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Risk scoring model for prediction of non-home discharge after transcatheter aortic valve replacement

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Abstract

Background Patients undergoing transcatheter aortic valve replacement (TAVR) are likely to be discharged to a location other than home. We aimed to determine the association between preoperative risk factors and non-home discharge after TAVR. **Methods** Patients discharged alive after TAVR at three centers were identified from a prospectively maintained database randomly divided into 80% derivation and 20% validation cohorts. Logistic regression models were fit to identify preoperative factors associated with non-home discharge in the derivation cohort. Multivariable models were developed and a nomogram based risk-scoring system was developed for use in preoperative counseling. **Results** Between June 2012 and December 2018, a total of 1,163 patients had TAVR at three centers. Thirty-seven patients who died before discharge were excluded. Of the remaining 1,126 patients (97%) who were discharged alive, the incidence of non-home discharge was 25.6% (n = 289). The patient population was randomly divided into the 80% (n = 900) derivation cohort and 20% (n = 226) validation cohort. Mean ± SD age of the study population was 83 ± 8 years. In multivariable analysis, factors that were significantly associated with non-home discharge were extreme age, female sex, higher STS scores, use of general anesthesia, elective procedures, chronic liver disease, non-transfemoral approach and postoperative complications. The unbiased estimate of the C-index was 0.81 and the model had excellent calibration. **Conclusions** One out of every four patients undergoing TAVR is discharged to a location other than home. Identification of preoperative factors associated with non-home discharge can assist patient counseling and postoperative disposition planning.

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1 Introduction

Transcatheter aortic valve replacement (TAVR) is now an intervention of choice among inoperable aortic patients and a viable alternative to surgery in high and intermediate operative risk patients with advanced age.[1] Advanced aged patients undergoing valve replacement can be complicated and sometimes challenging to manage mainly due to their advanced age, multiple comorbidities and frail state. In addition to the disease burden carried by inoperable aortic, these co-existing factors can affect their daily lifestyle and thus creating an malfunctional state of health.[2,3]

As the number of TAVR procedures has increased over the past decade, better quality of life has surpassed increased survival as the main goal for treatment especially for advanced aged patients.[4,5] The multiple co-existing conditions TAVR patients present with, render them prone to slower postoperative recovery. Moreover, some of these patients are frail and may observe a decline in functional capacity, thus necessitating discharge to a location other than home.

Approximately 20% of patients who undergo valve surgeries and 11% of patients who have coronary artery bypass graft (CABG) surgeries are discharged to a skilled nursing facility.[6] Among patients undergoing conventional valve surgeries, those discharged to a facility other than home report worse survival in the long-term.[7] Only 30% of CABG patients discharged to long-term acute care facilities post-procedure are alive at one-year follow-up and most of them do not return to their previous lifestyles.[8] For TAVR

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patients, the use of these facilities is expected to increase, given the extreme age of patients and concerted push for shorter hospital stay post-procedure.

The implications of discharge locations on healthcare resource utilization are important to optimize the benefits of this evolving technology. The present study aims to describe the incidence of non-home discharge after TAVR and develop a risk scoring system to assist patient counseling and postoperative disposition planning.

2 Methods

2.1 Study population

This study is a retrospective chart review of a prospectively maintained TAVR database of all patients who underwent TAVR at three centers between June 2012 and December 2018. Study inclusion criteria were patients who (1) fulfilled the criteria for inoperable aortic, per the American College of Cardiology/American Heart Association guidelines;[1] (2) were discharged alive after TAVR; and (3) had complete information on discharge location post-TAVR. Preoperative assessment was done by a heart team that included at least two cardiac surgeons and an interventional cardiologist. TAVR was proposed as a treatment option for patients who were deemed non-eligible for surgical valve replacement based on their overall surgical risk. The Society of Thoracic Surgeons (STS) risk score and frailty status of patients were two main elements used to risk stratify patients.

