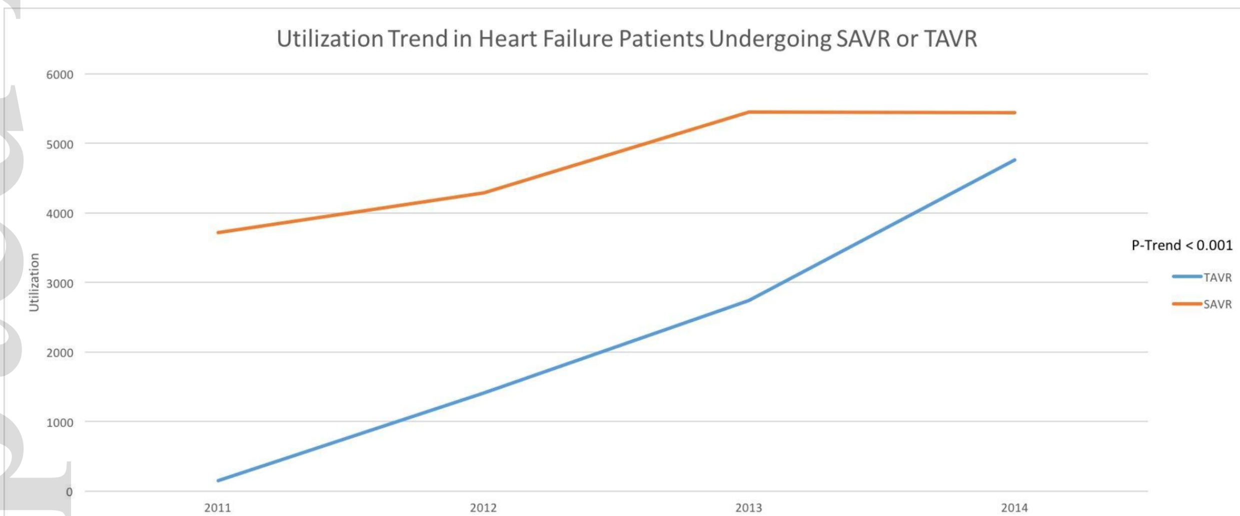
Utilization Trend in Heart Failure Patients Undergoing SAVR or TAVR
6000
5000
4000
3000
2000
1000
0
Utilization
2011
2012
2013
2014
P-Trend < 0.001
TAVR
SAVR

Table 1. Baseline characteristics for patients undergoing TAVR and SAVR

| Variable | TAVR Group | SAVR Group | P-Value |
|---|---|---|---|
| Age | 81.71 ± 7.69 | 70.40 ± 12.12 | <0.001 |
| Sex | | | |
| Female, % | 48.3 | 39.9 | <0.001 |

| | | | |
|---|---|---|---|
| Race, % | | | <0.001 |
| White | 87.0 | 81.6 | |
| Black | 4.5 | 7.1 | |
| Hispanic | 3.5 | 5.1 | |
| Asian or Pacific Islander | 0.7 | 1.2 | |
| Native American | 0.0 | 0.3 | |
| Other | 1.4 | 4.7 | |
| Elective hospitalization, % | 84.2 | 75.1 | <0.001 |
| Primary expected payer, % | | | <0.001 |
| Medicare | 91.6 | 71.1 | |
| Medicaid | 0.5 | 4.4 | |
| Private Insurance | 6.5 | 20.5 | |
| Self-Pay | 0.4 | 1.7 | |
| No Charge | 0.1 | 0.2 | |
| Other | 1.0 | 2.1 | |
| Median Household Income, % | | | <0.001 |
| 0 to 25 percentiles | 19.6 | 22.9 | |
| 26 to 50 percentiles | 24.7 | 25.7 | |
| 51 to 75 percentile | 28.6 | 27.0 | |
| 76 to 100 percentile | 27.1 | 24.4 | |
| Bed Size, % | | | <0.001 |
| Small | 4.4 | 5.9 | |
| Medium | 15.8 | 19.0 | |
| Large | 79.8 | 75.0 | |
| Location/Teaching Status, % | | | <0.001 |
| Rural | 1.0 | 1.6 | |
| Urban Nonteaching | 10.8 | 20.0 | |
| Urban Teaching | 88.2 | 78.2 | |
| Hospital Region, % | | | 0.002 |
| Northeast | 25.7 | 24.9 | |
| Midwest | 26.3 | 27.1 | |

