Impact of frailty on outcomes and readmissions after transcatheter and surgical aortic valve replacement in a national cohort

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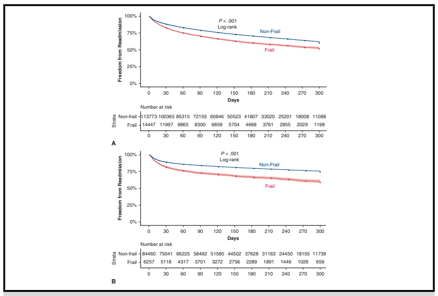
ABSTRACT

Objective: We examined the effect of frailty on in-hospital mortality, readmission rates, and hospitalization costs after transcatheter and surgical aortic valve replacement in a population-level cohort.

Methods: The Nationwide Readmissions Database was queried for patients who underwent transcatheter or surgical aortic valve replacement during 2016-2018. Multivariate logistic regression was used to discern independent effects of frailty on outcomes. Kaplan–Meier time-to-event analysis was used to evaluate the effect of frailty on freedom from readmission.

Results: A total of 243,619 patients underwent aortic valve replacement: 142,786 (58.6%) transcatheter aortic valve replacements and 100,833 (41.4%) surgical aortic valve replacements. Frail patients constituted 16,388 (11.5%) and 7251 (7.2%) in the transcatheter aortic valve replacement and surgical aortic valve replacement cohorts, respectively. Compared with nonfrail patients, frail patients had greater in-hospital mortality (transcatheter aortic valve replacement: 3.2% vs 1.1%; surgical aortic valve replacement: 6.1% vs 2.0%; both $P < .001$), longer length of stay (transcatheter aortic valve replacement: 4 vs 2 days; surgical aortic valve replacement: 13 vs 6 days; $P < .001$), and greater cost (transcatheter aortic valve replacement: $51,654 vs $44,401; surgical aortic valve replacement: $60,782 vs $40,544; $P < .001$). Time-to-event analysis showed that frail patients had higher rates of readmission over the calendar year in both transcatheter aortic valve replacement ($P < .001$) and surgical aortic valve replacement ($P < .001$) cohorts. This association persisted on adjusted multivariate regression for mortality (transcatheter aortic valve replacement odds ratio [95% CI] 1.98 [1.65-2.37], surgical aortic valve replacement 1.96 [1.60-2.41]), 30-day readmission (transcatheter aortic valve replacement 1.38 [1.27-1.49], surgical aortic valve replacement 1.47 [1.30-1.65]), and 90-day readmission (transcatheter aortic valve replacement 1.41 [1.31-1.52], surgical aortic valve replacement 1.60 [1.43-1.79]) ($P < .001$ for all).

Conclusions: For patients undergoing transcatheter or surgical aortic valve replacement, frailty is associated with in-hospital mortality, readmission, and higher costs. Further efforts to optimize outcomes for frail patients are warranted. (JTCVS Open 2024;20:14-25)



Frailty's impact on freedom from readmission in patients who undergo (A) TAVR or (B) SAVR.

CENTRAL MESSAGE

Frailty is associated with elevated in-hospital mortality, rates of readmission, LOS, and costs for patients who undergo TAVR and SAVR.

PERSPECTIVE

Frailty is a well-known risk factor for mortality after cardiac surgery. The effect of frailty on outcomes beyond mortality, specifically in patients undergoing SAVR and TAVR, is less clear. Using a large national database, we found that frailty was associated with greater readmission rates, cost, and LOS in both groups.

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Abbreviations and Acronyms

ICD-10-CM = International Classification of Diseases, 10th Revision, Clinical Modification
ICD-10-PCS = International Classification of Diseases, 10th Revision, Procedure Classification System
JH-ACG = Johns Hopkins Adjusted Clinical Groups
LOS = length of stay
NRD = Nationwide Readmissions Database
SAVR = surgical aortic valve replacement
TAVR = transcatheter aortic valve replacement

Frailty is a condition characterized by greater vulnerability to stressors secondary to decreased physiologic reserve.[1] The effect of frailty on outcomes in patients with cardiovascular disease has been increasingly recognized.[2] The prevalence of frailty is increasing among patients undergoing cardiac surgery, driven by an aging and increasingly complex patient population.[3] The emergence and refinement of nonsurgical treatments, particularly transcatheter aortic valve replacement (TAVR), have stimulated further study of the impact of frailty on outcomes and decision-making in both TAVR and surgical aortic valve replacement (SAVR).[4]

Prior cohort studies have demonstrated frailty to be an independent risk factor for death and disability after both TAVR and SAVR.[5-9] Beyond mortality, frailty has been associated with greater readmission rates and resource use after TAVR.[10,11] Readmission rate and hospitalization cost are important metrics because they reflect not only hospital performance but also patient quality of life. Assessing these outcomes may yield insights to enhance care in these domains. However, data—particularly national-level data—are scarce regarding the effect of frailty on readmission rate and cost after both TAVR and SAVR.

In this study, we examined the effect of frailty, as measured by the validated Johns Hopkins Adjusted Clinical Groups (JH-ACG) frailty indicator,[12,13] on outcomes after TAVR and SAVR in a population-based sample from the Nationwide Readmissions Database (NRD). We hypothesized that frailty would be associated with adverse clinical outcomes such as mortality, readmission, and greater cost after both SAVR and TAVR.

MATERIAL AND METHODS

Data Source

The NRD was used to identify patients who underwent TAVR or SAVR from January 2016 to December 2018. The NRD features a clustered, post-stratified sample design that enables national estimates and reliably links patient readmissions over a calendar year. In accordance with the Health Insurance Portability and Accountability Act, patient information in the NRD is deidentified, including demographic, clinical, and hospital information; thus, Institutional Review Board approval was not required for this study. All studies incorporated survey-based design, and survey-adjusted variances were used for all statistics.

