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ORIGINAL RESEARCH

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Association between Red Blood Cell Transfusion and 30-day Readmission Following Transcatheter Aortic Valve Replacement

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ABSTRACT

Background: We sought to evaluate the association between post-procedural packed red blood cell (PRBC) transfusion following transcatheter aortic valve replacement (TAVR) and 30-day all-cause readmission. We assessed incidence, causes and predictors of 30-day readmission.

Methods: We retrospectively analyzed 417 patients who underwent TAVR and survived the index hospitalization. A propensity-score adjusted multivariable logistic regression model was utilized to relate PRBC transfusion to 30-day readmission and to identify predictors of 30-day readmission.

Results: The overall 30-day readmission rate was 19.4% and was for non-cardiac causes in 54.3% of patients. Of patients who received PRBC transfusion and those who were not transfused, 30.9% and 21.7% were readmitted within 30 days, respectively ($p = 0.08$). After propensity adjustment, the odds of readmission were not different among transfused and non-transfused patients (1.33 [95% CI 0.74, 2.40, $p = 0.34$]). However, among non-anemic patients, transfusion was associated with a greater likelihood of readmission (50% vs. 11.8%, OR 4.92 [95% CI 1.74, 13.91], $p = 0.003$), in contrast to anemic patients in whom it was not (OR 0.96, [95% CI 0.53, 1.73], $p = 0.89$; interaction $p = 0.002$). Independent predictors of 30-day readmission included history of atrial fibrillation (OR: 2.06; CI: 1.23, 3.46, $p = 0.006$), urgent TAVR procedure (OR: 2.29; CI: 1.20, 4.38, $p = 0.020$), discharge to nursing home or rehabilitation facility (OR: 1.95; CI: 1.11, 3.44, $p = 0.014$) and any post-operative complication (OR: 2.08; CI: 1.19, 3.63, $p = 0.007$).

Conclusions: Pre-procedure atrial fibrillation and urgent procedures are novel predictors of early readmission following TAVR. PRBC transfusion did not independently predict 30-day readmission following TAVR.

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KEYWORDS Aortic stenosis; transcatheter aortic valve replacement; post-procedural packed red blood cell transfusion; readmission

Introduction

Thirty-day readmission after hospitalization for cardiovascular conditions and procedures such as acute myocardial infarction (MI), heart failure and coronary artery bypass graft surgery (CABG) is common and adversely impacts health care costs.[1–7] Since rates of 30-day readmission are considered a marker of quality and hospital performance,[8,9] identifying predictors of early, unplanned readmission has been the subject of research. Transcatheter aortic valve replacement (TAVR) is increasingly performed in patients with symptomatic severe aortic stenosis (AS) who are deemed to be at prohibitive, high or intermediate surgical risk,[10] and 30-day readmission rates following TAVR range from 14.6% to 20.9%.[11–15] Readmission predictors include multiple baseline comorbidities, including anemia and lower left ventricular ejection fraction (LVEF) and procedural and post-procedural factors such as transapical access, peri-procedural bleeding, acute kidney injury (AKI), prolonged index hospitalization (> 5 days) and discharge to a nursing home.[14,15] Interestingly, while packed red blood cell (PRBC) transfusion following surgical aortic valve replacement (SAVR) is associated with higher readmission rates at 1 and 3 months,[16] no study has investigated whether post-TAVR PRBC transfusion is associated with readmission. PRBC transfusion has previously been associated with increased mortality and major adverse events in the setting of acute coronary syndrome,[17] percutaneous coronary intervention (PCI),[18] and cardiac surgery.[19] Different pathophysiologic mechanisms may explain the association of PRBC transfusion with mortality, including impaired oxygen delivery, decreased deformability of stored red blood cells, prothrombotic effects from increased release of procoagulant factors and transfusion-related immunosuppression.[18] The purpose of our study was to relate post-procedural PRBC transfusion with 30-day readmission following TAVR. Additionally, we sought to determine the incidence and causes of early readmission following TAVR and identify independent readmission predictors.

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Supplemental data for this article can be accessed here.
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Materials and methods

Data collection

All relevant demographic, clinical, procedural and follow-up variables were obtained from our institutional Transcatheter Valve Therapy (TVT) and Society of Thoracic Surgeons (STS) quality registries. Additional chart review was performed to address missing data. After hospital discharge, follow-up data, including vital status, was entered into the database after abstraction from hospital or office follow-up and referring physician encounters.

Study population

Consecutive patients with severe, symptomatic AS, who were deemed inoperable, high- or intermediate-risk for SAVR and treated with TAVR from March 2012 to December 2017 in a single center were eligible for inclusion. We excluded patients who died during index hospitalization (n = 12), resulting in a final population of 417 patients. Of note, of the 12 patients who died during index hospitalization, 10 (83.3%) received at least one unit of PRBC transfusion and 9 received three or more units. The study was approved by our Institutional Review Board and performed in accordance with the ethical standards defined in the 1964 Declaration of Helsinki. The need for informed consent was waived.

TAVR procedure

A multidisciplinary structural heart team performed patient screening and selection. Two interventional cardiologists and three cardiac surgeons performed the procedures using either the Edwards Sapien, Edwards Sapien XT, Edwards Sapien 3 or Medtronic CoreValve prosthesis. Vascular access sites included transfemoral, transapical, subclavian, and direct aortic. The procedures were performed under general anesthesia or conscious sedation. Our institutional practice has been to offer TAVT to inpatients presenting with a heart failure hospitalization, especially if multiple such admissions have occurred. The TVT registry considers TAVR procedures to be urgent when performed in patients hospitalized non-electively.

