

Volume of frail patients predicts outcome in frail patients after cardiac surgery



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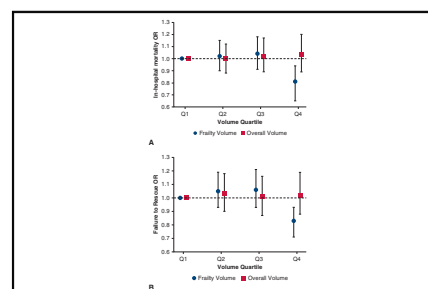
ABSTRACT

Objective: Recent data from major noncardiac surgery suggest that outcomes in frail patients are better predicted by a hospital's volume of frail patients specifically, rather than overall surgical volume. We sought to evaluate this “frailty volume-frailty outcome relationship” in patients undergoing cardiac surgery.

Methods: We studied 72,818 frail patients undergoing coronary artery bypass grafting or valve replacement surgery from 2010 to 2014 using the Nationwide Readmissions Database. Frailty was defined using the Johns Hopkins Adjusted Clinical Groups frailty-defining diagnoses indicator. Multilevel logistic regression was used to assess the independent effect of frailty volume by quartile on mortality, surgical complications, failure to rescue, nonhome discharge, 30-day readmissions, length of stay, and hospital costs in frail patients.

Results: In comparing the highest volume quartiles with the lowest, both overall cardiac surgical volume and volume for frail patients were significantly associated with shorter length of stay and reduced costs. However, frailty volume was also independently associated with significantly reduced in-hospital mortality (odds ratio, 0.79; 95% confidence interval, 0.67–0.94; $P = .006$) and failure to rescue (odds ratio, 0.83; 95% confidence interval, 0.70–0.98; $P = .03$), whereas no such association was seen between overall volume and either mortality (odds ratio, 0.94; 95% confidence interval, 0.74–1.10; $P = .43$) or failure to rescue (odds ratio, 0.98; 95% confidence interval, 0.83–1.17; $P = .85$). Neither frailty volume nor overall volume showed any significant relationship with the rate of 30-day readmissions.

Conclusions: In frail patients undergoing cardiac surgery, surgical volume of frail patients was a significant independent predictor of in-hospital mortality and failure to rescue, whereas overall surgical volume was not. Thus, the “frailty volume-outcome relationship” superseded the traditional “volume-outcome relationship” in frail patients with cardiac disease. (*J Thorac Cardiovasc Surg* 2022;163:151–60)



Frailty volume has a greater influence on outcomes for frail patients than overall volume.

CENTRAL MESSAGE

A hospital's annual volume of frail patients undergoing cardiac surgery better predicts outcomes for frail patients than overall cardiac surgical volume.

PERSPECTIVE

We find that the “frailty volume-outcome relationship” supersedes the more traditional “volume-outcome relationship” for frail patients. This finding has been reported for major noncardiac surgery, but never before in cardiac surgery. Such data have fundamental implications for how we think of so-called centers of excellence with respect to our highest risk patient populations.

See Commentaries on pages 161, 162, and 164.

As the US population continues to age, the burden of cardiac disease in older adult patients is expected to increase significantly in the coming decades. Already, the number

of patients aged more than 75 years undergoing major cardiac surgery in the United States is increasing.¹ These patients tend to present with multiple medical comorbidities and are generally at greater risk of surgical complications than their younger counterparts. The concept of frailty has recently emerged as an important metric for understanding and predicting surgical risk especially in these older

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Read at the 99th Annual Meeting of The American Association for Thoracic Surgery, Toronto, Ontario, Canada, May 4–7, 2019.

Received for publication Aug 15, 2019; revisions received April 3, 2020; accepted for publication April 14, 2020; available ahead of print May 4, 2020.

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0022-5223/\$36.00

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<https://doi.org/10.1016/j.jtcvs.2020.04.097>



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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
FTR	= failure to rescue
IQR	= interquartile range
LOS	= length of stay
NRD	= Nationwide Readmissions Database
OR	= odds ratio

patients. Frailty describes the biological syndrome of decreased physiologic resilience and reserve, causing a heightened vulnerability to adverse outcomes after an acute stressor.² In patients undergoing cardiac surgery, frailty is known to predict increased rates of postoperative delirium, greater length of intensive care unit and hospital stay, discharge to an intermediate-care facility, in-hospital mortality, and other markers of poor outcome.³⁻⁶ Moreover, the addition of frailty metrics to more traditional cardiac surgery risk assessment tools, such as the Society of Thoracic Surgeons score and the European System for Cardiac Operative Risk Evaluation, has been shown to more accurately predict outcomes in frail patients.^{7,8}

In cardiac surgery, the relationship between increased hospital and surgeon volume and improved outcomes is well established.⁹⁻¹¹ However, less is known about the importance of this volume-outcome relationship, particularly in high-risk patient populations, such as the frail and octogenarians. A growing body of data suggest that high-volume centers may achieve improved outcomes largely through earlier and more effective intervention after an initial perioperative complication, thus preventing progression to further complications and ultimately death.¹²⁻¹⁴ This is a concept known as “failure to rescue” (FTR). FTR is thought to play a particularly important role in frail patients, who are defined by their decreased capacity to respond to physiologic insult after surgery.¹⁵ Indeed, recent data from major noncardiac surgery suggest that outcomes in frail patients are better predicted by a hospital’s volume of frail patients in particular, as opposed to overall surgical volume for a given procedure.¹⁶ This concept of a volume-outcome relationship specific to frail patients has not been studied in cardiac surgery. We sought to evaluate this relationship and the effect on 30-day morbidity, mortality, readmissions, and costs of care in a large retrospective cohort of patients undergoing elective cardiac surgery from the Nationwide Readmissions Database (NRD).

MATERIALS AND METHODS**Data Source**

We performed a retrospective cohort study using data from the NRD from 2010 to 2014. The NRD is a large, publicly available, all-payer database of inpatient hospital stays sponsored by the Agency for Healthcare

Research and Quality as part of the Healthcare Cost and Utilization Project.¹⁷ The NRD is drawn from State Inpatient Databases, which included data from 22 states in the study period and accounted for approximately 50% of all US hospitalizations. An advantage of the NRD over other nationally representative databases such as the Nationwide Inpatient Sample is that the NRD also contains verified patient-linkage numbers that can track patients across hospitals to facilitate readmission analysis. Further details on the NRD are available online.¹⁷ Because the NRD is a publicly available database containing deidentified patient information, full review by the University of Pennsylvania Institutional Review Board was not required.

Study Cohort

Adult (age ≥ 18 years) patients undergoing valve replacement surgery, coronary artery bypass grafting (CABG), or both from 2010 to 2014 were identified using Clinical Classification Software codes for the International Classification of Diseases, Ninth Edition, Clinical Modification. Codes 43 and 44 were used to define valve replacement surgery and CABG, respectively (Table E1). These operations were chosen because they are commonly grouped to study cardiac surgery outcomes,^{18,19} and Clinical Classification Software codes have been validated to confirm the accurate identification of patients undergoing these surgeries.²⁰ If the same patient underwent multiple cardiac operations over the study period, only the first operation was included to ensure a patient-level analysis. The final study cohort included only such patients who were deemed frail using the frailty assessment tool described next.