Study Cohort

Patients aged 18 years or older who underwent isolated TAVR or SAVR were identified using International Classification of Diseases, 10th Revision, Procedural Classification System (ICD-10-PCS) and Clinical Modification (ICD-10-CM) codes. Table E1 lists all ICD-10 codes used for patient inclusion and exclusion. Patients were stratified by method of valve replacement with the ICD-10-PCS codes 02RF3 and 02RF0 for TAVR and SAVR, respectively. Isolated TAVR and SAVR procedures were identified by excluding patients who underwent concomitant procedures such as percutaneous coronary intervention, coronary artery bypass grafting, and other valve repair or replacement. Patients who underwent SAVR for endocarditis were excluded. Index admission and readmissions were identified for the patient cohort within each calendar year.

Frailty was defined by the JH-ACG, a multidimensional frailty index designed and validated for use in administrative claims data and therefore optimized for use with the NRD.[12,13] The JH-ACG was chosen over alternative claims-based instruments such as the Hospital Frailty Risk Score and the Preoperative Frailty Index because these measures potentially overestimate frailty in the cardiac surgery population.[14,15] Frailty is indicated through binary classification based on clusters of frailty-indicating ICD-10 diagnoses. The JH-ACG has been used to assess outcomes in patients undergoing coronary artery bypass grafting.[16] Because the JH-ACG is proprietary, specific diagnostic codes cannot be provided here.

Patient and Hospital Characteristics

Patient characteristics and demographics were analyzed, including age, sex, case urgency, and insurer for the index admission. Patient comorbidity burden was assessed with the Elixhauser comorbidity index. Specifically, the *comorbidity* R package was used with Agency for Healthcare Research and Quality weighting for scoring. Additional cardiovascular risk factors such as smoking history and hyperlipidemia were included. Hospital characteristics including teaching status, hospital bed size, and urban or rural designation were examined.

Outcomes

Outcomes assessed for index hospitalizations included in-hospital mortality, length of stay (LOS), and discharge disposition. Admission costs were estimated from Agency for Healthcare Research and Quality cost-to-charge ratios, and readmission rates were assessed at 30 and 90 days. In the NRD, admissions for a given patient are only linked within each calendar year; therefore, only patients with index admissions from January to November were included in the 30-day readmission rates. Likewise, only patients with index admissions from January to September were included in the 90-day readmission rates. Additional readmission outcomes were death on readmission, readmission LOS, and readmission cost. Patients who died during their index admission were excluded from analyses of outcomes aside from in-hospital mortality because including them would potentially confound the interpretation of these outcomes.

Kaplan–Meier Readmissions Analysis

Calendar-year freedom from readmission was evaluated with Kaplan–Meier analysis for patients with an index admission between January and November of each year. Because the NRD does not specify discharge dates within each month, discharges were presumed to have occurred on the last day of the month for data censoring. A survey-adjusted log-rank test was used to determine significant differences between curves.

Risk-Adjusted Analysis

A training set of 80% of the overall cohort was used for multivariable logistic regression. Models were developed by using in-hospital mortality, 30-day readmissions, and 90-day readmissions as separate dependent variables. The remaining 20% of the cohort was used as a test set, and area under the curve calculations were used to optimize independent regression variables (Figures E1-E3).

Statistical Analysis

Table E2 lists packages used within R version 4.1 for statistical analyses. Data clustering, poststratification, and discharge sample weights necessary for national estimates were accounted for by the R package *survey.* Categorical variables were analyzed with chi-square tests with the Rao and Scott adjustment; continuous variables were analyzed with the Kruskal–Wallis rank-sum test for complex survey design. All tests and models accounted for the sampling design of the NRD. Percentages are used to summarize categorical data, and mean ± SD or median with interquartile range is used for continuous data, as applicable.

RESULTS

Preoperative Characteristics

A total of 243,619 patients underwent aortic valve replacement: 142,786 (58.6%) TAVRs and 100,833 (41.4%) SAVRs (Figure 1). Overall, 23,639 patients (9.7%) were classified as frail according to the JH-AHG: 16,388 patients (11.5%) in the TAVR cohort and 7251 patients (7.2%) in the SAVR cohort (Table 1). For both TAVR and SAVR, frail patients were older (TAVR: 83 vs 81 years; SAVR: 71 vs 67 years, both $P < .001$), more likely to be female (TAVR: 47.6% vs 45.2%; SAVR: 42% vs 38%, both $P < .001$), and more often insured by Medicare (TAVR: 93.0% vs 91.0%; SAVR: 75.3% vs 58.6%; both $P < .001$) than nonfrail patients.

Frail patients in both cohorts displayed higher median Elixhauser comorbidity scores (TAVR: 17 vs 11; SAVR: 22 vs 10; both $P < .001$) (Table 2). Individual comorbidities with higher proportions in frail patients included chronic heart failure (TAVR: 81.3% vs 74.5%; SAVR: 58.4% vs 38.1%; both $P < .001$), arrhythmias (TAVR: 63.9% vs 56.0%; SAVR: 73.8% vs 57.2%; both $P < .001$), pulmonary circulation disorder (TAVR: 23.6% vs 18.5%; SAVR: 21.9% vs 13.0%; both $P < .001$), peripheral arterial disease (TAVR: 24.2% vs 23.1%, $P < .029$; SAVR: 22.9% vs 17.7%, $P < .001$), and renal failure (TAVR: 41.2% vs 35.5%; SAVR: 27.6% vs 15.1%; both $P < .001$) (Table 2).