PRBC transfusion

Blood transfusion was defined as any red blood cell product given to a patient after the TAVR, during index hospitalization. We defined pre-operative anemia according to the World Health Organization (WHO) criteria as Hg< 12 g/dL in females and < 13 g/dL in males. In our institution, patients with Hg< 7 g/dL undergoing TAVR, routinely received PRBC transfusion before or after the procedure. Patients may have been transfused at higher levels of Hg earlier during the study period, in the presence of bleeding or vascular complications, or in the setting of hypotension or shock. In all instances, the decision to transfuse was left to the discretion of the treating physicians.

Outcomes

The primary outcome was the association between post-operative PRBC transfusion and 30-day unplanned readmission following TAVR. We also sought to determine predictors of 30-day readmission, independent of PRBC transfusion. All clinical end-points were defined as stipulated by the Valve Academic Research Consortium-2 (VARC-2).[20] Readmission included hospital ward or intensive care unit admissions within 30 days following index hospital discharge for TAVR. Time to readmission was calculated as the number of days between hospital discharge after index TAVR and the day of hospital readmission. For patients who had multiple readmissions within 30 days, only the first readmission was included. Causes of readmission were grouped as cardiac and noncardiac. Cardiac causes included: heart failure, acute coronary syndrome (unstable angina or MI), arrhythmia, conduction abnormalities, hypertension, pericardial effusion/tamponade and valve-related (endocarditis and prosthesis-related mechanical complications). Noncardiac causes included: cerebrovascular (ischemic or hemorrhagic stroke, transient ischemic attack), bleeding, respiratory (including pneumonia), infections, peripheral vascular complications, gastrointestinal, metabolic, trauma/falls, and other.

Statistical analysis

Continuous variables are presented as mean ± standard deviation (SD) in cases of a normal distribution or median with interquartile range in cases of a skewed distribution; these were compared with Student's t or Wilcoxon rank sum tests, respectively. Categorical data are presented as frequencies and percentages and were compared with Chi-square test or Fisher's exact test, as appropriate. Baseline patient characteristics, procedural characteristics and in-hospital complications were compared between patients who received and did not receive PRBC transfusion. Variables that differed at a significance level of $p < 0.2$ on univariate analysis were entered into multivariable regression models, to identify independent predictors of 30-day readmission. In order to minimize selection bias and confounding, we developed a propensity model to match patients on the likelihood of post-TAVR PRBC transfusion. The following variables were included in the propensity model: age, sex, race, body mass index (BMI), history of diabetes, prior stroke, history of peripheral artery disease (PAD), history of coronary artery disease (CAD), New York Heart Association (NYHA) functional class, LVEF before the procedure, access site, fluoroscopy time, platelets, international normalized ratio (INR) and creatinine before the procedure, major vascular complication and anesthesiologist in the procedure. When pre-procedure hemoglobin was included, it dominated the propensity model, with a c-statistic that showed near separation (c = 0.90) between those with and without transfusion. Consequently, pre-procedure hemoglobin was removed. The remaining variables discriminated well between patients who did and those who did not receive transfusion (c statistic = 0.81). A multivariable logistic regression model, adjusted for the propensity score was then constructed to predict the primary outcome. The results are

presented as odds ratios (OR) with 95% confidence intervals (CI). Statistical analysis was performed with SAS 9.2 (Cary, NC, USA). The level of statistical significance was set at $p < 0.05$.

Results

Patients

During the study period, 417 patients underwent TAVR at our Center. Clinical characteristics appear in Table 1. The average age of our population was 81.8 ± 8.1 years, 53% were male and 97.8% were white; 92.5% of the overall cohort had hypertension and 36.6% were diabetics. The overwhelming majority of patients had NYHA Class III or IV symptoms (90%). The mean LVEF was 55 ± 13%. Most patients had anemia at baseline; mean pre-procedure hemoglobin (g/dL) was 11.8 ± 1.8.

PRBC transfusion

PRBC transfusion post-TAVR occurred in 98 patients (23.5%); 33.3% of patients received at least 2 PRBC units (Figure 1). Patients who received PRBC transfusion were older than those who did not (83.6 ± 7.5 vs. 81.2 ± 8.2, $p = 0.013$), had a lower BMI (25.6 ± 6 vs. 28.8 ± 9.8, $p = 0.002$) and lower LVEF (52.5 ± 13.4 vs. 55.7 ± 12.8, $p = 0.03$). The transfusion rate for the transfemoral vs. transapical TAVR patients was 20.2% vs. 43.1% ($p < 0.001$).

TAVR

Procedural characteristics appear in Table 2. The majority of the patients in both groups underwent the procedure via a trans-femoral approach (83.2%) and almost all patients in our cohort received a version of the Edwards Sapien valve

Table 1. Baseline characteristics according to PRBC transfusion during index hospitalization.