Study Variables

The exposure of interest was the number of frail patients undergoing cardiac surgery cared for in the year of the index surgery at the index hospital. We identified frailty using the Johns Hopkins Adjusted Clinical Groups frailty-defining diagnoses indicator, an externally validated instrument developed for use in health administrative data.²¹ This binary measure assesses frailty using 10 clusters of frailty-defining diagnoses (Table 1) and has been used to study frailty-related surgical outcomes.²²⁻²⁵ Clinical characteristics of patients with the adjusted clinical groups frailty tag were consistent with multidimensional frailty including fall risk, impaired cognitive functioning, need for assistance in personal care, and worse global functional scores compared with nonfrail patients.²⁶

Annual frail surgical volume was modeled as equal-sized quartiles based on the number of frail patients who underwent cardiac surgery cared for in the year of the index surgery at each patient’s hospital. The range for the number of frail patients cared for at each hospital in each volume quartile was as follows: Q1 = 1-10, Q2 = 11-21, Q3 = 22-44, and Q4 = 45-302. These values were chosen such that the number of patients (rather than the number of hospitals) was roughly equal in each quartile. The number of individual hospitals included in frailty quartiles 1 to 4 are 1660, 526, 275, and 96, respectively. We also calculated the total number of CABG or valve replacement surgery surgeries performed at each hospital in the year of each patient’s index surgery as a measure of the overall cardiac surgery volume at each institution.

Outcomes

The primary outcome was in-hospital mortality during the index surgery admission. Secondary outcomes included in-hospital complications, FTR, nonhome discharge, 30-day readmission, length of hospitalization, and hospital costs. We identified patients experiencing in-hospital complications using ICD-9 codes previously described by Gonzalez and colleagues¹⁴ for cardiac surgery (Table E1). These included acute renal failure, venous thromboembolism, stroke, pneumonia, pulmonary failure, postoperative hemorrhage, and surgical site infection. FTR was defined as in-hospital death that occurred after a surgical complication. Nonhome discharge was defined as discharge to a nursing facility or short-term

TABLE 1. Frailty-defining diagnoses in the Johns Hopkins Adjusted Clinical Groups Frailty Indicator with corresponding International Classification of Diseases, 9th Revision Codes

Category	Diagnoses	ICD-9-CM codes	Prevalence in frail patients (n = 72,818)*
Malnutrition	Nutritional marasmus Other severe protein-calorie malnutrition	261, 262, 263.8, 263.9, V77.2	48,999 (67.3%)
Dementia	Senile dementia with delusional or depressive features Senile dementia with delirium	290.20, 290.21, 290.3	182 (0.3%)
Severe vision impairment	Profound impairment, both eyes Moderate or severe impairment, better eye/lesser eye: profound	369.0, 369.00, 369.01, 369.03, 369.04, 369.06, 369.07, 369.08	1384 (1.9%)
Decubitus ulcer	Decubitus ulcer	707.0, 707.00, 707.01, 707.02, 707.03, 707.04, 707.05, 707.06, 707.07, 707.09, 707.20, 707.21, 707.22, 707.23, 707.24, 707.25	11,505 (15.8%)
Incontinence of urine	Incontinence without sensory awareness Continuous leakage	788.34, 788.37	73 (0.1%)
Loss of weight	Abnormal loss of weight and underweight Feeding difficulties and mismanagement	783.2, 783.21, 783.22, 783.3	4733 (6.5%)
Fecal incontinence	Incontinence of feces	787.6	57 (0.1%)
Social support needs	Lack of housing Inadequate housing Inadequate material resources	V60.0, V60.1, V60.2	1966 (2.7%)
Difficulty in walking	Difficulty in walking Abnormality of gait	719.7, 781.2	7719 (10.6%)
Fall	Fall on stairs or steps Fall from wheelchair	E880, E880.0, E880.1, E880.9, E884.3	54 (0.1%)

ICD-9-CM, International Classification of Disease, Ninth Revision. *Categories are not mutually exclusive; a patient may meet criteria for more than 1 category at once.

hospital. Transfer from one acute care hospital to another is accounted for separately in the NRD. In-hospital costs of the index admission were calculated using standard methods described by Healthcare Cost and Utilization Project. Inpatient costs were converted from NRD charges using the hospital-specific cost-to-charge ratios provided by the NRD and adjusted for inflation to 2014 dollars using the medical component of the consumer price index.²⁷ Cost and length of stay (LOS) are non-normally distributed (high positive skew), compromising the interpretation of measures of central tendency commonly used in regression analysis of continuous outcomes (Figure E1).

When analyzing discharge destination and LOS, patients who died before discharge were excluded. When analyzing 30-day readmissions, we excluded certain patients to account for the readmission tracking methodology used by the NRD. From an initial sample of 72,818 patients, we excluded patients who died during index admission (in-hospital mortality 10.2%, n = 7444), patients who were discharged in the month of December (n = 5307) to ensure full 30-day follow-up, and patients whose index admission was in a state different from their state of residence (n = 5297). Thus, for readmission analysis the study cohort included 54,770 patients. Hospital transfers were not considered readmissions.

Covariates

Patient-level characteristics included age 75 years or more, sex, primary payer (private insurance, Medicare, or Medicaid), neighborhood income quartile (based on ZIP code of residence), admission from the emergency department, urgency of admission (elective vs urgent/emergency), surgical procedure (CABG, valve replacement surgery, or combined), and comorbidity. Comorbidity was graded using the Charlson index²⁸ as implemented

by Deyo and colleagues.²⁹ Hospital-level characteristics included hospital bed size (low, medium, or high), teaching status, and hospital frailty volume or overall volume.

Statistical Analysis

Patient characteristics of each frailty volume quartile were compared using chi-square tests. A multilevel mixed-effects logistic regression model was used to evaluate the independent association between volume quartile and outcomes, with patient-level and hospital-level variables as described earlier. Nonbinary outcomes like LOS and cost were similarly analyzed by multilevel linear regression. Costs and LOS are non-normally distributed (high positive skew), compromising the interpretation of measures of central tendency commonly used in regression analysis of continuous outcomes. To account for this, we analyzed these outcomes using generalized linear regression modeling with a log link and gamma-distributed errors. Potential collinearity of frailty volume and overall volume was assessed by computing the variance inflation factor between these 2 variables. Patient and hospital factors significantly associated with frailty volume on univariate analysis were included as covariates in the multivariable models. In addition to multivariable analysis, we performed a 1:1 nearest-neighbor propensity score matching analysis to assess the effect of frailty volume and overall volume on outcome. Propensity-matched pairs of patients from the highest and lowest frailty volume quartiles were compared (2553 pairs), and the same was done for pairs of patients from the highest and lowest overall volume quartiles (2708 pairs). All covariates included in the multivariable models were accounted for in propensity matching. We confirmed balance across the covariates within the 2 matched groups using standardized differences, which were less than 0.2 for all covariates.

Sensitivity analysis modeling a linear relationship between frailty volume (as a continuous variable) and mortality risk was also performed. Statistical tests were 2 sided. Statistical analyses were performed using Stata 14 (StataCorp LP, College Station, Tex).

RESULTS

We identified 72,818 patients undergoing CABG or valve replacement surgery in the study period with a frailty-defining diagnosis, treated at 1693 different hospitals. Among frail patients, 94% were considered to be frail based on a single criterion (Table 1). The most common diagnostic cluster was malnutrition (67%), followed distantly by decubitus ulcers (15%), difficulty in walking (11%), and weight loss (7%). The remaining diagnoses occurred most frequently in combination. Frail patients were older (median age = 71 years; interquartile range [IQR], 61-79) and often had 2 or more comorbid conditions (54%). The rate of in-hospital mortality among frail patients was 10.2% (n = 7444), and the rate of FTR was 9.6% (n = 6959). This compares with a mortality and FTR rate of 2.6% and 2.0% in the nonfrail cohort. More than 65% of frail patients experienced at least 1 in-hospital complication (compared with 28.7% in the nonfrail cohort), and 24.3% of patients who survived index hospitalization were readmitted within 30 days of discharge (13.3% in the nonfrail cohort). The median hospital LOS was 19 days (IQR, 12-31 days), and the median cost of index hospitalization was \$75,242 (IQR, \$49,452-\$119,873). In the nonfrail cohort, median LOS was 8 days (IQR, 6-12 days), and median cost was \$40,317 (IQR, \$30,842-\$54,306).