Preoperative screening also included transesophageal echocardiography, cardiac catheterization, thoracic and abdominal computer tomography and objective frailty assessment. Frailty was assessed by using a frailty index that represented the different domains of frailty previously described by Freid, *et al*.[9] Our method of assessing frailty has been previously described in detail.[10] In brief, patients were assigned a score of 0 or 1 when deemed as non-frail or frail per the four domains of frailty. A combined score ranging from 0 to 4 that consisted of scores from frailty components was developed. Patients were classified as frail if their total frailty score was greater than 3 out of 4 and non-frail if their total frailty score was less than 3 out of 4. Patients with inadequate iliofemoral access based on imaging findings were recommended a non-trans femoral approach for TAVR. Among these patients, TAVR was performed via the transapical, transaortic, subclavian and trans-axillary routes. The final study population did not include patients who attempted TAVR, but later had it converted to an open procedure.

Preoperative and postoperative clinical and echocardiographic data of patients were collected and compared among patient groups. Data collected included baseline clinical, demographics and peri-procedural. Patient's co-morbidities were obtained by using the definitions provided by the STS data collection system. Peri-operative morbidities were defined per criteria defined by the second version of the Valve and Academic Research Consortium (VARC-2).[11]

Study patients were divided into two groups according to their discharge disposition. Patients who were discharged home after the procedure were defined as the discharge to home group, whereas those discharged to a location other than home were described as non-home discharge group. Demographics and baseline clinical characteristics were collected and compared for both home and non-home discharge groups.

2.2 Statistical analysis

The entire patient population was randomly divided into 80% derivation ad 20% validation groups. Cross-validation was applied to observe how the model classifies the new data set. Data were summarized using standard descriptive statistics, mean ± SD for continuous variables, and frequency and percentage for categorical variables. The primary outcome of interest was non-home discharge. Two groups of comparisons for non-home discharge and home were analyzed via two-tailed Student's *t*-tests or Pearson's chi-square test for continuous and categorical variables. To determine the independent risk factors for non-home discharge, univariate and multivariable logistic regression models were constructed. The results of the logistic regression models were reported using odds ratio (OR), 95% confidence interval (CI), and *P*-value. The variables that are significant at P-value < 0.20 in univariate logistic regression models were maintained for the multivariable logistic regression model. Backward elimination with likelihood ratio test was performed with *P*-values are 0.05 and 0.10 for model entry and removal in backward elimination, respectively. Receiver operating characteristic (ROC) analysis was conducted to specify cut-off point for the predicted probabilities in logistic regression. A nomogram based on the final model's predicted probabilities for non-home discharge was created. Discrimination and calibration was assessed for the final model by using 1,000 bootstrap samples with the same sample size in the final model. A logistic regression model was conducted in each bootstrap sample. Calibration was figure out by plotting the observed proportion of a non-home discharge versus the predicted probabilities estimated from the model. The Hosmer-Leesha χ^2 goodnes-of-fit statistic was reported. Further sensitivity analyses were performed to determine the different risk categories for non-home discharge. Patients were risk stratified into low, intermediate and high risk categories. All data were analyzed using conducted in RStudio (version 1.1.442). The level of statistical significance was set at *P*-value < 0.05.

3 Results

Between June 2012 and December 2018, a total of 1,163 patients had TAVR at three centers. Thirty-seven patients who died before discharge were excluded from the present study. Of the remaining 1,126 patients (97%) who were discharged alive, the incidence of non-home discharge was 25.6% (*n* = 289). Respective locations of non-home discharge were (1) rehabilitation facility (*n* = 205); (2) long term care (*n* = 47); and (3) nursing home (*n* = 37). The patient population was randomly divided into the 80% (*n* = 900) derivation cohort and 20% (*n* = 226) validation cohort.