	All patients (n = 417)	PRBC transfusion (n = 98)	No PRBC transfusion (n = 319)	*p*-value
Age (years)	81.8 ± 8.1	83.6 ± 7.5	81.2 ± 8.2	0.013
Male	221 (53%)	44 (44.9%)	177(55.5%)	0.07
White race	405 (97.8%)	97 (99.0%)	308 (97.5%)	0.69
BMI	28 ± 9.1	25.6 ± 6.0	28.8 ± 9.8	0.002
Hypertension	385 (92.5%)	92 (93.9%)	293 (92.1%)	0.57
Hyperlipidemia	371 (89.6%)	83 (85.6%)	288 (90.9%)	0.14
Diabetes	153 (36.6%)	42 (42.9%)	111 (34.8%)	0.5
Coronary artery disease	289 (69.3%)	71 (72.4%)	218 (68.3%)	0.44
Previous myocardial infarct	170 (40.9%)	46 (46.9%)	124 (39.0%)	0.16
Previous PCI	143 (34.4%)	28 (28.6%)	115 (36.1%)	0.17
Previous CABG	114 (27.3%)	26 (26.5%)	88 (27.6%)	0.84
Peripheral vascular disease	102 (24.5%)	31 (31.6%)	71 (22.3%)	0.06
COPD	134 (32.1%)	34 (34.7%)	100 (31.3%)	0.54
Previous pacemaker	41 (11.3%)	9 (10.5%)	32 (11.5%)	0.79
Previous ICD	43 (11.1%)	12 (12.2%)	31(10.7%)	0.67
Atrial fibrillation	163 (39.1%)	42 (42.9%)	121 (37.9%)	0.38
Hemodialysis	10 (2.4%)	7 (7.1%)	3 (0.9%)	0.002
Smoking	21 (5.8%)	6 (7.0%)	15 (5.4%)	0.6
Previous CVA	77 (18.4%)	15 (50.1%)	62 (19.4%)	0.22
Liver disease	17 (4.1%)	5 (5.2%)	12 (3.8%)	0.56
Cancer within 5 years	49 (12%)	11 (11.6%)	38 (12.1%)	0.90
NYHA Class III–IV	369 (90%)	94 (95.9%)	275 (88.1%)	0.02
Heart failure	403 (97.3%)	96 (99.0%)	307 (96.8%)	0.47
Angina	61 (14.6%)	19 (19.4%)	42 (13.2%)	0.13
Syncope	40 (9.7%)	14 (14.4%)	26 (8.2%)	0.07
Pre-procedure hemoglobin	11.8 ± 1.8	10.3 ± 1.5	12.2 ± 1.6	<0.001
Pre-procedure creatinine	1.2 ± 0.7	1.4 ± 0.9	1.2 ± 0.6	0.001
Pre-procedure platelets	199,619 ± 73,295	198,824 ± 76,679	199,861 ± 72,355	0.90
Pre-procedure INR	1.2 ± 0.4	1.2 ± 0.3	1.2 ± 0.4	0.49
Surgical risk:				
Inoperable (extreme risk or technical reason)	60 (16.6%)	21 (24.4%)	39 (14.1%)	0.25
High	208 (57.5%)	40 (56.3%)	168 (57.7%)	
Intermediate	89 (24.6%)	17 (23.9%)	72 (24.8)	
Mortality STS score	7.9 ± 5.5	10.6 ± 6.6	7.1 ± 4.9	<0.001
Mean LVEF (%)	55 ± 13	52.5 ± 13.4	55.7 ± 12.8	0.03
LVEF< 40%	59 (14.2%)	21 (21.4%)	38 (11.9%)	0.22

Note. PRBC, packed red blood cell; BMI, body mass index; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; ICD, implantable cardioverter-defibrillator; CVA, cerebrovascular accident; NYHA, New York Heart Association; INR, international normalized ratio; LVEF, lef ventricular ejection fraction.

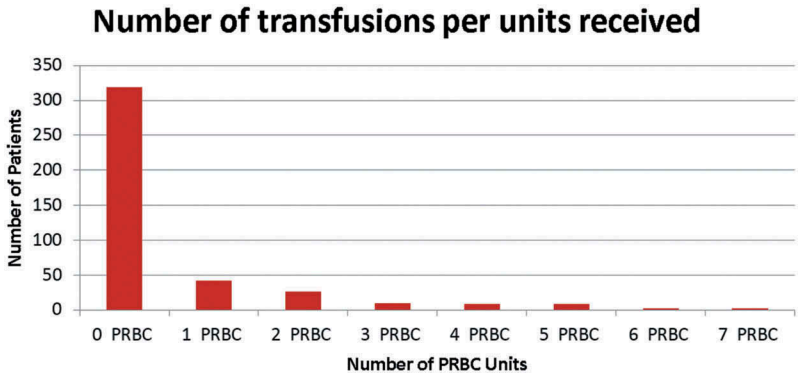

Figure 1. Rate of PRBC transfusion by number of units received. PRBC, packed red blood cell.

Table 2. Procedural characteristics.

	All patients (n = 417)	PRBC transfusion (n = 98)	No PRBC transfusion (n = 319)	*p*-value
Transfemoral access	347 (83.2%)	70 (71.4%)	277 (86.8%)	<0.001
Transapical access	53 (12.7%)	23 (23.5%)	30 (9.4%)	
Direct aortic access	8 (1.9%)	5 (5.1%)	3 (0.9%)	
Subclavian/axillary access	9 (2.2%)	0 (0.0%)	9 (2.8%)	
Edwards Sapien valve	406 (98.3%)	96 (99.0%)	310 (98.1%)	1.00
Medtronic Corevalve	7 (1.7%)	1 (1.0%)	6 (1.9%)	
Valve-in valve	30 (8.3%)	5 (5.8%)	25 (9.0%)	0.34
General anesthesia	289 (70.1%)	90 (92.8%)	199 (63.2%)	<0.001
Fluoroscopy time (mins)	17 ± 8.4	19.1 ± 11.0	16.3 ± 7.2	0.006
Contrast volume (cc)	88.8 ± 46.1	98.5 ± 60.3	85.9 ± 40.4	0.021
Procedure length (hours)	1.7 ± 0.7	2.1 ± 1.1	1.6 ± 0.4	<0.001
Urgent procedure	56 (13.5%)	21 (21.4%)	35 (11.0%)	0.008

Note. PRBC, packed red blood cell.

(98.3%). General anesthesia was administered to 70.1% of the patients and the procedure was performed urgently in 13.5% of cases. Standard anti platelet therapy consisted of aspirin 81 mg indefinitely and either clopidogrel, in the light of recent percutaneous coronary intervention or warfarin, if the patient was previously on warfarin for atrial fibrillation or other indication. The usual anticoagulation during the procedure was unfractionated heparin (86% of patients, 81% in the transfusion group and 88.2% in the non-transfusion group).