Characteristics of the patient population stratified by annual volume of frail patients at the treating hospital are shown in Table 2. Although hospitals of different frailty volume differed significantly across many patient factors, no difference was found in overall patient comorbidity according to the Charlson comorbidity index ($P = .73$). Hospitals in the highest quartile of frailty volume performed fewer CABG procedures (36% vs 51%) and more valve-related procedures (39% vs 31%) relative to the overall average among hospitals operating on frail patients. On univariate analysis, the highest quartile of frailty volume was associated with significantly better outcomes across all outcome measures compared with the lowest quartile. A largely linear relationship was observed between frailty volume and reduced hospital LOS and hospital costs.

Results of multivariable analysis of frailty volume, overall procedure volume, and outcome in frail patients are given in Table 3. Complete models are provided in Tables E2 through E5. Beta values for continuous variables (LOS and cost) represent the predicted in difference in each for variable given a change in frailty volume quartile, given all other covariates remain unchanged. After adjusting for other covariates, both frailty volume and overall volume were significantly associated with shorter LOS, reduced

costs, and discharge home from the hospital when comparing the highest and lowest quartiles. However, frailty volume was also independently linked with reduced rates of in-hospital mortality (odds ratio [OR], 0.81; 95% confidence interval [CI], 0.65-0.94; $P = .009$) and FTR (OR, 0.83; 95% CI, 0.71-0.93; $P = .008$) when comparing highest and lower quartiles, whereas no such association was seen between overall volume and either mortality (OR, 1.03; 95% CI, 0.89-1.20; $P = .68$) or FTR (OR, 1.03; 95% CI, 0.91-1.24; $P = .76$) (Figure 1). For both mortality and FTR, the highest quartile of frailty volume was associated with significantly improved outcome compared with all other quartiles, whereas no difference was observed when the first, second, and third quartiles were compared with one another. Neither frailty volume nor overall volume showed any meaningful relationship with the rate of post-surgical complications or 30-day readmissions.

A limited propensity matching analysis was also performed (Table E6) to expand on and further evaluate the conclusions reached in multivariable modeling. Outcomes in propensity matched patients from the highest and lowest quartiles of frailty volume were compared. Likewise, outcomes in propensity-matched patients from the highest and lowest quartiles of overall volume were also compared. These results largely agree with the key conclusions of multivariable analysis. In propensity matching, high frailty volume was associated with significantly reduced mortality (OR, 0.72; 95% CI, 0.56-0.94; $P = .014$) and FTR (OR, 0.73; 95% CI, 0.56-0.95; $P = .021$), whereas overall volume was not. Sensitivity analysis modeling a continuous linear relationship between frailty volume and mortality was also performed (Figure E2). No obvious frailty volume cut point at which the slope of the mortality hazard ratio changes was apparent. A quintile-based analysis comparing frailty volume, overall volume, and mortality and FTR similar to the quartile-based analysis of Figure 1 is also provided in Figure E3. Results of this quintile-based analysis clearly agree with Figure 1 in that patients in the highest quartile of frailty volume demonstrated significantly better outcome compared with the lowest quartile, whereas no such association was seen with overall volume.

The relationship between overall volume and frailty volume of all hospitals included in the study is illustrated in Figure 2, A. Each data point represents a single hospital surveyed in the NRD. The correlation of determination (R^2) between overall volume and frailty volume was 0.43 (95% CI, 0.40-0.46). The variance inflation factor among frailty volume and overall volume was 1.75, suggesting that collinearity among variables was not significant. Figure 2, B demonstrates the relationship between overall volume decile and the fraction of patients operated on at those hospitals who are frail. Hospitals in the lowest and highest deciles of overall volume tended to operate on a frailer patient

TABLE 2. Characteristics and outcomes of study population by frailty volume quartile

	Frail patients at Q1 hospitals (n = 17,682)	Frail patients at Q2 hospitals (n = 18,127)	Frail patients at Q3 hospitals (n = 18,705)	Frail patients at Q4 hospitals (n = 18,304)	P value	All frail patients (n = 72,818)	Nonfrail patients (n = 1,435,081)
Patient characteristics							
Age, y (median, IQR)	70 (61-78)	71 (61-78)	71 (61-79)	71 (61-79)	.07	71 (61-79)	67 (59-75)
Male	10,733 (60.7)*	11,158 (61.6)	11,357 (60.7)	10,942 (59.8)	.15	44,189 (60.7)	979,156 (68.2)
Primary payer							
Private	2699 (15.3)	2972 (16.4)	2887 (15.4)	3554 (19.4)	<.001	12,111 (16.6)	426,650 (29.7)
Medicare	13,725 (77.6)	14,019 (77.3)	14,701 (78.6)	13,750 (75.1)	-	56,195 (77.2)	831,055 (57.9)
Medicaid	1166 (6.6)	1097 (6.1)	1072 (5.7)	967 (5.3)	-	4302 (5.9)	85,387 (6.0)
Other	91 (0.5)	39 (0.2)	46 (0.2)	33 (0.2)	-	210 (0.3)	92,132 (6.4)
Median household Income by ZIP code							
25th percentile	5348 (30.8)	5727 (32.2)	5620 (30.7)	4975 (27.6)	<.001	21,669 (30.3)	385,032 (26.8)
26th-50th percentile	4636 (26.7)	4881 (27.4)	5322 (29.1)	4643 (25.7)	-	19,482 (27.2)	380,070 (26.5)
51st-75th percentile	4231 (24.4)	4151 (23.3)	3981 (21.7)	4106 (22.8)	-	16,469 (23.0)	354,465 (24.7)
76th-100th percentile	3141 (18.1)	3026 (17.0)	3392 (18.5)	4319 (23.9)	-	13,877 (19.4)	314,713 (21.9)
Comorbidities							
Myocardial infarction	1637 (9.3)	1501 (8.3)	1756 (9.4)	1841 (10.1)	.002	6735 (9.2)	176,228 (12.3)
Congestive heart failure	3149 (17.8)	2878 (15.9)	3333 (17.8)	2804 (15.3)	<.001	12,164 (16.7)	35,447 (2.4)
Peripheral vascular disease	2345 (13.3)	2659 (14.7)	2818 (15.1)	2749 (15.0)	.004	10,570 (14.5)	176,945 (12.3)
Cerebrovascular disease	973 (5.5)	887 (4.9)	879 (4.7)	779 (4.3)	.003	3517 (4.8)	26,693 (1.9)
Dementia	69 (0.4)	80 (0.4)	90 (0.5)	109 (0.6)	.27	348 (0.5)	1134 (0.1)
Chronic pulmonary disease	4589 (26.0)	4724 (26.1)	4946 (26.4)	4535 (24.8)	.09	18,795 (25.8)	307,394 (21.4)
Diabetes mellitus	4925 (27.9)	4909 (27.1)	4980 (26.6)	4519 (24.7)	<.001	19,333 (26.5)	443,153 (30.9)
Diabetes mellitus with complications	1679 (9.5)	1471 (8.1)	1385 (7.4)	1573 (8.6)	<.001	6108 (8.4)	78,355 (5.5)
Chronic renal disease	5250 (29.7)	5379 (29.7)	5552 (29.7)	5787 (31.6)	.014	21,970 (30.2)	241,811 (16.9)
Mild liver disease	172 (1.0)	170 (0.9)	217 (1.2)	234 (1.3)	.12	792 (1.1)	7175 (0.5)
Moderate or severe liver disease	1592 (9.0)	1729 (9.5)	1754 (9.4)	1562 (8.5)	.12	6637 (9.1)	39,034 (3.0)
Rheumatologic disease	93 (0.5)	104 (0.6)	106 (0.6)	110 (0.6)	.94	413 (0.6)	6745 (0.5)
Peptic ulcer disease	197 (1.1)	141 (0.8)	164 (0.9)	165 (0.9)	.16	666 (0.9)	2583 (0.2)
Hemiplegia or paraplegia	658 (3.7)	689 (3.8)	648 (3.5)	662 (3.6)	.69	2657 (3.6)	10,476 (0.7)
AIDS	32 (0.2)	37 (0.2)	27 (0.1)	48 (0.3)	.41	143 (0.2)	1263 (0.1)
Any malignancy	534 (3.0)	518 (2.9)	611 (3.3)	583 (3.2)	.44	2246 (3.1)	30,280 (2.1)
Metastatic solid tumor	81 (0.5)	72 (0.4)	81 (0.4)	78 (0.4)	.94	312 (0.4)	2727 (0.2)
Charlson Comorbidity Index							
<2 comorbidities	8162 (46.2)	8280 (45.7)	8527 (45.6)	8285 (45.3)	.73	33,253 (45.7)	920,461 (64.1)
2-3 comorbidities	5911 (33.4)	6473 (35.7)	6609 (35.3)	6505 (35.5)	-	25,498 (35.0)	244,394 (17.0)
>3 comorbidities	3608 (20.4)	3374 (18.6)	3569 (19.1)	3515 (19.2)	-	14,067 (19.3)	270,226 (18.8)
Hospital characteristics							
Teaching	8134 (46.0)	11,277 (62.2)	14,493 (77.5)	17,386 (95.0)	<.001	51,290 (70.4)	959,208 (66.8)
Hospital bed size							
Small	1733 (9.8)	1098 (6.1)	742 (4.0)	0.0 (0.0)	<.001	3573 (4.9)	86,966 (6.1)
Medium	4400 (24.9)	3246 (17.9)	1029 (5.5)	1702 (9.3)	-	10,377 (14.3)	235,066 (16.4)
Large	11,549 (65.3)	13,783 (76.0)	16,935 (90.5)	16,602 (90.7)	-	58,868 (80.8)	1,113,049 (77.6)
Overall CABG and valve surgery volume (median, IQR)	160 (100-232)	306 (211-441)	473 (341-662)	763 (494-1171)	<.001	398 (215-649)	371 (212-620)
Surgery and admission characteristics							
Nonelective admission	6511 (36.9)	6869 (37.9)	6888 (36.9)	8167 (44.8)	<.001	28,435 (39.1)	652,244 (45.5)
Admission from ED	8528 (48.2)	7944 (43.8)	7745 (41.4)	5962 (32.6)	<.001	30,180 (41.4)	397,948 (27.7)