Randomly assigned derivation and validation cohorts were compared according to their baseline demographic and clinical characteristics (Table 1). Given in Table 2 are results of the multivariable stepwise logistic regression analysis. In multivariable analysis, factors that were significantly associated with non-home discharge were extreme age (OR = 1.08, 95% CI: 1.051–1.109, *P* = 0.001), female sex (OR = 0.45, 95% CI: 0.31–0.67, *P* = 0.001), elective procedures (OR = 0.258, 95% CI: 0.153–0.433, *P* < 0.001), history of CABG (OR = 0.486, 95% CI: 0.283–0.833, *P* = 0.009), dyslipidemia (OR = 0.671, 95% CI: 0.455–0.989, *P* = 0.044), chronic liver disease (OR = 4.143, 95% CI: 1.415–12.126, *P* = 0.009), history of pacemaker (OR = 2.241, 95% CI: 1.335–3.706, *P* = 0.002), non-transfemoral approach (OR = 0.436, 95% CI: 0.278–0.684, *P* < 0.001) and postoperative complications (OR = 2.672, 95% CI: 1.970–3.633, *P* < 0.001). Other factors were STS class (OR = 1.037, 95% CI: 0.996–1.080, *P* = 0.079), use of general anesthesia (OR = 1.891, 95% CI: 0.984–3.632, *P* = 0.056), previous cerebrovascular accident (OR = 1.598, 95% CI: 0.914–2.793, *P* = 0.100) and postoperative vascular events (OR = 2.113, 95% CI: 2.216–8.425, *P* = 0.076).

By using the independent variables identified as significantly associated with non-home discharge, a nomogram was generated to quantify patients' individual risk of non-home discharge based on preoperative variables (Figure 1). Figure 2 illustrates the ROC from the final model. Discrimination was measured using the C-index. The unbiased estimate of the C-index derived from bootstrap resamples was excellent, at 0.826. Calibration was assessed graphically by examining how far the predicted probabilities are from the actual observed proportion with non-home discharge. The model had excellent calibration, as illustrated in the calibration plot in Figure 3. In further sensitivity analyses, patients were classified based on the overall risk of non-home discharge as low risk (< 10%), intermediate risk (10%–20%) or high risk (> 20%).

4 Discussion

Findings from the present study showed that about one out of four TAVR patients are discharged to a location other than home. Advanced age, high STS scores, non-transfemoral approach, female sex and developing a complication after the procedure are among factors predictive of not being discharged home after TAVR.

Previous studies have identified preoperative factors that increases an individual's risk of not being discharged home after cardiac surgery.[7,8,12] In a study by Henry, *et al*.,[7] advanced age, female gender and concomitant valve/CABG were factors associated with discharge to a location other than home after heart valve surgery. The authors also found preoperative chronic lung disease and STS mortality risk scores as predictors of non-home discharge. A separate study by Edgerton, *et al*.[12] studied the same issue in patients undergoing CABG. STS mortality risk scores > 2% was found to be strongly associated with a > 22.5% risk of being discharged to a nursing home, rehabilitation facility or long-term care. Findings from the present study are in line with what has been previously reported as patients who were not discharged home after TAVR were older, had higher STS scores and female. In addition, the significant association between STS risk scores and the odds of being discharged to a location other than home confirms the results from the study by Edgerton, *et al*.[12]

Discharge to a location other than home has important implications for health care resource utilization. Patients discharged to another location other than home stayed longer in the hospital after TAVR than those who were discharged home. Longer postoperative hospitalizations may be due to a complicated postoperative course or prolonged intensive care unit stays. Most of these patients ended up being discharged to a rehabilitation facility and the cumulative cost of care undoubtedly has severe implications on total healthcare costs. Moreover, since a significantly greater proportion of these patients die within one-year post-procedure, a disproportionate amount of funds is allocated to these group of patients without desired outcomes. These findings are alarming and encourage further research to better understand the sole impact of discharge disposition and long-term outcomes after TAVR.

Table 1. Baseline demographic and clinical characteristics of patients stratified by presence or absence of peri-procedural complication.