In-Hospital Outcomes

Frail patients had a 3-fold higher risk of in-hospital mortality than nonfrail patients (TAVR: 3.2% vs 1.1%; SAVR: 6.1% vs 2.0%; both $P < .001$) (Table 3). Relative risk of mortality for frail patients was 2.85 [2.58-3.16] and 3.04 [2.74-3.38] for TAVR and SAVR, respectively. Additionally, frail patients were found to have longer median LOS (TAVR: 4 vs 2 days; SAVR: 13 vs 6 days; $P < .001$) and

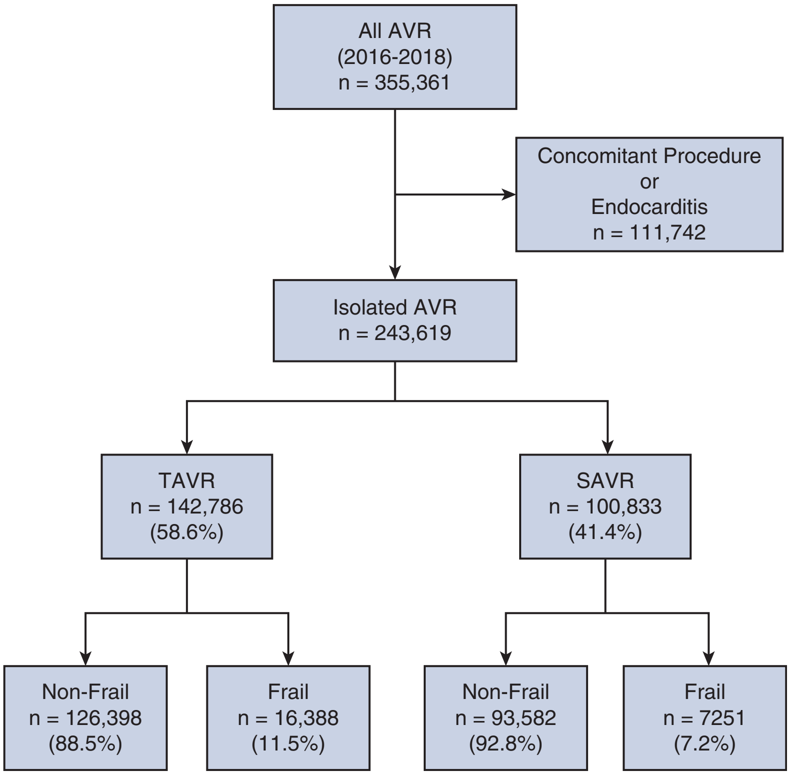

FIGURE 1. Flowchart diagram showing patient identification, exclusion, and stratification. *AVR*, Aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement.

TABLE 1. Characteristics of frail and nonfrail patients who underwent surgical aortic valve replacement versus transcatheter aortic valve replacement

Characteristic	Overall (N = 243,619) Nonfrail (n = 219,980)	Overall Frail* (n = 23,639)	Overall *P* value†	TAVR (n = 142,786) Nonfrail (n = 126,398)	TAVR Frail* (n = 16,388)	TAVR *P* value†	SAVR (n = 100,833) Nonfrail (n = 93,582)	SAVR Frail* (n = 7251)	SAVR *P* value†
Age (y)	76 (67-83)	80 (72-86)	<.001	81 (75-86)	83 (77-87)	<.001	67 (59-74)	71 (64-78)	<.001
Female gender	93,050 (42.3)	10,843 (45.9)	<.001	57,120 (45.2)	7799 (47.6)	<.001	35,930 (38.4)	3043 (42.0)	<.001
Income quartile			.135			.263			.007
1	45,743 (20.8)	5011 (21.2)		25,273 (20.0)	3232 (19.7)		20,470 (21.9)	1779 (24.5)	
2	63,147 (28.7)	6731 (28.5)		35,929 (28.4)	4629 (28.2)		27,218 (29.1)	2101 (29.0)	
3	60,044 (27.3)	6219 (26.3)		34,667 (27.4)	4378 (26.7)		25,377 (27.1)	1841 (25.4)	
4	51,046 (23.2)	5678 (24.0)		30,529 (24.2)	4149 (25.3)		20,517 (21.9)	1530 (21.1)	
Primary payer			<.001			<.001			<.001
Medicaid	6583 (3.0)	608 (2.6)		1317 (1.0)	169 (1.0)		5266 (5.6)	438 (6.0)	
Medicare	169,627 (77.2)	20,684 (87.6)		114,841 (91.0)	15,225 (93.0)		54,786 (58.6)	5459 (75.3)	
Other	4024 (1.8)	372 (1.6)		2177 (1.7)	263 (1.6)		1848 (2.0)	108 (1.5)	
Private insurance	37,682 (17.1)	1818 (7.7)		7444 (5.9)	662 (4.0)		30,238 (32.3)	1156 (15.9)	
Self-pay	1616 (0.7)	125 (0.5)		428 (0.3)	53 (0.3)		1188 (1.3)	72 (1.0)	

Values are presented as n (%) or median (25%-75% interquartile range). *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement. *Frail was defined as having at least 1 of the following 10 characteristics: malnutrition, dementia, impaired vision, decubitus ulcer, incontinence, weight loss, poverty, barriers to access to care, difficulty walking, and falls. †Continuous variables were analyzed with the Kruskal–Wallis rank-sum test, and categorical variables were analyzed with the chi-square test with the Rao and Scott second-order correction.

greater cost (TAVR: $51,654 vs $44,401; SAVR: $60,782 vs $40,544; *P* <.001). The proportion of patients discharged to their home was lower in the frail patients (TAVR: 68.3% vs 90.0%; SAVR: 61.1% vs 85.4%; both *P* <.001). Adjusted multivariate regression analysis showed frailty to be an independent risk factor for in-hospital mortality after both TAVR (odds ratio [95% CI]: 1.98 [1.65-2.36], *P* <.001) and SAVR (1.86 [1.51-2.28], *P* <.001) (Figure 2).