| | | | |
|---|---|---|---|
| South | 30.4 | 31.9 | |
| West | 17.5 | 16.1 | |
| Comorbidities, % | | | |
| Hypertension | 81.3 | 74.4 | <0.001 |
| Dyslipidemia | 68.9 | 59.7 | <0.001 |
| Atrial fibrillation | 45.3 | 51.2 | <0.001 |
| Carotid disease | 6.9 | 5.9 | 0.002 |
| Smoking | 1.9 | 8.3 | <0.001 |
| Coronary artery disease | 70.1 | 59.9 | <0.001 |
| Prior PCI | 22.0 | 9.1 | <0.001 |
| Prior CABG | 22.7 | 6.6 | <0.001 |
| Prior stroke | 13.5 | 8.8 | <0.001 |
| Acquired immune deficiency | 0.0 | 0.1 | 0.028 |
| Alcohol Abuse | 0.9 | 2.9 | <0.001 |
| Deficiency Anemia | 23.8 | 18.9 | <0.001 |
| Rheumatoid arthritis/collagen vascular diseases | 5.7 | 3.4 | <0.001 |
| Chronic blood loss anemia | 0.9 | 1.0 | 0.383 |
| Chronic pulmonary disease | 33.9 | 24.8 | <0.001 |
| Coagulopathy | 20.9 | 34.7 | <0.001 |
| Depression | 7.5 | 7.9 | 0.203 |
| DM, uncomplicated | 28.9 | 27.1 | 0.002 |
| DM, complicated | 5.7 | 6.7 | 0.001 |
| Drug abuse | 0.1 | 1.2 | <0.001 |
| Hypothyroidism | 21.0 | 14.2 | <0.001 |
| Liver disease | 2.3 | 2.1 | 0.440 |
| Lymphoma | 1.2 | 1.0 | 0.124 |
| Metastatic cancer | 0.4 | 0.1 | <0.001 |
| Solid tumors without metastasis | 1.6 | 1.4 | 0.103 |
| Fluid and Electrolyte disorders | 21.2 | 34.8 | <0.001 |
| Other neurological disorders | 6.6 | 5.3 | <0.001 |

| | | | |
|---|---|---|---|
| Obesity | 15.9 | 24.3 | <0.001 |
| Paralysis | 1.3 | 1.6 | 0.067 |
| Renal failure | 37.2 | 23.6 | <0.001 |
| Peripheral vascular disease | 29.9 | 22.3 | <0.001 |
| Pulmonary circulation disorders | 4.2 | 0.9 | <0.001 |
| Psychosis | 1.2 | 2.4 | <0.001 |
| Peptic ulcer disease | 0.0 | 0.0 | 0.038 |
| Weight loss | 3.5 | 6.3 | <0.001 |

Abbreviations: CABG – coronary artery bypass grafting; PCI – percutaneous coronary intervention; TAVR – Transcatheter aortic valve replacement; SAVR – Surgical aortic valve replacement.