Transfusion and 30-day readmission

Overall, 81 (19.4%) patients were readmitted within 30 days and median time to readmission was 10 (IQR 3–18) days. Unadjusted readmission rates among those who received and did not receive PRBC transfusions were 30.9% and 21.7%, respectively (p = 0.08). After propensity adjustment, the odds of readmission in the overall cohort for those who received PRBC transfusion were 1.33 (95% CI 0.74, 2.40; p = 0.34). However, among non-anemic patients, transfusion was associated with a greater likelihood of readmission (50% vs. 11.8%, OR 4.92 [95% CI 1.74, 13.91], p = 0.003); this was in contrast to anemic patients in whom readmission was no more likely following transfusion (OR 0.96, [95% CI 0.53, 1.73], p = 0.89; interaction p = 0.002). PRBC transfusion was also related to the composite outcome, 30-day death/readmission (33.3% vs. 18.4% for transfused vs. not transfused, p = 0.001), but after propensity-adjustment, this difference was of borderline significance (OR: 1.72, 95% CI: 0.99, 2.98; p = 0.054).

Predictors of 30-day readmission

Compared with patients who were not readmitted within 30 days, those readmitted had higher prevalence of pre-procedure atrial fibrillation (53.1 % vs. 35.7%, p = 0.004) and transient ischemic attack (TIA)/stroke (24.7% vs. 17%, p = 0.05) (Supplemental Table 1). Most procedural characteristics were similar regardless of readmission status, except urgent TAVR, which was performed in 24.7% of patients who were readmitted but 10.7% of patients who were not (p < 0.001) (Supplemental Table 2). Patients who were readmitted within 30 days had a higher incidence of in-hospital complications compared to those not readmitted, including stroke and TIA (13.5% vs. 2.4%, p < 0.001), AKI (21.0% vs. 6.8%, p < 0.001), need for cardiac surgery following TAVR (4.9% vs. 0.6%, p = 0.01) and infectious complications (14.8% vs. 5.4%, p = 0.003) (Supplemental Table 3). Post-procedure Hg on the 30-day readmission group was 9.5 ± 1.5 vs. 9.9 ± 1.7 (p = 0.004) for the group that was not readmitted. Similarly, the Hg at discharge for the group that was readmitted was 10 ± 1.4 vs. 10.5 ± 1.6 (p = 0.001) for the non-readmission group. Index hospital length of stay was also longer in the readmission than non-readmission group (7.2 ± 6.5 vs. 5.1 ± 4.8, p = 0.001) and readmitted patients were more likely to have been discharged to a nursing home or rehabilitation facility compared to non-readmission patients (51.8% vs. 30.6%, p = 0.003). On multivariable analysis, history of atrial fibrillation (OR: 2.08; 95% CI: 1.23, 3.46; p = 0.006), urgent TAVR procedure (OR: 2.19; 95% CI: 1.13, 4.24; p = 0.020), discharge to nursing home or rehabilitation facility (OR: 1.95; CI: 1.11, 3.44; p = 0.014) and any post-operative complication (OR: 2.08; CI: 1.19, 3.63; p = 0.007) predicted 30-day readmission (Figure 2). Pre-procedure Hg, Hg at discharge and PRBC transfusion were not independent predictors of this outcome. STS Score was not an independent predictor of 30-day readmission in our cohort.

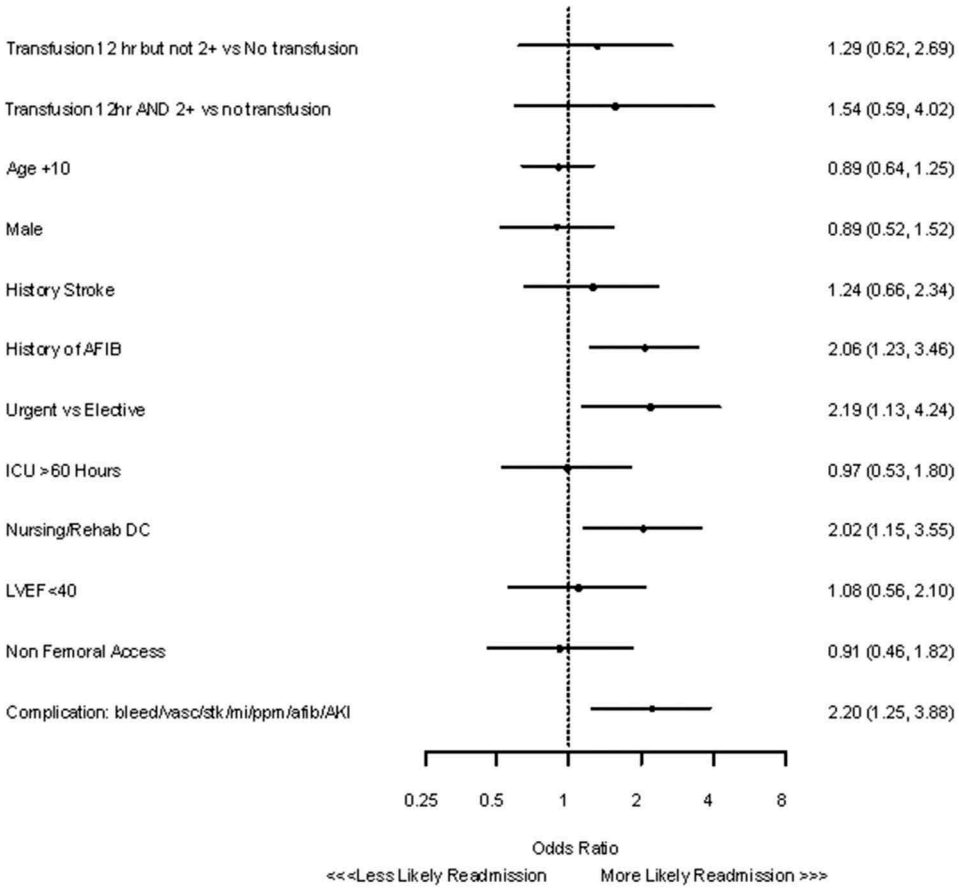

Figure 2. Independent predictors of 30-day readmission after TAVR. AFIB, atrial fibrillation; ICU, intensive care unit; DC, discharge; LVEF, left ventricular ejection fraction; TAVR, transcatheter aortic valve replacement.