TABLE 2. Comorbidities of frail and nonfrail patients who underwent transcatheter aortic valve replacement versus surgical aortic valve replacement

Comorbidity	TAVR (n = 142,786) Nonfrail (n = 126,398)	TAVR Frail* (n = 16,388)	TAVR *P* value†	SAVR (n = 100,833) Nonfrail (n = 93,582)	SAVR Frail* (n = 7251)	SAVR *P* value†
Elixhauser score	11 (6-17)	17 (9-26)	<.001	10 (2-19)	22 (11-34)	<.001
Hypertension	113,279 (89.6)	14,596 (89.1)	.187	73,521 (78.6)	5886 (81.2)	.002
Congestive heart failure	94,185 (74.5)	13,326 (81.3)	<.001	35,675 (38.1)	4234 (58.4)	<.001
Arrhythmia	70,825 (56.0)	10,476 (63.9)	<.001	53,489 (57.2)	5350 (73.8)	<.001
Diabetes mellitus	48,193 (38.1)	5932 (36.2)	.003	25,922 (27.7)	2425 (33.4)	<.001
Renal failure	44,895 (35.5)	6747 (41.2)	<.001	14,088 (15.1)	1998 (27.6)	<.001
COPD	36,260 (28.7)	4682 (28.6)	.851	19,088 (20.4)	1993 (27.5)	<.001
Peripheral artery disease	29,142 (23.1)	3958 (24.2)	.028	16,526 (17.7)	1657 (22.9)	<.001
Hypothyroidism	25,010 (19.8)	3610 (22.0)	<.001	12,597 (13.5)	1137 (15.7)	<.001
Obesity	25,305 (20.0)	2522 (15.4)	<.001	25,727 (27.5)	1622 (22.4)	<.001
Pulmonary circulation disorder	23,341 (18.5)	3860 (23.6)	<.001	12,141 (13.0)	1586 (21.9)	<.001
Coagulopathy	15,644 (12.4)	2939 (17.9)	<.001	31,518 (33.7)	3242 (44.7)	<.001
Depression	9488 (7.5)	2106 (12.8)	<.001	9223 (9.9)	1175 (16.2)	<.001
Weight loss	302 (0.2)	4356 (26.6)	<.001	84 (0.1)	2811 (38.8)	<.001
Liver disease	3948 (3.1)	677 (4.1)	<.001	3293 (3.5)	743 (10.2)	<.001
Drug abuse	529 (0.4)	97 (0.6)	.012	1695 (1.8)	161 (2.2)	.080

Values are presented as n (%) or median (25%-75% interquartile range). *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement; *COPD*, chronic obstructive pulmonary disease. *Frail was defined as having at least 1 of the following 10 characteristics: malnutrition, dementia, impaired vision, decubitus ulcer, incontinence, weight loss, poverty, barriers to access to care, difficulty walking, and falls. †*P* values were obtained from a chi-square test with the Rao and Scott second-order correction.

TABLE 3. In-hospital outcomes of nonfrail and frail patients who underwent transcatheter aortic valve replacement or surgical aortic valve replacement

Outcome	TAVR (n = 128,220) Nonfrail (n = 113,773)	TAVR Frail* (n = 14,447)	P value†	SAVR (n = 90,717) Nonfrail (n = 84,460)	SAVR Frail* (n = 6257)	P value†
In-hospital mortality	1423/126,398 (1.1)	526/16,388 (3.2)	<.001	1874/93,670 (2.0)	444/7294 (6.1)	<.001
LOS (d)	2 (2-4)	4 (2-11)	<.001	6 (5-8)	13 (7-23)	<.001
Cost (USD)	44,401 (35,080-56,408)	51,654 (39,167-70,202)	<.001	40,544 (31,710-54,044)	60,782 (42,645-94,516)	<.001
Discharged home	102,392 (90.0)	9873 (68.3)	<.001	72,121 (85.4)	3826 (61.1)	<.001
30-d readmissions	13,602 (12.0)	2501 (17.3)	<.001	9531 (11.3)	1178 (18.7)	<.001
90-d readmissions	18,994/91,026 (20.9)	3438/11,721 (29.3)	<.001	11,248/69,750 (16.1)	1416/5132 (27.6)	<.001
Died on readmission	1007/126,398 (0.8)	293/16,388 (1.8)	<.001	386/93,670 (0.4)	97/7294 (1.3)	<.001
Readmission LOS (d)	3 (2-6)	4 (3-7)	<.001	3 (2-6)	5 (2-8)	<.001
Readmission cost (USD)	9390 (5481-16,975)	9707 (5689-17,533)	.035	8744 (5082-16,140)	10,239 (6023-19,708)	<.001

Values are presented as n (%), n/N (%), or median (25%-75% interquartile range). *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement; *LOS*, length of stay; *USD*, United States dollar. *Frail was defined as having at least 1 of the following 10 characteristics: malnutrition, dementia, impaired vision, decubitus ulcer, incontinence, weight loss, poverty, barriers to access to care, difficulty walking, and falls. †Continuous variables were analyzed with the Kruskal–Wallis rank-sum test, and categorical variables were analyzed with the chi-square test with the Rao and Scott second-order correction.

Readmission Outcomes

The observed readmission rates were higher in frail patients at both 30 days (TAVR: 17.3% vs 12.0%; SAVR: 18.7% vs 11.3%; both $P < .001$) and 90 days (TAVR: 29.3% vs 20.9%; SAVR: 27.6% vs 16.1%; both $P < .001$) (Table 3). Furthermore, frailty was associated with greater readmission mortality (TAVR: 1.8% vs 0.8%; SAVR: 1.3% vs 0.4%; both $P < .001$) and cost (TAVR: $9707 vs $9390, $P < .05$; SAVR: $10,239 vs $8744, $P < .001$). The greater readmission risk associated with frailty persisted on risk-adjusted multivariate regression for 30-day (TAVR 1.97 [1.66-2.36], SAVR 1.37 [1.21-1.54], $P < .001$) and 90-day readmission (TAVR 1.32 [1.22-1.43], SAVR 1.46 [1.30-1.64], $P < .001$).