Table 2. In-hospital outcome of Heart failure patient undergoing SAVR or TAVR

| **Outcome** | **TAVR** | **SAVR** | **UOR (95% CI) TAVR*** | **aOR (95% CI) TAVR** | **Unadjusted P-Value** | **Adjusted P-Value** |
|---|---|---|---|---|---|---|
| Overall (n) | 9,074 | 18,899 | | | | |
| HFrEF | 6,820 | 10,861 | | | | |
| HFpEF | 2,254 | 8,047 | | | | |
| In-Hospital Mortality | 1.8% | 3.0% | 0.59 (0.49-0.70) | 0.63 (0.50-0.79) | <0.001 | <0.001 |
| HFrEF | 1.3% | 3.1% | 0.41 (0.28-0.61) | 0.46 (0.27-0.78) | <0.001 | 0.004 |
| HFpEF | 2.0% | 3.0% | 0.65 (0.53-0.80) | 0.62 (0.47-0.82) | <0.001 | 0.001 |
| Length of Stay Median (IQR) | 5 (3-7) | 8 (6-12) | | | | <0.001 |
| HFrEF (days) | 5 (3-7) | 8 (6-12) | | | | <0.001 |
| HFpEF (days) | 5 (3-8) | 8 (6-13) | | | | <0.001 |
| Transfusion | 11.6% | 22.5% | 0.45 (0.42-0.48) | 0.47 (0.43-0.52) | <0.001 | <0.001 |
| HFrEF | 11.0% | 21.3% | 0.45 (0.39-0.52) | 0.49 (0.41-0.58) | <0.001 | <0.001 |
| HFpEF | 11.8% | 23.4% | 0.43 (0.40-0.47) | 0.45 (0.40-0.50) | <0.001 | <0.001 |
| Vascular Complications | 3.5% | 2.0% | 1.78 (1.53-1.07) | 1.96 (1.60-2.38) | <0.001 | <0.001 |
| HFrEF | 2.8% | 1.9% | 1.53 (1.14-2.06) | 3.24 (2.09-5.01) | 0.004 | <0.001 |
| HFpEF | 3.7% | 2.1% | 1.79 (1.49-2.15) | 1.61 (1.27-2.04) | <0.001 | <0.001 |
| Cardiac Complications | 16.3% | 19.9% | 0.78 (0.73-0.84) | 0.89 (0.82-0.97) | <0.001 | 0.010 |
| HFrEF | 13.3% | 18.7% | 0.66 (0.58-0.76) | 0.83 (0.69-0.98) | <0.001 | 0.021 |
| HFpEF | 17.3% | 20.8% | 0.79 (0.73-0.86) | 0.91 (0.82-1.08) | <0.001 | 0.071 |
| Permanent Pacemaker Implantation | 10.0% | 6.2% | 1.67 (1.53-1.83) | 1.67 (1.48-1.88) | 0.021 | <0.001 |
| HFrEF | 7.3% | 5.0% | 1.47 (1.22-1.78) | 1.43 (1.12-1.83) | <0.001 | 0.004 |
| HFpEF | 10.9% | 7.1% | 1.59 (1.43-1.77) | 1.72 (1.49-1.98) | <0.001 | <0.001 |
| Respiratory Complications | 11.8% | 22.4% | 0.46 (0.43-0.49) | 0.47 (0.43-0.52) | <0.001 | <0.001 |
| HFrEF | 11.0% | 21.2% | 0.46 (0.40-0.53) | 0.62 (0.51-0.74) | <0.001 | 0.037 |
| HFpEF | 12.1% | 23.4% | 0.45 (0.41-0.49) | 0.42 (0.37-0.47) | <0.001 | <0.001 |
| Postprocedural Stroke | 1.1% | 0.8% | 1.32 (1.03-1.70) | 0.97 (0.66-1.42) | 0.030 | 0.897 |
| HFrEF | 1.1% | 0.6% | 1.72 (1.06-2.78) | 4.27 (1.36-13.35) | 0.026 | 0.012 |

| | | | | | | |
|---|---|---|---|---|---|---|
| HFpEF | 1.1% | 1.0% | 1.12 (0.83-1.52) | 0.69 (0.43-1.12) | 0.427 | 0.138 |
| AKI | 13.9% | 21.2% | 0.60 (0.56-0.64) | 0.54 (0.49-0.59) | <0.001 | <0.001 |
| HFrEF | 16.3% | 21.4% | 0.71 (0.63-0.80) | 0.53 (0.47-0.66) | <0.001 | <0.001 |
| HFpEF | 13.1% | 21.0% | 0.56 (0.52-0.61) | 0.52 (0.46-0.58) | <0.001 | <0.001 |

TAVR – Transcatheter aortic valve replacement; SAVR – Surgical aortic valve replacement; UOR – Unadjusted odds ratio; aOR – Adjusted odds ratio; AKI – Atrial kidney injury; IQR – Interquartile range. *when compared with SAVR

Table 3. Baseline characteristics of propensity score matched groups

| Variable | TAVR Group | SAVR Group | P-Value |
|---|---|---|---|
| Age | 80.08 ± 8.12 | 76.95 ± 8.54 | <0.001 |
| Sex | | | |
| Female, % | 46.6 | 45.1 | 0.415 |
| Race, % | | | 0.234 |
| White | 86.5 | 84.1 | |
| Black | 5.3 | 5.9 | |
| Hispanic | 3.3 | 3.8 | |
| Asian or Pacific Islander | 0.8 | 1.0 | |
| Native American | 0.0 | 0.4 | |
| Other | 4.2 | 4.8 | |
| Elective hospitalization, % | 80.4 | 77.6 | 0.079 |
| Primary expected payer, % | | | 0.005 |
| Medicare | 91.2 | 87.0 | |
| Medicaid | 0.6 | 1.6 | |
| Private Insurance | 7.3 | 9.6 | |
| Self-Pay | 0.5 | 0.8 | |
| No Charge | 0.1 | 0.0 | |
| Other | 0.4 | 0.9 | |
| Median Household Income, % | | | 0.598 |
| 0 to 25 percentile | 19.4 | 21.5 | |
| 26 to 50 percentile | 25.4 | 24.5 | |
| 51 to 75 percentile | 27.0 | 26.2 | |
| 76 to 100 percentile | 28.3 | 27.8 | |
| Bed Size, % | | | 0.246 |
| Small | 4.6 | 5.8 | |
| Medium | 20.1 | 18.4 | |
| Large | 75.3 | 75.8 | |
| Location/Teaching Status, % | | | 0.024 |