(Continued)

TABLE 2. Continued

	Frail patients at Q1 hospitals (n = 17,682)	Frail patients at Q2 hospitals (n = 18,127)	Frail patients at Q3 hospitals (n = 18,705)	Frail patients at Q4 hospitals (n = 18,304)	P value	All frail patients (n = 72,818)	Nonfrail patients (n = 1,435,081)
Procedure type							
CABG	9071 (51.3)	8858 (48.9)	8100 (43.3)	6604 (36.1)	<.001	32,633 (44.8)	854,734 (59.6)
Valve surgery	5527 (31.3)	6046 (33.4)	7350 (39.3)	8853 (48.4)	-	27,776 (38.1)	414,812 (28.9)
CABG + valve surgery	3083 (17.4)	3223 (17.8)	3256 (17.4)	2847 (15.6)	-	12,409 (17.0)	165,465 (11.5)
Outcomes							
In-hospital mortality	1791 (10.1)	1850 (10.2)	2084 (11.1)	1720 (9.4)	.004	7444 (10.2)	36,882 (2.6)
LOS, d (median, IQR)	21 (13-33)	19 (12-31)	20 (12-32)	17 (10-29)	<.001	19 (12-31)	8 (6-12)
Complications	11,834 (66.9)	12,419 (68.5)	12,733 (68.1)	12,063 (65.9)	.014	49,051 (67.4)	411,294 (28.7)
FTR	1640 (9.3)	1738 (9.6)	1962 (10.5)	1619 (8.8)	.004	6959 (9.6)	28,989 (2.0)
Nonhome discharge	7740 (43.8)	7733 (42.7)	7871 (42.1)	6882 (37.6)	<.001	30,274 (41.6)	252,861 (17.6)
30-d readmissions*	1922 (23.8)	3321 (24.4)	4296 (25.5)	3772 (23.3)	.015	13,309 (24.3)	179,134 (13.3)
Cost in 2014 USD (median, IQR)	78,601 (52,065- 123,972)	74,882 (49,413- 118,000)	75,664 (49,575- 119,638)	71,831 (47,091- 117,414)	.001	75,242 (49,452- 119,873)	40,317 (30,842- 54,306)

Q, Quartile; IQR, interquartile range; AIDS, acquired immunodeficiency syndrome; CABG, coronary artery bypass graft; ED, emergency department; LOS, length of stay; FTR, failure to rescue. *Analysis of readmissions excluded patients who died during index hospitalization or whose surgery took place in the month of December.

population compared with hospitals in the middle deciles, to a statistically significant degree (Figure 3).

DISCUSSION

In this study of the NRD, we found that the annual volume of frail patients treated at a given hospital was independently associated with improved outcome in frail patients undergoing cardiac surgery, specifically with respect to cost, LOS, mortality, and FTR. Overall patient volume was not independently associated with improved mortality or FTR among frail patients, unlike frailty volume. Altogether, these findings suggest that a “frailty volume-outcome relationship” might supersede the more established “volume-outcome relationship” in this important high-risk patient population. Although McIsaac and colleagues¹⁶ recently demonstrated a robust frailty volume-frailty outcome relationship in patients undergoing major noncardiac surgery, to our knowledge this concept has not been explored in patients with cardiac disease before this study.

Our study findings indicate that the primary driver of this trend may be the differences in acute postoperative care among hospitals. Specifically, we found a significant difference in mortality and FTR associated with hospital frailty volume, but no discernible difference in the rate of surgical complications. In other words, those hospitals with the highest frailty volume and the lowest mortality differed only from the worst performing hospitals in the rate at which they allowed surgical complications to progress to mortality—not at the rate at which surgical complications occurred in the first place. Similar trends have been shown to drive the overall volume-outcome relationship seen in the general surgery patient population, according to prior work.^{11,12} McIsaac and colleagues¹⁶ also identified this same pattern underlying the frailty

volume-outcome relationship they described in patients without cardiac disease.

We make sense of this finding by recalling that frailty is meant to capture a patient’s weakened capacity to recover from physiologic stress. Even in the ideal case, cardiac surgery represents a massive stress on the body. Frail patients respond to that stress differently from the typical nonfrail patient, and true surgical complications may not always be necessary for the frail patient with cardiac disease to experience a rocky postoperative course. Thus, outcomes in frail patients with cardiac disease are more likely a product of what takes place after surgery involving their acute postoperative management rather than the operative skill of the surgeon. Although operative skill and technique are understood to be well correlated with overall surgical volume, the nuances of caring for frail patients after cardiac surgery are more likely correlated with frailty volume in particular. The findings of this study suggest that critical care teams with more experience caring for frail patients with cardiac disease have learned to intervene more effectively when these patients decompensate after surgery and thus achieve measurably better in-hospital outcomes. Durable long-term outcomes may rely more on thoughtful perioperative optimization, discharge planning, and transition to the community, which are critical to lasting success in these complex and vulnerable patients.