Causes of 30-day readmission

Of the 81 readmissions in our cohort, 37 (45.7%) were the result of cardiac causes. Heart failure was most common among these (48%), followed by cardiac arrhythmia (20%), which was mainly driven by atrial fibrillation (13%). MI accounted for 15% of cardiac readmission, while readmission for permanent pacemaker and pericardial effusion were relatively uncommon. No patient was readmitted within 30 days for aortic valve re-intervention or mechanical complication. The most common causes of noncardiac readmissions were infections (19.5%), respiratory issues (17.3%), bleeding (15.2%, mainly gastrointestinal), and TIA/stroke (15.2%).

Discussion

In our study we report several important findings: (1) 19.4% of patients undergoing TAVR were readmitted within 30 days of their procedure; (2) history of atrial fibrillation and urgent TAVR procedure are novel independent predictors of 30-day readmission; (3) More than half of 30-day readmissions were for noncardiac causes; (4) Unlike in patients who undergo SAVR, PRBC transfusion does not appear to independently predict 30-day readmission; (5) PRBC transfusion is associated with higher 30-day readmission rate in patients who do not have anemia at baseline.

Readmission rates following cardiac procedures constitute a quality performance measure. At 30 days, they range from 9% to 24% after percutaneous coronary intervention and cardiac surgery[5–9] and approximately 20% following isolated SAVR.[21] National TAVR registries have reported 30-day readmission rates of 17–19%.[12,13,15] Our observed findings are in concordance with prior studies.

The ability to identify patients at risk for early readmission following TAVR is critical in optimizing associated health care resource utilization and cost. Prior studies have demonstrated that the presence of multiple (> 4) comorbidities in patients undergoing TAVR, particularly chronic kidney disease (CKD), predicts early readmission.[15] Others have demonstrated that comorbidities such as atrial fibrillation, CKD, PAD, and chronic obstructive lung disease predict late readmission between 30-days and 1 year following TAVR.[14] A history of major arrhythmia has also been associated with late readmission in prior reports.[14,22] We observed that the presence of pre-procedure atrial fibrillation was associated with early readmission post-TAVR. Although prior studies of TAVR have not identified history of atrial fibrillation as a predictor of 30-day readmission,[14,15] pre-procedure atrial fibrillation has been identified as a predictor of early readmission following CABG.[9,16] Urgent or emergent TAVR in patients who are in cardiogenic shock or decompensated heart failure is not frequently performed. A prior report

Table 3. In-hospital (index hospitalization) clinical outcomes/complications.

	All patients (n = 417)	PRBC transfusion (n = 98)	No PRBC transfusion (n = 319)	*p*-value
Stroke	13 (3.1%)	3 (3.1%)	10 (3.1%)	1.00
TIA	6 (1.4%)	1 (1.0%)	5 (1.6%)	
Peri-procedure RV perforation/tamponade	12 (2.9%)	11 (11.2%)	1 (0.3%)	<0.001
Myocardial infarction	3 (0.7%)	1 (1.0%)	2 (0.6%)	0.55
Cardiogenic shock	8 (1.9%)	7 (7.1%)	1 (0.3%)	<0.001
New atrial fibrillation	32 (7.7%)	9 (9.2%)	23 (7.2%)	0.52
New pacemaker	38 (9.1%)	11 (11.2%)	27 (8.5%)	0.41
Post-op creatinine	1.3 ± 1.1	1.7 ± 1.4	1.2 ± 0.9	<0.001
New hemodialysis	1 (0.2%)	0 (0.0%)	1 (0.3%)	1.00
Major vascular complication	42 (10.1%)	22 (22.4%)	20 (6.3%)	<0.001
Major bleeding	24 (5.7%)	22 (22.5%)	2 (0.6%)	<0.001
Cardiac surgery post procedure	6 (1.4%)	4 (4.1%)	2 (0.6%)	0.029
Infectious complication	30 (7.2%)	15 (15.3%)	15 (4.7%)	<0.001
Post-procedure hemoglobin	9.9 ± 1.7	8.4 ± 1.1	10.3 ± 1.5	<0.001
Hemoglobin at discharge	10.4 ± 1.6	9.5 ± 1.0	10.7 ± 1.6	<0.001
Length of hospital admission (days)	5.5 ± 5.2	9.2 ± 6.4	4.4 ± 4.2	<0.001
Surgery to discharge (days)	4.2 ± 3.6	6.8 ± 4.5	3.4 ± 2.9	<0.001
Total ICU hours	62.9 ± 51.6	87.0 ± 64.2	53.7 ± 42.5	<0.001
Discharge location				<0.001
Home	266 (64.3%)	44 (45.4%)	222 (70.0%)	
Transitional care unit/rehabilitation	130 (31.4%)	43 (44.3%)	87 (27.4%)	
Nursing home	14 (3.4%)	7 (7.2%)	7 (2.2%)	
Hospice	4 (1%)	3 (3.1%)	1 (0.3%)	

