Original Article

Long term mortality and readmissions after transcatheter aortic valve replacement

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Background: Readmissions following transcatheter aortic valve replacement (TAVR) are common but detailed analysis of cardiac and non-cardiac inpatient readmissions beyond thirty days to different levels of care are limited.

Methods: Our study population was 1,037 consecutive patients who underwent TAVR between 2011–2017 within a multi-hospital quaternary health system. A retrospective chart review was performed and readmissions were adjudicated and classified based on primary readmission diagnosis (cardiac versus noncardiac) and level of care [intensive care unit (ICU) admission *vs.* non-ICU admission]. Incidence, causes, and outcomes of readmissions to up to three years post procedure were evaluated.

Results: Of the 1,017 patients who survived their index hospitalization, there were readmissions due to noncardiac causes in 350 (34.4%) and cardiac causes in 208 (20.5%) during a mean 1.96 years of follow-up. The most common non-cardiac causes of readmission were sepsis/infection (14.3%), gastrointestinal (8.3%), and respiratory (4.8%), whereas heart failure (14.0%) and arrhythmias (4.6%) were the most common cardiac causes of readmission. A total of 191 (18.8%) patients were readmitted to the ICU and 372 patients (36.6%) were non-ICU readmissions. The risk of a noncardiac readmission was highest in the period immediately following TAVR (~4.5% per month) with an early high hazard phase that gradually declined over months. However, the risk of cardiac readmission remained stable at ~1% per month throughout. TAVR patients that were readmitted for any cause had markedly increased mortality; this was especially true for patients readmitted to an ICU.

Conclusions: In TAVR patients who survived their index hospitalization, non-cardiac readmissions were more prevalent than cardiac. The risk of readmission and subsequent mortality was highest immediately post-procedure and declined thereafter. Readmission to ICU portends the highest risk of subsequent death in this cohort. Patient baseline co-morbidities are an important consideration for TAVR patients and play a significant role in readmissions and outcomes.

Keywords: Transcatheter aortic valve replacement (TAVR); TAVR readmissions; TAVR outcomes

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Introduction

Transcatheter aortic valve replacement (TAVR) has revolutionized our approach to treating severe aortic stenosis (AS). Despite significant improvements in mortality, readmissions after TAVR are common (1) and associated with increased health costs (2). Previous studies have examined 30-day readmissions and have estimated a significant associated health burden (2). However, limited data are available on TAVR readmissions beyond this time frame.

According to the 2016 Annual Report of the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapy Registry (3), 54,782 patients had undergone TAVR in the United States from 2012 to 2015. Despite the increase in volume of TAVRs from 4,627 in 2012 to 24,808 by the end of 2015, observed in-hospital mortality and 1-year mortality rates had declined over that time period (3).

TAVR was initially approved for patients with severe symptomatic aortic stenosis with high or prohibitive risk for surgical aortic valve replacement (4). Given the advanced age and significant comorbidities of these patients, thirty-day all-cause readmissions rates have remained high and range from 14.6% to 20.9% (1,2,5-7). In a study by Kolte *et al.*, (2), of 2,188 readmissions, the majority (61%) were due to a non-cardiac primary diagnosis. However, limited data are available on the causes and the temporal distribution of readmissions post-TAVR beyond this time frame. Further detailed analysis of longer outcomes beyond thirty days may provide better insight on the natural history of this patient population.

Unplanned readmissions to the intensive care unit are associated with higher rates of in-hospital mortality (8,9). Elderly individuals who survive their ICU stay have shown higher mortality than hospital controls (10). Several studies have shown a significant increase in mortality, re-hospitalizations, and increased healthcare utilization after an ICU admission (11,12). No data exists on long term outcomes in TAVR patients after unplanned ICU admissions.

Accordingly, the main objectives of our study were to characterize the incidence, causes, and outcomes of long-term readmissions for up to 3-year after TAVR. We also sought to examine outcomes in readmissions between different levels of care (ICU *vs*. non-ICU settings).

We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/cdt-20-916).

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the UPMC Institutional Review Board Committee (No. 18120143) with a waiver of individual consent due to the retrospective nature of the study.

Study population

We included all consecutive patients with severe aortic stenosis referred for TAVR from 2011 through 2017 at the University of Pittsburgh Medical Center (UPMC) and affiliated hospitals. Patients underwent comprehensive clinical evaluation by the designated Heart Team and deemed appropriate to undergo TAVR as suggested by the current 2017 ACC expert consensus decision pathway guidelines for TAVR (13). Clinical, laboratorial and procedural data were collected. Patients were clinically followed up in our program at 1, 6-, and 12-month post-TAVR, and annually thereafter. A full description of the clinical care received by patients is described in the Supplementary Data (Appendix 1). Detailed demographics, baseline comorbidities, echocardiographic parameters, procedural characteristics, and outcomes were recorded.