One-Year Freedom From Readmission

Time-to-event analysis showed that frail patients had higher rates of readmission over the calendar year in

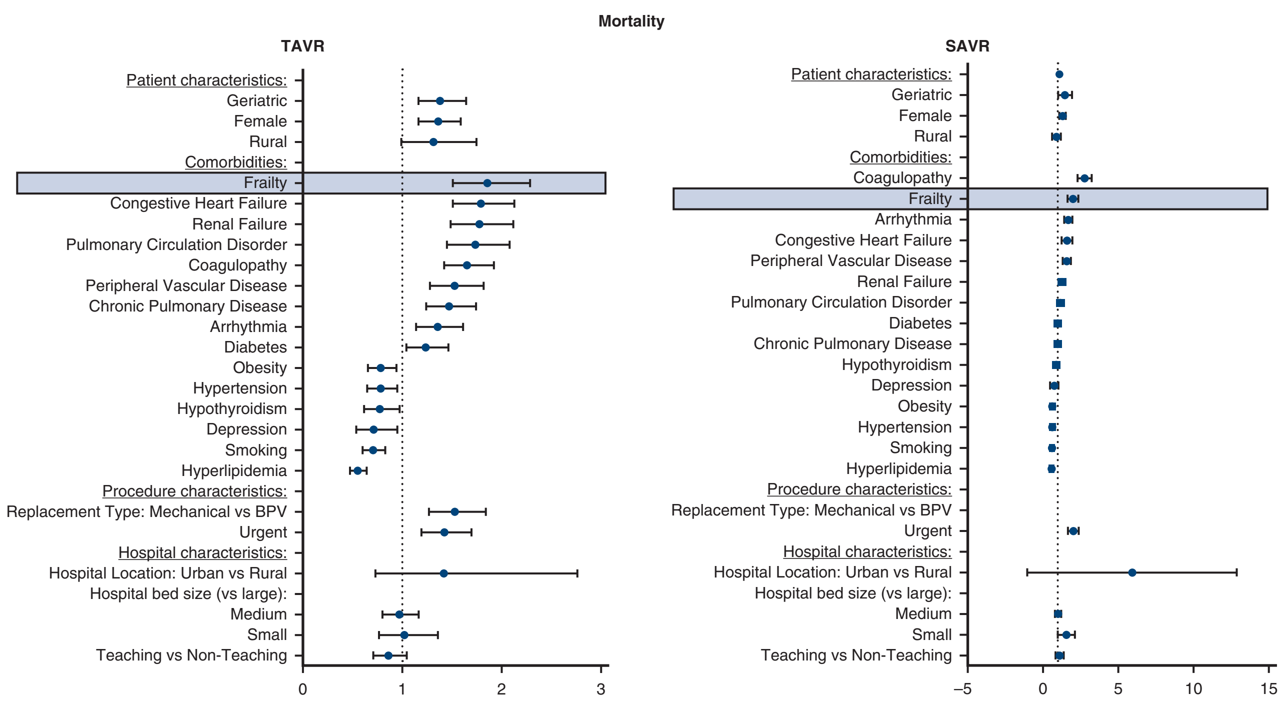

FIGURE 2. Forest plot depicting predictors of mortality after TAVR or SAVR. *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement; *BPV*, bioprosthetic valve.

both TAVR ($P < .001$) and SAVR ($P < .001$) cohorts (Figure 3). A multivariable Cox proportional hazards analysis revealed frailty as a significant risk factor for readmission after both TAVR (hazard ratio [95% CI]: 1.27 [1.22-1.32], $P < .001$) and SAVR (1.34 [1.25-1.45], $P < .001$). Additional predictors for readmission were arrhythmia (TAVR 1.32 [1.28-1.36]; SAVR 1.29 [1.23-1.35], both $P < .001$), congestive heart failure (TAVR 1.17 [1.12-1.21]; SAVR 1.26 [1.20-1.33], both $P < .001$), and renal failure (TAVR 1.34 [1.29-1.38]; SAVR 1.34 [1.27-1.42], both $P < .001$).

DISCUSSION

This study investigated the influence of frailty on outcomes of TAVR and SAVR in a national cohort of 243,629 patients by using a validated, claims-based frailty assessment. Our principal finding was that frailty is associated with greater in-hospital mortality risk, readmission risk, and hospitalization cost regardless of approach (Figure 4). These results reinforce prior findings associating frailty with adverse outcomes in many different clinical situations. Prior guidelines have suggested that patient frailty should bias treatment decisions toward TAVR rather than