Note. PRBC, packed red blood cell; TIA, transient ischemic attack; RV, right ventricle; ICU, intensive care unit.

demonstrated increased 30-day mortality after emergent/urgent TAVR[23] and a recent study showed higher 1-year mortality in that same group, compared to patients undergoing the procedure electively.[24] However, our study is the first to identify that patients who undergo the procedure urgently are at increased risk for 30-day readmission as well. Additionally, peri-procedural complications, mainly driven by AKI, independently predicted 30-day readmission, a finding consistent with observations in prior studies.[25,26] In contrast to prior work,[14] bleeding complications and anemia at discharge did not predict readmission in our cohort. Finally, discharge to a nursing home or rehabilitation facility was an independent predictor of readmission, likely reflecting the frailty and comorbidities seen in this population.[15,27]

The majority of unplanned early readmission following TAVR in our cohort was noncardiac. Infections and respiratory disorders accounted for the majority of noncardiac readmission. Attention to proven strategies for reducing respiratory and access site infections may reduce readmission rates. As in prior reports,[14,15] the most common cause of cardiac readmission was for heart failure, which may be explained by the older population and the high prevalence of comorbidities such as hypertension, atrial fibrillation, CKD, CAD, and concomitant non-aortic valvular disease.[28–30] Interventions proven to decrease heart failure readmission from any cause may be helpful in the TAVR population as well.[31–33] Cardiac arrhythmia and especially post-operative atrial fibrillation is a known predictor of rehospitalization following cardiac surgery,[7,34] and TAVR[35,36] and was the second most common cause of cardiac readmission in our study.

Our study is the first to specifically investigate the association of PRBC transfusion post TAVR with 30-day readmission. We were unable to demonstrate that PRBC transfusion is an independent predictor of early readmission following the procedure. We did, however, observe a numerical difference in 30-day death/readmission rates between patients who received PRBC transfusion and those who did not, however this difference was of borderline statistical significance. Further investigation of the association between PRBC transfusion and 30-day readmission in larger registries may be worthwhile, as PRBC transfusion post-TAVR has been associated with other adverse outcomes, including increased morbidity and mortality.[37–39]

PRBC transfusion and 30-day readmission rates have significantly decreased over time in our institution (Figure 3). There are multiple possible explanations for this observation, including advances in equipment, improvement in operator technical expertise, changes in patients' selection, greater utilization of transfemoral access site and implementation of a more restrictive transfusion strategy. As highlighted in the figure, the rate of vascular and bleeding complications remained low and relatively stable over the course of the study period.

The majority of patients in our study had anemia at baseline. Baseline pre-procedural anemia is a known predictor of increased mortality in patients undergoing TAVR. Studies have shown that anemic patients require more PRBC transfusion and have increased 30-day and 1-year mortality.[40,41] Pre-procedure anemia has also been identified as a predictor of early readmission following TAVR. In our study, we showed that patients who did not have baseline anemia and received PRBC transfusion during index hospitalization had a higher 30-day readmission rate compared to those who had baseline anemia and were

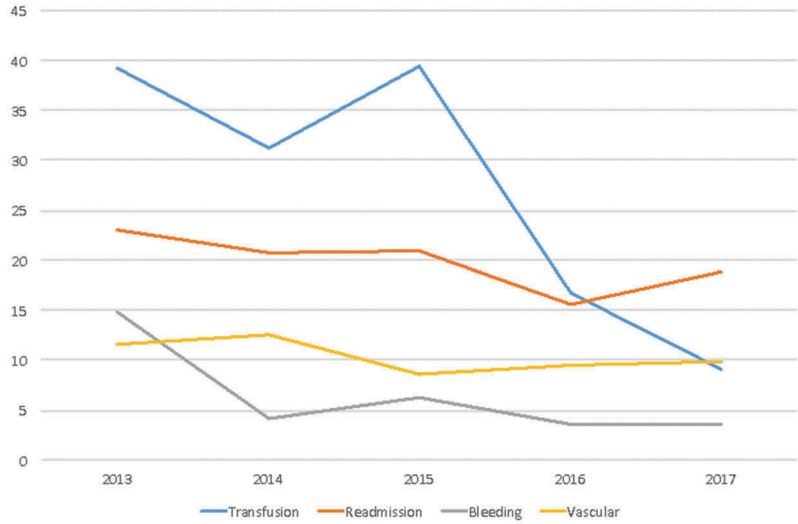

Figure 3. Rate of readmission, PRBC transfusion and bleeding/vascular complications over time in a single institution. PRBC, packed red blood cell.

transfused. That observation may be explained by the fact that non-anemic patients likely received transfusion for a complication associated with the procedure (vascular or bleeding complication or hypotension/shock), likely representing "a sicker population," which subsequently translated to need for repeat hospitalization. That said, our study was not designed to evaluate the association between pre-procedure anemia and readmission, but rather that of PRBC transfusion and readmission following TAVR.

Our study has several limitations. It is a retrospective, observational, single-center cohort; consequently, unmeasured confounders may have affected the results and results may not be applicable to all patients who undergo TAVR. In addition, the small number of patients and small number of clinical outcomes may have limited our statistical power, especially with respect to the relationship between PRBC transfusion and readmission.

Conclusion

PRBC transfusion did not independently predict 30-day readmission following TAVR. Pre-procedure atrial fibrillation, urgent TAVR, peri-procedure complications and discharge to a nursing home or rehabilitation facility independently predicted early readmission. The identification of patients at risk and the implementation of strategies to reduce readmission are critical to reducing adverse outcomes while improving healthcare resource utilization.

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Disclosure statement

No potential conflicts of interest were reportd by the authors.