Outcomes

All-cause readmission was defined as any readmission occurring after discharge from the index TAVR procedure hospitalization. All readmissions were tracked within a large 40-hospital system and adjudicated via review of the electronic heath records (MHS) and classified based on primary readmission diagnoses (cardiac versus non-cardiac) and level of care (ICU versus non-ICU). In the case of discrepancies between diagnosis codes or lack of clarity, a consensus agreement (MHS, AM, SM) was reached on the primary readmission diagnosis. Cardiac readmissions were classified into TAVR-related, coronary artery disease, heart failure, arrhythmia, valvular, and pericardial disease. Non-cardiac readmissions were categorized into sepsis/infection, respiratory, liver disease, gastrointestinal, renal, trauma, vascular, hematological, neurological, malignancy, musculoskeletal, or others (Table S1). Secondary readmission diagnoses were not included. We used overlapping Kaplan-Meier curves, each illustrating freedom from readmission for the whole cohort for cardiac and non-cardiac readmissions. All-cause mortality was obtained from the review of the expiration summary for

Table 1 Baseline characteristics

	Total
Patients	1,037
Patient characteristics	
Age	81.8±7.85
Female	518 (50.0%)
Race	
White	970 (93.5%)
Black	21 (2.0%)
Other	46 (4.4%)
BMI	28.2±6.87
BSA	1.84±0.24
STS risk score	7.96±4.72
History and risk factors	
Diabetes	432 (41.7%)
Hypertension	927 (89.4%)
Tobacco use	
Current, every day smoker	55 (5.3%)
Former smoker	375 (36.2%)
Severe chronic lung disease	130 (12.5%)
Liver disease	98 (9.5%)
Sleep apnea	171 (16.5%)
Depression	161 (15.5%)
Dyslipidemia	833 (80.3%)
Dialysis	50 (4.8%)
History of cancer within 5 years	85 (8.2%)
Peripheral arterial disease	383 (36.9%)
CVA	138 (13.3%)
TIA	109 (10.5%)
Carotid stenosis	
Right	37 (3.6%)
Left	36 (3.5%)
Both	26 (2.5%)
Prior CABG	269 (25.9%)
Prior valve	115 (11.1%)
Prior PCI	362 (34.9%)
Prior MI	404 (39.0%)
Heart failure	839 (80.9%)
Arrhythmia	546 (52.7%)
Cardiogenic shock	2 (0.2%)

*All continuous variables are presented as mean ± SD. CVA, cerebrovascular accident; TIA, transient ischemic attack; CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention; MI, myocardial infarction

patients who died during a readmission, and through the Social Security Death Index (obtained from the updated Social Security Administration Death Master file, where our health-care system is certified by the Social Security Administration as an organization that is exempt from the three-year delay) for patients who were not readmitted.

Statistical analysis

Continuous variables are presented as mean ± SD and categorical variables as frequency (percentage). We analyzed inpatient readmissions based on primary diagnosis, ICU versus non-ICU designations, and time to readmission from index discharge (≤30 days, 30–90 days, 90 days <1-year). Kaplan Meier curves were used to estimate survival and readmission for both cardiac and non-cardiac causes. Instantaneous hazard functions were obtained (calculated as percent/month) to estimate the hazard of experiencing a cardiac or non-cardiac readmission and mortality stratified by level of care (ICU and non-ICU). Instantaneous hazard has been used previously to describe temporal risk of outcomes in TAVR patient populations (14). We have used readmission and mortality hazard curves to depict risk gradients over time.

For mortality after readmission, time zero was the day of procedure for those patients who did not have an inpatient readmission. For all other patients, time zero was the first day of the readmission. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Study population

Baseline characteristics of the 1,037 TAVR patients who survived their index hospitalization are shown in

Table 2 Post-procedural outcomes during index TAVR hospitalization

Variable	Total (n=1,037)
Sepsis	4 (0.4%)
Stroke	
Yes	5 (0.5%)
Yes, Hemorrhagic	1 (0.1%)
Yes, Embolic or Ischemic	23 (2.2%)
TIA	10 (1.0%)
Mechanical Ventilation >24 hrs	26 (2.5%)
Pneumonia	7 (0.7%)
Venous thrombosis or thromboembolic event	1 (0.1%)
Pleural effusion requiring drainage	35 (3.4%)
Acute or worsening renal failure	13 (1.3%)
New renal dialysis requirement	9 (0.9%)
Dialysis required after discharge	3 (0.3%)
Iliac or femoral artery dissection	1 (0.1%)
Limb ischemia	7 (0.7%)
Dysrhythmia requiring Perm. Device	
Pacemaker [1]	93 (9.0%)
ICD [2]	2 (0.2%)
Pacemaker/ICD [3]	1 (0.1%)
Cardiac arrest	14 (1.4%)
Aortic dissection	1 (0.1%)
Bleed/hemorrhage/embolic event due to anticoagulant therapy	4 (0.4%)
Tamponade	0 (0.0%)
Multisystem organ failure	5 (0.5%)
Atrial Fibrillation (excluding those in AFib at start of procedure)	82 (7.9%)

*All Continuous variables are presented as mean ± SD. TAVR, transcatheter aortic valve replacement.