| | | | |
|---|---|---|---|
| Rural | 1.2 | 1.1 | |
| Urban Nonteaching | 13.5 | 17.4 | |
| Urban Teaching | 85.2 | 81.5 | |
| Hospital Region, % | | | 0.397 |
| Northeast | 27.9 | 28.0 | |
| Midwest | 21.6 | 21.8 | |
| South | 34.4 | 32.0 | |
| West | 16.1 | 18.2 | |
| Comorbidities, % | | | |
| Hypertension | 80.5 | 78.2 | 0.159 |
| Dyslipidemia | 67.7 | 63.9 | 0.041 |
| Atrial fibrillation | 49.6 | 53.9 | 0.028 |
| Carotid disease | 6.9 | 6.8 | 0.933 |
| Smoking | 2.4 | 4.2 | 0.016 |
| Coronary artery disease | 68.3 | 64.0 | 0.019 |
| Prior PCI | 15.9 | 13.0 | 0.029 |
| Prior CABG | 14.9 | 10.4 | <0.001 |
| Prior stroke | 12.4 | 10.5 | 0.117 |
| Alcohol Abuse | 1.1 | 1.7 | 0.224 |
| Deficiency Anemia | 23.5 | 21.5 | 0.223 |
| Rheumatoid arthritis/collagen vascular diseases | 5.5 | 4.4 | 0.215 |
| Chronic blood loss anemia | 0.9 | 1.3 | 0.438 |
| Chronic pulmonary disease | 30.9 | 28.0 | 0.101 |
| Coagulopathy | 25.1 | 31.2 | <0.001 |
| Depression | 7.4 | 8.1 | 0.520 |
| DM, uncomplicated | 30.5 | 29.1 | 0.457 |
| DM, complicated | 5.7 | 5.7 | 0.993 |
| Drug abuse | 0.1 | 0.3 | 0.306 |
| Hypothyroidism | 19.5 | 17.0 | 0.097 |
| Liver disease | 1.9 | 2.0 | 0.868 |

| | | | |
|---|---|---|---|
| Lymphoma | 0.8 | 1.1 | 0.302 |
| Metastatic cancer | 0.3 | 0.2 | 0.738 |
| Solid tumors without metastasis | 1.8 | 1.5 | 0.521 |
| Fluid and Electrolyte disorders | 24.6 | 29.0 | 0.010 |
| Other neurological disorders | 6.4 | 6.3 | 0.912 |
| Obesity | 17.3 | 20.2 | 0.057 |
| Paralysis | 1.2 | 1.4 | 0.741 |
| Renal failure | 33.9 | 28.6 | 0.003 |
| Peripheral vascular disease | 27.5 | 24.6 | 0.082 |
| Pulmonary circulation disorders | 2.3 | 1.2 | 0.029 |
| Psychosis | 1.9 | 1.9 | 0.949 |
| Weight loss | 3.9 | 5.2 | 0.113 |

Abbreviations: CABG – coronary artery bypass grafting; PCI – percutaneous coronary intervention; TAVR – Transcatheter aortic valve replacement; SAVR – Surgical aortic valve replacement.

Table 4. Propensity score matched groups in-hospital outcome of Heart failure patient undergoing SAVR or TAVR

| Outcome | TAVR (n = 1,064) | SAVR (n = 1,824) | P-value |
|---|---|---|---|
| In-hospital mortality | 1.8% | 3.3% | 0.017 |
| Bleeding requiring transfusion | 11.4% | 22.3% | <0.001 |
| Vascular complications | 3.7% | 2.0% | 0.008 |
| Cardiac complications | 16.8% | 19.0% | 0.139 |
| Permanent pacemaker implantation | 10.4% | 6.7% | <0.001 |
| Respiratory complications | 11.7% | 21.5% | <0.001 |
| Post-procedural stroke | 0.8% | 1.0% | 0.519 |
| AKI | 14.2% | 23.0% | <0.001 |