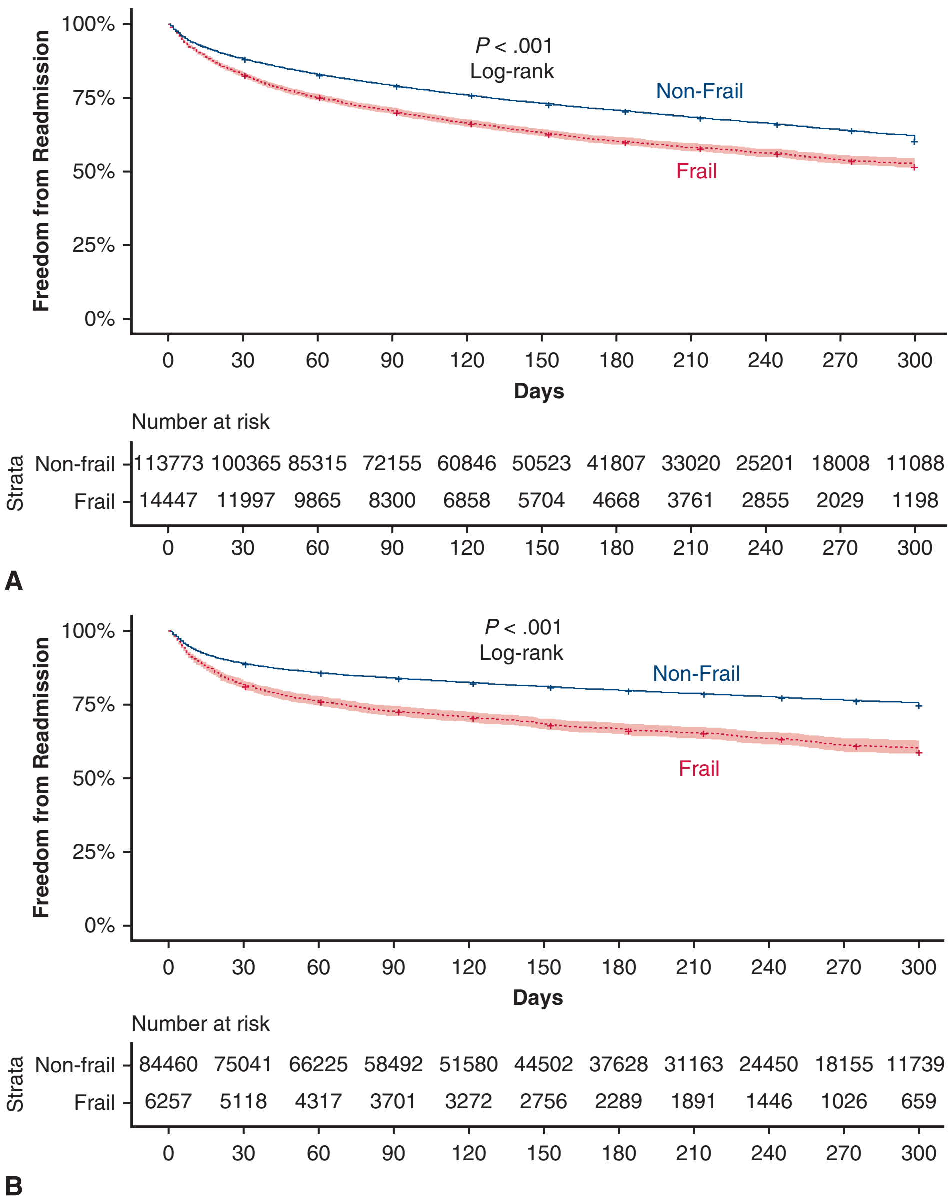

FIGURE 3. Kaplan–Meier estimates of readmission of patients who underwent (A) TAVR or (B) SAVR, stratified by frailty status. Freedom from readmission within 1 year was lower for frail patients after both TAVR and SAVR ($P < .001$ for both, log-rank test). *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement.

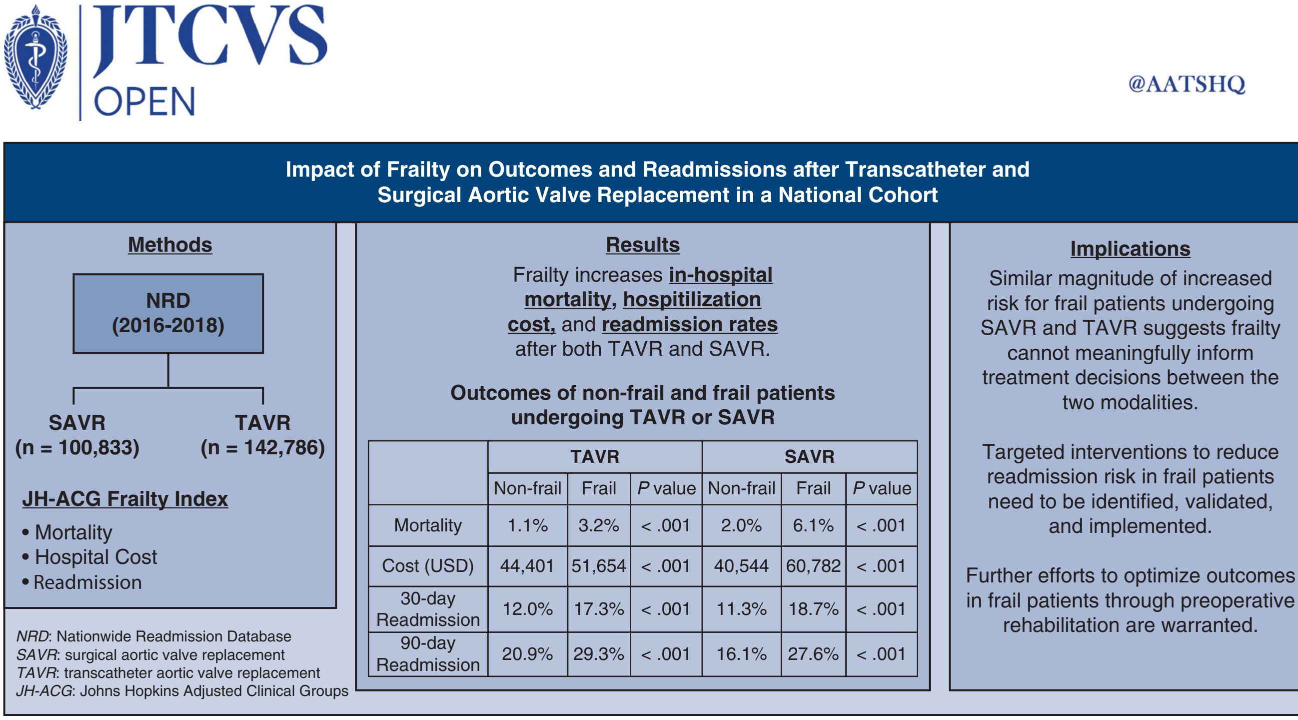

FIGURE 4. Impact of frailty on outcomes of TAVR and SAVR. From 2016 to 2018, 243,619 patients underwent TAVR or SAVR. Of these, 23,639 (9.7%) were classified as frail. Frailty was associated with increased in-hospital mortality, costs, and readmission after both TAVR and SAVR. *TAVR*, Transcatheter aortic valve replacement; *SAVR*, surgical aortic valve replacement

SAVR.[17] However, the magnitude of elevated risk for frail patients was similar for TAVR and SAVR, suggesting that frailty may not meaningfully inform treatment decisions when deciding between the 2 modalities.

This study's results build on evidence from previous studies regarding the adverse effect of frailty in this patient population. The FRAILTY-AVR study found that frailty, defined variably with multiple different indices, was independently associated with death and disability in a cohort of patients who underwent TAVR and SAVR at 14 centers.[5] However, studies using clinical trial data found no difference in survival or functional outcomes for frail patients undergoing TAVR versus SAVR.[18,19] Leveraging a population-based sample, our study found that the relative risk of mortality for frail patients was comparable between the 2 cohorts (TAVR: 2.85 [2.58-3.16] vs SAVR: 3.04 [2.74-3.38]), suggesting that frailty's impact on in-hospital mortality is similar between the 2 interventions. These results add to the existing body of strong evidence associating frailty with adverse outcomes after aortic valve replacement, but they also suggest that the value of frailty in differentiating optimal treatment strategy for patients with aortic stenosis may be limited. Frailty is one of many considerations influencing the choice between TAVR or SAVR, and in light of the findings of this study, we favor using objective risk-assessment tools such as that provided by the Society of Thoracic Surgeons over frailty assessments when assessing surgical risk.