Tables 1,2. The Society of Thoracic Surgeons Predicted Risk of Mortality (STS-PROM) was obtained on 942 of the 1,037 patients (mean STS Score 7.96±4.72). The mean age at the time of the procedure was 81.8±7.85 years, 518 (50%) were females. Patient comorbidities included diabetes (41.7%), hypertension (89.4%), history of heart failure (80.9%) current smoking status (5.2%), sleep apnea (16.5%), dialysis (4.8%), history of CVA (13.3%), history of TIA (10.5%), prior CABG (25.9%), prior valve surgery (11.1%), and prior MI (39%).

Over 75% of patients had NYHA Class III/IV at the time of the procedure. Initial presentation with cardiogenic shock was seen in 0.2% of the patients. Significant CAD (single vessel or more) was present in 65% of patients. Table S2 illustrates the echocardiographic characteristics of these patients. Pulmonary artery systolic pressure was 49.4±17.1 mmHg. Left ventricular ejection fraction (EF) was less than 50% in 28.1% of patients and 75.4% had aortic valve mean gradients of >40 mmHg. 11.3% of patients had an aortic mean gradient <40 mmHg and an EF <50 %.

Outcomes

There were readmissions due to noncardiac causes in 350 (34.4%) and cardiac causes in 208 (20.5%) during a mean 1.96 years of follow-up. The most common non-cardiac causes of readmission were sepsis/infection (14.3%), gastrointestinal (8.3%), and respiratory (4.8%), whereas heart failure (14.0%) and arrhythmias (4.6%) were the most common cardiac causes of readmission (*Table 3*).

Overall, the rate of non-cardiac readmissions was greater than the rate of cardiac readmissions and this trend persisted up to three years from the time of index discharge (*Figure 1*). Figure S1 illustrates the instantaneous hazard function for overall readmission, and shows the risk of a noncardiac readmission was highest in the period immediately following TAVR (~4.6%/month) with an early high hazard phase that gradually declined to 2.5%/month at 6-month, 1.7%/month at 1-year, 1.3%/month at 2-year, and 0.7%/month at 3-year. However, the risk of cardiac readmission remained stable throughout the 3-year follow-up period ranging from 0.7% to 1.2% per month.

Non-cardiac readmissions remained more prevalent than cardiac readmissions whether admitted to the ICU or a non-ICU setting (Figures S2,S3). The risk of non-cardiac readmissions exhibited a similar early high hazard phase immediately following TAVR (Figures S4,S5) in both ICU and non-ICU readmissions.

The overall mortality was 14.9% at 1-year, 25.2% at 2-year, and 38.3% at 3-year (*Figure 2*). Instantaneous hazard estimates of mortality showed an early high hazard phase shortly after TAVR (3.3% per month) that declined and stabilized but gradually increased after three years (1.1%/month at 6 months, 1%/month at 1-year, 1.3% at 2-year, 2.1% at 3 years) (Figure S6).

Table 3 Outcomes based on primary diagnosis of inpatient readmissions (N=1,037)

	Patients	Total number of events	Events/100 patient years*
Mortality	338		
Total readmissions	438	1,122	55.2
Cardiac	208	354	17.4
Ischemic heart disease	40	51	2.5
Heart failure	142	214	10.5
Arrhythmia	47	63	3.1
Valvular	17	20	1.0
Pericardial disease	5	6	0.3
Other TAVR related	3	4	0.2
Non-cardiac	350	764	37.6
Respiratory	49	66	3.2
Sepsis/infection	145	209	10.3
Liver disease	7	18	0.9
Gastrointestinal	84	113	5.6
Renal	35	42	2.1
Trauma	24	27	1.3
Vascular	20	27	1.3
Hematological	28	34	1.7
Neurological	46	50	2.5
Malignancy	26	38	1.9
Musculoskeletal	46	49	2.4
Endocrine	6	7	0.3
Genitourinary	2	2	0.1
Surgical	11	13	0.6
Urological	5	6	0.3
Other	57	63	3.1
ICU	191	260	12.8
Cardiac	66	81	4.0
Ischemic heart disease	8	8	0.4
Heart failure	38	46	2.3
Arrhythmia	14	15	0.7
Valvular	8	10	0.5
Pericardial disease	2	2	0.1
Other TAVR related	1	1	0.0
Non-cardiac	141	178	8.8

Table 3 (*continued*)

Table 3 (*continued*)