References

1. Ashton CM, Del Junco DJ, Souchek S, Wray NP, Mansyur CL. The association between quality of inpatient care and early readmission: a meta-analysis of the evidence. *Med Care*. 1997;35:1044–1059.
2. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the medicare fee-for service program. *N Engl J Med*. 2009;360:1418–1428. doi:10.1056/NEJMsa0803563.
3. Curtis JP, Schreiner G, Wang Y, et al. All-cause readmission and repeat revascularization after percutaneous coronary intervention in a cohort of medicare patients. *J Am Coll Cardiol*. 2009;54:903–907. doi:10.1016/j.jacc.2009.04.076.
4. Wasfy JH, Strom JB, O'Brien C, et al. Causes of short-term readmission after coronary percutaneous intervention. *Circ Cardiovasc Interv*. 2014;7:97–103. doi:10.1161/CIRCINTERVENTIONS.113.000988.
5. Iribarne A, Chang H, Alexander JH, et al. Readmissions after cardiac surgery: experience of the National Institutes of Health/Canadian Institutes of Health research cardiothoracic surgical trial network. *Ann Thorac Surg*. 2014;98:1274–1280. doi:10.1016/j.athoracsur.2014.06.059.
6. Maniar HS, Bell JM, Moon MR, et al. Prospective evaluation of patients readmitted after cardiac surgery: analysis of outcomes and identification of risk factors. *J Thorac Cardiovasc Surg*. 2014;147:1013–1018. doi:10.1016/j.jtcvs.2013.10.066.
7. Shahian DM, He X, O'Brien SM, et al. Development of a clinical registry-based 30-day readmission measure for coronary artery bypass grafting surgery. *Circulation*. 2014;130:399–409. doi:10.1161/CIRCULATIONAHA.113.007541.
8. Cassel CK, Conway PH, Delbanco SF, Jha AK, Saunders RS, Lee TH. Getting more performance from performance measurement. *N Engl J Med*. 2014;371:2145–2147. doi:10.1056/NEJMp1408345.
9. Horwitz LI, Partovian C, Lin Z, et al. Development and use of an administrative claims measure for profiling hospital-wide performance on 30-day unplanned readmission. *Ann Intern Med*. 2014;161(Suppl 10):S66–75. doi:10.7326/M13-3000.
10. Holmes DR, Nishimura RA, Grover FL, et al. Annual outcomes with transcatheter valve therapy: from the STS/ACC TVT registry. *J Am Coll Cardiol*. 2015;66:2813–2823. doi:10.1016/j.jacc.2015.10.021.
11. Hannan EL, Samadashvili Z, Jordan D, et al. Thirty-day readmissions after transcatheter aortic valve implantation versus surgical aortic valve replacement in patients with severe aortic stenosis in New York State. *Circ Cardiovasc Interv*. 2015;8:e002744. doi:10.1161/CIRCINTERVENTIONS.115.002744.