Characteristics	All patients (*n* = 1,126)	Derivation cohort (*n* = 900)	Validation cohort (*n* = 226)	*P*-value
Age, yrs	83 ± 8	83 ± 9	82 ± 8	0.711
Female	591 (52%)	478 (53%)	113 (50%)	0.403
Race				
Caucasian	993 (88%)	793 (88%)	200 (89%)	0.788
African American	118 (10%)	94 (10%)	24 (10%)	
Hispanic	15 (2%)	13 (2%)	2 (1%)	
Body mass index, kg/m^2	28.5 ± 6.8	28.3 ± 6.5	29.4 ± 7.8	0.035
NYHA class (III or IV)	821 (73%)	661(73%)	160 (71%)	0.426
STS score	6.8 ± 5.5	6.6 ± 5.1	6.9 ± 5.7	0.426
Frailty status				
Frail	152 (13%)	118 (13%)	34 (15%)	0.452
Medical history				
Hypertension	933 (83%)	746 (83%)	187 (83%)	0.959
Pulmonary hypertension	208 (18%)	157 (17%)	51 (23%)	0.082
Dyslipidemia	758 (67%)	603 (67%)	155 (69%)	0.649
Chronic lung disease	212 (19%)	165 (18%)	47 (21%)	0.402
Home oxygen	40 (4%)	28 (3%)	12 (5%)	0.129
Coronary artery disease	629 (56%)	509 (57%)	120 (53%)	0.349
Diabetes	385 (34%)	305 (34%)	80 (35%)	0.669
IDDM	75 (7%)	53 (6%)	22 (10%)	0.058
NIDDM	310 (28%)	252 (28%)	58 (26%)	0.479
Peripheral vascular disease	204 (18%)	160 (18%)	44 (19%)	0.558
Cerebrovascular accident	116 (10%)	95 (11%)	21 (9%)	0.572
Chronic renal failure	246 (22%)	201 (22%)	45 (20%)	0.427
Dialysis	54 (5%)	38 (4%)	16 (7%)	0.086
Pacemaker placement	165 (15%)	132 (15%)	33 (15%)	0.980
Previous surgery history				
CABG	187 (17%)	150 (17%)	37 (16%)	0.915
PCI	274 (24%)	225 (25%)	49 (22%)	0.294
Approach				
Transfemoral	949 (84%)	754 (88%)	195 (86%)	0.348
Anesthesia type				
Conscious sedation	164 (15%)	136 (15%)	28 (12%)	0.292
General	963 (85%)	765 (85%)	198 (88%)	
Ejection fraction, %	53.4 ± 13.1	52.6 ± 13.7	51.6 ± 14.8	0.349
Aortic valve area, cm^2	0.7 ± 0.3	0.7 ± 0.2	0.7 ± 0.2	0.931
Mean gradient, mmHg	44.9 ± 14.3	45.4 ± 14.8	45.2 ± 15.5	0.853
≥ Aortic regurgitation	264 (23%)	216 (24%)	48 (21%)	0.377
≥ Mitral regurgitation	569 (51%)	443 (49%)	126 (56%)	0.079
≥ Tricuspid regurgitation	144 (13%)	114 (13%)	30 (13%)	0.808

Data are presented as means ± SD or *n* (%). CABG: coronary artery bypass graft; IDDM: insulin dependent diabetes mellitus; NIDDM: non-insulin dependent diabetes mellitus; NYHA: New York Heart Association; PCI: percutaneous coronary intervention; STS: Society of Thoracic Surgeons.

The utilization of nomograms in the prediction of treatment outcomes is not new to valvular heart diseases. In a study by Javadikasgari, *et al*.,[13] nomograms were used to estimate and predict survival among patients with degenerative mitral valve disease undergoing mitral valve repair versus replacement. In their analysis, mitral valve repair was found to be significantly associated with better survival as compared with replacement. We propose that a nomogram such as ours may add quality of life data that may assist providers in addressing patients' expectations regarding the social consequences that primary surgery may bear. Our concordance index was calculated to be 0.826, which is

Table 2. Results of univariate and multivariable logistic regression analyses.