One other important finding of this study was that, with respect to multiple key outcome measures, only the highest quartile of frailty volume was associated with better outcome, whereas the first 3 quartiles showed no significant difference from one another. This pattern applied to mortality, FTR, and nonhome discharge. Overall, this finding suggests a thresholding effect, where the benefits associated with a high frailty volume are not realized in a significant

TABLE 3. Multivariable analysis of frailty volume and outcomes

	Q1	Q2	Q3	Q4
In-hospital mortality				
Frailty volume OR (95% CI)	1.00	1.02 (0.90-1.15)	1.04 (0.91-1.18)	0.81 (0.65-0.94)
P value	-	.79	.53	.009
Overall volume OR (95% CI)	1.00	1.00 (0.88-1.12)	1.02 (0.89-1.17)	1.03 (0.89-1.20)
P value	-	.94	.24	.76
LOS (d)				
Frailty volume beta (95% CI)	1.00	-1.1 (-2.0 to -0.3)	-1.6 (-2.5 to -0.6)	-3.1 (-4.5 to -1.8)
P value	-	.007	.002	<.001
Overall volume beta (95% CI)	1.00	-1.1 (-2.0 to -0.3)	-1.7 (-2.7 to -0.7)	-1.7 (-2.0 to -0.5)
P value	-	.009	.001	.003
Complications				
Frailty volume OR (95% CI)	1.00	1.10 (0.99-1.20)	1.05 (0.96-1.15)	0.99 (0.90-1.09)
P value	-	.08	.27	.85
Overall volume OR (95% CI)	1.00	1.09 (1.00-1.19)	1.09 (0.98-1.19)	0.94 (0.86-1.04)
P value	-	.06	.09	.23
FTR				
Frailty volume OR (95% CI)	1.00	1.05 (0.93-1.19)	1.06 (0.93-1.21)	0.83 (0.71-0.93)
P value	-	.46	.37	.008
Overall volume OR (95% CI)	1.00	1.05 (0.92-1.18)	1.07 (0.93-1.23)	1.06 (0.91-1.24)
P value	-	.49	.37	.45
Nonhome discharge				
Frailty volume OR (95% CI)	1.00	0.99 (0.90-1.08)	0.94 (0.84-1.04)	0.86 (0.75-0.99)
P value	-	.83	.23	.039
Overall volume OR (95% CI)	1.00	1.09 (0.99-1.19)	1.04 (0.96-1.15)	0.88 (0.76-0.98)
P value	-	.08	.24	.025
30-d readmissions				
Frailty volume OR (95% CI)	1.00	0.99 (0.89-1.10)	1.05 (0.95-1.17)	0.89 (0.80-1.00)
P value	-	.83	.31	.059
Overall volume OR (95% CI)	1.00	1.03 (0.89-1.18)	1.03 (0.89-1.19)	1.01 (0.87-1.18)
P value	-	.73	.72	.88
Cost (USD)				
Frailty volume beta (95% CI)	1.00	-4402 (-7990 to 816)	-6850.91 (-11,241 to -2457)	-7.558 (14,047.84 to -1067)
P value	-	.016	.002	.022
Overall volume beta (95% CI)	1.00	-8147 (-11,1743 to -4551)	-12,459 (-17,072 to -7847)	-9302 (-14,950 to -3653)
P value	-	<.001	<.001	.001

Q, Quartile; OR, odds ratio; CI, Confidence interval; LOS, length of stay; FTR, failure to rescue; USD, US dollars.

way until a critical volume of frail patients is reached. In our study, the hospitals in the highest quartile of frailty volume were defined as those treating greater than 44 frail patients per year undergoing the procedures in question (CABG or valve replacement surgery). Thus, our data suggest a critical volume of frail patients greater than 44 per year, although a quartile-based analysis may not be sufficiently granular to tease out a truly quantitative relationship between volume and outcome, nor was that level of detailed quantitative analysis the goal of this study. In general though, these data do support a so-called centers of excellence approach to the treatment of frail patients with cardiac disease, wherein these patients are preferentially funneled to a select group at regional centers with a high frailty volume. Of note, the thresholding trend observed in our study was the opposite of that observed by McIsaac

and colleagues,¹⁶ who noted that hospitals in the third to fifth quartiles of frailty volume all showed significantly improved outcome of similar magnitude compared with hospitals in the lowest quartile. We ascribe this difference to the fact that cardiac procedures are of inherently greater risk and involve more critical and complex postoperative care than many of the noncardiac procedures studied by McIsaac and colleagues,¹⁶ such as total hip or knee replacement and laparoscopic sleeve gastrectomy. Thus, a greater threshold of frailty volume may be required before differences in outcome become apparent.

Study Limitations

This study has a few important limitations to note. First, because this study relies on a large, administrative dataset, granular clinical data and certain data specifically relevant

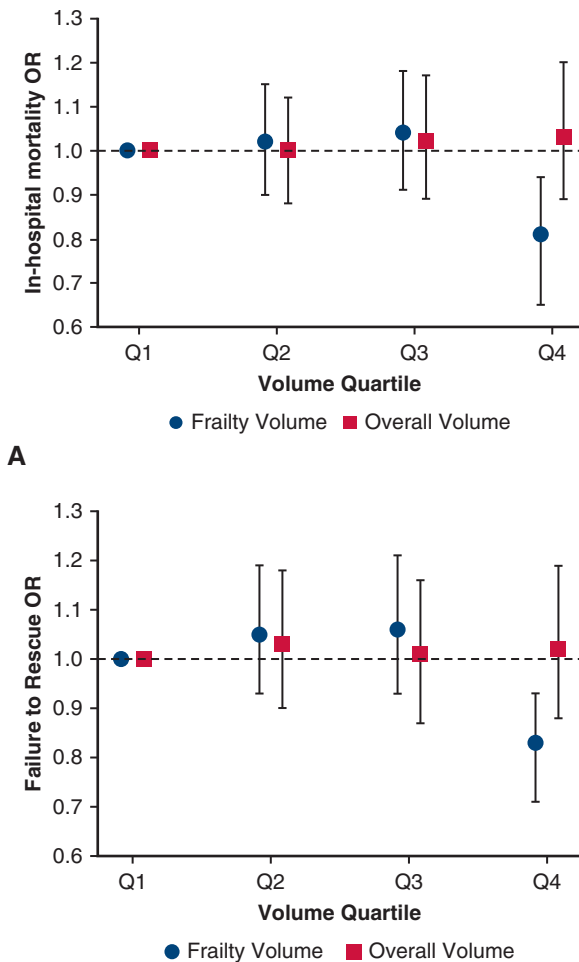


FIGURE 1. Comparison of the independent effect of overall and frailty volume on in-hospital mortality (A) and FTR (B), expressed as an adjusted OR relative to patients treated in the lowest volume quartile, demonstrating that frailty volume better predicts outcomes in frail patients compared with overall volume. Error bars represent 95% CIs. OR, Odds ratio; Q, quartile.

to cardiac surgery are not available for analysis. This includes preoperative ejection fraction and other quantitative measures of cardiac function, the Society of Thoracic Surgeons score and European System for Cardiac Operative Risk Evaluation for estimating preoperative risk, a patient's preoperative functional status and level of independence, preoperative geriatrics consultation, intensive care unit staffing models, and clinical severity of important comorbidities such as heart failure and chronic obstructive pulmonary disease. Second, this study made use of a claims-based binary metric for defining frailty. Although use of this metric was advantageous in that it is designed for and validated in administrative datasets, we are unable to measure the severity of a patient's frailty and understand its effect on study outcomes. Moreover, many other clinical studies in cardiac surgery use clinical metrics of frailty (eg, anemia, hypoalbuminemia, sarcopenia, gait speed, grip strength, or