	Patients	Total number of events	Events/100 patient years*
Respiratory	16	20	1.0
Sepsis/infection	49	57	2.8
Liver disease	4	4	0.2
Gastrointestinal	25	25	1.2
Renal	8	8	0.4
Trauma	8	8	0.4
Vascular	5	5	0.2
Hematological	8	9	0.4
Neurological	16	16	0.8
Malignancy	6	6	0.3
Musculoskeletal	9	9	0.4
Endocrine	1	1	0.0
Genitourinary	1	1	0.0
Surgical	2	2	0.1
Urological	1	1	0.0
Other	6	6	0.3
Non-ICU	372	862	42.4
Cardiac	171	273	13.4
Ischemic heart disease	32	43	2.1
Heart failure	118	168	8.3
Arrhythmia	34	48	2.4
Valvular	10	10	0.5
Pericardial disease	4	4	0.2
Other TAVR related	2	3	0.1
Non-cardiac	291	586	28.8
Respiratory	37	46	2.3
Sepsis/infection	111	152	7.5
Liver disease	6	14	0.7
Gastrointestinal	64	88	4.3
Renal	30	34	1.7
Trauma	17	19	0.9
Vascular	16	22	1.1
Hematological	21	25	1.2
Neurological	31	34	1.7
Malignancy	22	32	1.6

Table 3 (*continued*)

Table 3 (*continued*)

	Patients	Total number of events	Events/100 patient years*
Musculoskeletal	38	40	2.0
Endocrine	5	6	0.3
Genitourinary	1	1	0.0
Surgical	10	11	0.5
Urological	4	5	0.2
Other	53	57	2.8

*Total follow-up time =2,033 years, mean follow-up time of 1.96 years. TAVR, transcatheter aortic valve replacement.

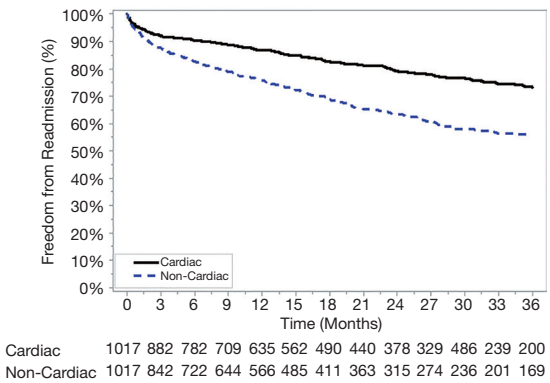

Figure 1 Kaplan-Meier estimates for overall readmissions (time from index discharge).

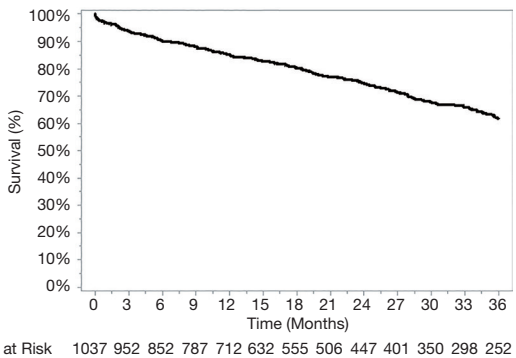

Figure 2 Kaplan-Meier estimates for overall mortality (time from procedure).

Mortality for patients who had no readmissions was approximately 0.8–1.1%/month throughout the 3-year follow-up period (*Figure 3*). Instantaneous hazard function estimates for mortality after readmissions ranged from 2.0–3.9%/month. Mortality risk was higher following any type of readmission as compared to no readmission (*Figure 3*). The highest risk for mortality was in the period shortly after TAVR (*Figure 3*). In addition, TAVR patients exhibited an increased risk of mortality after any ICU readmission during the three-year follow up period (*Figure 4*). Mortality rates after ICU readmissions ranged from 2.2–7.6%/month (*Figure 4*).

Discussion

There are three important observations from this analysis. First, our data show that non-cardiac causes remain the most common reason for readmissions after long term follow up. Second, there is a strong association between any readmission and mortality and the highest risk of readmission and subsequent mortality occurs immediately after the TAVR procedure. Finally, there is a high risk of mortality after any readmission at any point within the 3-year follow-up period, but it is particularly high after an ICU readmission.

Readmissions after TAVR are common with approximately 15–17% of patients requiring hospital readmission within 30 days and nearly half within one year of their procedure (1,2,6). Several studies have explored the incidence and outcomes of TAVR patients within 30-day (2) and 1-year (6,15,16) and have shown predominant non-cardiac causes of readmissions. Our data are consistent with these findings but extend them to up to a 3-year follow-up period. Moreover, one advantage of our study is that the causes of readmissions were individually adjudicated which is a limitation in other studies.

Given the observation that non-cardiac readmission is a significant issue among post-TAVR patients, it is increasingly relevant for those involved in the evaluation of such patients

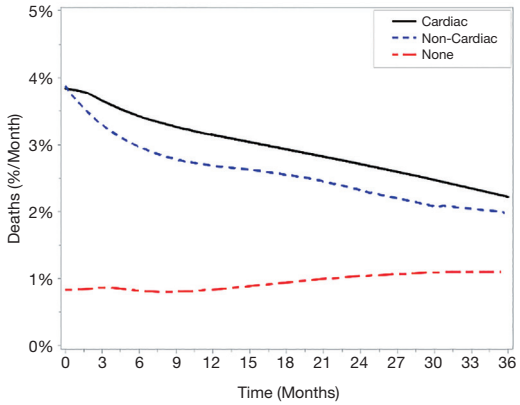

Figure 3 Mortality after readmission.