Variable	Univariate logistic regression		Multivariable logistic regression	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Age, yrs	1.079 (1.056–1.103)	< 0.001	1.080 (1.051–1.109)	< 0.001
Female	Reference			
Male	0.452 (0.329–0.617)	< 0.001	0.447 (0.305-0.656)	< 0.001
Body mass index, kg/m^2	0.980 (0.956–1.003)	0.096		
Source of admission				
Transfer from other facility	Reference			
Elective	0.198 (0.128–0.304)	< 0.001	0.258 (0.153–0.433)	< 0.001
Inpatient	0.727 (0.423–1.246)	0.247	1.081 (0.578–2.021)	0.807
Race				
Other	Reference			
White	0.805 (0.529–1.135)	0.405		
STS score, %	1.130 (1.092–1.170)	< 0.001	1.037 (0.996–1.080)	0.079
Procedure approach				
Non-transfemoral	Reference			
Transfemoral	0.367 (0.254–0.531)	< 0.001	0.436 (0.278–0.684)	< 0.001
Anesthesia				
Conscious sedation	Reference			
General anesthesia	3.986 (2.288–7.543)	< 0.001	1.891 (0.984–3.632)	0.056
Dyslipidemia	0.775 (0.567–1.062)	0.111	0.671 (0.455–0.989)	0.044
History of permanent pacemaker	1.723 (1.145–2.567)	0.008	2.241 (1.355–3.706)	0.002
History of cerebrovascular accident	1.566 (0.984–2.454)	0.054	1.598 (0.914–2.793)	0.100
History of CABG	0.538 (0.341–0.822)	0.006	0.486 (0.283–0.833)	0.009
Chronic liver disease	2.466 (1.028–5.795)	< 0.038	4.143 (1.415–12.126)	0.009
Vascular complication	4.276 (2.216–8.425)	< 0.001	2.113 (0.925–4.826)	0.076
Number of complications				
0	Reference			
1	2.463 (1.782–3.407)	< 0.001	2.493 (1.685–3.689)	< 0.001
≥ 2	4.410 (2.479–7.853)	< 0.001	3.778 (1.844–7.74)	< 0.001

CABG: coronary artery bypass graft; CI: confidence interval; OR: odds ratio; STS: Society of Thoracic Surgeons.