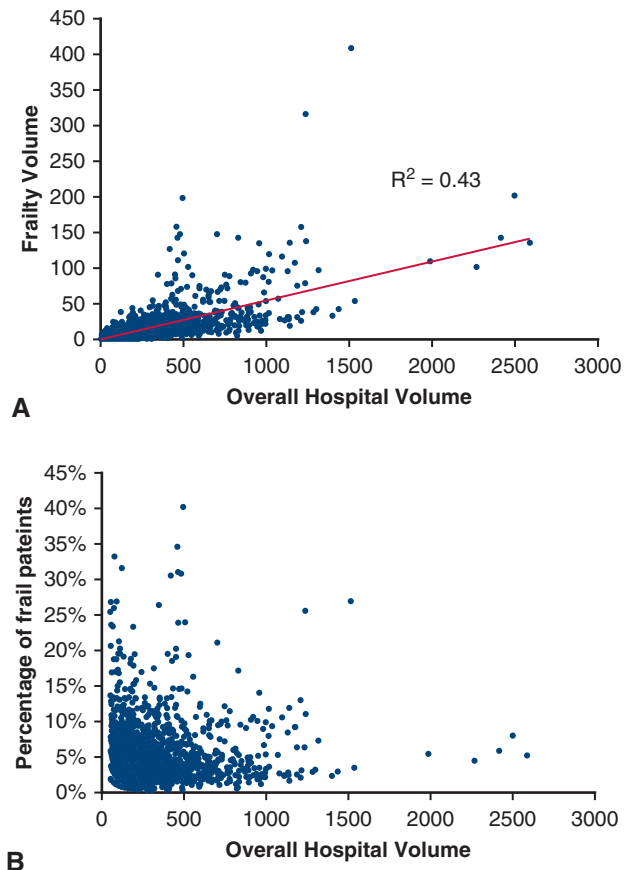


FIGURE 2. Scatter plot of individual hospitals demonstrating the positive correlation among the overall hospital volume, frailty volume (A), and percentage of patients operated on who are frail (B). Volume is assessed as the number of annual valve replacement or coronary bypass operations, and frailty volume includes operations on those patients who are frail.

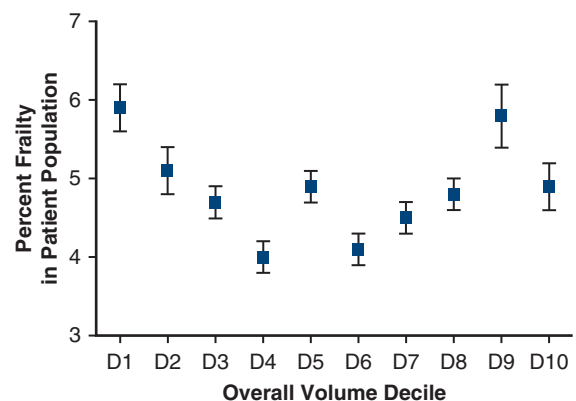


FIGURE 3. Percentage of patients undergoing cardiac surgery at individual hospitals who are frail compared with overall cardiac surgical volume decile. Volume is assessed as the number of annual valve replacement or coronary bypass operations. Patients at the largest and smallest hospitals in terms of cardiac surgery volume tend to treat the highest fraction of frail patients. Error bars represent 95% CIs.



Surgical volume of frail patients predicts outcomes in frail patients undergoing cardiac surgery

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VIDEO 1. Authors' brief discussion of key study findings and conclusions. Video available at: [https://www.jtcvs.org/article/S0022-5223\(20\)31057-6/fulltext](https://www.jtcvs.org/article/S0022-5223(20)31057-6/fulltext).

others) that differ from the claims-based metric used in this study. Last, only data from the 30 days after index surgery are available in the NRD, and thus medium- and long-term outcomes cannot be explored in this study.

CONCLUSIONS

This study demonstrates that in frail patients undergoing cardiac surgery, greater surgical volume of frail patients at a given center predicts lower in-hospital mortality and rates of FTR, whereas overall surgical volume does not (Video 1). These findings highlight the importance of the “frailty volume-outcome relationship” in cardiac surgery. They suggest that frail patients in need of open cardiac intervention should, when possible, seek out centers with a proven record of success in caring for frail, high-risk patients undergoing cardiac surgery. Further study is needed to confirm these findings across other cardiac surgery populations and other clinical measures of frailty and to elucidate the differences in systems and practices among hospitals of differing frailty volumes that may explain these results.

Webcast

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Conflict of Interest Statement

The authors reported no conflicts of interest.

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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: frailty, outcomes, failure to rescue

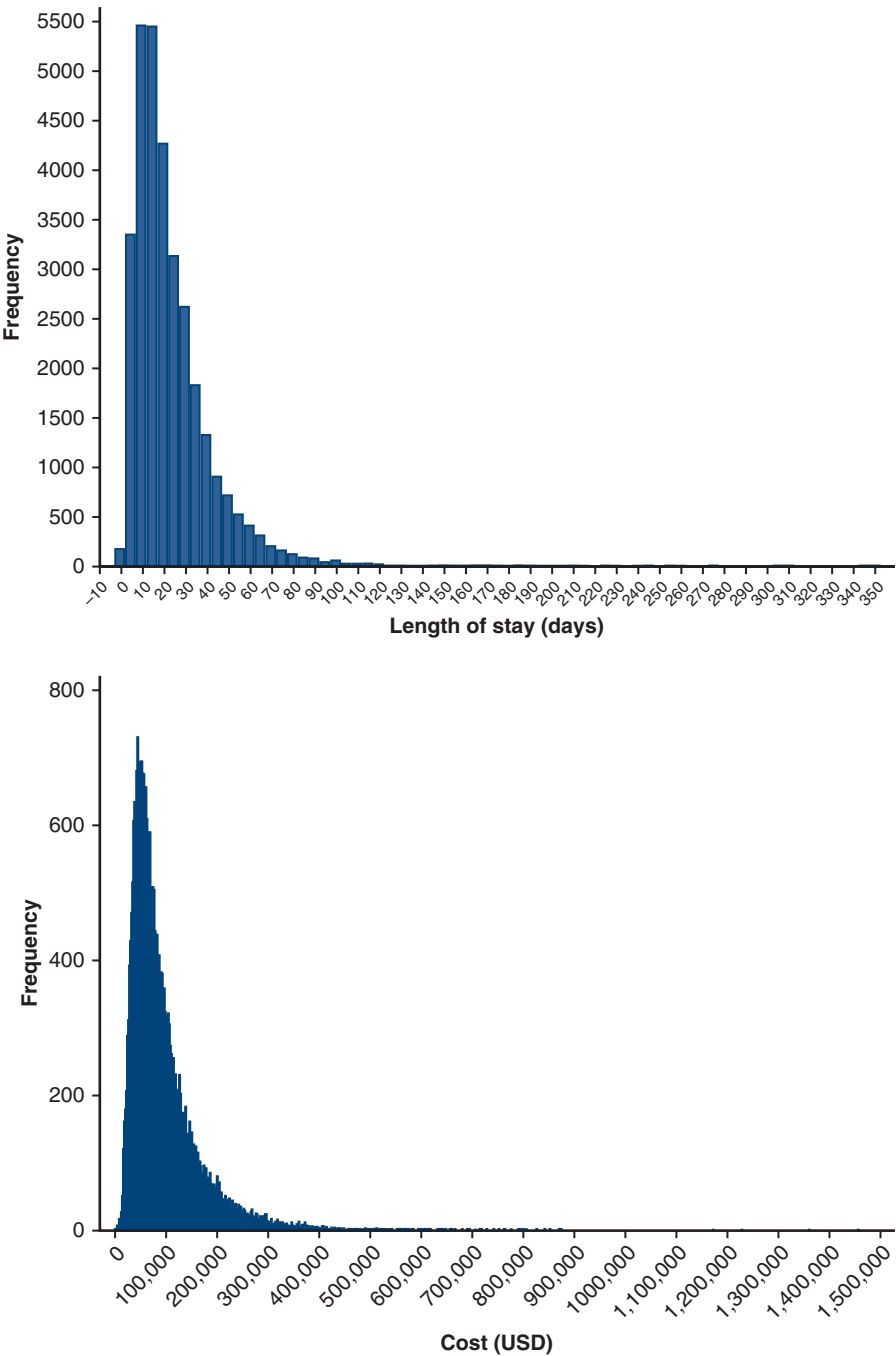


FIGURE E1. Histograms demonstrating positively skewed distribution of both direct hospital costs and length of stay for the index admission for the frail cohort. *USD*, United States dollars.