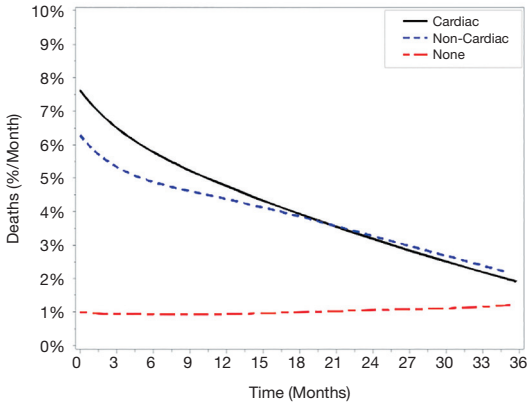

Figure 4 Mortality after ICU readmission.

to be attuned to the important non-cardiac issues, particularly in the highest risk patients. Patient baseline co-morbidities are an important consideration and play an ever-increasing role in patient selection and outcomes. In patients with end-stage renal disease who underwent TAVR, readmissions within 30 days was ~18.9% with significant post-procedure complications and 6-month mortality (25.6%) (17) which is greater than that seen in our mixed cohort (9.5% were dialysis dependent) (*Table 1*) All-cause mortality was found to be higher in patients with moderate to severe chronic lung disease despite improvement in functional class and quality of life (18) after TAVR which is an important consideration given that 12.5% of our population had severe lung disease. Cirrhotic patients showed readmission rates of ~16.2% with the majority of readmissions due to non-cardiac causes (85.7%) (19). Our data has shown that overall the most common non-cardiac causes of readmissions are due to sepsis/infection, gastrointestinal and respiratory causes.

Our data are consistent with previous findings of a preponderance of non-cardiac readmissions during early (<30 days) (2,6,7), and late (30 days to 1-year) (6,15,16) follow-up. Non-cardiac readmissions were predominant up to 3-year post-TAVR. Our data are unique in that we examined post-TAVR outcomes beyond 30-days to up to 3-year post procedure. The high incidence of noncardiac readmissions throughout this period is likely reflective of the advanced age and baseline comorbidities of the patients undergoing TAVR. This provides useful insight when informing patients of subsequent risks and projected outcomes.

There has been considerable change in the TAVR landscape over the past few years with improvements in TAVR technology, increased expertise, more high-volume centers (20), and wider selection of patients with less comorbidities. Since the advent of the SURTAVI (21) and PARTNER-2 intermediate risk trial (22), The United States Food and Drug Administration has expanded the use of TAVR for patients with severe aortic stenosis with intermediate surgical risk for surgical aortic valve replacement. This will potentially lead to including more patients with fewer comorbidities. Given the timeframe within which the present study performed these TAVR procedures, a high proportion of patients were of higher or prohibitive surgical risk as evidenced by the STS-PROM risk. Consequently, the evolving criteria for TAVR-eligible patients will lead to a shift of the characteristics of this population and future analyses will likely show better outcomes. Our analysis provides an important baseline comparator against which future studies could measure long-term outcomes following TAVR in the more modern era.

One advantage of our study is that all readmissions were adjudicated through the electronic medical records to determine the accuracy of the primary readmission diagnosis. 19 (1.7%) of the 1,123 readmissions were erroneously categorized. The primary readmission diagnosis was recategorized from noncardiac to cardiac in 12 of the readmissions.

The examination of both non-ICU and ICU readmissions after TAVR and their association with mortality has not been previously evaluated. Our analysis included instantaneous hazard function estimates for readmissions and mortality. There was an early high hazard phase with the highest risk for noncardiac readmissions immediately after the procedure which steadily declined thereafter. Overall, noncardiac readmissions were as high as 4.6%/month and declined to 0.7%/month by three years. In contrast, cardiac readmissions did not exhibit an early hazard phase and were stable over

this time period. When comparing this with instantaneous hazard function estimates for mortality, there is a similar early hazard phase that coincides with the high non-cardiac readmission rate. One potential explanation is that there is a higher mortality associated with these early non-cardiac readmissions due to the patients' baseline comorbidities. This will lead to an observed decrease in noncardiac readmissions because of mortality in this cohort due to competing risk. Mortality was higher for patients who had any type of readmission when compared to TAVR patients who were not readmitted. It is evident that mortality is highest amongst those TAVR patients who are readmitted to the ICU. Another important use of these observations is that it suggests that there may be opportunities to pay greater attention and divert more healthcare resources to patients who may have high risk for preventable readmissions. However, that will require further study.