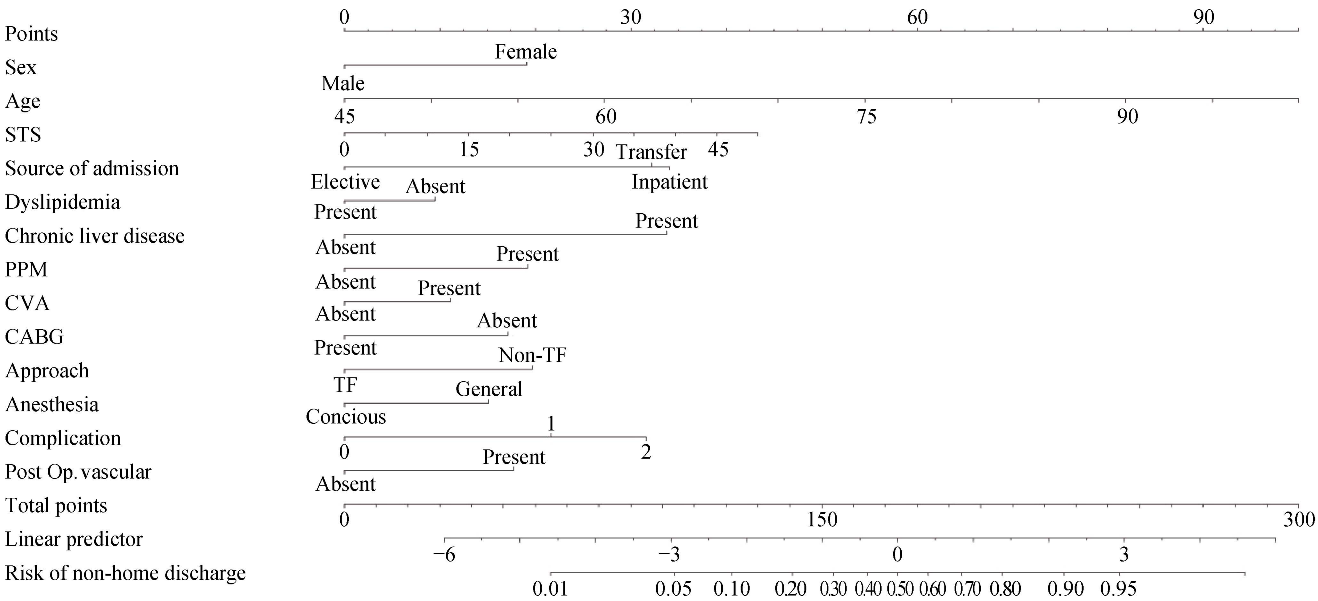

Figure 1. Nomogram predicting the risk of non-home discharge based on independent factors identified from multivariate logistic regression. Higher total points based on summation of points from individual risk factors indicates a higher risk of non-home discharge. CABG: coronary artery bypass graft; CVA: cerebrovascular accident; PPM: permanent pacemaker; STS: Society of Thoracic Surgeons; TF: transfemoral.

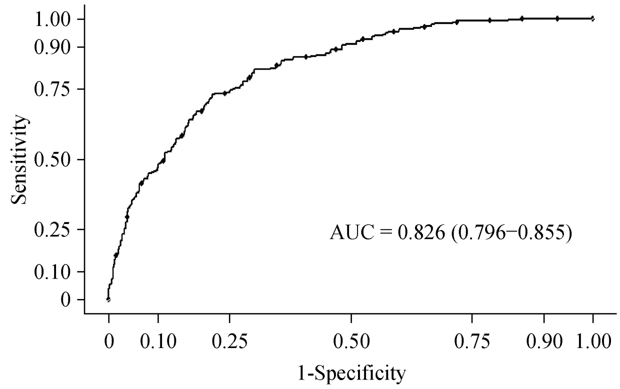

Figure 2. ROC curve based on predicted probabilities obtained from logistic regression. With a chosen cut-off point of 0.228 regarding to Youden's index in ROC analysis for specifying non-home discharge; accuracy, sensitivity and specificity were calculated as 0.730, 0.819 and 0.700, respectively from the derivation data. AUC: area-under-the-curve; ROC: receiver operating characteristic.

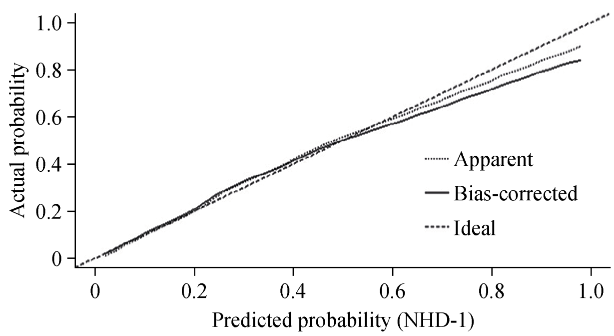

Figure 3. Graphical representation of calibration plot of the predicted probabilities are from the actual observed proportion with non-home discharge. C-index = 0.81 which indicates a strong discrimination.

comparable to nomograms previously developed in other surgical areas. We predict that our newly developed risk scoring system can serve as a helpful tool for social workers to enable them a patient's likelihood of postoperative discharge to a skilled nursing facility, thus allowing for preoperative planning and arrangement.

4.1 Limitations

The current study is limited by being retrospective and single-centered. Detailed information regarding the selection criteria for discharge to a location was not considered for the present analysis. Also, follow-up data on specific discharge locations were not included in the analysis. Information regarding the number of patients who returned home permanently after being discharged to another location would be important to understand the overall impact of discharge disposition on quality of life post-TAVR. Further analysis taking total costs into consideration was not performed as such, the impact of discharge disposition on resource utilization cannot be inferred from the present findings.

4.2 Conclusions

In conclusion, the present study shows that a considerable number of advanced aged patients undergoing TAVR are not discharged home after the procedure. A simple risk scoring system based on preoperative risk factors can help guide pre-operative decision making, counselling and planning.

Acknowledgments

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