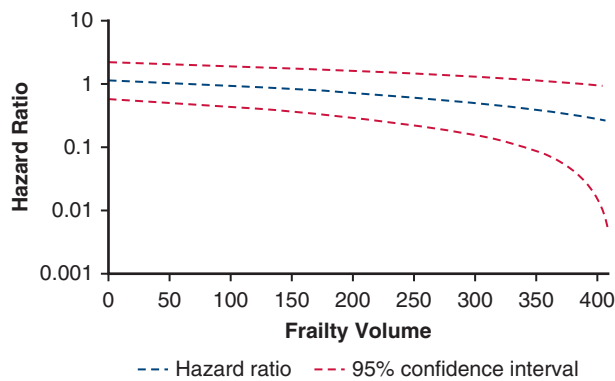


FIGURE E2. The adjusted relationship between frailty volume and mortality risk when frailty volume is modeled as a continuous variable. It is similar to the quintile-based analysis demonstrated in Table 2. No obvious frailty volume cut point at which the slope of the hazard ratio changes is apparent. USD, United States dollars.

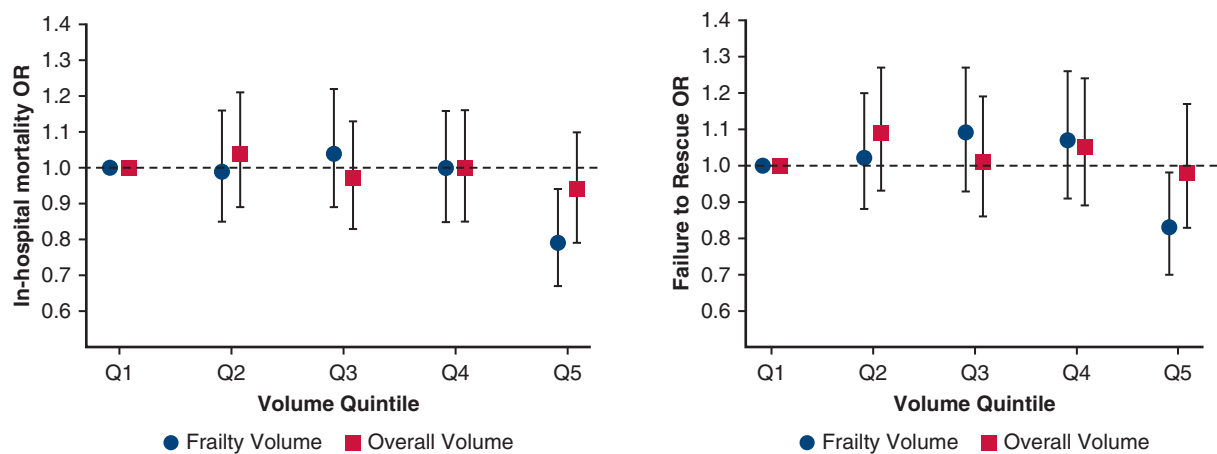


FIGURE E3. Rate of mortality and failure to rescue according to overall volume and frailty volume by volume quintile, rather than quartile. A similar trend to the quartile analysis is demonstrated, wherein patients in the highest quintile of frailty volume experience significantly improved outcomes, whereas overall volume has no significant effect on outcome. OR, Odds ratio; Q, quartile.

TABLE E1. International Classification of Diseases 9th Revision codes defining the study cohort and surgical complications

Procedure	ICD-9-CM codes	CCS code
CABG	36.1x, 36.20-36.39	44
Valve surgery	35.00-35.04, 35.10-35.14, 35.20-35.28, 35.96-35.99	43
Surgical complications	ICD-9-CM codes	
Myocardial infarction	410.00-410.91	
Acute renal failure	584	
Venous thromboembolism	415.1, 451.11, 451.19, 451.2, 451.81, 453.8	
Pneumonia	481, 482.0-482.9, 483, 484, 485, 507.0	
Pulmonary failure	518.81, 518.4, 518.5, 518.8	
Postoperative bleeding	998.11, 998.12	
Surgical site infection	958.3, 998.3, 998.5, 998.59, 998.51	
Stroke	431, 433.x1, 434.x1, 436, 997.02	

ICD-9-CM, International Classification of Disease, Ninth Revision, Clinical Modification; CCS, Clinical Classification Software; CABG, coronary artery bypass grafting.

TABLE E2. Full multivariable model analyzing effect of frailty and overall volume on mortality

Variables	Frailty volume model		Overall volume model	
	OR (95% CI)	P value	OR (95% CI)	P value
Patient characteristics				
Primary payer				
Private	Ref (-)	-	Ref (-)	-
Medicare	1.22 (1.07-1.40)	.004	1.23 (1.07-1.41)	.003
Medicaid	1.03 (0.82-1.30)	.79	1.04 (0.82-1.31)	.75
Other	0.85 (0.38-1.91)	.70	0.86 (0.39-1.93)	.72
Median household income by ZIP code				
1st-25th percentile	Ref (-)	-	Ref (-)	-
26th-50th percentile	0.89 (0.78-1.00)	.06	0.89 (0.78-1.00)	.055
51st-75th percentile	1.01 (0.88-1.14)	.94	1.00 (0.88-1.14)	.95
76th-100th percentile	0.94 (0.83-1.07)	.35	0.93 (0.82-1.06)	.30
Comorbidities				
Congestive heart failure	1.88 (1.69-2.10)	<.001	1.89 (1.69-2.10)	<.001
Peripheral vascular disease	0.95 (0.84-1.08)	.45	0.95 (0.84-1.08)	.44
Cerebrovascular disease	0.46 (0.34-0.62)	<.001	0.46 (0.34-0.62)	<.001
Diabetes mellitus	0.66 (0.58-0.74)	<.001	0.66 (0.59-0.74)	<.001
Diabetes mellitus with complications	0.65 (0.52-0.80)	<.001	0.64 (0.52-0.80)	<.001
Chronic renal disease	1.39 (1.26-1.53)	<.001	1.39 (1.26-1.53)	<.001
Hospital and admission characteristics				
Teaching hospital	1.07 (0.95-1.20)	.26	1.03 (0.92-1.15)	.62
Hospital bed size				
Small	Ref (-)	-	Ref (-)	-
Medium	1.33 (1.02-1.72)	.032	1.29 (0.99-1.67)	.06
Large	1.41 (1.10-1.79)	.006	1.35 (1.06-1.71)	.015
Nonelective admission	0.87 (0.77-0.98)	.026	0.87 (0.77-0.98)	.023
Admission from ED	0.96 (0.85-1.08)	.50	0.97 (0.86-1.09)	.60
Procedure type				
CABG	Ref (-)	-	Ref (-)	-
Valve surgery	1.38 (1.23-1.53)	<.001	1.37 (1.22-1.52)	<.001
CABG + valve surgery	1.54 (1.36-1.75)	<.001	1.54 (1.36-1.75)	<.001

OR, Odds ratio; CI, confidence interval; ED, emergency department; CABG, coronary artery bypass grafting.