It is important to consider the financial and economic burden of repeated admissions. Although TAVR costs were found to decrease over time while surgical replacement remained stable, aggregate costs of TAVR were significantly higher and dis not account for repeated readmissions (23).

Healthcare providers caring for TAVR patients should be cognizant of the many noncardiac issues that require a multidisciplinary approach for management. These comorbidities are significant factors not only in the pre-TAVR assessment but also ongoing care of the post-TAVR patient. Our study emphasizes the higher noncardiac readmission rates as well as increased mortality shortly after TAVR and after any readmission. This highlights the importance of robust discharge protocols and more intensive follow up and surveillance especially immediately after TAVR and after readmissions.

Limitations

There are limitations to our study which include the inherent drawbacks of any retrospective chart review. Despite adjudication of readmissions, categorization of primary readmission diagnosis was dependent on information available in the medical chart, however, we were encouraged by the consistent admissions diagnosis reporting of billing codes after chart review. Mortality data was obtained from the Social Security Death Index which does not provide detailed information regarding the cause of death.

We studied patients who had undergone TAVR at a quaternary referral center and affiliated hospitals. Our data does not include readmissions in hospitals outside the system, however many of these patients are subsequently transferred to our health care system. Given the size of our healthcare system within Western Pennsylvania we believe this represents a small proportion of the patient population.

The role of TAVR has expanded to include patients with intermediate risk and has shown similar 5-year outcomes to surgical aortic valve replacement (24). More recent trial have shown patients with aortic stenosis and low surgical risk having improved one year outcomes compared to surgery (25,26). With this ever-changing landscape it is unclear what the role of readmissions will play.

Another limitation of our study is the lack of details on subsequent discharge location [discharged home (self-care) or to nursing facilities] which could play a role in readmissions and mortality. Most of our patients were higher surgical risk patients with advanced age and baseline comorbidities. In light of changing cohorts referred for TAVR we expect lower non cardiac readmissions, but it is unclear whether cardiac readmissions will be more prevalent. High noncardiac readmissions may not be as prominent in intermediate risk patients who undergo TAVR. Future studies looking at readmissions in this patient population are warranted.

Conclusions

In a cohort of TAVR patients, non-cardiac readmissions were more prevalent than cardiac readmissions which persisted up to three years post procedure. The risk of readmission and mortality is highest immediately post-procedure and declines thereafter. Readmission to the ICU portends the highest risk of subsequent death in this cohort. Patient baseline co-morbidities are an important consideration for TAVR patients and play a significant role in readmissions and outcomes.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the UPMC Institutional Review Board Committee (No. 18120143) with a waiver of individual consent due to the retrospective nature of the study.

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Supplementary

Description of clinical care for TAVR patients

Pre-TAVR

At our institution, patients with severe symptomatic aortic stenosis (Stage D disease) who have been risk stratified and deemed as having high or surgically prohibitive risk by cardiothoracic surgery are referred for TAVR. They are evaluated by our designated Heart Team in either an outpatient or inpatient setting during which they undergo a thorough integrated personalized risk/benefit profile and a shared decision-making process. Standard TAVR workup includes an overall clinical and functional assessment of the patient and review of comorbid conditions. Patients will undergo a thorough echocardiographic assessment which may include transesophageal echocardiography. Computed tomography (CT) angiography is also performed to further delineate anatomy for optimal valve sizing and positioning. All patients undergo cardiac catheterization for a complete hemodynamic evaluation and coronary angiography. CT angiography of the thoracoabdominal and iliofemoral arteries is performed to determine suitability for access. After initial assessment and work up, eligible candidates are scheduled for their procedure. Other patients may undergo additional testing and subspecialist referral and are re-evaluated after optimization of their comorbid conditions.

TAVR procedure

TAVR at our institution is performed by a dedicated experienced joint team of interventional cardiologists and cardiothoracic surgeons in a hybrid operating room setting. The procedure is performed under general anesthesia. Patients receive prophylactic antibiotics pre- and post-procedurally. They are pre-treated with aspirin (81-325 mg) daily and receive a loading dose of clopidogrel 300 mg prior to the procedure. The procedure is performed under continuous invasive hemodynamic monitoring with fluoroscopic and transesophageal guidance.

Post-TAVR

Patients are monitored post procedurally in an ICU setting for at least 24 hours. Patients are mobilized early and discharged within several days. Long term TAVR follow up is provided at a specialized Heart Valve Clinic at 1, 6, and 12 months post TAVR wherein patients undergo clinical and echocardiographic assessment. Patients continue aspirin indefinitely and clopidogrel 75 mg daily for 3 months (self-expanding valves) or 6 months (balloon expandable valves). Patients maintain their routine follow up with their primary care providers.