In the present study, frailty was a strong independent predictor of readmission and greater cost after both TAVR and SAVR. Although previous studies have investigated the influence of frailty on readmission[11] and resource use[10] after TAVR, until now there has been little data on readmission rates and cost for frail patients undergoing SAVR. To our knowledge, this study is the first to report the impact of frailty on readmission and cost for patients undergoing TAVR and SAVR in a national cohort using the JH-ACG frailty index. Altogether, these findings emphasize the importance of postdischarge planning and recognition of frailty as a risk factor for adverse events at discharge. Targeted interventions to reduce readmission risk in frail patients need to be identified, validated, and implemented.

Recognition of frailty as a risk factor for adverse outcomes in cardiology and cardiac surgery has led to increased focus on strategies to mitigate frailty preoperatively.[20] Preoperative rehabilitation ("prehabilitation") consists of a multimodal strategy for enhancing physiologic reserve and fitness through exercise, nutrition, and psychological interventions.[21] Several studies suggest that prehabilitation can improve outcomes in frail patients undergoing surgical procedures such as colorectal cancer resection.[22,23] Although less data are available, small studies suggest potential benefits from prehabilitation in frail patients undergoing cardiac surgery.[24,25] Additional studies focused on preoperative optimization of frail patients are ongoing.[26]

This study has several advantages over previously published work in the field. First, we used high-quality, population-based data and the largest patient cohort to date to examine outcomes of frail patients who undergo TAVR and SAVR. Second, we used a frailty instrument designed for use in administrative claims data that has been externally validated and has demonstrated good discriminatory capability.[27] Third, by studying outcomes in both TAVR and SAVR cohorts, our study provides a comprehensive picture of the impact of frailty in this patient population.

Study Limitations

Our findings should be interpreted in the context of several important limitations. Data in an administrative, claims-based database can suffer from coding inaccuracies and may lack the granularity provided by institutional and clinical trial databases. Although we minimized the influence of baseline covariates by using established comorbidity codes, several potential unmeasured confounders such as race, ethnicity, lesion severity, and operative risk could not be controlled for. Furthermore, given the rapidly expanding indications for TAVR, the TAVR cohort in this study may not reflect the current TAVR population. Additionally, the NRD does not provide outcomes beyond a single calendar year, so long-term outcomes were not examined in this study. Functional and other patient-centered outcomes are not available in the NRD but are important considerations in clinical decision-making, particularly for frail patients with limited life expectancy. Last, the JH-ACG frailty indicator is a binary classifier derived from ICD-10 codes and therefore does not provide the intermediate or more granular levels of frailty available from clinical frailty assessments. Nonetheless, the JH-ACG has been shown to reliably identify frailty in administrative databases, allowing a population-level assessment of the impact of frailty in patients who undergo aortic valve replacement.

CONCLUSIONS

Frailty is associated with greater in-hospital mortality, readmission rates, and costs after both TAVR and SAVR. Frail patients should be identified preoperatively given this elevated risk of adverse outcomes. Moreover, efforts to optimize outcomes through a comprehensive preoperative program incorporating physical therapy, nutritional optimization, and psychological assessment in frail patients should be considered before AVR. Although it is intuitive that frail patients will have higher risk of morbidity and mortality, studies are needed to demonstrate that interventions in frail patients can improve outcomes.

Conflict of Interest Statement

J.S.C. participates in clinical studies with or consults for Terumo Aortic, Medtronic, WL Gore & Associates, CytoSorbents, Edwards Lifesciences, and Abbott Laboratories, and receives royalties and grant support from Terumo Aortic. M.R.M. is a consultant/advisory board member for Medtronic and Edwards Lifesciences. S.C. has served on advisory boards for Edwards Lifesciences, La Jolla Pharmaceutical Company, Eagle Pharmaceuticals, and Baxter Pharmaceuticals. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: aortic valve replacement, frailty, Nationwide Readmissions Database

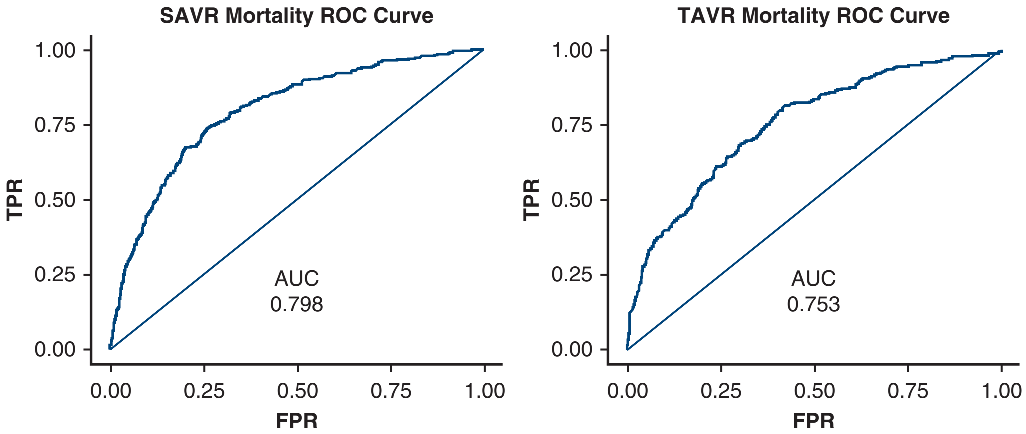

FIGURE E1. Receiver operating characteristic curve for the multivariable logistic regression for in-hospital mortality in the SAVR and TAVR cohorts. *SAVR*, Surgical aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *ROC*, receiver opreating characteristic; *TPR*, true-positive rate; *AUC*, area under the curve; *FPR*, false-positive rate.