TABLE E3. Full multivariable model analyzing effect of frailty and overall volume on failure to rescue

Variables	Frailty volume model		Overall volume model	
	OR (95% CI)	P value	OR (95% CI)	P value
Patient characteristics				
Primary payer				
Private	Ref (-)	-	Ref (-)	-
Medicare	1.20 (1.04-1.39)	.011	1.21 (1.05-1.40)	.008
Medicaid	1.03 (0.81-1.31)	.78	1.04 (0.82-1.32)	.74
Other	0.91 (0.41-2.04)	.82	0.92 (0.41-2.06)	.84
Median household income by ZIP code				
1st-25th percentile	Ref (-)	-	Ref (-)	-
26th-50th percentile	0.88 (0.78-1.00)	.048	0.88 (0.77-1.00)	.046
51st-75th percentile	1.03 (0.91-1.18)	.64	1.03 (0.90-1.17)	.66
76th-100th percentile	0.96 (0.84-1.10)	.55	0.95 (0.83-1.09)	.48
Comorbidities				
Congestive heart failure	1.93 (1.71-2.16)	<.001	1.94 (1.73-2.17)	<.001
Peripheral vascular disease	0.95 (0.83-1.08)	.41	0.95 (0.83-1.08)	.41
Cerebrovascular disease	0.43 (0.32-0.58)	<.001	0.44 (0.32-0.68)	<.001
Diabetes mellitus	0.64 (0.57-0.72)	<.001	0.64 (0.57-0.72)	<.001
Diabetes mellitus with complications	0.61 (0.49-0.76)	<.001	0.61 (0.48-0.86)	<.001
Chronic renal disease	1.38 (1.25-1.52)	<.001	1.37 (1.24-1.51)	<.001
Hospital and admission characteristics				
Teaching hospital	1.03 (0.92-1.16)	.58	0.99 (0.88-1.12)	.93
Hospital bed size				
Small	Ref (-)	-	Ref (-)	-
Medium	1.43 (1.10-1.86)	.008	1.38 (1.06-1.80)	.017
Large	1.50 (1.17-1.93)	.001	1.44 (1.12-1.84)	.004
Nonelective admission	0.88 (0.77-0.99)	.037	0.87 (0.77-0.98)	.033
Admission from ED	0.94 (0.83-1.06)	.29	0.95 (0.84-1.07)	.37
Procedure type				
CABG	Ref (-)	-	Ref (-)	-
Valve surgery	1.37 (1.23-1.53)	<.001	1.36 (1.22-1.52)	<.001
CABG + valve surgery	1.56 (1.37-1.78)	<.001	1.56 (1.37-1.78)	<.001

OR, Odds ratio; CI, confidence interval; ED, emergency department; CABG, coronary artery bypass grafting.

TABLE E4. Full multivariable model analyzing effect of frailty and overall volume on nonhome discharge

Variables	Frailty volume model		Overall volume model	
	OR (95% CI)	P value	OR (95% CI)	P value
Patient characteristics				
Primary payer				
Private	Ref (-)	-	Ref (-)	-
Medicare	2.20 (2.03-2.39)	<.001	2.21 (2.04-2.40)	<.001
Medicaid	0.70 (0.60-0.81)	<.001	0.70 (0.60-0.81)	<.001
Other	1.75 (1.15-2.67)	.009	1.81 (1.19-2.76)	.006
Median household income by ZIP code				
1st-25th percentile	Ref (-)	-	Ref (-)	-
26th-50th percentile	1.07 (0.99-1.16)	.07	1.07 (0.99-1.15)	.08
51st-75th percentile	1.07 (0.99-1.15)	.11	1.07 (0.99-1.16)	.09
76th-100th percentile	1.07 (0.99-1.16)	.09	1.09 (1.00-1.18)	.046
Comorbidities				
Congestive heart failure	1.33 (1.22-1.43)	<.001	1.33 (1.23-1.44)	<.001
Peripheral vascular disease	1.06 (0.98-1.15)	.14	1.06 (0.98-1.14)	.16
Cerebrovascular disease	1.00 (0.87-1.14)	.96	1.00 (0.87-1.14)	.97
Diabetes mellitus	0.93 (0.87-0.99)	.025	0.64 (0.87-0.99)	.027
Diabetes mellitus with complications	0.97 (0.88-1.08)	.62	0.98 (0.88-1.08)	.64
Chronic renal disease	1.09 (1.03-1.16)	.005	1.09 (1.03-1.16)	.006
Hospital and admission characteristics				
Teaching hospital	1.02 (0.95-1.10)	.52	0.98 (0.91-1.05)	.50
Hospital bed size				
Small	Ref (-)	-	Ref (-)	-
Medium	0.73 (0.63-0.87)	<.001	0.72 (0.61-0.85)	<.001
Large	0.69 (0.59-0.80)	<.001	0.64 (0.55-0.75)	<.001
Nonelective admission	0.78 (0.72-0.84)	<.001	0.78 (0.72-0.84)	<.001
Admission from ED	1.02 (0.95-1.10)	.25	1.03 (0.96-1.11)	.41
Procedure type				
CABG	Ref (-)	-	Ref (-)	-
Valve surgery	1.16 (1.09-1.24)	<.001	1.16 (1.09-1.24)	<.001
CABG + valve surgery	1.47 (1.36-1.59)	<.001	1.47 (1.36-1.59)	<.001

OR, Odds ratio; CI, confidence interval; ED, emergency department; CABG, coronary artery bypass grafting.

TABLE E5. Full multivariable model analyzing effect of frailty and overall volume on surgical complications

Variables	Frailty volume model		Overall volume model	
	OR (95% CI)	P value	OR (95% CI)	P value
Patient characteristics				
Primary payer				
Private	Ref (-)	-	Ref (-)	-
Medicare	1.07 (0.99-1.16)	.07	1.07 (0.99-1.16)	.08
Medicaid	0.98 (0.86-1.11)	.71	0.97 (0.85-1.10)	.64
Other	1.26 (0.80-1.99)	.33	1.27 (0.80-2.02)	.30
Median household income by ZIP code				
1st-25th percentile	Ref (-)	-	Ref (-)	-
26th-50th percentile	0.98 (0.91-1.06)	.68	0.98 (0.91-1.07)	.70
51st-75th percentile	0.96 (0.88-1.04)	.29	0.96 (0.88-1.04)	.32
76th-100th percentile	0.86 (0.79-0.93)	<.001	0.87 (0.80-0.95)	.001
Comorbidities				
Congestive heart failure	2.86 (2.59-3.16)	<.001	2.86 (2.59-3.16)	<.001
Peripheral vascular disease	1.01 (0.93-1.09)	.85	1.01 (0.93-1.09)	.86
Cerebrovascular disease	1.07 (0.93-1.24)	.35	1.07 (0.92-1.23)	.39
Diabetes mellitus	0.74 (0.69-0.79)	<.001	0.74 (0.69-0.79)	<.001
Diabetes mellitus with complications	0.75 (0.67-0.84)	<.001	0.75 (0.67-0.84)	<.001
Chronic renal disease	2.04 (1.90-2.19)	<.001	2.04 (1.91-2.19)	<.001
Hospital and admission characteristics				
Teaching hospital	1.00 (0.93-1.08)	.99	1.00 (0.93-1.08)	.93
Hospital bed size				
Small	Ref (-)	-	Ref (-)	-
Medium	1.22 (1.03-1.45)	.019	1.21 (1.02-1.43)	.027
Large	1.13 (0.97-1.32)	.12	1.12 (0.95-1.30)	.17
Nonelective admission	0.65 (0.60-0.70)	<.001	0.64 (0.59-0.70)	<.001
Admission from ED	1.13 (1.04-1.22)	.003	1.12 (1.04-1.21)	.004
Procedure type				
CABG	Ref (-)	-	Ref (-)	-
Valve surgery	1.26 (1.18-1.35)	<.001	1.27 (1.18-1.35)	<.001
CABG + valve surgery	1.70 (1.56-1.86)	<.001	1.70 (1.56-1.86)	<.001

OR, Odds ratio; CI, confidence interval; ED, emergency department; CABG, coronary artery bypass grafting.

TABLE E6. Propensity-matched comparison of outcomes in patients in highest and lowest quintiles of frailty and overall volume

	Frailty volume Q1 vs Q4 OR, 95% CI	P value	Hospital volume, Q1 vs Q4 OR, 95% CI	P value
In-hospital mortality	0.72 (0.56-0.94)	.014	0.85 (0.66-1.10)	.22
Complications	1.18 (1.01-1.39)	.039	1.04 (0.89-1.20)	.64
Failure to rescue	0.73 (0.56-0.95)	.021	0.88 (0.67-1.14)	.35
Nonhome discharge	0.87 (0.74-1.02)	.08	0.97 (0.84-1.13)	.73

Q, Quartile; OR, odds ratio; CI, confidence interval.