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Table S1 Primary readmission diagnosis categories

CARDIAC
Ischemic heart disease
Non-ST-elevation Myocardial Infarction
ST-elevation Myocardial Infarction
In-stent restenosis
Heart Failure
Acute decompensated heart failure with reduced ejection fraction
Acute decompensated heart failure with preserved ejection fraction
Volume/Fluid overload secondary to heart disease
Arrhythmia
Atrial Fibrillation with rapid ventricular rate
Supraventricular tachycardia
Sinoatrial Block
Atrioventricular Block
Ventricular tachycardia and fibrillation
Syncope secondary to arrhythmia
Pacemaker or Defibrillator malfunction
Sick Sinus Syndrome
Pacemaker induced tachycardia
Valvular Heart disease
Paravavular leak
Valvular regurgitation or Stenosis
Acute infective endocarditis
Leaflet thrombosis
TAVR PROCEDURE RELATED
Heart Block directly related to Transcatheter Aortic Valve Replacement procedure
Transcatheter Aortic valve Replacement access site complications
Wound seroma
Wound dehiscence
Psuedoaneurysm
NON-CARDIAC
Respiratory
Acute exacerbation of chronic obstructive pulmonary disease
Hypercapnic respiratory failure
Pulmonary Fibrosis
Interstitial Lung disease

Table S1 (*continued*)

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Table S1 (*continued*)

CARDIAC
Tracheostomy malfunction
Symptomatic pleural effusions
Sepsis/Infections
Methicillin resistnt staphylococcus aureus bacteremia (No endocarditis)
Gram negative septicemia
Pseudomonas Bacteremia
Aspiration Pneumonia
Pyocystitis
Acute Enterocolitis due to Clostridium difficile
Cellulitis
Abscess
Viral infections
Influenza infection
Respiratory Syncytial Virus
Listerial sepsis
Osteomyelitis
Gastrointestinal
Acute Diverticulitis
Upper gastrointestinal bleeding
Lower gastrointestinal bleeding
Acute cholecystitis without obstruction
Angiodysplasia with bleeding
Acalculous cholecystitis
Acute intestinal obstruction without surgery
Peptic ulcer disease
Gastritis
Liver Disease
Acute Encephalopathy
Ascites
Hepatohydrothorax
Acute Liver Failure/Necrosis
Spontaneous bacterial peritonitis
Renal
Acute kidney injury
Uremia

Table S1 (*continued*)

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Table S1 (*continued*)

CARDIAC
Electrolyte Imbalance with need for urgent dialysis
Acute Interstitial Nephritis
Nephrotic Syndrome
Severe Hyponatremia
Trauma
Nasal bone fractures
Mechanical falls leading to fractures
Lacerations
Vascular (not related to TAVR)
Femoral Abscess
Arteriovenous Fistula repair/thrombectomy
Acute Limb ischemia
Gangrene
Pseudoaneurysm
Ocular
Acute angle closure glaucoma
Hematological/Bleeding (not including ICH)
Blood transfusion
Iron Deficiency Anemia
Supratherapeutic International Normalized ratio
Bleeding Diathesis
Unexplained pancytopenia
Thrombocytopenia
Neurological
Spontaneous intracerebral hemorrhage
Embolic Stroke (not in the immediate post Transcatheter Aortic Valve Replacement period)
Transient Ischemic Attack
Atraumatic subdural hematoma
Malignancy
Myelodysplastic Disorders
Leukemia
Lymphoma
Cervical Cancer
Musculoskeletal
Compression fractures

Table S1 (*continued*)

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Table S1 (*continued*)

CARDIAC
Atraumatic fractures
Peri-prosthetic fractures
Myalgias
Myositis
Spondylosis
Radiculopathy
Other
Alcohol Intoxication
Generalized weakness
Non-cardiac chest pain
Bleeding after dental extractions
Sacral Decubitus Ulcers
Epistaxis
Drug reactions/severe side effects
Major Depression
Acute Delirium
Epistaxis
Orthostatic hypotension
Failure to thrive

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Table S2 Echocardiographic baseline characteristics

Hemodynamics	Data
Left Ventricular Systolic Diameter	33.0 ± 9.41
Left Ventricular End-Diastolic Diameter	45.8 ± 8.20
Pulmonary Artery Systolic Pressure	49.4 ± 17.1
Ejection Fraction	53.3 ± 13.6
Ejection Fraction >=50%	746 (71.9%)
Aortic Mean Gradient (mmHg)	48.4 ± 14.4
<40 mmHg	233 (22.5%)
Aortic Valve Area (cm^2)	0.64 ± 0.18
Aortic Insufficiency	
None (0)	91 (8.8%)
Trace/Trivial (1)	238 (23.0%)
Mild (2)	397 (38.3%)
Moderate (3)	163 (15.7%)
Severe (4)	41 (4.0%)
Mitral Insufficiency	
None	28 (2.7%)
Trace/Trivial	204 (19.7%)
Mild	466 (44.9%)
Moderate	231 (22.3%)
Severe	56 (5.4%)
Mitral Stenosis	138 (13.3%)
Tricuspid Insufficiency	
None	11 (1.1%)
Trace/Trivial	258 (24.9%)
Mild	419 (40.4%)
Moderate	200 (19.3%)
Severe	50 (4.8%)
Aortic Valve Mean Gradient and Ejection Fraction	
AV Mean Gradient<40 and EF<50	117 (11.3%)
AV Mean Gradient<40 and EF≥50	116 (11.2%)
AV Mean Gradient≥40 and EF<50	162 (15.6%)
AV Mean Gradient≥40 and EF≥50	620 (59.8%)