12. Holmes DR, Brenna JM, Rumsfeld JS, et al. STS/ACC TVT registry. Clinical outcomes at 1 year following transcatheter aortic valve replacement. *JAMA*. 2015;313:1019–1028. doi:10.1001/jama.2015.1474.
13. Murugiah K, Wang Y, Desai NR, Nuti SV, Krumholz HM. Hospital variation in outcomes for transcatheter aortic valve replacement among medicare beneficiaries, 2011 to 2013. *J Am Coll Cardiol*. 2015;66:2678–2679. doi:10.1016/j.jacc.2015.10.008.
14. Nombela-Franco L, Del Trigo M, Morrison- Polo G, et al. Incidence, causes and predictors of early (<30 days) and late unplanned hospital readmissions after transcatheter aortic valve replacement. *JACC Cardiovasc Interv*. 2015;8:1748–1757. doi:10.1016/j.jcin.2015.07.022.
15. Kolte D, Khera S, Sardar R, et al. Thirty-day readmissions after transcatheter aortic valve replacement in the United States, insights from the nationwide readmissions database. *Circ Cardiovasc Interv*. 2017;10:e004472. doi:10.1161/CIRCINTERVENTIONS.116.004472.
16. Pack Q, Priya A, Lagu T, et al. Development and validation of a predictive model for short- and medium-term hospital readmission following heart valve surgery. *J Am Heart Assoc*. 2016;5(9):e003544. doi:10.1161/JAHA.116.003544.
17. Chatterjee S, Wetterslev J, Sharma A, Lichstein E, Mukherjee D. Association of blood transfusion with increased mortality in myocardial infarction: a meta-analysis and diversity-adjusted study sequential analysis. *JAMA Intern Med*. 2013;173:132–139. doi:10.1001/jamainternmed.2013.2512.
18. Doyle BJ, Rihal CS, Gastineau D, Holmes DR Jr. Bleeding, blood transfusion, and increased mortality after percutaneous coronary intervention: implications for contemporary practice. *J Am Coll Cardiol*. 2009;53:2019–2027. doi:10.1016/j.jacc.2008.12.073.
19. Murphy GJ, Reeves BC, Rogers CA, Rizvi SI, Culliford L, Angelini GD. Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. *Circulation*. 2007;116:2544–2552. doi:10.1161/CIRCULATIONAHA.107.698977.
20. Kappetein AP, Head SJ, Genereux P, et al. Valve academic research consortium-2. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the valve academic research consortium-2 consensus document. *J Am Coll Cardiol*. 2012;60:1438–1454. doi:10.1016/j.jacc.2012.09.001.
21. Barreto-Filho JA, Wang Y, Dodson JA, et al. Trends in aortic valve replacement for elderly patients in the United States, 1999-2011. *JAMA*. 2013;310:2078–2085. doi:10.1001/jama.2013.282437.
22. Lindman BR, Stewart WJ, Pibarot P, et al. Early regression of severe left ventricular hypertrophy after transcatheter aortic valve replacement is associated with decreased hospitalizations. *JACC Cardiovasc Interv*. 2014;7(6):662–673. doi:10.1016/j.jcin.2014.02.011.
23. Frerker C, Schewel J, Schluter M, et al. Emeregncy transcatheter aortic valve replacement in patients with cardiogenic shock due to acutely decompensated aortic stenosis. *EuroInterevntion*. 2016;11(13):1530–1536. doi:10.4244/EIJY15M03_03.
24. Kolte D, Khera S, Vemulapalli S, et al. Outcomes following urgent/emergent transcatheter aortic valve replacement: insights form the STS/ACC TVT registry. *JACC Cardioavsc Interv*. 2018. doi:10.1016/j.jcin.2018.03.002.
25. Genereux P, Kodali SK, Green P, et al. Incidence and effects of acute kidney injury after transcatheter aortic valve replacement using the new valve academic research consortium criteria. *Am J Cardiol*. 2013;111:100–105. doi:10.1016/j.amjcard.2012.08.057.
26. Arsalan M, Squiers JJ, Farkas R, et al. Prognostic usefulness of acute kidney injury after transcatheter aortic valve replacement. *Am J Cardiol*. 2016;117:1327–1331. doi:10.1016/j.amjcard.2016.01.037.
27. Lee DH, Buth KJ, Martin BJ, Yip AM, Hirsch GM. Frail patients are at increased risk for mortality and prolonged institutional care after cardiac surgery. *Circulation*. 2010;121:973–978. doi:10.1161/CIRCULATIONAHA.108.841437.
28. Rodes- Cabau J, Webb JG, Cheung A, et al. Long-term outcomes after transcatheter aortic valve implantation: insights on prognostic factors and valve durability from the Canadian multi-center experience. *J Am Coll Cardiol*. 2012;60:1864–1875. doi:10.1016/j.jacc.2012.08.960.
29. Urena M, Webb JG, Eltchaninoff H, et al. Late cardiac death in patients undergoing transcatheter aortic valve replacement: incidence and predictors of advanced heart failure and sudden cardiac death. *J Am Coll Cardiol*. 2015;65:437–448. doi:10.1016/j.jacc.2014.11.027.
30. Himbert D, Vahanian A. Transcatheter aortic valve replacement for patients with heart failure. *Heart Fail Clin*. 2015;11:231–245. doi:10.1016/j.hfc.2014.12.003.
31. Bradley EH, Curry L, Horwitz LI. Hospital strategies with 30-day readmission rates for patients with heart failure. *Circ Cardiovasc Qual Outcomes*. 2013;6:444–450. doi:10.1161/CIRCOUTCOMES.111.000101.
32. Jack BW, Chetty VK, Anthony D, et al. A reengineered hospital discharge program to decrease rehospitalization: a randomized trial. *Ann Intern Med*. 2009;150:178–187. doi:10.7326/0003-4819-150-3-200902030-00007.
33. Naylor MD, Brooten DA, Campbell RL, Maislin G, McCauley KM, Schwartz JS. Transitional care of older adults hospitalized with heart failure: a randomized, controlled trial. *J AM Geriatr Soc*. 2004;52:675–684. doi:10.1111/j.1532-5415.2004.52202.x.
34. Aranki SF, Shaw DP, Adams DH, et al. Predictors of atrial fibrillation after coronary artery surgery; Current trends and impact on hospital resources. *Circulation*. 1996;94:390–397. doi:10.1161/01.CIR.94.3.390.
35. Chopard R, Teiger E, Meneveau N, et al. FRANCE-2 investigators. Baseline characteristics and prognostic implications of pre-existing and new-onset atrial fibrillation after transcatheter aortic valve implantation: results from the FRANCE-2 registry. *JACC Cardiovasc Interv*. 2015;8:1346–1355. doi:10.1016/j.jcin.2015.06.010.
36. Biviano AB, Nafiz T, Dizon J, et al. Atrial fibrillation is associated with increased mortality in patients undergoing transcatheter aortic valve replacement.: insights form the placement of aortic transcatheter valve (PARTNER) trial. *Circ Cardiovasc Interv*. 2016;9:e002766. doi:10.1161/CIRCINTERVENTIONS.115.002766.
37. Tchetche D, Van der Boon RM, Dumonteil N, et al. Adverse impact of bleeding and transfusion on the outcome post-transcatheter aortic valve implantation: insights from the Pooled-RotterdAm-Milano-Toulouse In Collaboration plus (PRAGMATIC plus) initiative. *Am Heart J*. 2012;164:402–409. doi:10.1016/j.ahj.2012.07.003.
38. Escarcega R, Lipinski M, Magalhaes M, et al. Impact of blood transfusions on short- and long-term mortality in patients who underwent transcatheter aortic valve implantation. *Am J Cardiol*. 2015;115(93e):99. doi:10.1016/j.amjcard.2014.09.046.
39. Seiffert M, Conradi L, Terstesse A, et al. Blood transfusion is associated with impaired outcome after transcatheter aortic valve implantation. *Catheter Cardiovasc Interv*. 2015;85:460–467. doi:10.1002/ccd.25691.
40. Nuis RJ, Sinning JM, Rodes-Cabau J, et al. Prevalence, factors associated with, and prognostic effects of preoperative anemia on short- and long-term mortality in patients undergoing transcatheter aortic valve implantation. *Circ Cardiovasc Interv*. 2013;6:625–634. doi:10.1161/CIRCINTERVENTIONS.113.000409.
41. Seiffert M, Conradi L, Gutwein A, et al. Baseline anemia and its impact on midterm outcome after transcatheter aortic valve implantation. *Cardiovasc Interv*. 2017;89:44–52. doi:10.1002/ccd.26563.