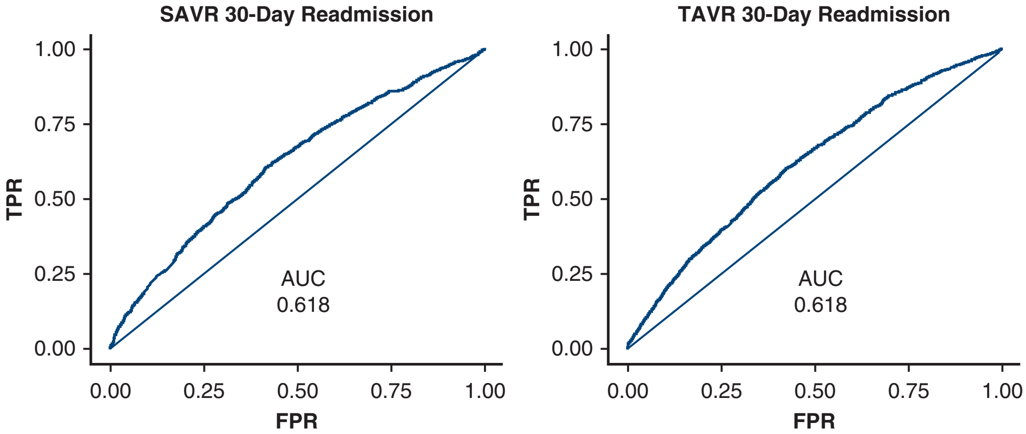

FIGURE E2. Receiver operating characteristic curve for the multivariable logistic regression for 30-day readmission in the SAVR and TAVR cohorts. *SAVR*, Surgical aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *TPR*, true-positive rate; *AUC*, area under the curve; *FPR*, false-positive rate.

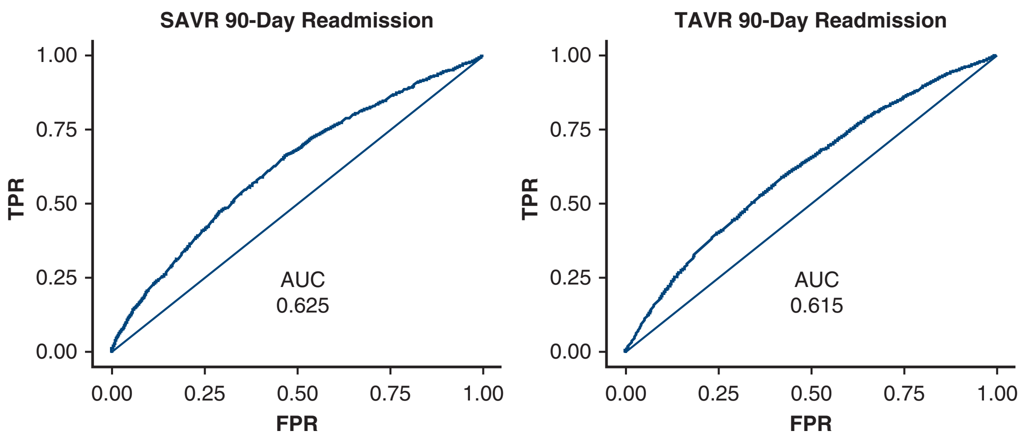

FIGURE E3. Receiver operating characteristic curve for the multivariable logistic regression for 90-day readmission in the SAVR and TAVR cohorts. *SAVR*, Surgical aortic valve replacement; *TAVR*, transcatheter aortic valve replacement; *TPR*, true-positive rate; *AUC*, area under the curve; *FPR*, false-positive rate.

TABLE E1. International Classification of Diseases 10th Revision codes used for patient inclusion and exclusion criteria

Codes used for inclusion	
ICD-10-CM 02RF3	Transcatheter aortic valve replacement (TAVR)
ICD-10-CM 02RF0	Surgical aortic valve replacement (SAVR)
Codes used for exclusion*	
ICD-10-CM I20	Angina pectoris
ICD-10-CM I21	Acute myocardial infarction
ICD-10-CM I22	Subsequent ST-elevation myocardial infarction (STEMI) and non–ST-elevation myocardial infarction (NSTEMI)
ICD-10-CM I23	Certain current complications after STEMI and NSTEMI myocardial infarction (within the 28-d period)
ICD-10-CM I24	Other acute ischemic heart diseases
ICD-10-CM I25.4	Coronary artery aneurysm and dissection
ICD-10-PCS 0210	Bypass, coronary artery, 1 artery
ICD-10-PCS 0211	Bypass, coronary artery, 2 arteries
ICD-10-PCS 0212	Bypass, coronary artery, 3 arteries
ICD-10-PCS 0213	Bypass, coronary artery, 4 or more arteries
ICD-10-PCS 02QG	Repair, mitral valve
ICD-10-PCS 02QF	Repair, aortic valve
ICD-10-PCS 02QH	Repair, pulmonary valve
ICD-10-PCS 02QJ	Repair, tricuspid valve
ICD-10-PCS 02RH	Replacement, pulmonary valve
ICD-10-PCS 02RJ	Replacement, tricuspid valve
ICD-10-PCS 02RX	Replacement of thoracic aorta, ascending/arch
ICD-10-PCS 02RW	Replacement of thoracic aorta, descending
ICD-10-PCS 02QX	Repair of thoracic aorta, ascending/arch
ICD-10-PCS 02QW	Repair of thoracic aorta, descending

ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification; *ICD-10-PCS,* International Classification of Diseases, 10th Revision, Procedure Classification System. *All combinations of characters following each listed prefix were included.

TABLE E2. *R* packages used in data analysis

HCUPr	MItools	Flextable	ggtext
data.table	buildmer	ggplot2	jstable
survey	poliscidata	MatchIt	gtsummary
magritter	weightedROC	survival	comorbidity
glmnet	officer	jskm	
caret	gtsummary	survminer	