*All Continuous variables are presented as Mean ± SD

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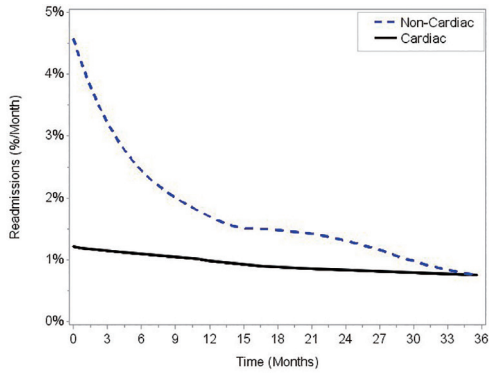

Figure S1 Instantaneous hazard function estimates for overall readmissions (N=1,017).

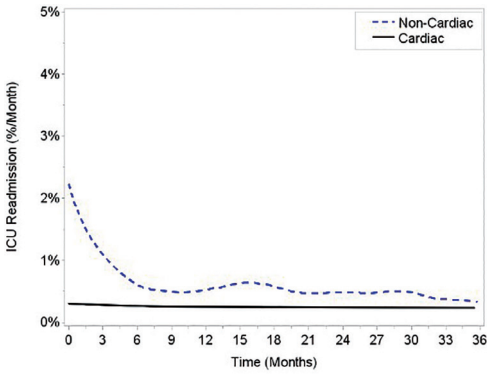

Figure S4 Instantaneous hazard function estimates for ICU readmission.

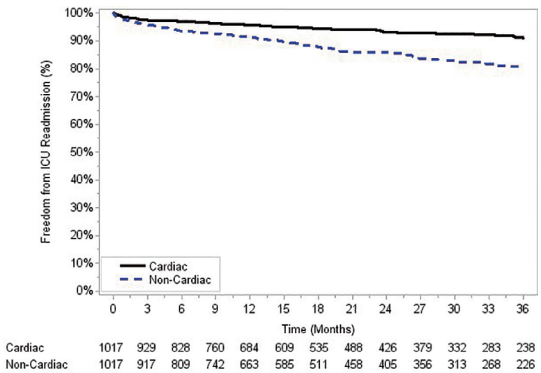

Figure S2 Kaplan-Meier Estimates for ICU readmissions (time from index discharge).

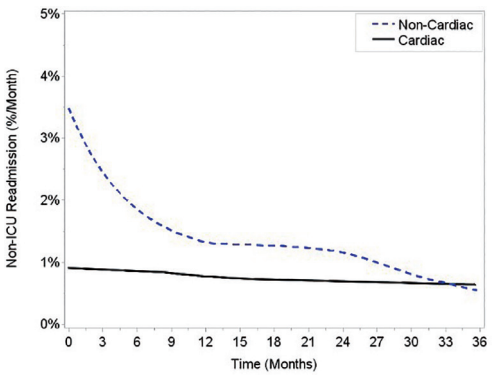

Figure S5 Instantaneous hazard function estimates for non-ICU readmissions.

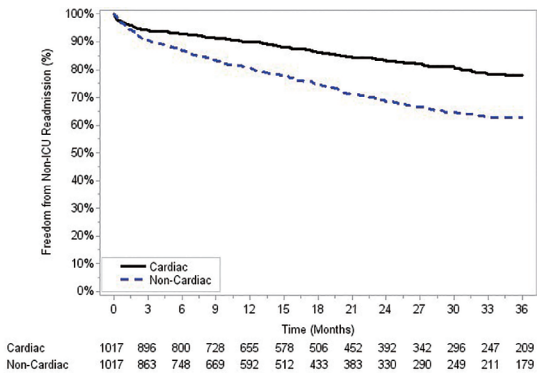

Figure S3 Kaplan-Meier estimates for non-ICU readmissions (time from index discharge).

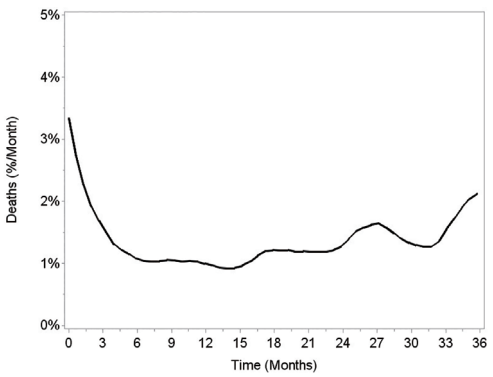

Figure S6 Instantaneous hazard function estimates for mortality (N=1,037).

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